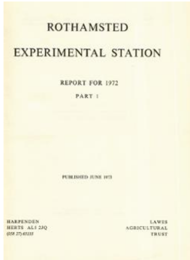
ROTHAMSTED RESEARCH

Report for 1972 - Part 1

Full Table of Content


ROTHAMSTED

EXPERIMENTAL STATION

REPORT FOR 1972

PART 1

Entomology Department

C. G. Butler

C. G. Butler (1973) *Entomology Department ;* Report For 1972 - Part 1, pp 195 - 224 **- DOI: https://doi.org/10.23637/ERADOC-1-127**

ENTOMOLOGY DEPARTMENT

C. G. BUTLER

The principal objectives of the Department are to develop ways of forecasting population levels of insects, slugs and some other pests of field crops, to estimate the damage such populations are likely to cause, and to explore ways of avoiding such damage. Progress towards these objectives involves using the present network of suction and light traps set up throughout Britain for the Rothamsted Insect Survey, which provides data on the movements of aphids, beetles, flies, moths and other insects; developing methods of surveying the current densities and distributions of various pests and their predators and determining the factors responsible for these and for fluctuations in their numbers in and outside crops; investigating the effects of pest infestation on crop growth and yields, and deciding whether it is worthwhile both in the short *and in the long term* to attempt to diminish the levels of infestation; and, if so, devising practical means of so doing. Much of the work of the Department has, therefore, an ecological basis. Behavioural and physiological studies, including work on host attractants, arrestants and pheromones of various pests, are also made; and insect pathogens are studied in attempts to explain and forecast their effects on pest populations and explore their use as a method of control.

The efficient use of honeybees and other insects as pollinators of fruit and seed crops, and the development of methods of keeping bees and controlling their diseases are also part of the Department's work.

The Rothamsted Insect Survey

L. R. Taylor and R. A. French

Suction traps. Daily sampling began on 4 April at all sites except East Craigs, where a new trap, replacing the one burned down last year, began sampling on 27 April. The first aphid bulletin, for the week beginning 24 April, was published 11 days later than in 1971, and included only eight species caught before 24 April. The last bulletin was for the week ending 5 November. The new trap operated by ADAS at Shardlow, near Rugby, started working on 20 March, and the Silwood trap was reconditioned. The Zeeland trap was moved on 6 June from Wilhelminadorp in Beveland, to a new site about 8 km north at Colynsplaat, North Beveland, and re-started on 7 June. The new site is in flat polder country similar to the old one except that it is closer to, and more sheltered by, buildings and trees. The standard four-week totals for the 32 species of aphids that are published in the bulletin, and from the 17 traps that contribute to it, are tabulated in *Rothamsted Report for 1972*, Part 2, 182–211.

In order to diminish catches to sizes that it was practicable to sort, the volume of air sampled by the Shardlow, Broom's Barn, Garston, Silwood Park, Wye, Hereford, and the three Rothamsted traps was halved from 16 July to 6 August, and by all traps, except the Zeeland one, from 25 September to 22 October. In addition, when catches were exceptionally large, the aphids were sub-sampled in the laboratory so that bulletins could be issued on time. Samples needed for critical analysis were subsequently fully identified or kept for confirmation. Sub-sampling was done by repeated use of a device that halved the contents of a 10 cm Petri dish until a reasonable number of insects remained. This technique was shown to be highly efficient when applied to a homogeneous sample, such as sorted aphids which disperse in alcohol and become almost uniformly

https://doi.org/10.23637/ERADOC-1-127

distributed. It cannot be used successfully with a heterogeneous mass of unsorted insects because these aggregate. It is probable, therefore, that the initial semi-skilled sorting of samples will ultimately become the limiting factor in survey sampling.

The cold spring delayed primary aphid migration by about two weeks (see Table 1a, *Rothamsted Report for 1972*, Part 2, 184–185) and the commonly very large early flight of *Drepanosiphum platanoidis* (Sycamore aphid) was missing, but more *Brachycaudus helichrysi* (Leaf-curling plum aphid) were caught than in other years. Not until the end of July did aphids reach their usual numbers, and the volume of air sampled per trap had to be halved for only three weeks instead of the more usual six.

A very large migration of *Hyalopterus pruni* (Mealy plum aphid) was recorded from the Dundee trap, from mid-August to the end of October with a maximum at the end of September. This is a unique occurrence at any site, so far as our records show.

Aphis fabae (Black bean aphid) was common in late July, especially at Silwood and Shardlow, and from mid-August into September in the northern traps. The return flight of this aphid to its winter hosts was larger than usual, especially in Zeeland, but not especially so. *Myzus persicae* (Peach-potato aphid) flights were fairly typical.

Although some insecticide manufacturers had forecast that *Phorodon humuli* (Damson-hop aphid) would migrate early and persistently, migration was, in fact, late and in some areas small, and hops were little damaged.

Two hundred and forty-seven species of aphids are now regularly identified in the suction trap catches. Four of these are additions to the British fauna (see Stroyan, H. L. G. (1972) *Transactions of the Royal Entomological Society of London*, **124**, 37–39), namely: *Therioaphis riehmi*, which was first caught in the Rothamsted Farm trap on 13 July 1969 and was subsequently found on *Melilotus officinalis* near Harpenden; *Melanaphis elizabethae*, found on *Phragmites communis* in 1970 on the shore of Loch Davan, Aberdeenshire, after being caught in the Dundee trap in 1968; *Rhopalosiphum rufulum*, found on *Acorus calamus* in 1971 at St. Neots, Huntingdonshire, after appearing in the Silwood, Rothamsted and Broom's Barn traps in 1970; *Nearctaphis bakeri*, caught in the Rothamsted Farm trap in 1969, has recently been reported from several European countries and Mr. H. L. G. Stroyan (MAFF Plant Pathology Laboratory) expects it to become established in Britain on its primary hosts, *Crataegus* spp., and secondary hosts, mainly Leguminosae.

Field trials were repeated for the fourth successive year to compare crop sampling with aerial sampling for primary migrant cereal aphids. Samples of six species of cereal aphids from two transects per field per week in 44 crops were collected by ADAS entomologists, and co-ordinated by Mr. R. Gair (ADAS) and Mr. K. George (MAFF). The dates when each of the six species were first recorded are tabulated along-side the first Survey records in the nearest trap, sometimes many miles distant, and the difference between these two dates listed (Table 1, p. 198).

The Survey traps are highly sensitive and register aerial populations of most species of aphid at densities that, when deposited on the ground, are difficult to detect even with intensive searching. However, the sensitivity of the Survey differs for different species because the samples are collected at one height only, except at Rothamsted, and different species fly at different heights; the present single height (12·2 m) is a compromise until correction can be made for specific height distribution. The sensitivity of the crop sample depends on accumulation on the crop, either by concentration into the crop from surrounding unsuitable hosts or by successive waves of immigration, and these also differ for different species. Thus, crop density increases until it reaches a level that crop sampling can detect. The crop samples considered here are at practicable working levels; samples that might be possible as a routine survey procedure, not the intensive experimental sampling that is needed to register first arrivals.

https://doi.org/10.23637/ERADOC-1-127

In many instances the crop samples failed to register immigrants when the traps succeeded. This presumably indicates the relative insensitivity of the crop sample and does not mean the crop was clean. In other instances crops were infested before traps recorded flight. This could be explained by lack of trap sensitivity for certain species, or because certain fields are more likely than others to become infested early because of topography, aspect or surrounding vegetation. Most of these records, however, are for *Metopolophium dirhodum* in 1972, as in previous years, and it may be that this species over-winters differently, and that some crops are infested before the high level spring migration begins.

Once again, the Survey traps recorded aphids first on most occasions and, on these occasions, the average interval was 24 days.

In the field trials during the last four years, the Survey traps have, on average, detected cereal aphid movement earlier than field samples, with less effort and greater accuracy; species identification in the field averages 65–70% correct. The results have been sufficiently consistent for the trials to be stopped and in future the Survey Bulletin will be the source of ADAS information on times of migration of cereal aphids. The four years comparative records will now be analysed to find, if possible, the distance over which the trap samples are effective and to see how the accumulated trap samples, which give information on the size of the migration as distinct from its timing, relate to the ultimate aphid infestation.

Light traps. Out of a total of 580 species of moths, 31 species of agricultural or other special interest were caught during 1971 (for details see *Rothamsted Report for* 1972, Part 2, 200–207) at 128 trap sites. By the end of 1972, 133 light traps were operating.

The distribution of light traps changes from year to year and in 1972 the south-west of Wales, which had previously been well covered, lacked samples for most of the year. It is hoped, in 1973, to revive these sites and to improve coverage of central Wales with five or six new hill sites, at Newton and Staylittle, Montgomeryshire; Llandrindod Wells, Radnorshire; at Brecon; and at Newport, Monmouthshire. The sites at Brecon and Staylittle are both at 1000 ft and more upland sites are needed to assess the effects of altitude on population structure and size. Other sites at Dorchester, Dorset, St. Mary's, Scilly, and Cambridge will help to fill gaps in the network. The deficiencies in coverage in the north are more serious, now that mapping of distributions of species is possible, and sites in the Socttish Border country, Westmoreland and Durham are especially needed.

Distribution of the pest species, tabled each year in *Rothamsted Report*, Part 2, can now be condensed to an annual map. Maps for cutworms (Noctuidae) for the last four years are being prepared for publication to show the changes in distribution, as well as abundance, from year to year. These maps are not yet perfected; deficiencies in the light trap as a sampling tool have not been eliminated, but some idea of seasonal redistribution can be obtained and may help to visualise future trends in pest infestation levels.

The sampling deficiencies of light traps are being studied. The work done at the East African Forest Research Organisation, Muguga in Kenya, on light traps has now been published (Taylor & Brown, publication p. 361) and the results of another experiment on the relative efficiency of different traps in woodland are being prepared for publication. Together these papers suggest that the vertical distribution of density determines the species structure of the sample and, more important, that the amount of linear movement of the species is a major factor in sample size. An experiment to relate light trap samples to absolute samples from suction traps was done this year in Geescroft Wilderness, Rothamsted Farm, with satisfactory preliminary results.

Industrial strikes put most traps out of action from 12 February to 4 March 1972;

https://doi.org/10.23637/ERADOC-1-127

TABLE 1

Cereal aphids, 1971; dates of first appearance in fields and traps

Aphid Species				*R. padi*			*M.dirhodum*			*M. festucae*		
				Date found		Days earlier in trap	Date found		Days earlier in trap	Date found		Days earlier in trap
ADAS Centre	Field No.	Crop	Trap site	Field	Trap		Field	Trap		Field	Trap	
N. Scotland	i	SB	Dundee	29/6	27/6	+2	29/6	22/5	+38	20/6	28/5	+23
N. Scotland	ii	SB	Dundee	4/7	27/6	+7	27/6	22/5	+36	29/5	28/5	+1
N. Scotland	iii	SB	Dundee	24/7	27/6	+27	12/6	22/5	+21	6/6	28/5	+9
W. Scotland	i		East Craigs	n.f.	10/5	+	14/6	17/5	+28	14/6	8/5	+37
W. Scotland	ii		East Craigs	n.f.	10/5	+	14/6	17/5	+28	n.f.	8/5	+
W. Scotland	iii		East Craigs	n.f.	10/5	+	26/7	17/5	+70	n.f.	8/5	+
N. England	i	SB	Newcastle	4/8	17/6	+48	22/6	28/6	−6	11/7	22/5	+50
N. England	ii	SB	Newcastle	n.f.	17/6	+	23/6	28/6	−5	1/8	22/5	+71
N. England	iii	SB	Newcastle	n.f.	17/6	+	16/6	28/6	−12	16/6	22/5	+25
N. England	iv	SB	Newcastle	2/8	17/6	+46	14/6	28/6	−14	27/6	22/-	+36
N. England	v	SB	Newcastle	20/7	17/6	+33	14/6	28 6	−14	20/7	22/5	+59
Yorks & Lancs	i	SW	H. Mowthorpe	n.f	11/7	+	n.f.	1/7	+	29/6	29/5	+31
Yorks & Lancs	ii	SW	H. Mowthorpe	n.f.	11/7	+	n.f.	1/7	+	n.f.	29/5	+
Yorks & Lancs	iii	SB	H. Mowthorpe	n.f.	11/7	+	n.f.	1/7	+	n.f.	29/5	+
Yorks & Lancs	iv	SB	H. Mowthorpe	n.f.	11/7	+	n.f.	1/7	+	n.f.	29/5	+
Yorks & Lancs	v	SB	H. Mowthorpe	n.f.	11/7	+	n.f.	1/7	+	n.f.	29/5	+
Yorks & Lancs	vi	SW	H. Mowthorpe	n.f.	11/7	+	n.f.	1/7	+	n.f.	29/5	+
W. Midlands	i	SB	Hereford	n.f.	12/7	+	15/5	21/6	−37	28/6	9/6	+19
W. Midlands	ii	SW	Hereford	n.f.	12/7	+	5/6	21/6	−16	5/6	9/6	−4
E. Midlands	i	SB	Shardlow Hall	n.f.	26/6	+	19/5	5/5	+14	9/6	12/5	+28
E. Midlands	ii	SW	Shardlow Hall	n.f.	26/6	+	2/6	5/5	+28	26/6	12/5	+45
E. Midlands	iii	SB	Shardlow Hall	n.f.	26/6	+	2/6	5/5	+28	26/6	12/5	+45
Eastern	i	SW	Brooms Barn	n.f.	12/5	+	13/6	24/6	−11	n.f.	31/5	+
Eastern	ii	SW	Brooms Barn	13/6	12/5	+32	n.f.	24/6	+	n.f.	31/5	+
Eastern	iii	SW	Brooms Barn	n.f.	12/5	+	n.f.	24/6	+	n.f.	31/5	+
Eastern	iv	SW	Brooms Barn	n.f.	12/5	+	6/6	24/6	−18	n.f.	31/5	+
Eastern	v	SW	Brooms Barn	n.f.	12/5	+	13/6	24/6	−11	n.f.	31/5	+
Eastern	vi	SW	Brooms Barn	n.f.	12/5	+	6/6	24/6	−18	4/7	31/5	+34
S.E. Wye	i	SB	Wye, Kent	n.f.	10/6	+	n.f.	11/6	+	n.f.	1/5	+
S.E. Wye	ii	SB	Wye, Kent	n.f.	10/6	+	24/5	11/6	−18	n.f.	1/5	+
S.E. Wye	iii	SB	Wye, Kent	n.f.	10/6	+	n.f.	11/6	+	n.f.	1/5	+
S.E. Reading	i	SW	Silwood Park	n.f.	21/5	+	n.f.	13/6	+	n.f.	2/5	+
S.E. Reading	ii	SW	Silwood Park	n.f.	21/5	+	1/6	13/6	−12	1/6	2/5	+30
S.E. Reading	iii	SW	Silwood Park	n.f.	21/5	+	9/6	13/6	−4	n.f.	2/5	+
S.W. Bristol	i	SW	Long Ashton	n.f.	15/6	+	25/5	14/4	+41	8/6	14/4	+55
S.W. Bristol	ii	SB	Long Ashton	n.f.	15/6	+	8/6	14/4	+55	n.f.	14/4	+
S.W. Bristol	iii	SW	Long Ashton	n.f.	15/6	+	29/6	14/4	+76	n.f.	14/4	+
S.W. Starcross	i	SW	Starcross	n.f.	23/5	+	7/7	22/5	+46	n.f.	21/6	+
S.W. Starcross	ii	SB	Starcross	n.f.	23/5	+	7/7	22/5	+46	n.f.	21/6	+
S.W. Starcross	iii	SB	Starcross	n.f.	23/5	+	7/7	22/5	+46	26/6	21/6	+5
Wales: Bangor	i	SB	Aberystwyth	n.f.	17/4	+	n.f.	12/7	+	n.f.	15/5	+
Wales: Aberystwyth	i	SB	Aberystwyth	n.f.	17/4	+	n.f.	12/7	+	n.f.	15/5	+
Wales: Aberystwyth	ii	SB	Aberystwyth	n.f.	17/4	+	17/5	12/7	−56	28/6	15/5	+44
Wales: Aberystwyth	iii	SO	Aberystwyth	n.f.	17/4	+	23/5	12/7	−50	n.f.	15/5	+

SB = Spring barley
SW = Spring wheat
SO = Spring oats

n.f. = aphids not found
+ means that the trap detected aphids, though field samples had none

https://doi.org/10.23637/ERADOC-1-127

TABLE 1 (*continued*)

Cereal aphids, 1971: dates of first appearance in fields and traps

S. fragariae			*S. avenae*			*R. insertum*						
Date found		Days earlier	Date found		Days earlier	Date found		Days earlier				
Field	Trap	in trap	Field	Trap	in trap	Field	Trap	in trap	Trap site	Crop	Field No.	ADAS Centre
20/6	13/6	+7	8/6	31/5	+8	n.f.	4/6	+	Dundee	SB	i	N. Scotland
23/6	13/6	+10	6/6	31/5	+6	n.f.	4/6	+	Dundee	SB	ii	N. Scotland
4/7	13/6	+21	6/6	31/5	+6	n.f.	4/6	+	Dundee	SB	iii	N. Scotland
n.f.	31/5	+	14/6	17/5	+28	n.f.	2/5	+	East Craigs		i	W. Scotland
14/6	31/5	+14	14/6	17/5	+28	14/6	2/5	+43	East Craigs		ii	W. Scotland
n.f.	31/5	+	14/6	17/5	+28	n.f.	2/5	+	East Craigs		iii	W. Scotland
11/7	22/6	+19	n.f.	14/7	+	n.f.	5/6	+	Newcastle	SB	i	N. England
23/6	22/6	+1	24/5	14/7	−51	n.f.	5/6	+	Newcastle	SB	ii	N. England
16/6	22/6	−6	n.f.	14/7	+	16/6	5/6	+11	Newcastle	SB	iii	N. England
20/6	22/6	−2	14/6	14/7	−30	8/6	5/6	+3	Newcastle	SB	iv	N. England
2/8	22/6	+41	13/7	14/7	−1	n.f.	5/6	+	Newcastle	SB	v	N. England
n.f.	29/6	+	29/6	11/6	+18	n.f.	31/5	+	H. Mowthorpe	SW	i	Yorks & Lancs
29/6	29/6	=	n.f.	11/6	+	2/6	31/5	+2	H. Mowthorpe	SW	ii	Yorks & Lancs
n.f.	29/6	+	2/6	11/6	−9	2/6	31/5	+2	H. Mowthorpe	SB	iii	Yorks & Lancs
9/6	29/6	−20	n.f.	11/6	+	n.f.	31/5	+	H. Mowthorpe	SB	iv	Yorks & Lancs
n.f.	29/6	+	n.f.	11/6	+	9/6	31/5	+9	H. Mowthorpe	SB	v	Yorks & Lancs
n.f.	29/6	+	n.f.	11/6	+	2/6	31/5	+2	H. Mowthorpe	SW	vi	Yorks & Lancs
28/6	22/5	+37	22/5	2/5	+20	n.f.	20/4	+	Hereford	SB	i	W. Midlands
16/6	22/5	+25	22/5	2/5	+20	22/5	20/4	+32	Hereford	SW	ii	W. Midlands
25/5	1/6	−7	26/6	1/6	+25	19/5	18/5	+1	Shardlow Hall	SB	i	E. Midlands
2/6	1/6	+1	n.f.	1/6	+	25/5	18/5	+7	Shardlow Hall	SW	ii	E. Midlands
2/6	1/6	+1	9/6	1/6	+8	2/6	18/5	+15	Shardlow Hall	SB	iii	E. Midlands
n.f.	1/6	+	6/6	19/5	+18	n.f.	2/6	+	Brooms Barn	SW	i	Eastern
n.f.	1/6	+	13/6	19/5	+25	n.f.	2/6	+	Brooms Barn	SW	ii	Eastern
n.f.	1/6	+	6/6	19/5	+18	n.f.	2/6	+	Brooms Barn	SW	iii	Eastern
n.f.	1/6	+	13/6	19/5	+25	n.f.	2/6	+	Brooms Barn	SW	iv	Eastern
n.f.	1/6	+	6/6	19/5	+18	n.f.	2/6	+	Brooms Barn	SW	v	Eastern
n.f.	1/6	+	6/6	19/5	+18	n.f.	2/6	+	Brooms Barn	SW	vi	Eastern
n.f.	1/6	+	23/5	10/5	+13	n.f.	21/5	+	Wye, Kent	SB	i	S.E. Wye
n.f.	1/6	+	24/5	10/5	+14	n.f.	21/5	+	Wye, Kent	SB	ii	S.E. Wye
n.f.	1/6	+	30/5	10/5	+20	n.f.	21/5	+	Wye, Kent	SB	iii	S.E. Wye
9/6	23/5	+17	1/6	1/5	+31	n.f.	26/4	+	Silwood Park	SW	i	S.E. Reading
1/6	23/5	+9	1/6	1/5	+31	n.f.	26/4	+	Silwood Park	SW	ii	S.E. Reading
1/6	23/5	+9	24/5	1/5	+23	n.f.	26/4	+	Silwood Park	SW	iii	S.E. Reading
25/5	25/5	=	25/5	11/5	+14	n.f.	14/5	+	Long Ashton	SW	i	S.W. Bristol
8/6	25/5	+14	8/6	11/5	+28	n.f.	14/5	+	Long Ashton	SB	ii	S.W. Bristol
29/6	25/5	+35	29/6	11/5	+49	n.f.	14/5	+	Long Ashton	SW	iii	S.W. Bristol
n.f.	28/5	+	26/5	21/5	+5	n.f.	20/5	+	Starcross	SW	i	S.W. Starcross
2/6	28/5	+5	16/6	21/5	+26	n.f.	20/5	+	Starcross	SB	ii	S.W. Starcross
7/7	28/5	+40	2/6	21/5	+12	n.f.	20/5	+	Starcross	SB	iii	S.W. Starcross
n.f.	4/6	+	9/6	24/6	−15	n.f.	15/7	+	Aberystwyth	SB	i	Wales: Bangor
n.f.	4/6	+	29/6	24/6	+5	23/5	15/7	−53	Aberystwyth	SB	i	Wales: Aberystwyth
n.f.	4/6	+	31/5	24/6	−24	n.f.	15/7	+	Aberystwyth	SB	ii	Wales: Aberystwyth
1/6	4/6	−3	23/5	24/6	−32	n.f.	15/7	+	Aberystwyth	SO	iii	Wales: Aberystwyth

SB = Spring barley
SW = Spring wheat
SO = Spring oats

n.f. = aphids not found
\+ means that the trap detected aphids, though field samples had none

https://doi.org/10.23637/ERADOC-1-127

however, few insects fly at this time of year so the loss was not as serious as it might have been. The coldest spring for many years diminished catches of many early species. For example, the Kielder site in Northumberland, which usually yields *Orthosia gothica* (Hebrew Character) in tens each day, averaging 25 in 1971, averaged only between one and two in 1972. By August and September, catches for most species appeared normal. It remains to be seen whether the diminished flight of the early species is reflected in their numbers and distribution in 1973.

In most years at least one unusual species is caught in the survey traps. In 1972, one *Heliothis viriplaca* (Marbled Clover) was recorded on 19/20 July at Broom's Barn, one *Cossus cossus* (Goat moth) at Jersey on 1/4 September, and one *Thecla quercus* (Purple Hairstreak) on 16/17 August at Aberystwyth. On 18/19 August 1971, one *Lymantria dispar*, the Gipsy Moth so destructive in North American forests, was caught in Guernsey. Except for one influx of *Plutella macullipennis* (Diamond-back moth), 1972 was not notable for migrants.

Analysis of trap records. A new system for reading punched cards on to magnetic tape, and editing, developed by Kempton (Statistics), has greatly facilitated extraction of data and updating of tapes.

All light trap catches for 1971 are now available on magnetic tape, and it is hoped that earlier records will also be available soon. The 1971 data have been used to develop programs for extracting total numbers of species and individuals, first and last dates of capture, accumulated catches, frequency distributions of individuals per species, and species lists and records for particular species (Table 2, pp. 200–207, *Rothamsted Report for 1972*, Part 2, was prepared directly from data storage). All the suction trap records that were on punched cards are now on magnetic tape and basic data are being extracted. The *Trichoptera* (Caddis-flies) records from light traps have been punched and are ready for transfer to tape.

Density distribution maps for selected species, produced for the first time last year using the Symap V program (Laboratory for Computer Graphics, Harvard) on the Edinburgh computer, are now made at Rothamsted. Even with the limitations imposed by our previous inability to extract much of the collected data, except by hand, sufficient has been done to show that annual redistribution of moth species, including pests, is a major factor in their population dynamics. Species are already showing profound differences in the extent of their redistribution, and the way annual trends in population density interact with distribution makes clear why attempts to interpret population change at a single site are usually futile. Mobility is an essential, highly specific component, of the population dynamics of winged insects.

Short period maps, daily, weekly and four-weekly, of aphid species show how quickly the pattern of distribution—and, therefore, deposition—can change and even reverse. The interpretation of such maps is a novel experience that will take time to perfect. But the redistribution of insects, especially the appearance of pests in new areas, will be followed more easily now that maps at successive time intervals can be subtracted, one from the other, and the areas newly colonised, or lost, can themselves be mapped.

The deficiencies of the maps originate in either deficiencies of the samples or in deficiencies in the distribution of the traps. Deficiencies of suction traps are negligible, but their distribution is restricted by the small number that can be operated because of the cost of identifying the aphids caught. However, experiments have shown that each trap captures a fair sample of the airborne insects over a wide area.

Our light traps are well distributed in some regions but individually each represents a small area and has inherent deficiencies as a sampling tool. Apart from the experimental standardisation of traps to improve mapping efficiency (p 197), it is believed that careful

https://doi.org/10.23637/ERADOC-1-127

analysis of maps, including summed maps, should yield much information on the deficiencies of the samples. At present, the biggest errors are introduced by the lack of suction traps in the north-west and our present inability to correct light trap samples for the effect of the immediate trap site.

Ancillary studies. With present facilities it is only possible for us to explore a few of the many important new fields of study made possible by the Survey material. We are, therefore, pleased to encourage workers elsewhere to use our material whenever possible. Some of the resulting studies have been:

Mr. J. Boorman (Virus Research Institute, Pirbright, Surrey) has examined Survey light trap samples from four widely separated sites to find out more about the distribution of 22 species of *Culicoides*, small biting flies of importance to stock farming and tourism.

Dr. D. R. Lees (University College, Cardiff) has used Survey light trap material to study the distribution of melanism in the polymorphic moth, *Phigalia pedaria.*

Dr. M. I. Crichton (University of Reading) has identified the *Trichoptera* (Caddis-flies) from some of the Survey light traps and is mapping the distribution of several species for subsequent analysis. Because the immature stages of caddis-flies are found only in fresh water and redistribution of their populations is by means of flying adults, a study of changes occurring in their distribution may help solve similar problems with other flying insects, including pest species.

Mr. C. J. Miller (Hey School, Prestwich) is using trap catches to study morphological variation in adults of *Spilosoma lubricipeda* (White Ermine moth) in relation to environment.

Dr. M. Archer (University of York) is using material from Survey suction and light traps to study the distribution of bees and wasps.

Dr. A. Stubbs (Nature Conservancy, Newbury, Berkshire) and Mr. D. Webley (ADAS Cardiff) are studying the *Tipulidae* (Crane-flies) caught in the Survey traps.

Bowden has added the Neuroptera (Lacewings) from all suction traps to the Orders of insects included in the records published in *Rothamsted Report for 1972*, Part 2, and has there discussed the samples from 1970 to 1972. The outstanding feature is the predominance of the aphid predator *Chrysopa carnea* which was the only species of lacewing caught in some traps and by far the most prevalent species in all traps. This was also true for light trap catches.

Cockbain (Plant Pathology Department) is identifying all species of the weevil genera *Apion* and *Sitona* from 14 of the suction traps to obtain information on flight activity and distribution. Interest centres on broad-bean stain and broad-bean true mosaic viruses, seed-borne viruses found in England about 12 years ago, which spread rapidly when *Apion vorax* is abundant.

Dunning and Thornhill (Broom's Barn) are using Survey material from our south-eastern traps to study the migration, from over-wintering quarters to the crop, of *Atomaria linearis* (Pygmy Mangold beetle) and *Chaetocnema concinna* (Mangold Flea beetle), which are of considerable agricultural interest especially on sugar beet crops.

Mr. J. Raynor (ADAS Wolverhampton) has extracted *Oscinella frit* (Frit fly) from catches by the Hereford suction trap with a view to relating migration to subsequent damage.

The Diptera, true flies, are a large and heterogeneous group of insects, difficult and therefore expensive to sort and identify, but many are very important pests. It is hoped that it will soon become possible to use Survey material to monitor changes in the population density and distribution of pest species of Diptera for advisory warning purposes, and to further our knowledge of them.

https://doi.org/10.23637/ERADOC-1-127

Light trapping in Africa

Effects of moonlight. Statistical analysis of an extensive series of nightly catches of insects from Kwadaso, Ghana, and Kawanda, Uganda, has been completed. It was found that most of the differences in average catch at different phases of the moon could be explained by linear regressions on the amounts of moonlight. Procedures were developed which enabled inferences to be drawn, from total nightly catches, about periods of insect activity which confirmed deductions that had been made previously from graphical analysis of changes in trap effectiveness (*Rothamsted Report for 1970*, Part 1, 192). An hypothesis is proposed to explain how a light trap affects insect behaviour. This hypothesis allows the changes in catch, during the lunar cycle, of most insects to be attributed to differences in the effectiveness of the trap caused by differences in background illumination. Comparison of catches, between different periods at one locality and between localities, show that the regression coefficients for each of the species that were compared have the same sign in each period and locality, so that the evidence on how night illumination affects catch, and on the times of night which have most effect, is consistent. Many factors may influence catch on any one night and only for a few species is variation in moonlight itself one of the major factors. There is strong support for a previous suggestion (*Rothamsted Report for 1970*, Part 1, 192–193) that the activity of many species is greatest on light nights at full moon. (Bowden, with Church, Statistics Department)

The pattern of moonlight in latitudes near the equator is relatively stable, there being little variation between successive lunar cycles or between times of the year. This consistency has made it possible to compile a table of amounts of moonlight which is applicable to all localities between 10°N and 10°S, thus providing a basis for the comparative analysis of light trap catches in equatorial latitudes. A further table, of grouped phases of the moon, has been compiled which can be used irrespective of latitude to arrange light trap catches (or other data) in direct relation to the phase of the moon. When catches are so arranged, characteristic catch curves are obtained which allow conclusions to be drawn as to which periods of the night particular species are most active. One such curve suggests that the amount and distribution of moonlight at and just after full moon, may have a marked photoperiodic effect on some aspects of insect behaviour.

In low latitudes, there is a period at full moon when night illumination in combination with the corresponding periods of daylight results in about 72 hours of continuous illumination above 0·1 lux. This period of continuous light is followed by lengthening intervals of darkness, beginning just after sunset, from about three nights after full moon, and the index of trap effectiveness (*Rothamsted Report for 1970*, Part 1, 192) shows a correspondingly rapid increase during the early part of the night. Several species show comparable increases in numbers caught just after full moon, suggesting that they may be active in the early party of the night, but, in most cases, at no point in the lunar cycle are the numbers caught greater than at new moon. However, catches of some species, notably of Mantispidae (Neuroptera) and of the noctuid moth, *Schalidomitra variegata*, increased rapidly just after full moon reaching numbers well above those at new moon. This suggests that their activity had been inhibited by too much light at full moon and was later released by the early evening darkness which recurred a few days after full moon. An analysis of published data (Nemec, S. J. (1971), *Journal of Economic Entomology* **64**, 860–864; Alam, M. M. & Hudson, J. C. (1969), *Proceedings of West Indies Sugar Technologists* 193–198) reveals a similar pattern in both light trap catches and oviposition of the American cotton bollworm, *Heliothis zea*, and in catches at light of adults of the sugar cane borer *Diatraea saccharalis*, so that in these species flight activity, and in *H. zea* oviposition as well, may be inhibited by bright moonlight at full

https://doi.org/10.23637/ERADOC-1-127

moon and released by subsequent dark intervals. A photoperiodic response, regulated by the amount and distribution of moonlight at and just after full moon, could form the basis for a simple but reliable method of predicting behaviour patterns such as peak oviposition or emergence periods. (Bowden)

Aphid migration and population density

Work done on the effect of population density on migratory morphology, physiology and behaviour in *Aphis fabae* (Black bean aphid) has been prepared for publication. As the aphid population density in field infestations of beans and sugar beet increased, more winged aphids were produced and, of these, more were migrants and less reproduced before flight. As the population declined, more forms intermediate between winged and wingless ones were produced and more nymphs deposited before migration.

Winged aphids produced on sugar beet were, on average, bigger than those produced on field beans, and broad-bean aphids were smaller; size diminished generally through the period of colonisation. Few of the very large or very small *A. fabae* from any crop were classed as migrants on physiological and behavioural grounds, nor were they caught in Survey traps while flying. Non-flying aphids had shorter wings than migrants, and aphids on sugar beet had shorter ones than those on beans. Aphids that reproduced before flight were initially heavier than those that flew immediately, but after reproduction and before flight they were lighter. The numbers of sense organs on the antennae of winged aphids differed more on different crops than between migratory classes on the same crop, but aphids presumed to be flying from field beans had more sense organs than those on the crop. Evidently the response to the host plant and the migratory status of the aphid interact in a highly complex way. (Shaw and Taylor)

Bean aphids

Further surveys were made in the Harpenden area of populations of *Aphis fabae* on its winter host, *Euonymus europaeus*, as part of a collaborative programme for predicing infestations on beans and sugar beet, organised by Professor M. J. Way. In 1971–72 overwintering populations were small, though larger than in the previous two years. Moderate infestations occurred on spring-sown field beans, up to 80% of the stems being infested on untreated plots.

Methods and times of applying insecticides were again compared on Rothamsted Farm, using demeton-s-methyl sprays at 240 g a.i./ha and phorate granules at 1·1 kg a.i./ha and applications both before and after flowering. Good control of aphids was obtained, especially with treatments applied before flowering, but yield differences between treatments were small and not significant. Yields varied from 2·99 to 3·32 t/ha, and differences between treatments were masked by a very heavy attack of stem eelworm, yields from eelworm-free crops elsewhere on the Farm being about half as large again. (Bardner and Fletcher, with Stevenson, Insecticides Department, and Moffatt, Farm)

Ecology of cereal aphids

The first alate specimens of *Sitobion avenae* and *Metopolophium festucae* were caught in the Survey suction trap on Rothamsted Farm at the end of May, about five weeks later than in 1971. The first individuals were found on cereals three or four weeks later. The first appearance of *Metopolophium dirhodum* in the trap and on cereals coincided. Aphids attacking cereals in mid-July, when numbers were greatest, were much fewer than in 1970, and only about half as many as in 1971. There were more *M. dirhodum* on oats (max.

https://doi.org/10.23637/ERADOC-1-127

39/1 ft of row) than on barley (max. 22/1 ft of row). *S. avenae* was present in similar numbers on both crops (14 and 11/1 ft of row). Most alate *M. dirhodum* and *S. avenae* were trapped between the middle of July and early August. The fewer *M. festucae*, mainly alatae and nymphs (max. < 2/1 ft of row) were commonest on the cereals early in July and in the trap in mid-July. The very few alate *Rhopalosiphum padi* found on cereals at Rothamsted did not appear to succeed in reproducing themselves.

Aphid populations probably remained small throughout 1972 because June was so cold and rainfall above average. Although very few ladybird and hoverfly predators were found, parasitisation of aphids by species of a Braconid wasp, *Aphidius*, occurred throughout the season, reaching a peak in July when up to 45% of *M. dirhodum*, 39% of *M. festucae* and 24% of *S. avenae* were attacked. Similarly, aphids infected by fungi, *Entomophthora* spp., were found in late June. Infection of *M. festucae* increased to a maximum of about 47% by early July, and that of *M. dirhodum* and *S. avenae* to about 46% by the end of the same month. (Dean)

Effects of temperature and host plants on cereal aphids. The effect of temperature within the range 10°–30°C on *Metopolophium dirhodum*, *Rhopalosiphum padi* and *Sitobion avenae* was measured in controlled environment cabinets. Development of the aphids from birth to maturity was determined by rearing them on segments of cereal leaves floating on a nutritive solution, while fecundity and survival of apterae were studied on young cereal plants growing in pots under lantern jars. Development rates increased with temperature to a maximum at 20°C for *M. dirhodum*, 22·5°C for *S. avenae* and 25°C for *R. padi*; decreasing thereafter to zero at 28–30°C when all the nymphs of all species died. Fourth instar nymphs and pre-reproduction adults appeared to be harmed by lower temperatures than younger instars.

Mortalities of immature *S. avenae* were similar between 10° and 25°C, but more immature *M. dirhodum* died at high, and *R. padi* at low, temperatures. Survival rates decreased with increase in temperature, and fecundity was greatest at 20°C.

Rates of increase became larger up to 20°C for *M. dirhodum* and *S. avenae*, and 25°C for *R. padi*. Above 15°C, *R. padi* multiplied 4–16 times more rapidly than the other two species, both because it developed faster and because it achieved its rate of maximum fecundity sooner. The rates of increase for *M. dirhodum* and *S. avenae* were similar up to 20°C.

In controlled temperature, light and relative humidity, *M. dirhodum* and *S. avenae* multiplied more on young barley (Proctor) than on oats (Blenda), and less on wheat (Cappelle). *R. padi* increased in number fastest on barley and slowest on oats. More *M. dirhodum* and *S. avenae* survived and developed more quickly when they were fed on barley than on wheat or oats. By contrast, *R. padi* did best on wheat. In outdoor cages, mature barley was attacked most by *M. dirhodum*, wheat by *R. padi*, and oats by *S. avenae*. (Dean)

Fungal diseases of aphids

Field incidence of Entomophthoraceae. Two samples, each of 100 adult apterous pea aphids, *Acyrthosiphon pisum*, were collected each week from 17 April to 13 November from the same plot of lucerne in Highfield that was sampled in 1970 and 1971, to estimate the incidence of *Entomophthora* spp. The aphid population remained less than 0·4 aphid/g dry weight of lucerne from 17 April until the end of June. It then increased to a maximum of 1·2 aphid/g in early July and subsequently declined. From mid-August until early October, aphids were very scarce but their numbers increased to 0·9 aphid/g by 6 November. These fluctuations in the aphid population on lucerne parallel those in the same field in 1971 although the population remained much smaller in 1972, the

https://doi.org/10.23637/ERADOC-1-127

maximum being only one quarter of that of the previous year. An average of 2·3% of the pea aphids were infected with *Entomophthora thaxteriana* from 17 April to 1 August, reaching a peak of only 10·0% on 24 April. As in 1971, a few aphids were infected with *E. thaxteriana* during October as the aphid population increased. *E. aphidis* infected an average of 2·5% of aphids from 14 July to 13 August, and *E. planchoniana* an average of 11·0% from 18 July to 7 August, reaching a maximum of 15·0% on 1 and 3 August.

Two samples, each of 50 pea aphid nymphs of each of the four instars, were collected each week, from the same site in Highfield, from 26 June to 1 August. Nymphs of each of the instars were found to be infected with the same three species of *Entomophthora* with which the adult aphids were infected, and, from 26 June to 17 July, the proportion of infected nymphs was the same in each instar as in adults in corresponding samples. However, from 20 July to 1 August twice as many adults as nymphs were infected.

In samples of alate bean aphids, *Aphis fabae*, removed within 24 hours of their having alighted on broad-bean plants, *Vicia faba*, at Rothamsted Lodge on most days from 10 August to 7 September, 19·7% were found to be infected with *Entomophthora* spp. Of these, 31·0% were infected with *E. aphidis*, 5·2% with *E. fresenii*, 60·3% with *E. planchoniana* and 3·4% with *E. thaxteriana*. It has been thought that *Entomophthora* spp. probably spread from one population of insects to another by means of airborne conidia. However, the observations described above, considered together with the fact that conidia quickly desiccate in dry air, suggest that the fungi were being distributed by flying, infected aphids. (Wilding and Brobyn)

Resting spore formation by *Entomophthora fresenii*. *E. fresenii* produces conidiophores on infected bean aphids (*Aphis fabae*) in summer, but in autumn an increasing proportion of infected aphids contain resting spores (*Rothamsted Report for 1970*, Part 1, 207). In order to find out whether temperature or day length affects the production of resting spores, groups of live bean aphids, some infected with *E. fresenii* and living on dwarf broad beans (*Vicia faba*), were kept at 7° and 14°C and exposed to six or 18 hours light every 24 hours. The saturation deficiency of the atmosphere surrounding the plants was kept at 1·9 mmHg in all treatments; the aphids living at 14°C were transferred every seven days, and those living at 7°C every 14 days, to fresh bean plants that had been grown at 20°C with 18 hours light per day. After six weeks at 14°C with an 18-hour day, no resting spores had been formed in the infected aphids; but of those infected aphids kept at 14°C with a six-hour day, resting spores had developed in 4, 26 and 55% after two, four and six weeks, respectively. Resting spores developed in 0, 0 and 24% of infected aphids in an 18-hour day, and in 0, 30 and 92% in a six-hour day, after two, four and six weeks, at 7°C, respectively. This shows that short day lengths and low temperatures, separately or, more effectively, together, induce *E. fresenii* to produce resting spores in infected aphids. It is not yet known, however, whether this fungus is influenced directly by the environmental factors or indirectly by the effect these factors have on the aphid or on its host plant.

Resting spores and conidiophores of *E. fresenii* were never found together in the same aphid. Furthermore, although an aphid's choice of feeding site on a plant was not obviously affected by environmental conditions, most aphids containing resting spores died on the stems or petioles of the plants, whereas those with conidiophores died on the leaves. (Wilding)

***Cephalosporium aphidicola*.** *C. aphidicola*, isolated from the aphid *Myzus persicae* from a glasshouse at the Glasshouse Crops Research Institute, Littlehampton, Sussex, and maintained *in vitro*, infected *Acyrthosiphon pisum*, *Aphis gossypii* and *M. persicae* when sprayed as a spore suspension on these aphids on plants. Fifty per cent of adult apterae

https://doi.org/10.23637/ERADOC-1-127

of *A. pisum* and *M. persicae* were killed on 10–20 cm high broad bean and turnip plants, respectively, when each plant was sprayed with about 5×10^6 spores in 3 ml water.

Because systemic fungicides are used in the routine control of cucumber powdery mildew, *Sphaerotheca fulginea*, the effects of some of these fungicides on *C. aphidicola* were studied before testing the possibility of controlling *A. gossypii* on cucumbers with this fungal pathogen, as part of an integrated control programme in glasshouses. Benomyl cannot be used in such a programme because it diminishes egg fertility and kills nymphs of the predatory mites, *Phytoseiulus* spp., used for controlling the red spider mite, *Tetranychus urticae*. However, because benomyl is currently the most important fungicide in chemical control programmes for cucumber mildew it was also examined in these tests. Growth of *C. aphidicola in vitro* was inhibited by benomyl and by triarimol but not by dimethirimol. *Aphis gossypii* experimentally infected with *C. aphidicola*, were fed on cucumber plants treated with the three fungicides. Benomyl was aphicidal, even at an eighth of its usual concentration, and its effect on the fungus in the host aphid could not, therefore, be seen, but triarimol and dimethirimol did not prevent fungal development in the host. Triarimol probably does not affect the growth of *C. aphidicola in vivo* because, as with all systemic fungicides in current use, it is not transported in the phloem where aphids feed. Presumably benomyl is so toxic that sufficient was taken up from other tissues to kill the aphids when they were probing.

These results suggest that *C. aphidicola* can be used to control *A. gossypii* when powdery mildew on cucumbers is being controlled with triarimol or dimethiriomol. This work is being continued by Dr. H. D. Burgess at the Glasshouse Crops Research Instiiute. (Wilding)

Wheat bulb fly

Behaviour and ecology. Observations were continued in Stackyard field, where an infestation of wheat bulb fly (*Leptohylemyia coarctata*) has been maintained since 1964 by rotating wheat with fallow. The egg population was 1·98 million/ha in the winter 1971–72. Wheat was sown early (14 October 1971) and this, together with the mild winter, aided plant establishment and shoot development so that bulb fly larvae had little difficulty in finding suitable shoots to attack. Twenty-eight per cent of eggs gave rise to adults, the highest figure we have recorded, and this resulted in a population of 0·54 million adults/ha, more than three and a half times as many as in 1971. This greatly facilitated observations on their movements, for monitoring which both water and suction traps were again used.

Suction-trapping on wheat and fallow areas of the field showed that adult flies emerged between about 27 June and 27 July, reaching a peak between 6 and 13 July; most being caught between 1730 and 2200 hours BST, the time of day when most eggs are laid. The maximum catch coincided with peak emergence in 1972 and contrasted greatly with that of the previous year when the maximum catch was at the end of the emergence period. This suggests that the adults were dying or dispersing sooner after emergence than they had done in 1971. Egg-laying was favoured by rainfall being below average in July and August, resulting in a population of about 4·32 million eggs/ha in the autumn of 1972.

Water traps in a crop of spring wheat half-a-mile from Stackyard field, the nearest known source of adult flies, caught immature females within a week of their emerging, showing that dispersal from emergence sites was quite rapid. Similar early catches of immature females were made by the water traps in the fallow parts of Stackyard field. All water trap catches fluctuated somewhat with weather and were diminished by heavy rain.

Catches by suction traps placed either at ear height in the wheat crop or at soil level in the fallow varied less with the weather than did those of water traps. As in 1970, the

https://doi.org/10.23637/ERADOC-1-127

suction traps in the fallow caught most flies when the females had mature ovaries and were egg-laying, which was during the week ending 10 August, about four weeks after they had emerged. A second batch of eggs were laid between 23 August and 14 September; there was no evidence that a third batch was laid. While the flies were laying the first batch of eggs, many of the flies were attacked by entomophagous fungi, chiefly by *Entomophthora muscae*. During the weeks ending 6 August, 10 August and 17 August, 88, 66 and 61%, respectively, of the flies caught in suction traps, and 57, 62 and 67%, respectively, of those caught in water traps were infected, a mean of 40% of flies caught during the egg-laying period being infected.

An attempt was made to measure the survival and dispersal rates of adult flies by marking over 8000 of them with fluorescent dusts. Unfortunately, the number recaptured was too small for these purposes, but enabled an estimate of the total adult population to be made, which was comparable to that obtained from emergence trap catches. (Bardner, Fletcher and Margaret Jones)

Adult wheat bulb flies

Activity of adults. Adult wheat bulb flies were kept, at 20°C with light from 0600 to 2200 hours each day, in a cage, 1 m square, designed automatically to record flight activity. The females were most active between 1400 and 2200 hours, showing very little activity in the early part of the day and none in darkness. This agrees very well with the time of day when most have been caught in suction traps in the field. Possible differences in activity patterns between the sexes and between mature and immature adults are being studied. (Bardner, with Arnold, Insecticides Department)

Population fluctuations of wheat bulb fly at Rothamsted. Several fields on Rothamsted Farm have rotations resulting each year in some plots being fallowed before being sown with winter wheat, so providing ideal conditions for maintaining natural populations of wheat bulb fly. In an attempt to improve prediction of severe infestations, records of these populations have been examined to determine the size and causes of population fluctuations from year to year.

Samples to determine the number of eggs laid have been taken in most years since 1952, the estimated numbers of eggs varying from 0·05 million/ha to 8·81 million/ha, with a mean of 2·67 million/ha. Populations varied synchronously in the three fields in which observations were made. Although the populations apparently cycled between peaks of abundance every 5–10 years, no consistent tendencies for populations to increase or decrease were apparent, and they seem to have been regulated by density-dependent factors, especially competition between larvae for wheat shoots, and also probably disease of adult flies. The cycles were probably caused by climatic fluctuations, because the numbers of eggs laid in the fields were significantly correlated with the weather conditions during the egg-laying periods, fewer eggs being laid when the weather was cold and wet in July and August. Weather may also affect the survival of newly hatched larvae. The maximum survival rate from egg to adult was 28%, the minimum 7%, the mean being 13%.

Records of wheat bulb fly infestation in Eastern England are now being examined to determine how much of the variation between districts and seasons can be explained by variations in weather and land use. (Bardner, Fletcher, Margaret Jones and Lofty)

Infection with fungi. In attempts in previous years to infect adult wheat bulb flies with the fungal pathogen *Entomophthora muscae*, the flies used had emerged in cages in an outdoor shelter from puparia collected in the field. Few of these experimental flies became

https://doi.org/10.23637/ERADOC-1-127

infected when caged with wheat bulb flies from which the conidia of *E. muscae* were being discharged. However, in July 1972, when flies that had recently been caught in the field and others that had emerged in cages were exposed to infection in the same way, 100% of the flies that had been caught in the field became infected whereas the others did not. Also, 60% of healthy field-caught flies, but none from cages, became infected when exposed to conidia of this fungus discharged from cabbage root flies, *Erioischia brassicae*. Unfortunately, further work was hampered by a high incidence of this disease in the field during August. It is clear, however, that previous unsuccessful attempts to transfer *E. muscae* from infected scatophagids, syrphids and other flies to wheat bulb flies must be repeated using wheat bulb flies caught in the field.

During 1972, wheat bulb flies were not sampled in the field each week to assess the proportion of infected ones, as in previous years, but many flies infected with *E. muscae* were seen at Streatley, Bedfordshire, from early July to early August, and on Rothamsted Farm from late July to the end of August; no flies infected with any other species of *Entomophthora* were seen. (Wilding)

Comparative effects of attack by wheat bulb fly on four wheat varieties. A further experiment was made in Stackyard field, with a wheat bulb fly egg population of 1·9 million/ha, to compare the effect of attack on the varieties Cappelle-Desprez, Joss Cambier, Maris Ranger and Maris Widgeon. An early sowing was made of each variety on 12 October, followed by a later one on 6 November. When the wheat bulb fly eggs hatched, plants from the earlier sowing each had two or three shoots and, although up to 50% of these plants were attacked, yields were very good (Table 2), except for Joss Cambier, the yield of which was depressed by yellow rust. By contrast, plants from the later sowing had only one shoot each when the eggs hatched, and many were attacked and killed. Ear production by plants from the later sowing was limited by the few shoots present when attack ceased early in May, and yields were only about half those of the plants from the earlier sowing.

TABLE 2

Yield of four wheat varieties attacked by wheat bulb fly (t/ha)

Variety	Date of sowing 12.10.71	6.11.71
Cappelle-Desprez	7·63	3·90
Joss Cambier	6·31	2·95
Maris Ranger	7·46	4·39
Maris Widgeon	7·39	4·23
S.E. of differences: Variety		±0·25
Sowing date		±0·18
Variety and sowing date		±0·36

Although differences in yield between the varieties were not significant, they corresponded with differences in the number of shoots per plant in March; Maris Ranger had the most shoots and Cappelle-Desprez the least. The differences between varieties were too small to be of much practical use, but the experiment confirmed that the response of other wheat varieties to attack was essentially similar to that of Cappelle-Desprez, with which most of our work on yield loss has been done. (Bardner and Fletcher)

Phenology of insects in a wheat field. As in the previous year, the populations of insects and spiders in Stackyard field were regularly monitored by means of pitfall traps and emergence cages, except when normal cultivations were being done. Twelve pitfall traps were sited in the growing wheat crop and left in the stubble after harvest. As in 1970–71,

https://doi.org/10.23637/ERADOC-1-127

the traps always contained spiders. During the winter, carabid beetle larvae, *Feronia* sp. and *Harpalus* sp. were caught, and as the soil warmed up from March onwards into the summer, other small carabids, such as *Bembidion* spp. and *Acupalpus meridionalis* became increasingly active. They were joined in April and May by *Notiophilus biguttatus*, *Agonum dorsale* and many small staphylinid beetles. In June and July, *A. dorsale* was caught most frequently, but *Feronia vulgaris* (= *melanaria*) and *Harpalus ruficornis* (= *rufipes*) were also common; other carabids and staphylinids occurred in smaller numbers. In October, the small carabid, *Trechus quadristriatus*, which eats wheat bulb fly eggs when offered them, was active and commoner than in the autumn 1971. On 4 September, the stubble was burnt and during the following week only three spiders and one *Feronia vulgaris* were caught. The effect of burning was gradually lost, for whereas after four weeks 17 spiders and nine beetles were caught, during the next four-week period the numbers rose to 45 spiders and 130 ground beetles. This compared with 25 spiders and 110 beetles caught during the four weeks previous to the firing of the stubble. There was, therefore, after one month a recolonisation by spiders and beetles of the area affected by the fire.

Ten emergence cage traps were kept over fallow until September when they were moved on to the burnt stubble. With some slight differences, the pattern of insect emergence was similar to that of 1971. Weevils of the genus *Sitona* (chiefly *S. lineatus*) were fairly common in March, and a fungus gnat, *Sciara* sp., was plentiful. The winter gnat, *Trichocera regulationis*, emerged during late February and early March. Also during the winter, a small fly, *Lonchoptera lutea*, which was not recorded during the winter 1970–71, appeared from early in December until the end of March. From March until the end of April, gall midges emerged from the soil in large numbers, continuing to do so sporadically until August. A chironomid midge, *Smittia* sp., was also common in March, April and May. Fungus gnats emerged continuously throughout the summer and early autumn, while phorids were numerous late in June and early in July. A chalcid wasp, parasitic on stem boring insects, *Cyrtogaster vulgaris*, was caught in small numbers during March, and other parasitic hymenoptera were present in small numbers in spring and autumn. Spiders were common throughout the year.

During the weeks following the burning of the stubble on 4 September, few arthropods were caught before the field was ploughed on 6 November, compared with the two previous years—e.g. in 1972: 1971: 1970—spiders, 18: 714: 107; phorids, 2: 77: 94; sciarids, 15: 456: 647; *Lonchoptera lutea*, 1: 252: 2; parasitic hymenoptera, 11: 517: 99; *Sitona lineatus*, 1: 4: 28. The 1970 catch was probably somewhat diminished because the field was ploughed on 3 October, earlier than in 1971 and 1972. It is clear that the stubble burning in 1972 affected the emergence of a number of insects, particularly sciarids and parasitic hymenoptera. (Margaret Jones)

Invertebrates and pasture productivity

Effect of pesticides on old and new grass. Investigations into the effect of insects and other invertebrates on the yield and botanical composition of grassland have been continued in collaboration with the Ecology Department, Grassland Research Institute, Hurley. Continued treatment of old grassland with high rates of pesticides, in a field experiment begun in 1969 at Rothamsted, produced small increases in yield (13 and 17%) in one of the three harvests, but did not affect total yield over the year. By contrast, continued treatment of perennial ryegrass (S 23), sown at Hurley in 1969, induced yield increases for the third successive year. Six of the treatments gave total annual increases of between 6 and 21%. (Henderson, with Mr. R. O. Clements, Grassland Research Institute, Hurley)

https://doi.org/10.23637/ERADOC-1-127

Differential persistence of soil insecticide. It was thought that the difference in yield response reported above might be caused, at least in part, by differences in the method of application of pesticides used at the two sites, resulting in differential rates of breakdown and loss, particularly of the persistent chlorinated hydrocarbons which are associated with increased yields in most instances.

To investigated this possibility, samples of soil were taken in November 1971 from plots on the experiments at Rothamsted and at Hurley, and analysed by using gas–liquid chromatography with an electron-capture detector. Peaks corresponding to aldrin and dieldrin were obtained with soils from both sites. The same amount of insecticide (emulsifiable aldrin in water at 22·4 kg/ha a.i.) had been applied at the same time at both sites, but whereas at Hurley it had been applied to bare soil which was then cultivated and sown with ryegrass, at Rothamsted it had been applied to the undisturbed surface of the old grass. Also, 'DD' soil fumigant was used at Hurley before sowing.

Much more of both aldrin, and its oxidation product dieldrin, were found in the Hurley soil (3·0 ppm aldrin + 2·1 ppm dieldrin) than in the Rothamsted soil (0·06 ppm aldrin + 0·65 ppm dieldrin), a difference in persistence probably caused by the different method of application. The apparently greater persistence of aldrin and its relatively slow conversion to dieldrin at Hurley, suggested that the conversion may have been inhibited by the 'DD' pretreatment, but a laboratory test using the Rothamsted soil failed to show any effect of 'DD' on the rate of conversion of aldrin to dieldrin. (Henderson, with Lord, Insecticides Department)

Effect of insecticides on ryegrass at four different sites. Yield measurements and faunal counts were continued during 1972 at the four sites, in Yorkshire, Lancashire, Kent and Devon, where treatment of two-year-old ryegrass swards with aldrin plus phorate was begun in spring 1971. At Helmshore (Lancs.) no yield response was obtained in any harvest. At Duggleby (Yorks.), and at Wye (Kent), treatment did increase yield in one cut but the total yield for the year was not significantly affected. At Starcross (Devon) treatment increased yield in three of the five harvests taken, and yield for the year was 24% greater than on untreated plots. Some differences in the insect fauna of the sites were found and a possible relationship between insect abundance and grass yield is being examined.

Laboratory experiments, to find out whether the observed effects of pesticides on yield of grass can be explained by something other than alterations in the numbers of living invertebrates present, have been continued. No direct growth stimulating effects were noted when grass grown in insect-free soil in pots received equivalent doses of the various pesticides used in the field experiments. The possible effect on growth, of the release of nutrients from the decaying bodies of earthworms that had been killed by pesticides, was also studied. Perennial ryegrass (S 23) receiving the equivalent of 0, 126, or 377 kg of nitrogen/ha was grown in soil in which macerated earthworms had been incorporated at rates equivalent to 0, 1121, or 2242 kg biomass/ha. Yield response to the fertiliser nitrogen was highly significant and virtually linear over this range, but no response to the addition of macerated earthworms was detected at any of the three levels of fertiliser nitrogen. (Henderson, with Mr. R. O. Clements, Grassland Research Institute, Hurley)

Invasion of perennial ryegrass swards by dipterous stem-borers. Stems of perennial ryegrass from swards of two different ages, one that had been sown in September 1970 and the other in April 1972, were examined for larvae of stem-boring Diptera. Four species of *Oscinella* and one of *Geomyza* were found; the species composition of the population apparently depending on the age of the grass. *G. punctata* was the most abundant species early in the season on young grass, whereas *O. vastator* was the most

https://doi.org/10.23637/ERADOC-1-127

numerous species attacking the older grass. By the end of 1972, however, *O. vastator* had become the dominant species on both swards, although differences were still apparent in the relative abundance of some of the other stem-borers. Larval density per unit area was similar on both swards, but because the number of grass stems on the younger sward was much less than on the older one, the percentage of attacked stems was much higher. (Henderson and Idowu)

Soil fauna

The effects of pesticides on predatory beetles. Carabid and staphylinid beetles are important predators of pests of agricultural crops, so that when there is a choice, a pesticide that avoids killing these beetles is to be preferred. Therefore, during the last four years we have compared the effects on these beetles of seven pesticides commonly used on the soil. All of these, except chlorfenvinphos, were found to be more or less toxic to them (see *Rothamsted Report for 1971*, Part 1, 210–211). This year, we have begun a field experiment to find out whether non-persistent pesticides applied one year before have any residual effects on the beetle population the following year. Because field experiments of this kind require the erection of barriers between plots and take a lot of time and labour, and because information on the susceptibility of predatory beetles to new pesticides is needed urgently, we have developed a laboratory method of screening pesticides for toxicity. Beetles are caught in pitfall traps in the field and, to avoid cannibalism, are kept individually in small, disposable containers on moist plaster of Paris and fed on aphids. The toxicity of a pesticide is assayed by applying known amounts externally to the thoraces of a series of test beetles, with a hypodermic syringe. Excellent, repeatable results can be obtained by this method, and each of the seven pesticides that had previously been tested in the field were assayed in the laboratory with very similar results, except that disulfoton was much less toxic in the laboratory than in the field. The probable explanation of this difference is that, because this is a systemic insecticide unlike the other six, and carabid beetles occasionally eat small amounts of plant material when animal food is scarce, more of them were killed in the field through eating contaminated plants. (Edwards, Lofty and Dodson)

Cutworms. Investigations of the biology, ecology and economic importance of several cutworms were begun in 1972. Daily records of flight were obtained with a Robinson mercury vapour light trap on Rothamsted Farm, from May to October (Table 3, p. 212).

These data indicate that, in common with many agricultural crops and other insects, the development, and hence the flight periods, of noctuid moths was delayed in 1972 by the cold weather in late spring and early summer.

Tungsten light traps were also installed at ground level at five other sites, in Perthshire, Lancashire, Leicestershire, Warwickshire and Devonshire. The records of temperature and daily catches of moths at each site, show that their flight periods occurred appreciably later in the north than in the south, and it is hoped that it will be possible to develop a temperature summation model for larval development. (Haines and Edwards)

Eggs were obtained from caged moths of several of the more common species. Many hatched when kept in crystallizing dishes on moist plaster of Paris; four species, *Agrotis segetum*, *A. exclamationis*, *Triphaena pronuba* and *Apamea secalis*, being reared successfully on fresh lettuce. It seems probable that other species can be reared in this way on other foods. (Edwards and Whiting)

Pesticides and earthworms. Field tests of the effects of pesticides on earthworm populations were continued. No significant effects were detected when the fungicides, formalde-

https://doi.org/10.23637/ERADOC-1-127

TABLE 3

Flight periods of cutworm moths at Rothamsted, 1972

Species	Flight period	Date of peak catch	Normal, annual flight period	Total moths caught
Turnip moth *Agrotis segetum*	20 June–31 July	21 July	June–July	52
Heart and Dart *Agrotis exclamationis*	10 June–4 Sept.	25 July	June–July	862
Rustic Shoulder Knot *Apamea sordens*	23 June–21 July	1 July	May–June	9
Large Yellow Underwing *Triphaena pronuba*	12 July–9 Oct.	3 Oct.	June–July	369
Common Rustic *Apamea secalis*	29 July–17 Sept.	26 Aug.	July–August	237
Lesser Yellow Underwing *Triphaena comes*	29 July–28 Sept.	27 Aug.	July–August	56
Garden Dart *Euxoa nigricans*	11 Aug.–7 Sept.	28 Aug.	July–August	15
Flounced Rustic *Luperina testacea*	26 Aug.–4 Sept.	30 Aug.	August–September	16

hyde (5050 litres/ha), captan (9·0 kg/ha), quintozene (5·6 kg/ha), thiram (6·7 kg/ha) and dicloran (2·0 kg/ha) were cultivated into the soil, but benomyl (10·0 kg/ha) was very toxic to them.

During the last ten years, we have tested about 40 pesticides in the field for toxicity to earthworms. However, because such tests are very laborious we have recently tried to develop a quicker and simpler method of testing. The earthworms were cultured in boxes of soil that had been treated with the recommended doses of pesticides, and their death-rate determined fortnightly. Tests of 28 pesticides by this method generally confirmed the results previously obtained in field tests, namely that diazinon, tetrachlorvinphos, fenitrothion, monocrotophos, methiocarb, disulfoton and trichlorphon have little effect on earthworms, and that chlordane, thionazin, benomyl and carbaryl are very toxic to them. Phorate was much less toxic than in field tests. However, thionazin, fonofos, methomyl and dazomet were all moderately toxic in box tests in the laboratory and there was some mortality in cultures treated with lindane, aldrin and dieldrin, whereas in field experiments, none of these compounds appeared to have much effect on earthworm numbers. There are several possible reasons for these differences, such as different degrees of mixing of the pesticides with soil, different activity of worms in culture, or their greater susceptibility in culture. Thus, it seems unlikely that such laboratory tests will prove a satisfactory substitute for field tests, although they provide valuable supplementary information. Other laboratory tests, in which earthworms were immersed in pesticide solutions, were also unsatisfactory. (Edwards and Lofty)

Uptake of pesticides by earthworms. It is well established that earthworms accumulate organochlorine insecticides from the soil in which they are living. In order to find out how quickly they do this and whether degradation occurs within worms, earthworms were kept in boxes of soil containing 1 ppm DDT. At intervals, four worms were removed and the DDT residues in them and in the soil assayed using GLC. The residues in the worms reached equilibrium with those in the soil after two or three months' exposure, with four or five times as much in the worms as in the soil, nearly half the residue in the worms being DDE. The rate of excretion was measured by keeping worms, that initially contained 5–6 ppm of DDT residues, in clean soil and periodically assaying samples of

https://doi.org/10.23637/ERADOC-1-127

the worms and of the soil. It was more than five months before the residues in the worms reached a very low level; the DDT was excreted very quickly but the DDE was much more persistent. (Edwards with Jeffs, Insecticides Department)

Earthworms at Saxmundham. In May 1972, earthworms were sampled at two sites at Saxmundham. On one of these cereals had been grown since 1965, although it was fallow at the time of sampling; the other site had been under grass for the same length of time. Twelve quadrats, each 0·37 m^2, were sampled with formaldehyde at each site (Table 4).

TABLE 4

Earthworms in samples of arable (4·44 m^2) and grassland (4·44 m^2) at Saxmundham

Species	*Lumbricus terrestris*	*Lumbricus castaneus*	*Allolobophora caliginosa*	*Allolobophora chlorotica*	Total number	Total weight (g)
No. in arable	2	3	4	6	15	5·2
No. in. grassland	66	1	—	—	67	82·0

Only 15 worms, weighing a total of 5·2 g, were obtained from the arable site, compared with 67, weighing 82 g, from the grassland. The much greater proportionate weight of worms from the grassland was because all but one worm was a large species, *Lumbricus terrestris*, whereas most of those from the arable were smaller species. The proportion of *L. terrestris* in the population from the arable site was exceptionally low, which may perhaps have been because of the small amount of surface litter present. It is interesting that the worm population of this arable site at Saxmundham is similar to that of a plot in Barnfield field, Rothamsted Farm, to which no nitrogen or other fertilisers have been applied for many years. Barnfield soil is similar to that at Saxmundham in having a high clay content, and being poor in organic matter, fairly alkaline and poorly drained.

The earthworm population at the grassland site was also exceptionally small, and composed almost exclusively of *L. terrestris*. However, this site was not typical of pasture because its soil had been compacted by traffic, so that many of those species which normally occur in the top few centimetres of grassland had probably been eliminated.

A more extensive sampling programme at Saxmundham is planned for next year in order to obtain a clearer picture of earthworm populations there. (Lofty).

Pesticides and the arthropod soil fauna. The effects of fungicides on populations of soil arthropods have been little studied. Even if they have no direct effects, it might be anticipated that their influence on soil micro-organisms, on which many of these animals feed, might cause changes in the numbers of the latter. During 1972, we tested the effects of formaldehyde (5050 litre/ha), captan (9·0 kg/ha), quintozene (5·6 kg/ha), thiram (6·7 kg/ha), and dicloran (2·0 kg/ha) on populations of soil arthropods in Road Piece field, Rothamsted Farm. None of these pesticides had a significant effect on the soil arthropod populations and, surprisingly, their effect on most soil micro-organisms was relatively transient, few effects lasting for more than a month after treatment. Treatments have been repeated twice to see if their effects are cumulative, and the experiment is continuing. (Edwards and Lofty, with Dr. G. Pugh, University of Nottingham)

The effects of two insecticides, monocrotophos (1·5 kg/ha) and endrin (4·0 kg/ha), two herbicides, 'Bladex' (4·0 kg/ha) and 'Suffix' (2·0 kg/ha), and the nematicides 'D-D' and dichloropropene (each at 440 kg/ha), on soil arthropods were tested in three field experiments in Kent. Monocrotophos, 'Bladex' and 'Suffix' had few effects but endrin, 'D-D' and dichloropropene were highly toxic, confirming results previously obtained

https://doi.org/10.23637/ERADOC-1-127

with the latter two chemicals (see *Rothamsted Report for 1971*, Part 1, 211). (Edwards and Stafford)

Pesticides and pond animals. Three ponds in Kent were treated with either an insecticide, chlorfenvinphos (4·0 kg/ha), or one of two herbicides, 'Suffix' (1·5 kg/ha) or 'Shell WL63611' (40* kg/ha) by spraying their surfaces. Three similar, but untreated, ponds served as controls. Samples of water, mud, aquatic plants, fish and invertebrates were taken at regular intervals after treatment. None of the pesticides had any significant effects on the populations of invertebrates living in the mud, but chlorfenvinphos killed some fish and newts. Residues of all three pesticides disappeared rapidly from the water, only traces remaining after two or three days, but residues remained in the mud for several weeks, and some were found in aquatic plants. (Edwards and Stafford)

Effect of pesticides on breakdown of maize litter. An experiment was made in Indiana U.S.A., from 1967 to 1970, to study the rate of decomposition of maize litter. The rate at which it broke down in untreated soil was compared with that in soil in which most of the invertebrate animals had been killed with chlordane and phorate. Although maize litter disappeared within a year in untreated soil, only 75–80% disappeared during the same period in the soil that had been treated with insecticides, probably because the earthworms in it had been killed. Such an effect could, if repeated for several years on land on which successive crops of maize are grown, result in accumulation of undecomposed organic matter. (Edwards)

Fauna of Park Grass. A study of the effects of the various manurial treatments on the populations of animals living in the soil of Park Grass was begun in spring 1972. Eight soil cores, each 50 mm diam. × 150 mm deep, were taken from each of 20 selected sub-plots, and the soil-inhabitating animals extracted in Rothamsted modified high-gradient Tullgren funnels. Earthworms were also sampled by an electrical method, using two probes, each with a row of three long rods; the rods being driven into the ground 1 m apart, with a 240 V AC generator supplying the electricity. This obviated the need to cool the probes and sampled a given area much better than the original method (see *Rothamsted Report for 1951*, 106). Differences in numbers of invertebrates between plots were much smaller than expected, and did not follow anticipated patterns. Neither organic manure nor greater amounts of nitrogen fertiliser increased populations, as they had been expected to do; and there tended to be more animals in the alkaline than in the acid plots. However, further sampling is necessary before definite conclusions can be drawn. (Edwards and Lofty)

Effects on temperature and moisture on populations of soil invertebrates. A series of experiments have been made on the effects of temperature on soil invertebrates (see *Rothamsted Reports for 1969, 1970, 1971*, Parts 1) in which some plots of grassland have been heated and others left unheated as controls. Because heat dries the plots, in the most recent experiments some of them have been watered to keep the moisture content of the soil similar to that of the unheated controls.

Heating the soil caused an initial increase in abundance of soil animals, but, thereafter, numbers gradually declined until, after 11 months, there were less than half the number of animals in the heated plots than there were in the unheated controls. An initial increase in population was also recorded in plots that were both heated and watered, and after 11 months there were still more animals in these plots than in the controls. After 16 months (in February 1972), all treatments were discontinued, at which time the number of animals in the heated but unwatered plots was still less than half that in the control

https://doi.org/10.23637/ERADOC-1-127

plots; the number in the heated and watered plots was intermediate between those in the control and in the heated, but unwatered, plots. The initial increase in abundance of animals in all the plots that were heated, occurred in winter when the soil temperature 50 mm below the surface in the control plots averaged about 4°C, occasionally falling to zero, whereas that in the heated plots averaged about 8°C and seldom fell below 4°C. In summer, the corresponding soil temperatures at 50 mm were about 17°C, occasionally reaching 20°C, in the control plots; 28°C, occasionally reaching 36°C, in the heated plots; and about 22°C, occasionally reaching 26°C, in the heated and watered plots.

Heating, whether water was added or not, initially increased the numbers of Acarina (mites), but later their populations declined to a level lower than in the controls. The long-term effect of adding water to heated plots was to increase the number of these animals to a level nearer that of the controls. The most abundant mites in all plots belonged to the Order Cryptostigmata; the next most abundant to the Order Prostigmata; the least abundant to the Astigmata, the members of which did not follow the general pattern of change brought about by heating, which caused them to continue to increase, both in watered and in unwatered plots. The majority of Collembola (springtails) showed an initial increase on heating, followed by a decline in numbers. Here again, however, those belonging to the Family Entomobryidae reacted differently, continuing to increase in the heated and watered plots until they were much more numerous than those in the control and in the heated but unwatered plots, which had similar numbers. Thysanoptera (thrips) followed a pattern of change in numbers in the heated plots similar to those shown by most mites and springtails.

Data are still being collected and analysed on the seasonal vertical distribution of animals in the plots, and on the influence of such factors as soil particle size, pore space, organic matter content and pH. (Haines and Edwards)

Slugs

Life histories and the effects of environmental factors. Studies of the life histories and population dynamics of slugs of agricultural importance have been greatly hampered by lack of efficient and simple means of enclosing populations in the field, and preventing ingress of slugs from outside, without seriously interfering with their environment. This has now been overcome by means of 'electric fences', each carrying a current of 6–12 V 50 Hz AC, consisting of two parallel aluminium strips, 3 mm apart. One 'fence' is mounted inside, and another outside, the tops of the waterproofed, hardboard walls of each 4 m^2 enclosure, the bottom of which is closed with 4 mm mesh plastic net to prevent ingress and egress of slugs through the soil. The walls of an enclosure are sunk in the ground to a depth of at least 300 mm and project about 150 mm above soil level. Tests with *Arion ater*, *A. hortensis*, *Agriolimax reticulatus* and *Milax budapestensis* have shown that these slugs will not cross an 'electric fence' and, further, that even when the gap between its aluminium strips was deliberately bridged with slug mucus, it did not short circuit the current and render the 'fence' inoperative.

Effect of atmospheric humidity on feeding. Starved adults of the slugs, *Agriolimax reticulatus* and *Arion hortensis*, were confined individually in 60 × 15 mm specimen tubes closed with plastic net, each containing a disc (10 mm diam.) cut from a clover leaf (*Trifolium pratense*). Twenty tubes with slugs were kept in darkness at 15°C in each of several desiccators at known humidities, the leaf discs being exchanged for fresh ones every other day for ten days whether feeding had occurred or not. The results (Table 5) showed that feeding by *A. reticulatus* during the ten-day period varied little at three

https://doi.org/10.23637/ERADOC-1-127

different humidities. However, although feeding by *A. hortensis* varied little at high atmospheric humidity, it decreased progressively at low humidity.

TABLE 5

Effect of atmospheric humidity on feeding by slugs during a ten-day period

	Saturation deficiency (mmHg)	Percentage of slugs feeding on day				
		2	4	6	8	10
A. reticulatus	0·8	90	72	82	80	70
	2·6	100	100	100	89	89
	3·8	100	100	95	90	80
A. hortensis	0·8	80	70	56	78	67
	3·8	95	90	60	40	25

These data suggest that *A. reticulatus* would probably continue to feed in an environment in which feeding by *A. hortensis* would be inhibited, and emphasise the need for a poison bait with a long field life which would remain available to control *A. hortensis* whenever field conditions favoured the surface feeding activities of this species. (Stephenson)

Release of sodium pentachlorophenate from cross-linked gelatin. Concentrations of 1–5 ppm sodium pentachlorophenate in water are lethal to all stages of aquatic snails and are used to control them. Whether gelatin, cross-linked by formalisation (see *Rothamsted Report for 1970*, Part 1, 198), used as a carrier for this molluscicide, would make it possible to maintain these concentrations in water for a long time, has now been studied. Gelatin discs, each 5 mm diam. × 2 mm thick, containing this molluscicide were prepared in six different ways. Each disc was immersed in 10 ml water at 20°C and the amount of sodium pentachlorophenate that had been released into the water determined 24 hours later by UV absorption measurements at 25 nm. After a determination, each disc was put into another 10 ml water. The rate the molluscicide was released during 21 days is shown in Table 6.

It is clear that sodium pentachlorophenate was released quite slowly from formulations 1 and 2, and that after 21 days this rate of release had resulted in the water containing

TABLE 6

Release of sodium pentachlorophenate (ppm) per day

	Formulation					
Day	1	2	3	4	5	6
1	50	140	500	800	920	1260
2	40	90	150	130	50	150
3	40	70	80	70	60	40
4	20	50	30	40	30	10
5	10	40	20	10	20	0
6	10	30	10	10	0	0
Mean day 7 to 21 inclusive	3·3	6·6	2·0	1·3	2·0	0·6

Formulations: (1) 2·5% a.i. incorporated in the gelatin solution before cross-linking.
(2) 5·0% a.i. incorporated as in (1).
(3) Cross-linked gelatin soaked for 16 hours while still soft in a solution containing 10% a.i.
(4) As in (3), but with 20% a.i.
(5) As in (3), but with 30% a.i.
(6) As in (5), but discs washed in running water for 20 hours until free from formaldehyde.

(All formations were cross-linked by soaking in 20% formaldehyde for 60 minutes at 15°C.)

https://doi.org/10.23637/ERADOC-1-127

more than a lethal dose of the molluscicide for snails and their eggs. By contrast, formulations 3 to 6 provided a high initial concentration of molluscicide which rapidly diminished, probably because most of the sodium pentachlorophenate was at or near the surface of the gelatin, from which it quickly diffused.—(Stephenson, with Briggs, Chemistry Department)

Gelatin baits for leaf-cutting ants. Tests of acceptability of gelatin-based ant baits have been made. Samples of raw and cross-linked gelatin, foamed by bubbling air through the warm gelatin solution until it set, were subjected to wetting and decay tests. Fine and coarse structured raw gelatin foams absorbed water to full capacity in 24 hours and collapsed because of bacterial decay in three or four days. Cross-linked gelatin foam took 19 days to absorb water to full capacity and was completely intact after 56 days. Foam that had been soaked in sugar and malt solution and cut into small pieces was readily accepted by *Atta cephalotes*, *A. sexdens* and *Acromyrmex octospinosus*. Foamed, cross-linked gelatin is, therefore, suitable as a carrier in formulations of ant baits.

Further experiments were made with both raw and cross-linked gelatin containing 0·35% sodium pentachlorophenate, which is a fungicide as well as a molluscicide, to develop sufficiently attractive baits to encourage leaf-cutting ants to collect them and carry them into their nests and add them to their fungal gardens. Mixtures of sugars and sunflower seed oil, or of dried citrus pulp and oil, were added to gelatin discs and tested as attractants for *Acromyrmex octospinosus*. All baits were more acceptable to, and more easily carried by, the ants when wet and pliable; this effect being most marked with cross-linked gelatin baits. Increasing the proportion of citrus pulp from 10% by weight to 20% increased acceptability. Bait attractiveness was further increased by replacing the citrus pulp with a sugar solution containing 0·5*M* concentrations of sucrose, fructose and mannitol. Two such formulations, with cross-linked gelatin as the carrier, containing 10% and 2% by volume of sunflower seed oil, respectively, were also tested. The latter, whether wet or dry, was the most acceptable of all the baits tested. (Stephenson with Dr. M. Cherrett, University College, North Wales)

Field beans

Damage caused by *Sitona* larvae. Larvae of weevils of the genus *Sitona* (chiefly *S. lineatus*) feed on the roots of field beans and, apart from any direct damage they cause, may perhaps encourage pathogens to enter the roots through the wounds they make. In previous attempts to assess crop loss caused by *Sitona* larvae, we have recorded increased yields up to 0·19 t/ha when these larvae were controlled with gamma-BHC, but, because this insecticide may be slightly toxic to bean plants, we have now compared the effect of dieldrin with that of gamma-BHC in two large field experiments (Table 7)

TABLE 7

Control of larvae of Sitona and yield of field beans

	Larvae/root		Yield (t/ha)	
Treatments	Gt. Knott	W. Barnfield	Gt. Knott	W. Barnfield
Untreated	59·8	20·5	3·43	3·58
gamma–BHC applied to soil (2·24 kg/ha)	1·9	0·0	3·60	3·70
dieldrin applied to soil (2·24 kg/ha)	13·9	2·6	3·58	3·92
S.E. of difference between yields			±0·13	±0·14

https://doi.org/10.23637/ERADOC-1-127

in which other pests and diseases were also studied (see Report of Plant Pathology Department, p. 144).

Both the insecticides controlled *Sitona* larvae effectively, but only with the dieldrin treatment on West Barnfield was a significant increase in yield (0·34 t/ha) obtained, although populations of larvae on the untreated plots in this experiment were smaller than in the other experiment on Great Knott. The infestation on Great Knott was the largest we have recorded but, unlike West Barnfield, the plants were also severely attacked by an eelworm, *Ditylenchus dipsaci*, which probably limited yields. The effect of many *Sitona* larvae on an otherwise healthy bean crop remains, therefore, unknown. (Fletcher and Bardner)

Potatoes

'Top-roll' of potato plants. 'Top-roll' is a condition of the potato plant in which the leaflets of the upper, and occasionally also the middle, leaves are rolled upwards around the midrib. This obscures any leaf-roll virus symptoms and so may prevent certification of affected seed crops. In addition, such rolling of the leaves may diminish their photosynthetic efficiency and decrease the crop of ware potatoes. Reports of 'top-roll' on field plants in England date back to at least 1944 and, although observations have suggested that aphids may be implicated, direct evidence has been lacking.

It has now been demonstrated that prolonged infestation by the potato aphid, *Macrosiphum euphorbiae*, on potato plants of the varieties Pentland Crown, Majestic and King Edward growing in glasshouses can induce rolling of their upper leaves which appears similar to 'top-roll' of field plants. The capacity of the aphids to induce leaf-rolling was not removed by rearing them on roses for several generations, and when all aphids were removed from such 'top-rolled' plants the fresh foliage they produced appeared normal. Furthermore, the leaves of plants colonised by only a few (about 20) aphids for a short time (five days) did not become rolled, suggesting that rolling is a direct result of many *M. euphorbiae* feeding on a plant and that it is unlikely to be caused by an aphid-transmitted pathogen.

In the field, caged plants of King Edward and Majestic potatoes infested with *M. euphorbiae* developed definite 'top-roll' symptoms, the proportion of affected plants in creasing with the size of the aphid population and duration of infestation by it. The total weight of potatoes produced by plots containing nearly 90% of 'top-rolled' plants was 40% less than that of control plots, the greatest reduction occurring in the yield of potatoes greater than 50·7 mm diameter. Treating uncaged plants with an aphicide prevented the development of 'top-roll' symptoms and, as in the glasshouse experiments, when destruction of aphids on 'top-rolled' plants was followed by production of new foliage, this foliage always appeared normal even when it arose from the axil of a rolled leaf. (Gibson)

Flight and migration

***Plusia gamma* (Lepidoptera, Noctuidae).** The relationship between the flight potential of a newly emerged moth (*P. gamma*) and its body weight, indicated in the results of earlier experiments, has been confirmed by flying unfed, newly emerged, tethered moths. A correlation was obtained between flight duration and amount of body fat (expressed as percentage live weight). The ratio between flight duration and amount of fat was remarkably similar to those obtained by other workers with insects as different as locusts and aphids, and strongly suggests that fat is the principal fuel used in flight in each case.

The excrement of a flying moth was found to change colour with time and/or flight experience, which might perhaps be useful in determining the ages of moths caught in

https://doi.org/10.23637/ERADOC-1-127

the field. A moth first excretes soon after emergence and before flying, its excrement being olive green in colour; it usually defaecates again a few minutes after starting to fly when the excrement voided is brick red. As the insect continues to fly its excrement becomes paler and, after three or four defaecations, becomes chalky white which, in turn, is followed by clear liquid and, eventually, by frothy white droplets as the insect approaches exhaustion. These colour changes are indicative of flight experience rather than age, because moths that were living in cages often produced red excrement when two days old, or clear liquid when they had flown extensively. (Macaulay)

Honeybees

Behaviour and physiology

Influence of hive space on tendency to rear queens. Putting large colonies into small hives can make them swarm very quickly without first starting to rear queens, but small colonies put into small hives and allowed to outgrow them show an association between swarming and queen rearing that is too close to be coincidental. Colonies that outgrow their hives are more likely to rear queens than colonies that do not outgrow their hives, but this could be merely because big colonies are more likely to rear queens than small ones. An experiment in which some small colonies were given small hives and other small colonies were given large hives has now confirmed that outgrowing the hive does encourage queen rearing. Little nectar was available throughout most of the experimental period and the colonies always had plenty of cells not filled with food or brood, so queen rearing was induced by congestion of adult bees and not by restriction of space for brood or food. (Simpson)

Habituation of colonies with laying queens to virgin queens. Honeybee colonies with laying queens are normally extremely hostile to young queens that have not yet begun laying. Nevertheless, from time to time colonies replace their queens efficiently by rearing young queens and allowing them to mate and start laying while their old ones are still alive and laying. A method by which beekeepers could induce colonies to behave in this way could be very useful, so the possibility of finding one has been investigated.

To introduce a young queen to a colony from which a laying queen has been removed, it is only necessary to cage the young queen in the colony until visible hostility towards her disappears—usually within 24 hours—and then allow the worker bees to release her from her cage by chewing or eating through some soft material. If the old queen is not removed from the colony, however, hostility towards the young queen does not quickly diminish and in a cage without food she dies within a day or two, although some of the workers appear to feed her. It has now been found that such early death can be prevented by supplying the young queen with sugar syrup on which to feed. In this way one young queen was kept alive in a colony with a laying queen for 37 days, but even at the end of that time the hostility of the workers had diminished little, if at all. It seems to be impossible to get a colony to accept a laying queen and a young non-laying one simultaneously merely by habituation. (Simpson and Greenwood)

Food hoarding. Experiments have been made, with groups of 50 bees in cages, to investigate the factors influencing storage of, and engorgement with, sugar syrup. More syrup was collected from the feeders by the bees when they were given comb, but those without it held more syrup in their honey stomachs. This tendency for caged, combless bees to keep more food than usual in their honey stomachs is also characteristic of swarming bees and those that have been disturbed by smoke. It seems probable that when bees have nowhere in which to store food they partly compensate by holding more than

https://doi.org/10.23637/ERADOC-1-127

usual in their bodies. It also became clear in these experiments that bees preferred to store food in old comb in which brood had been reared, or in which pollen had been stored, rather than in new comb. They also preferred to store in worker cells rather than in drone cells. When larvae were present, the bees collected and stored less food. The presence of a queen in a cage, encouraged food collection and storage, as did darkness and warmth. The amount collected by a bee was directly related to its age until it became about 18 days old. The longer a bee had been confined in a cage the more it was inclined to hoard food, and even a short time without food subsequently led to a great increase in its collection and storage. (Free and Williams)

Pheromones of queen honeybees. Honeybee queens influence the behaviour of worker bees by means of substances (pheromones) which are most abundant in their mandibular glands but are also detectable on their abdomens—i.e. remote from these glands. The mechanisms and rates of movement of these substances both throughout a colony, and on or in the bodies of individual bees are largely unknown. 9-oxodecenoic acid is a major biologically active component of queens' mandibular gland secretion and tritiated 9-oxodecenoic acid has now been used in experiments to follow the movement of this compound on the bodies of both queens and worker bees whose wings had been removed and whose legs were held so that they could not groom themselves and transfer material while so doing. Application of this radioactive material to bees' thoraces, followed by extracting their heads and abdomens, has shown that 9-oxodecenoic acid can move about the bodies of both queens and workers. Translocation was much less with dead bees than with live ones, and superficial washing followed by thorough extraction in methanol showed that there was more translocated radio-active material in the interior of the bee than on the surface thus allowing that 9-oxodecenoic acid may be transported in a bee's circulatory system. (Butler and Simpson, with Callow and Greenway, Insecticides Department)

In further studies on queen perception in the hive by worker honeybees, it was found that the numbers of workers that gathered on cages containing mated, laying queens, when they were placed over normal, queenright colonies, were much diminished when they could not touch the caged queen or when she was dead, or when her mandibular glands had been removed. The numbers of bees on the cages were correlated with the amount of 9-oxodecenoic acid in the queens' heads; and workers were found to gather on cages containing this acid on filter-paper that they could not touch, indicating that they were able to smell it. As reported previously (*Rothamsted Report for 1971*, Part 1, 224), 'court' formation round a queen that was able to move freely on the combs in a hive was not diminished by removing her mandibular glands. However, this operation did not necessarily render her head entirely devoid of 9-oxodecenoic acid, and the reason why removing her glands had little influence on the tendency of the workers to form a 'court' round her may, therefore, be that 'court' formation is shown only by bees that are close enough to a queen to perceive odour derived from a very small amount of material. However, no method has yet been found by us, or so far as we know by others, of inducing formation of a *normal* 'court', comparable with that round a living queen, with any inanimate object, even when covered with 9-oxodecenoic acid. Our finding that more bees accumulated on cages containing live queens or workers than on cages containing dead ones, indicates that accumulation on a cage is encouraged by some stimulus that only a live bee can provide and suggests that 'court' formation may be largely dependent on that stimulus. It may be heat or movement (in any of its manifestations, including vibration in solids and air), or some as yet undetected pheromone. We failed to detect any hitherto unknown substances affecting workers' behaviour, or any demonstrably communicative sounds, but that does not, of course, exclude the possibility that such

https://doi.org/10.23637/ERADOC-1-127

things exist; nor can the possibility of mutual release of pheromones when queens and workers meet be excluded. Time lapse photography showed that workers did not move far towards a queen to form a 'court' round her, and it seems clear that the behaviour of an undisturbed colony with a mated, laying queen does not involve attraction of workers towards the queen except over very short distances. (Butler, Koster and Simpson, with Callow, Insecticides Department).

Honey

Flavour of honey. When necessary, beekeepers feed their colonies with sucrose solution, which the bees store in cells in the same way as honey produced from nectar. Recent use of dyed sucrose for feeding bees resulted in the production of coloured honey, thus upsetting a beekeeping tradition that with good management adulteration of honey with sugar that is fed to bees can easily be kept negligible. What effect dilution with the products of sugar feeding has on the flavour of honey is, therefore, of interest. When pure sugar-syrup honey was mixed with genuine honey in different proportions, nearly all of the 14 people who took part in taste tests readily distinguished between either of the pure materials and a mixture containing 50% of each of them. Most detected a 25% addition of real honey to sugar-syrup honey, and half also detected a 25% addition of sugar-syrup honey to real honey. The fact that most tasters made some mistakes even when comparing the pure materials and their comments on the flavour of the sugar-syrup honey, suggested that part of the characteristic flavour of honey comes from the bees that prepare it rather than from the nectar from which it is prepared. When sugar-syrup honey was diluted with water to the same consistency as the sugar syrup that had been fed to the bees originally, the tasters easily distinguished between the diluted sugar-syrup honey and sugar syrup, and even distinguished between the latter and a mixture containing 75% sugar syrup and 25% sugar-syrup honey.

To obtain some idea of the magnitude of the bee component of honey flavour, colonies of bees were fed sugar syrups containing strong artificial flavours, to find out whether the bee-produced component was detectable by man against a strongly flavoured background. These experiments were unsuccessful, because most of the flavour disappeared while the bees were preparing the sugar-syrup honeys from the flavoured syrups. Furthermore, when flavoured syrups were exposed at colony temperature in a well-ventilated incubator, the flavours were lost, presumably by evaporation, within a few hours. This was true even of syrup strongly flavoured with clove oil. It seems likely that the few strongly flavoured honeys that occur naturally must contain relatively involatile flavouring substances, and that any deterioration in the taste of honey during its extraction from the comb and subsequent handling is probably because of decomposition of the flavouring substances it contains, or contamination, rather than because of loss of flavour. (Simpson, Moxley and Greenwood)

Field behaviour

Pollination. Strains of honeybees that prefer to collect much pollen from lucerne (*Medicago sativa*), and others that collect little, have been isolated in the U.S.A. To find out whether this is a unique case, or whether different strains of bees have innate preferences for different kinds of flowers, we have compared the foraging preferences of the worker offspring of queens from widely separated places. To obviate possible effects of differences in the environment in which the workers of the different queens lived before they began foraging, all were reared from eggs in one colony; nevertheless, they exhibited consistent preferences for different kinds of flowers. Such innate preferences could help

https://doi.org/10.23637/ERADOC-1-127

explain why the different colonies in an apiary often collect different proportions of their food from the various kinds of flowers available. The degree of difficulty with which bees can obtain pollen from the various species of flowers did not seem to be important in determining such preferences, which were sometimes clearly shown even between kinds of flowers in which food was apparently very easily accessible. These observations indicate that it would probably be possible to select and maintain strains of bees for pollinating particular kinds of crops, though whether this would be economically worth while is doubtful. (Free and Williams)

Difficulties in commercial production of insect pollinated hybrid seed crops have recently appeared, because, in some cases, the bees used have apparently failed to transfer pollen between cultivars. We have investigated the reasons for some of the difficulties encountered and found, for example, that when ten varieties of Brussels sprouts were grown in a field, different bees preferred different varieties, and persisted in visiting them to the neglect of others. These preferences may perhaps in some cases have been associated with differences in availability of nectar. A similar preference was shown by honeybees visiting kale, when only about half of them moved freely between the flowers of the varieties being grown.

The structure of a Brussels sprout flower enables honeybees to obtain nectar by inserting their tongues betweeen the bases of the perianth segments. Because this habit, which is often extensive, can diminish pollinating efficiency, we have studied how it is acquired and how to prevent it. Bees had difficulty in obtaining nectar through the mouths of young flowers because they were stiff and had vertical anthers. Even when they could reach the inner nectaries, they were often unable to reach the outer ones past the anthers. For these reasons the bees soon learned to reach the outer nectaries from outside the flowers. With older flowers in which the parts were splayed apart the bees easily found their way from the inside to the outside of the flower, to which they then confined their visits. Within about two hours of a colony being released in a cage of Brussels sprouts plants, about one-third of its foragers were obtaining nectar from outside the flowers, and within two days 80% or more were doing so. This behaviour was more common with some varieties, particularly those with large flowers. Feeding colonies with sugar syrup greatly increased the proportion of foragers that collected pollen and so could not avoid pollinating the flowers.

Attempts have been made to find how much the yield of field beans is limited in practice by insufficient pollination. In 1970, in each of 31 fields of spring sown beans, 20 plants were cross-pollinated by hand, 20 self-pollinated by hand, and 20 left to depend on insect pollination. No differences in yield were detected. In 1971, a similar survey was made of seven crops of spring beans and four crops of winter beans. To diminish the effect of plant variation, each plant received all three treatments. Cross-pollination by hand increased yield in only two of the spring bean crops and none of the winter bean crops. (Free and Williams)

Bee diseases

Paralysis. Although chronic bee-paralysis particles vary considerably in size, and are grouped into at least three sedimenting components, they all have the same buoyant density of 1·33 g/cc in gradients of caesium chloride. Therefore, their sedimentation behaviour depends only on their size. All particles also formed a single component in moving boundary electrophoresis, so the particles seem qualitatively very alike. The longest components, partially purified by centrifugation in sucrose gradients, were more infective than equivalent concentrations (measured by their absorbancy at 260 nm) of shorter ones. or of combinations of short and long particles, so infectivity seems to be

https://doi.org/10.23637/ERADOC-1-127

determined by the completeness of information per particle and not by combined information from different particles. (Bailey with Woods, Plant Pathology Department)

Nosema apis. Spores of lyophilised abdomens of freshly killed bees infected with *N. apis* were no less infective than spores from freshly killed but otherwise untreated bees, and were much more infective than spores in bees that had been preserved for long at $-20°C$. (Bailey)

Sacbrood. Reports from elsewhere claim that European foulbrood is caused by a combination of sacbrood virus and *Streptococcus faecalis*. Field tests at Rothamsted, in which individually identified larvae were inoculated with *S. faecalis* and sacbrood virus, showed that a mixture of virus and bacteria caused sacbrood only. European foulbrood is characterised by the death of mature, unsealed larvae, but very few of such larvae died in these tests, and no more larvae died or disappeared before sealing in their cells when they were inoculated with sacbrood virus + *S. faecalis*, than when they were infected with sacbrood virus only. (Bailey and Stanley)

European foulbrood. Many colonies of bacteria resembling *Streptococcus pluton* were isolated from diseased larvae of *Apis cerana* (spp. *indica*) sent from India. However, they were all very small, transparent, flattened and umbonate, whereas *S. pluton* from *Apis mellifera* formed white, opaque, dome-shaped, easily visible colonies, as usual. Moreover, multiplication of the bacteria from *A. cerana* was much inhibited by 20% or more CO_2, whereas *S. pluton* from *A. mellifera* was unaffected. Nevertheless, when an extract of yeast autolysed at 50°C was used in the culture medium instead of standard proprietary yeast extracts, the Indian streptococci multiplied vigorously, forming colonies indistinguishable from those of *S. pluton*, and were uninhibited by CO_2.

In agglutination tests using an *S. pluton* antiserum with an homologous titre of 1024, Indian streptococci grown with standard yeast extract reacted weakly and the antiserum titre was only 32. However, those grown with autolysed yeast extract reacted strongly and the antiserum titre was 512–1024. Therefore, although *A. cerana* suffers from a disease similar to European foulbrood of *A. mellifera*, the respective pathogens are slightly but distinctly different. (Bailey)

Staff

C. G. Johnson, head of the Entomology Department since 1961, retired and, when the Bee and Entomology Departments were combined on 1 April, C. G. Butler became head of the Department. Catherina G. Koster and Ellen Moxley resigned, and Susan Greenwood and Patricia Brobyn were appointed. P. L. Sherlock, Susan W. Lewin and C. Wall also joined the Department. N. E. Ellement and Cita D. Cooper retired, and H. H. Franklin resigned to farm.

G. J. W. Dean was awarded a Ph.D. degree by London University, as was E. F. W. Fernando who returned to Ceylon. H. Dodson, Dorothy E. Gennard and Deborah Sweeting worked in the Department as sandwich course students.

L. Bailey was awarded a Senior Foreign Scientist Fellowship by the U.S. National Science Foundation to work as a Visiting Professor at the University of Arkansas for seven months, and gave the Grace H. Griswold lecture on Insect Pathology at Cornell University. C. A. Edwards visited the U.S.A. on a lecture tour in January and gave the Lockwood lecture at Connecticut Agricultural Experiment Station. He was also a delegate at the synthesis (Productivity Terrestrial) meeting of the International Biological Programme in Belgium in July. I. F. Henderson and Margaret G. Jones attended the

https://doi.org/10.23637/ERADOC-1-127

14th International Congress of Entomology in Canberra, where the latter read a paper, and also the 21st Anniversary Conference of the Entomological Society of New Zealand. J. B. Free gave the opening lecture at an International Symposium of Pollination in Turin, and also visited Kenya in October, on behalf of ODA, to advise on pollination and beekeeping. R. Bardner chaired a meeting of a study group of the International Organisation for Biological Control on integrated control of soil pests at Silwood Park at the end of August. L. R. Taylor and R. A. French visited Den kgl. Veterinaer-og Landbohøjskole, Zoologisk Institut, Copenhagen, to service the aerial sampling station and give a seminar; R. A. French and I. P. Woiwod visited Mr. D. Hille Ris Lambers and re-sited the sampling station in Zeeland, Netherlands.

https://doi.org/10.23637/ERADOC-1-127