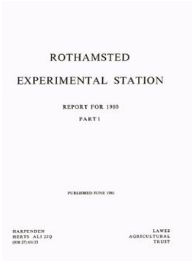

Report for 1980 - Part 1

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Insecticides and Fungicides Department

M. Elliott

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Introduction

The work of the Department on pesticides and behaviour controlling compounds to protect crops is organised as a number of multidisciplinary projects to establish essential fundamental principles. These complement the more immediate aims of the agrochemical industry, and specialised research in universities.

In one project entomologists assessing the relative potencies of synthetic insecticides against several species collaborated with chemists to establish principles for developing improved insecticides rationally. After greatly improving the insecticidal activity of analogues of the natural pyrethrins, the range of properties evaluated was broadened to include mammalian toxicity, photostability and susceptibility to soil degradation. From the general conclusions, desired combinations of properties were incorporated into new compounds, leading to the photostable synthetic pyrethroids, a group of lipophilic insecticides now being rapidly developed by industry under licences from the NRDC. However, the essential molecular characteristics associated with the favourable properties of the group are not yet fully defined. Therefore, synthesis and testing of key compounds continues, leading to definitive relationships such as that reported this year between insecticidal activity and the characteristics of the α-substituent in the alcoholic components of pyrethroidal esters. Another incentive to explore new structure activity relationships is the need, unfulfilled by present commercial products, for pest control compounds with selective potency, and a preliminary survey described in this Report has shown that a range of pyrethroids and other insecticides have sufficiently variable selectivity to a conveniently accessible pest–parasite combination to justify further exploration.

Other types of activity such as rapid knock-down, repellency and anti-feeding behaviour reported for pyrethroids are also examined. Recent collaboration with the Plant Pathology Department has shown that deltamethrin ('NRDC 161', formerly decamethrin) restricts transmission of non-persistent viruses by *Myzus persicae*, an effect apparently related to speed of knock-down. Such control is potentially valuable because deltamethrin and other recent pyrethroids are sufficiently photostable for field use.

A second broad project concerns development of resistance to insecticides and strategies for countering it. For a valuable period lipophilic insecticides, first DDT and HCH, later other chlorinated hydrocarbons, controlled a wide range of insects effectively. However, application rates of these relatively stable compounds were usually above 500 g ha^{-1}, and widespread use inevitably led to residues accumulating in the environment, and to conditions under which resistance to some important species developed. Synthetic pyrethroids have shown that lower field application rates, 1–200 g ha^{-1}, are attainable, as are probably other desirable properties (selectivity, low toxicity to fish, controlled persistence, etc.). If economically important insect species remained susceptible, the existing range of insecticides might be adequate to maintain, or even improve upon present standards of control, and new discoveries could bring additional benefits and greater efficiency. However, at least 400 insect species now resist one or more insecticides, and fewer new insecticides are available as suitable products become progressively more difficult to discover and expensive to commercialise. Further, insect populations exposed to several groups of insecticides may be formidably protected through multiple and multiplicate resistance against any new types of poisons, which may therefore be only transiently effective.

The problem of development of resistance thus becomes progressively more serious. Knowledge of its nature and development is necessary to use existing insecticides as effectively as possible, and to develop new compounds to which resistant insects are susceptible. The demonstration that 'knock-down' resistance (*kdr*) to pyrethroids

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and DDT may be associated with a change in the phospholipids of the nerve cell membranes of insects is therefore significant, indicating for the first time the biochemical nature of this important resistance mechanism. The esterase in *Myzus persicae* responsible for organophosphate and carbamate resistance has also been shown to hydrolyse selectively one of the four isomers of permethrin. The implication of this specificity is not yet clear, for the sensitive isomer is the least active insecticide of the four.

The concern over supercession of the less by the more stable pyrethroids to control houseflies on animal farms because resistance might develop has been justified by field observations. Consequently, we are studying how persistent and non-persistent pyrethroids affect the rate of development of housefly resistance on animal farms in an area of about 100 km^2 around Rothamsted, in an investigation in which all relevant disciplines (ecology, toxicology, qualitative and quantitative genetics and biochemistry) are represented and coordinated.

Laboratory and field studies of insecticides and of their mode of action, particularly in relation to countering resistance, parallel work on fungicides. We are examining the effects of 'Milstem' (a.i. ethirimol) treatment of winter barley on nearby spring-sown barley, the variation in response of barley pathogens to triadimenol and the mode of action of tridemorph.

Pesticides which move downwards in plants to control harmful soil–borne organisms or upwards to act against insects and fungi have many advantages, but the physical and chemical properties necessary are not yet well known, more attention having been given in the Department to lipophilic compounds such as pyrethroids, which have neither systemic, nor translaminar characteristics. Study of transport has therefore been intensified, and two experimental plant systems suitable for examining phloem mobility have been developed. Related work in the Chemical Liaison Unit with phenylureas has shown that uptake and translocation into roots from nutrient solutions depends on the polarity of the compounds involved. The decrease in severity of potato common scab and clubroot of cabbage when 3,5-D (an analogue of the herbicide, 2,4-D), is sprayed on leaves demonstrates the potential of downwards translocated compounds; 3,5-D was most effective against scab when applied as early as possible and appears to act by altering tuber physiology.

Advances in' isolation, manipulation and structure determination have facilitated identification of compounds that mediate insect behaviour, a preliminary to developing practical control procedures. The larval mandibular glands of *Ephestia kuehniella*, of which the structures of two compounds were reported earlier, have now been shown to contain seven more related 2-acylcyclohexane-1,3-diones, all of which elicit an oviposition response from the parasite *Venturia canescens*. The honeybee alarm pheromone contains a previously undetected and active constituent, (Z)-11-eicosen-1-ol. A common problem in using insect control compounds is instability under field conditions, so that ensuring that an adequate quantity is available at the appropriate time and place is difficult. A solution being investigated is to use derivatives (e.g. the sulpholene derived from E(β)-farnesene, the aphid alarm pheromone) which will decompose slowly under field conditions, releasing the active compound.

Development of spraying systems has continued, leading to two charged atomisers through which aqueous or non-aqueous standard formulations can be sprayed; these have been patented by the NRDC and two non-exclusive licences granted. In addition, a hand-held unit which will increase the scope of the system has been developed and is now being evaluated.

The work of the Department, disrupted whilst the Ogg Building was refurbished, has benefited greatly since the early summer, when much of the improved accommodation became available.

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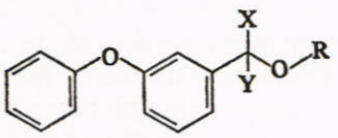
Insecticides

Relationships between molecular structure and insecticidal activity of pyrethroids.

α-Substituted 3-phenoxybenzyl esters. Previous work established that the insecticidal activity of pyrethroidal 3-phenoxybenzyl esters varied widely but without obvious correlation with the nature of α-substituents. Detailed examination of the influence of 40 substituents in esters (I) of two typical acids has now shown that:

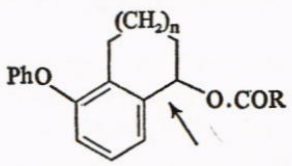
1. Esters of the dibromo acid are usually about eight times more active than the corresponding chrysanthemates.
2. Compounds with substituents of larger *volume* are generally less active.
3. Bulk near C-α diminishes activity most, so that compounds with linear substituents are relatively more active.
4. The exceptional extent to which the α-cyano group enhances activity is probably associated with secondary effects such as polarity or disturbance of electron densities.
5. Substituents enhance activity from only one of the enantiotopic C-α sites, and in the other site *all* substituents (including—CN) diminish activity drastically; enhancing substituents must therefore exert their influence from a sterically non-disruptive region.



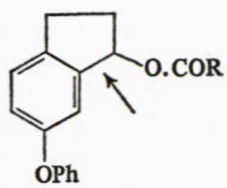
(I)

R = (1R) *trans*-chrysanthemate or (1R) *cis*-3-(2,2-dibromovinyl) 2,2-dimethylcyclopropane carboxylate

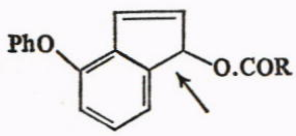
X = H, Y = H, CN, F, alkyl, CF_3, $COCH_3$, CH═CH . Z (Z = H, Br, alkyl, aryl)
C≡C—Z (Z = H, alkyl, alkenyl, aryl), substituted phenyl, heteroaryl
X, Y = Me, C≡CH



(II)



(III)



(IV)

Conformationally restrained 3-phenoxybenzyl esters. The strong evidence for the great importance of shape in determining the insecticidal activity of pyrethroids implies that at the site of action each bond about which free rotation is normally possible is restrained to a particular conformation. To pursue this concept, molecules in which the C-α to aryl bonds (indicated in figure) are constrained by additional bridging rings, were examined.

The activity of all the compound types (II–IV) was lower than that of corresponding unbridged compounds, suggesting that in none was the conformation optimum for activity fully achieved. However, 6-phenoxyindanyl esters (III) were significantly less active than those bridged in the alternative orientation (II, n = 0) and activity was retained in the indene analogues (IV), which must therefore both approximate more closely to the necessary conformation.

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TABLE 1

Insecticidal activities of compound types (II–IV)

Compound type	Relative activity[a] against *Musca domestica*	Relative activity[a] against *Phaedon cochleariae*
(II); n=0	0·5	2·0
(II); n=1	<0·1	<0·1
(III)	<0·1	<0·1
(IV)	0·9	1·9

[a] Bioresmethrin taken as standard, with activity = 100; results for all types are averaged activities of esters from the two acids used to examine α-substituents (above)

(Chemical work: Elliott, Janes, Johnson, Khambay and Pulman; biological work: Farnham, Jenkinson and O'Dell)

Influence of synergists on the action of synthetic pyrethroids. Although some synthetic pyrethroids (bioresmethrin, cismethrin, deltamethrin, 'Kadethrin' ('RU 15525'), etc.) permitted cockroaches treated with them to recover during a period 5 h to 2 days after treatment, three others (3-phenoxybenzyl (1R)-*trans* and (1R)-*cis*-3-(2,2-dibromovinyl)-2, 2-dimethylcyclopropane carboxylates ('NRDC 163 and 157', respectively) and 2,3,4,5-6-pentamethylbenzyl (1RS)*cis,trans* chrysanthemate) allowed no recovery (*Pesticide Science* (1977) **8,** 681). To investigate whether recovery was associated with partial reversal of the primary toxic action by metabolic detoxification, the action of the compounds in the presence of synergists considered to block detoxification was studied. Adult male *Periplaneta americana* were treated topically with a range of doses of deltamethrin in acetone (1 μl) with or without the synergist, *n*-propyl-2-propynylphenyl phosphonate ('NIA 16388') (100 μg). Unexpectedly, until 12 h after treatment 'NIA 16388' antagonised deltamethrin, decreasing its potency up to four times, but from 12 h onwards it increasingly synergised the insecticide, prevented recovery, and ultimately, 10 days after treatment, achieved a synergistic factor of 13–18 times. Similar results were obtained with 'Kadethrin', which, unsynergised, permitted more recovery than deltamethrin, but 'NRDC 157', from which there was no recovery, was synergised only 1·7–1·9 times 10 days after treatment. If the synergist was injected rather than applied topically it initially antagonised 'NRDC 157', but not deltamethrin or 'Kadethrin'. These results suggest that recovery is associated with detoxification and that the α-cyano group in deltamethrin (absent in 'NRDC 157') as well as enhancing activity (see previous section) is also a site for metabolism. Tested similarly, the synergist piperonyl butoxide also antagonised deltamethrin and 'NRDC 157' initially but 10 days after treatment it synergised deltamethrin only 2·4 times and 'NRDC 157' not at all. Although the cause is not yet known, antagonism is obviously important for practical use of these synergists. The implication of these results for mode of action studies and structure-activity relationships is being pursued. (Burt and Goodchild)

Action of insecticides on insect nervous systems

Neuroanatomy of the insect central nervous system. The basic organisation of the thoracic and suboesophageal ganglia of three locust species, *Chortoicetes terminifera*, *Schistocerca gregaria* and *Locusta migratoria migratorioides*, was examined as a further step in mapping ganglion structure to complement electrophysiological studies of pyrethroid mode of action. The overall plan of the ganglia in all three proved similar and offers a framework into which more detailed observations on individual nerve cells can be fitted. In the simpler mesothoracic and prothoracic ganglia nine longitudinal

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nerve fibre tracts are in each half of the neuromere, and six dorsal and four ventral transverse commissures link the two halves. Four vertical or oblique tracts are also recognisable, the T-tract, ring tract, C-tract and I-tract. Major roots of each peripheral nerve were numbered. Two regions of fine fibrous neuropile are prominent, the ventral association centre and an area associated with the anterior part of the ring tract. The metathoracic ganglion consists of the metathoracic and first three abdominal neuromeres fused together. In all four the basic plan is modified chiefly in the pattern of the ventral commissures and the degree of development of the ventral association centre. In the suboesophageal ganglion three neuromeres, mandibular, maxillary and labial, are fused. They show increasing modification of the basic plan anteriorly. Additional anterior longitudinal tracts are present, dorsal commissures are much reduced, and the ventral commissures of all three neuromeres differ considerably from those of the thoracic ganglia. (Gregory, with Dr N. M. Tyrer, UMIST, Manchester)

Resistant houseflies

Biological studies. Continuing previous work (last year's *Report*, Part 1, 114), cross-resistance spectra to 17 insecticides for populations of houseflies on 29 animal farms near Harpenden were studied. All populations resisted tetrachlorvinphos, malathion, trichlorphon, DDT, and dieldrin strongly and parathion, dimethoate, bioresmethrin, permethrin, deltamethrin, synergised and unsynergised pyrethrins and 'NRDC 116' weakly.

Strong pyrethroid resistance in the populations is still fortunately rare but on the few farms where the more persistent pyrethroids had been used for one or more years, resistance to all pyrethroids tested was very strong.

Preliminary studies of housefly population dynamics showed the life span of adults to be very short (3–5 days) (cf. P. Ystrom, *Danish Pest Infestation Report for 1979*, 149) in contrast to that of laboratory reared cultures; the reasons for this are being investigated. Detailed studies on overwintering and dispersal have now started on suitable farm clusters.

Genetic analysis has shown that a strain of houseflies strongly resistant to pyrethroids collected *c.* 50 km from Harpenden has *super-kdr* on chromosome 3 and two factors of resistance on chromosome 2, one an esterase very frequent in most local housefly populations and suspected of causing weak resistance to pyrethroids. Genetic crosses, followed by bioassays and biochemical investigations, have confirmed identity of *super-kdr* in the Danish 153y_3 (*Rothamsted Report for 1978*, Part 1, 133) and British strains. (Denholm, Devonshire, Farnham, Moores, O'Dell, Sawicki and Willott)

Biochemical examination of knock-down resistance (*kdr*) in houseflies. Diminished nerve sensitivity to pyrethroids or DDT characteristic of *kdr* houseflies could be associated with changes in the lipids or the proteins of nerve cell membranes. Because lipids modulate the properties of membrane-bound enzymes, Arrhenius plots for such enzymes often show discontinuities, generally attributed to abrupt changes in the viscosities of the lipids as they change phase at characteristic temperatures.

To study the properties of the lipids in houseflies, membrane-bound acetylcholinesterase, from the heads of various strains, was examined at temperatures between 5° and 35°C. Transition temperatures in the resulting Arrhenius plots were at 14° (susceptible), 19° (*kdr*) and 21°C (*super-kdr*), and these changes were associated with a progressive decrease in activation energies, both above and below the transition temperatures, with increasing resistance.

The properties of the enzyme from F_1 hybrids of the cross *super-kdr* × susceptible

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were the same as those from susceptible insects, consistent with the recognised recessive character of the *kdr* mechanism.

Digestion with phospholipase A_2 did not affect the Arrhenius plots for acetylcholinesterase from *super-kdr* houseflies, whereas both the transition temperature and activation energies of the enzyme from susceptible flies changed markedly to resemble more closely the properties of the enzyme from *kdr* flies.

The *kdr* mechanism is therefore associated with a change in the phospholipids of the nerve cell membranes, which may influence the conformation of the target(s) for DDT and pyrethroids. (Chiang and Devonshire)

Resistant aphids

Influence of deltamethrin and of dodecanoic acid on plant virus transmission by the peach potato aphid, *Myzus persicae*. Preventing virus transmission by repelling aphid vectors is potentially a powerful adjunct to control with aphicides, which rarely prevent infection of crops with non-persistent viruses. Infected (virus source) or uninfected (virus receptor) plants were therefore sprayed with the non-insecticidal dodecanoic acid (DA) or with the very powerful pyrethroid insecticide deltamethrin ('NRDC 161'), two putative insect repellents. Even sublethal doses of deltamethrin decreased transmission of all the viruses tested by temporarily disturbing the aphids; the effect was smallest with aphids most resistant to organophosphorus insecticides and pyrethroids. DA decreased transmission of semi-persistent or persistent viruses, but increased transmission of the non-persistent potato virus Y (PVY). (Jhala, Rice, Sawicki and Stribley, with R. W. Gibson, Plant Pathology Department)

Stereospecific hydrolysis of permethrin by carboxylesterase E4 from *Myzus persicae*. Populations of *M. persicae* resist many organophosphorus and carbamate insecticides by producing more of an enzyme, carboxylesterase E4, that both hydrolyses these insecticidal esters and acts as an efficient sink for binding a large proportion of the toxic dose (*Rothamsted Report for 1978*, Part 1, 131–132). The increase in E4 activity is associated with cross-resistance to pyrethroids suggesting that E4 also interacts with pyrethroid esters.

The ability of purified E4 to hydrolyse the isomers of permethrin was therefore studied *in vitro* with ^{14}C esters. Whereas (1RS)*cis*-permethrin was not hydrolysed by the enzyme, the (1RS)*trans*-ester was hydrolysed rapidly but to no more than 50%. This suggested that E4 might be specific for one of the *trans* enantiomers. Each of these, radiolabelled in the 3-phenoxybenzyl group, was therefore synthesised and incubated with the enzyme. Only (1S)*trans*-permethrin was attacked and no hydrolysis of its enantiomer nor of the *cis* isomers could be detected even with large amounts of enzyme. The specificity is unexpected because (1S)*trans* is the least toxic of the four isomers and its metabolism would be expected to have little effect on overall resistance to the mixture. The activity of the enzyme at substrate concentrations giving V_{max} could not be measured because the water solubility of the ester was limited. However at 1μM, (1S)*trans*-permethrin was hydrolysed *c*.250 times as fast as dimethylphosphate esters (at V_{max}). (Devonshire and Moores)

Compounds influencing invertebrate behaviour

Field studies with honeybees. Lures containing synthetic Nasonov pheromone components (six monoterpenoids and (E,E)-farnesol) (i) attract honeybees to flowering plants: 82% of foraging honeybees visited plots with lures and (ii) attract swarms of honeybees to unoccupied hives: 12 of 50 hives with lures were occupied in contrast to 0 of 50 without

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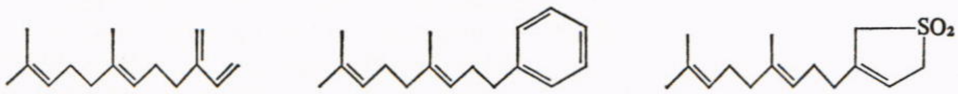
lures. Adding honeybee queen pheromone to lures improves swarm attracting efficiency. (Pickett and M. C. Smith, (i) with Williams, Entomology Department, and (ii) with Free, Entomology Department)

Aphid alarm pheromone. Larger and purer samples of (E)-β-farnesene (V), the main component of the aphid alarm pheromone, than were available by dehydration of nerolidol with phosphorus oxychloride were obtained at 200°C *in vacuo* over alumina deactivated with pyridine (44% pure, 60% yield). Although the new product was very active (99±0·6% of aphids responded to the vapour), special storage conditions were devised because α-farnesenes, which protected the earlier product from oxidation, were almost completely absent.

For sustained activity in the field, more stable related compounds were investigated. The vapours of benzylgeranyl (VI) and 3-(4,8-dimethyl-3,7-nonadienyl)sulpholene (VII) were inactive in one test but an aqueous formulation of (VII) suppressed the settling of *M. persicae* by 94±0·6% when painted on leaves of *Brassica pekinensis* probably because it slowly decomposes to (E)-β-farnesene. The principle of using such derivatives is therefore being explored with other compounds.



(V) (VI) (VII)

The greatest alarm response from *M. persicae*, as measured by movement from feeding sites, is obtained only in air saturated with (E)-β-farnesene dispensed slowly. Over 90% of aphids infesting large *Brassica pekinensis* plants responded to air saturated with (E)-β-farnesene dispensed at *c.* 230 mm s^{-1}. (Dawson, Griffiths, Pickett, M. C. Smith and Woodcock)

Honeybee alarm pheromone. An important new pheromonal component of the sting apparatus, first detected during electroantennogram investigations of the Nasonov pheromone, was identified by GLC–MS and microchemical studies as (Z)-11-eicosen-l-ol. Previously only more volatile components had been identified, and activity proved for one, isopentyl acetate. However, the new constituent is essential for full activity. (Pickett, with Williams and Martin, Entomology Department)

Sex attractants for pea moth. (E,E)-8,10-dodecadien-l-yl acetate, (E)-10-dodecen-l-yl acetate and (E,E)-8,10-dodecadien-l-ol attract males of *Cydia nigricana* (in descending order of activity). In surveying related compounds that might synergise or inhibit their action (*Rothamsted Report for 1979*, Part 1, 117) (E,E)-8,10-dodecadienal was also found to be an attractant. Higher doses (10^2–10^4 μg) in rubber lures were as effective as lures from (E)-10-dodecen-l-yl acetate (10^3 μg) but the aldehyde was relatively less potent at the 10 μg level. (Greenway, with Wall, Entomology Department)

Pheromones of *Ephestia kuehniella*. Reverse phase high pressure liquid chromatography at low pH separated a series of 2-acylcyclohexane-1,3-diones (1, 2 and 3) and 4-hydroxy analogues (4, 5, 6, 7 and 8) (related to the 2-oleoyl compounds (3 and 9) described previously (*Rothamsted Report for 1978*, Part 1, 137) from the larval mandibular glands of *E. kuehniella*. These structures were deduced from a combination of chemical ionisation and electron impact high resolution mass spectrometry, with infrared, ultraviolet, ^{13}C and ^{1}H nuclear magnetic resonance spectroscopy and GLC–MS analysis of ozonolysis products.

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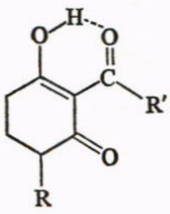
The chemical and biological properties of these natural products are unusual. They are acidic enols with side chains some of which, especially the *cis,trans* diene of (1) and (4), are not directly related to components found previously in insects; they have higher molecular weights and are less volatile than most insect pheromones. All the new components elicit an oviposition response from the larval parasite *Venturia canescens*: their relative potencies for this and other activities are being determined. (Mudd)



R = H (1, 2, 3) or OH (4, 5, 6, 7, 8 and 9)
R′ = (Z, E)-11,13-pentadecadienyl (1, 4)
or (E)-9-pentadecenyl (2)
or (Z)-8-heptadecenyl (3, 9)
or (E)-13-pentadecenyl (5)
or (Z)-10-pentadecenyl (6)
or (Z)-8-pentadecenyl (7)
or (Z)-6-pentadecenyl (8)

Pesticides and beneficial insects

Field poisoning of honeybees. Insecticide poisoning (last year's *Report*, Part 1, 117) was confirmed in 53 samples of allegedly poisoned bees submitted via MAFF in 1980 compared with 97 in 1979. Poisoning by aerial and ground application of triazophos to oilseed rape in 1978 (136 samples) was less extensive in 1979 (36 samples) largely because aerial spraying was prohibited, and again in 1980 (16 samples, or less than ten cases if multiple consequences of single spray operations are allowed for). This welcome drop was probably because the hazard was better recognised and prolonged poor weather during flowering made bees less active.

Of the remaining samples examined in 1980, 22 involved other anticholinesterases, several used on wheat, nine had organochlorine residues (HCH, dieldrin) some from wood preservatives, and two from orchards were due to carbaryl. (Smart and Stevenson)

Selectivity of insecticides between beneficial and pest insects. Studies of the relative activity of pyrethroid insecticides against the lepidopterous stored product pest *Ephestia kuehniella* and its hymenopterous parasite *Venturia canescens* continued (*Rothamsted Report for 1978*, Part 1, 134). Insecticides selective in favour of beneficial species are important in integrated pest control programmes and our results (Table 2) indicate considerable variation in relative toxicity among the pyrethroids, some, deltamethrin, 'NRDC 185', bioallethrin, the two dibromopermethrins and 'NRDC 108', being notably favourable to the parasite. (Elliott, Janes, Stevenson and Walters)

Soil-borne pests

Control of wheat bulb fly larvae. Soil treatments (chlorfenvinphos, fonofos and chlorpyrifos) applied at sowing, and seed treatments (chlorfenvinphos, fonofos and permethrin) were compared at two sowing depths, sown early (3–12 October) or late (26–28 November) in two contrasting soils. Plants sown early in peaty loam were so well tillered that additional benefit from treatment was small, and in clay loam damage by slugs and rodents hampered assessment.

No single treatment was effective in all conditions, but both soil and seed treatments controlled wheat bulb fly best in the shallow plots. Most of the seed treatments were more active than soil treatments, but, except for permethrin, generally produced early phytotoxic symptoms. Most compounds, particularly permethrin, persisted adequately. (Griffiths, Scott, C. Smith and Woodcock)

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TABLE 2

Relative toxicity of pyrethroid and other insecticides to Ephestia kuehniella *and* Venturia canescens (*LD50 in* μg g^{-1} *insect*)

	Ephestia	*Venturia*	Ratio *Venturia/ Ephestia*
'Kadethrin'	0·067	12	180
Bioallethrin	0·11	11	96
'NRDC 185'[a]	0·12	9·5	78
'NRDC 108'[b]	0·16	8·0	50
Rotenone	160	8000	50
'Dibromo *cis* permethrin'[c]	0·08	3·4	42
'Dibromo *trans* permethrin'[d]	0·21	6·4	32
Deltamethrin	0·013	0·40	31
'Pentamethrin'[e]	2·7	60	22
[IR,*cis*]-permethrin	0·10	2·2	21
Cyhalothrin[f]	0·0053	0·10	19
Biopermethrin	0·16	2·6	16
'NRDC 145'[g]	0·27	3·4	13
Cismethrin	0·19	2·4	13
Endosulfan	1·7	20	12
Fenvalerate	0·17	1·9	11
'NRDC 101'[h]	0·49	4·4	9·0
Bioresmethrin	0·29	2·4	8·3
'NRDC 181'[i]	0·21	1·3	6·2
'RU 11679'[j]	0·11	0·60	5·5
Pirimicarb	110	220	2·0
'NRDC 100'[k]	2·5	3·4	1·4
Phosalone	11	4·6	0·42

[a] (RS)-α-cyano-3-benzoylbenzyl (1R)*cis*-3-(2,2-dibromovinyl)-2, 2-dimethylcyclopropanecarboxylate
[b] 5-benzyl-3-furylmethyl 2,2,3,3-tetramethylcyclopropanecarboxylate
[c] 3-phenoxybenzyl (1R)*cis*-3-(1,2-dibromo-2,2-dichloroethyl)-2,2-dimethylcyclopropanecarboxylate
[d] 3-phenoxybenzyl (1R)*trans*-3-(1,2-dibromo-2,2-dichloroethyl)-2,2-dimethylcyclopropanecarboxylate
[e] 2,3,4,5,6-pentamethylbenzyl (1RS)*cis,trans*-chrysanthemate
[f] (Z),(1R)*cis*-(S)-α isomer, generously provided by ICI (UK) Ltd.
[g] 5-benzyl-3-furylmethyl (1R)*trans*-2,2-dimethyl-3-methoximinomethylcyclopropanecarboxylate
[h] 4-allyl-2,6-dimethylbenzyl (1RS)*cis,trans*-chrysanthemate
[i] [RS]-α-cyano-3-phenoxybenzyl (RS)-2(4-chlorophenyl) cyclopropylacetate
[j] 5-benzyl-3-furylmethyl (1R)*trans*-3-cyclopentylidenemethyl-2,2-dimethylcyclopropanecarboxylate
[k] 4-allylbenzyl (1RS)*cis,trans*-chrysanthemate.

Seed treatments against slugs in cereals. In a field trial on seed treatments to control slugs (*Deroceras reticulatum*) on direct drilled winter wheat, adverse growing conditions following a late sowing caused several compounds to show phytotoxic effects, thus masking possible benefits. Further laboratory tests examined the effectiveness of chemicals related to ioxynil (20 compounds) and nereistoxin (11 compounds). Two promising compounds, 3,5-diiodo-4-hydroxybenzoic acid ('May & Baker 10903', an analogue of ioxynil), and cartap, an analogue of nereistoxin, will be tested under field conditions. (Griffiths, Pickett, Scott and Woodcock)

Control of spring barley pests

A field experiment on spring barley sown at two different dates examined the effects of four different aphicide treatments. Although there were few cereal aphids (*Metopolophium dirhodum* and *Sitobion avenae*) yield of barley sown on 28 April was increased 25% by three applications of demeton-S-methyl and 10% by a single application. These effects

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cannot be attributed alone to control of aphids or suppression of the virus BYDV for which they are vectors, but rather must be associated with elimination of damage by a complex of insect pests throughout the growing season, particularly dipterous stem borers (*Oscinella* spp. and *Chlorops pumilionis*) and thrips. A further experiment will study the relative importance of these pests and the benefit to be gained from insecticides. (Griffiths, Scott and Woodcock)

Behaviour of pesticides in soil

Winter leaching in the field. Continuing investigations reported previously (last year's *Report*, Part 1, 118), and in association with work in CLU (q.v.), fluometuron, [^{14}C]-aldicarb sulphone and Na^{36}Cl were incorporated into the top 2·5 cm of soil in plastic pipes driven into heavy clay soil at Compton Beauchamp. After 93 days, maximum concentrations of chloride and fluometuron were at depths of 30 and 3·75 cm, respectively (mean recoveries, 31 and 59%) with traces of fluometuron (3% maximum concentration) at 40 cm. This contrasts with the small summer movements reported in 1979.

The behaviour of fluometuron was simulated by two different computational models, that of Leistra (*Rothamsted Report for 1977*, Part 1, 156) modified to calculate degradation as a function of soil temperature and water content and that of Addiscott originally constructed to describe movement of anions but adapted for movement of a compound that is reversibly adsorbed by the soil and subject to degradation. Both models correctly predicted that most fluometuron remained in the top 7·5 cm but overestimated the amount between 10 and 22·5 cm. Neither model predicted well the amounts which leached below 25 cm; however both gave a useful estimate of the pattern of fluometuron movement in a soil of a type in which prediction would be expected to be difficult, especially in winter, the season of greatest leaching. (Nicholls, with Bromilow, Chemical Liaison Unit, and Addiscott, Soils and Plant Nutrition Department)

Systemic transport of pesticides in plants

This new project aims to establish fundamental structure–mobility relationships as a basis for designing compounds which will move downwards in plants and control pests and diseases underground following foliar application; two systems suitable for the investigations have been developed. In one, areas on the second leaves of growing pea plants are stripped of cuticular wax with 'Nuloidin', then drops of solution of ^{14}C test compound are applied. Subsequently radioactivity in the stem and petiole is mapped by counting extracts of small segments. Although this procedure has already given interesting distribution profiles for a number of known phloem-mobile compounds (sucrose, maleic hydrazide, 2,4-dichlorophenoxyacetic acid and 3-amino-1,2,4-triazole), there are limitations due to variability between replicates. The second system uses *Ricinus communis*; ^{14}C test compounds are injected or perfused directly into the hollow petiole and their movement monitored continuously by collecting phloem exudate from a cut in the stem bark below the treated leaf. Fewer replicates for each treatment are necessary and quantitative results are possible. (Bailey, Butcher, Chamberlain and Searle)

Foliar sprays

Electrically charged spray application systems. Two new charged rotary atomiser heads, the APE 80, and a substantially modified form of the Micron Micromax have been developed and patented with support from the National Research Development

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Corporation. Both systems charge by ion injection or attachment, without physical contact between the discharge electrode and the liquid to be atomised.

The APE 80 operates at 28 kV maximum and at that voltage draws 1–6 μA, depending on the resistivity of the formulation. The power supply module is energised from the 12V tractor battery and can charge 20 or more spray heads; the APE 80 head is also the basis for a recently developed hand held sprayer. Typical application rates are 2–4 litres ha^{-1}. In trials on field beans with the APE 80, the gross deposition of the spray when charged was increased more than 3- and 2½-fold for oil-based and water-based formulations, respectively. The underleaf coverage was also significantly greater with charge ($\times 7$, oil based and $\times 5$, water based), as was stem deposition. However when the beans had grown to about 1 m, and formed a more complete canopy, penetration by charged drops was inferior to uncharged ULV sprays of both oil and water formulations. Preliminary results therefore indicate that electrostatically charged sprays produce less drift with greater deposition and generally increased under leaf coverage on plants than equivalent uncharged systems.

The larger spray head based on the Micron Micromax being tested in the laboratory will allow greater liquid flow rates and thus higher ground speeds. Isolation of the main tank supply and incorporation of a positive liquid flow system are also being investigated. (Arnold and Pye, with Cayley, Chemical Liaison Unit)

Controlled drop application (CDA)

Placement spraying. A range of controlled drop sprays were applied against powdery mildew on barley and compared with conventional medium volume hydraulic sprays (cf. *Rothamsted Report for 1978*, Part 1, 144). Incidence of powdery mildew in untreated plots was high (59% on leaf 3, Zadoks G.S. 59) but good control was achieved with both hydraulic sprays and CDA treatments at the full rate of tridemorph (525 g a.i. ha^{-1} as 'Calixin'). In CDA-treated plots receiving full rate tridemorph, disease incidence was related to drop density: for double, standard and half drop number corresponding disease percentages were 6, 12 and 24% respectively. Yields generally reflected these differences in disease control, with increases up to 30%. (Etheridge and Phillips)

Drift spraying. To establish deposition contours under field conditions (cf. *Rothamsted Report for 1978*, Part 1, 145) a radiolabelled 'Risella–Shellsol' mixture was applied by a multidisc drift sprayer to a crop of spring barley with wind speeds averaging 6·5 km h^{-1}. Scintillation counting of leaf samples collected immediately after spraying showed that deposits were high over the first 10 m downwind, and then gradually decreased, with measurable deposits up to 150 m. A net at 200 m suspended 3 m above the crop intercepted insignificant amounts of radioactivity compared with even the lowest deposits on the crop.

Counts on samples collected 4 months later from upper leaves and grain heads in the high deposit area suggested that the formulation base, Risella oil, or its metabolites, may be slightly systemic in barley.

The work supports earlier conclusions that at wind speeds of between 6 and 8 km h^{-1} an effective drift swath width of between 25 and 30 m is attained. (Etheridge and Phillips)

Bird repellents

Effects of formulation on persistence of deposits. Further studies evaluated eight treatments on redcurrant bushes, the first four also on plum trees; chlorpyrifos ('Dursban') emulsion concentrate and microencapsulated technical chlorpyrifos; fentin hydroxide wettable powder, with and without 'Acronal 4D' sticker; bendiocarb ('Ficam') wettable

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powder, with and without 'Acronal 4D' sticker; methyl anthranilate quick-breaking emulsion and technical methyl anthranilate with 'Acronal 4D' sticker.

Chemical analyses by Fisons Ltd on samples from the bendiocarb treatments (taken 1 day, 6 or 12 weeks after application) showed that higher depositions and greater persistence were achieved when sticker was present. Analyses here of chlorpyrifos samples confirmed that greatest persistence was achieved by microencapsulation, as found earlier with 'PP199.' Thus, after 1 day, 6 and 12 weeks the residues on the twigs (mg m^{-2}) were respectively 370, 180 and 120 for the emulsion formulation and 840, 390 and 370 for the microcapsule formulation.

Because of wide variations in bud damage by birds on both plums and redcurrants, damage after treatments did not differ significantly from controls. However, yields of redcurrants treated with bendiocarb plus 'Acronal 4D' sticker were significantly higher than controls (approx. double). Conversely, Fentin hydroxide with 'Acronal 4D' sticker gave a significantly lower yield (approx. one quarter) probably due to phytotoxicity. (Etheridge and Phillips, with Dr D. A. Kendall and Dr B. D. Smith, Long Ashton Research Station)

Formulation

Microencapsulation techniques. Microencapsulated formulations were prepared as aqueous slurries by interfacial polymerisation condensation containing chlorpyrifos (for field trials as a bird repellent), benomyl and carbendazim (as soil fungicides) and ioxynil (as a possible molluscicide). (Etheridge and Phillips)

Insect species reared

Homoptera
Aphis fabae Scop.;
Megoura viciae Buckt.;
Metapolophium dirhodum (Wlk.);
Myzus persicae (Sulz.) (Susceptible and several resistant strains);
Rhopalosiphum padi (L.);
Sitobion avenae (F.).

Coleoptera
Phaedon cochleariae (F.).

Dictyoptera
Periplaneta americana (L.).

Diptera
Delia antiqua (Meig.);
Drosophila melanogaster Meig. (Vestigial wing strain);
Lucilia cuprina (L.);
Musca domestica L.;
Strains:
- wild-type susceptible;
- *ac*: *ar*; *bwb*; *ocra*—called 608, multi-marker susceptible.
- SKA-diazinon selected, very resistant to many organophosphorus insecticides.
- Several derived from the dimethoate resistant $49r_2b$, resistant to dimethoate and other organophosphorus insecticides.
- 290BIO, a substrain of the dimethoate/bio-resmethrin resistant 290rb derived by selection with bioresmethrin.
- Several derived from 290BIO each resistant to pyrethroids and DDT.
- NPR-pyrethrum extract selected.
- 538ge-*kdr* knock-down resistant.
- IPSWICH pyrethroid-resistant. Several derived from IPSWICH resistant to pyrethroids.

Hymenoptera
Aphidius matricariae (Haliday);
Venturia canescens (Grav.).

Lepidoptera
Ephestia kuehniella Zeller;
Plutella xylostella (L.).

also Mollusca
Deroceras reticulatum (Muller).

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Fungal diseases and fungicides

Clubroot disease: the host–parasite relationship. Further evidence suggests that changes in the metabolism of auxin-related indoles are important in the response of the host to infection by *Plasmodiophora brassicae*. The rate of conversion of tryptophan to 3-indolylacetaldoxime (IAO), 3-indolylmethyl glucosinolate (IMG) and 3-indolylacetonitrile (IAN), measured with ^{14}C labelled compounds, is greater in infected than in control tissues. Infected tissues can degrade IMG to IAN, and contain nitrilase, the enzyme necessary for conversion of IAN to the auxin 3-indolylacetic acid (IAA), so in infected tissues metabolism of IMG to IAN and IAA may be increased and cause the observed excessive and abnormal growth of the host. If clubroot disease is associated with this mechanism, control may be possible either by treatments to prevent auxin release, or by breeding brassicae deficient in IMG. (Bailey, Butcher, Chamberlain and Searle)

Control of soil-borne diseases by foliar sprays. Earlier work showed that foliar sprays of ethionine, or the downward translocated compound 3,5-D (the 3,5-analogue of the herbicide 2,4-D) decreased the severity of potato common scab (*Streptomyces scabies*) and clubroot of cabbage (*P. brassicae*). Results against scab suggest that 3,5-D suppresses development of symptoms by altering tuber physiology.

Clubroot of cabbage. Spraying healthy or diseased glasshouse plants with DL-ethionine (2·5 or 5·0 g litre^{-1}) or 3,5-D (0·2 or 0·5 g litre^{-1}) decreased growth of roots, whether fibrous or clubbed. There were no changes in the weights of tops, which were evidently supported even by diminished roots under the experimental conditions of unrestricted water and nutrients. (McIntosh, with Macfarlane, Plant Pathology Department)

Amino acids in clubroot disease of cabbage. An alternative systematic approach to possible control methods for clubroot involved analogues of amino acids found in infected hypocotyls, where metabolism is deranged as clubs form.

Bacterial contamination and osmotic instability have so far prevented the direct use of isolated plasmodia in these metabolic studies. However, in hypocotyls of infected plants, the total soluble pool of arginine, combined aspartate+asparagine, and combined glutamate+glutamine increased at various stages of infection, with corresponding decreases in leaves. Incubated slices from infected hypocotyls, supplied with ^{14}C-labelled citric acid, produced labelled glutamate, glutamine, aspartate and 4-aminobutyric acid; slices from healthy hypocotyls produced labelled glutamate and 4-aminobutyric acid only.

In the glasshouse, analogues of glutamate, glutamine, aspartate, asparagine and others were therefore tested as foliar sprays against clubroot, but did not decrease severity. (Burrell and Mills, with Dr D. H. Lewis, University of Sheffield)

3,5-D and scab: mode of action. Experiments on whole plants indicated that the anti-scab action of 3,5-D is not related to its known property as an anti-auxin, neither does it affect the structural changes in developing lenticels, the main site of entry of *S. scabies* into young tubers.

The development of scab lesions by tuber tissue, in response to infection by *S. scabies*, involves formation of phenolic compounds. Similar changes also occur in the normal wound-healing response, which was conveniently followed on discs cut from young developing tubers. Results of many radiotracer experiments on incubated discs suggested that 3,5-D inhibits the metabolism of phenylalanine to phenolic compounds and that

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this effect, specific to the wound/scab infection response, is enough to decrease the formation of scab lesions.

Other experiments with discs concerned the possible development of a rapid method for assessing anti-scab action, which at present can be measured only in tests on growing plants. Discs normally become brown after incubation for 24–48 h, but the browning was decreased by small amounts of 3,5-D. Inhibition of browning by analogues of 3,5-D was roughly correlated with their effects against scab as foliar sprays (last year's *Report*, Part 1, 121); further work is needed to confirm this. (Burrell)

3,5-D and scab: analogues, and spray timing. In glasshouse tests, analogues were sprayed at 0·9 mM (e.g. 0·2 g litre^{-1} for 3,5-D) on the foliage of single-stem potato plants (cv. Maris Bard) 2 weeks after potting in scab-infested soil. The following were as effective as 3,5-D in suppressing scab: 3,5-dibromophenoxyacetic acid (A); 3,5-di(trifluoromethyl)-phenoxyacetic acid (B); 4-(3,5-dichlorophenoxy)-n-butyric acid (C). Compounds A and C, like 3,5-D itself, slightly increased the number of tubers per plant and caused some tuber distortion; compound A also decreased yield of tubers. Compound B, however, had fewer side effects on tuber development than the others. With the exception of 3,5-dichloro-*trans*-cinnamic acid, which decreased scab slightly, all other analogues were ineffective: 3-chloro-5-methylphenoxyacetic acid; 3,5-diiodophenoxyacetic acid; 3,5-dichlorophenylthioacetic acid; 3,5-dichlorophenyliminoacetic acid; 2-(3,5-dichlorophenoxy)propionic acid; 2-(3,5-dichlorophenoxy)isobutyric acid: 3,5-dichlorophenoxyacetone; 3,5-dichlorophenylacetic acid; 3-(3,5-dichlorophenyl) propionic acid.

Other glasshouses tests showed that 3,5-D was most effective against scab when sprayed as early as practicable, i.e. one week after potting, but tuber distortion was then also increased.

Unusually wet weather in June prevented scab formation in a trial designed to find the optimum timing and concentration for 3,5-D sprays in the field. (Chamberlain, Dawson and McIntosh)

Fungicides for soil-borne diseases of wheat. In further pot tests (cf. last year's *Report*, Part 1, 121) to clarify the effects of soil drench treatments against take-all on young wheat plants, benomyl and iprodione suspensions were effective against deep inoculum (5 cm below the seed) only in sand. Benomyl was effective at this depth in loam–sand mixture when it was applied with an alcohol ethoxylate surfactant. In long-term outdoor experiments two spring drenches with benomyl gave some benefit to plants nearing maturity, probably by protecting the crown and crown root initials rather than by deep penetration of the soil. Long-term protection was also given by microencapsulated carbendazim mixed with the soil.

In a field experiment, fungicides were watered on to plots just before sowing in October (followed by rotary harrowing) or in April. Take-all was suppressed up to July by benomyl applied in autumn at 20 kg ha^{-1} and by nuarimol applied in autumn and spring at 4·4 kg ha^{-1}. Take-all was not severe enough to affect yield, which was, however, slightly decreased by nuarimol. (Bateman)

'Milstem' treatment of winter barley: effects on spring-sown barley. Re-introduction of 'Milstem' (a.i. ethirimol) as a seed treatment against mildew for autumn-sown winter barley prompted concern that overwintering mildew might become resistant and spread to spring-sown barley. The winter 1978–79 was too severe for mildew to overwinter at Woburn, but the 1979–80 field trial gave definite results. Plots of spring barley (cv. Wing) treated or untreated with 'Milstem' were flanked by plots of similarly treated autumn sown Hoppel.

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TABLE 3

'Milstem' use on winter and spring barley

Treatments		Yield of Wing	Mildew levels on Wing at G.S. 52 (% leaf area infected)	Ethirimol resistance of mildew on Wing at G.S. 52 (ED50 μg ml^{-1})
Hoppel	Wing	(t ha^{-1})		
None	None	4·78a	70a	0·84a
'Milstem'	None	4·83a	64a	0·88a
None	'Milstem'	5·41b	23c	2·67b
'Milstem'	'Milstem'	5·02ab	46b	2·54b

Values followed by the same letter were not significantly different ($P=0·05$). For statistical analysis disease levels were transformed to logits ($z=1/2 \log_e (p/q)$) and ED50s to $\log_{10}$ μg ml^{-1}

The results in Table 3 show that autumn application of 'Milstem' diminished its effectiveness on spring-sown barley. This could not be attributed to increased ethirimol resistance in inoculum originating from 'Milstem'-treated Hoppel in the spring. Instead 'Milstem' ensured that more foliage overwintered, so that treated Hoppel plots, when no longer protected by fungicide the following spring, provided more inoculum than untreated Hoppel. Mildew epidemics that developed on treated Wing plots reflected this difference in inoculum levels. (Hollomon)

Variation in response of barley pathogens to the fungicide triadimenol. Large quantities of fungicides, especially those that inhibit sterol biosynthesis, are used on barley but little is known about the variation within pathogen populations. Bioassays have been developed that assess the sensitivity of *Erysiphe graminis* f.sp. *hordei* and *Ryhnchosporium secalis* to one such fungicide, triadimenol. Remarkably little variation was detected in either pathogen, and no field-resistant isolates could be clearly identified in the laboratory assays. These data therefore constitute standards for comparison should triadimenol resistance develop in the future. Attempts to induce triadimenol-resistant mutants of *R. secalis* were unsuccessful using near u.v. light but resistance factors of 10 were achieved in some isolates through culturing on agar containing increasing amounts of triadimenol. The significance of this resistance is being examined. (Brewster, Butters and Hollomon)

Mode of action of tridemorph. To develop strategies to minimise the incidence of resistance, knowledge of the mode of action of mildew fungicides is required. However, even for tridemorph which has been used for over a decade without significant resistance, the mode of action is still not firmly established. Recent evidence suggests that it inhibits sterol biosynthesis (*Pesticide Biochemistry and Physiology* (1980) **12,** 195), but earlier work implicated protein synthesis (*Pesticide Science* (1974) **5**, 219). In a cell-free heterologous protein synthesising system using ribosomes from *E. graminis* conidia and other components from *Neurospora crassa*, tridemorph had no effect on poly-U directed polyphenylalanine synthesis. (Hollomon).

Other projects

In addition to work already noted, collaboration as follows is listed in other sections of the *Rothamsted Report*:

Entomology Department

Etheridge and Goodchild, with Macaulay—monitoring for pea moth.
Griffiths, with Bardner and Fletcher—control of *Sitona.*
Pickett, with Free and Williams—honeybee pheromones.

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Soil Microbiology Department

Burrell, with Maskell—biochemistry of VA mycorrhiza.

Statistics Department

Greenway, with Perry (Statistics Department) and Wall and Sturgeon (Entomology Department)—contamination of vegetation with (E,E)-8,10-dodecadien-1-yl acetate.

THE CHEMICAL LIAISON UNIT

Measurements of traces of pesticides is an essential part of our contributions to collaborative investigations on pest and disease control. The chemical methods essential for assay of residues in the field are being improved continuously and the range of compounds extended. The increased sensitivity of analytical methods for selected compounds makes it possible to trace the movement of droplets within the crop canopy, in addition to measuring deposits resulting from application of pesticides by differing techniques and residues remaining in crops and soils. Information on the sorption, degradation and movement of chemicals in crops and soils continues to be collected, using radiotracers as appropriate. This provides a firm basis for developing and testing theories and models for describing the fate and behaviour of chemicals with the objectives of increasing efficacy or avoiding adverse effects of pesticides.

Behaviour of pesticides in plants

Root uptake. Studies of the uptake of ^{14}C-labelled phenylureas by barley plants from nutrient solutions (*Rothamsted Report for 1976*, Part 1, 184–185) were extended to wheat, maize and field beans. The results with all four species were similar; for translocation there was an optimum lipophilicity, measured by the octanol–water partition coefficient, while root accumulation steadily increased with increasing lipophilicity.

The uptake properties of 3-methylthiophenylurea were similar to those of other phenylureas of comparable lipophilicity although most of the compound in the plant was metabolised to and probably translocated as the more polar sulphoxide metabolite. Initial penetration of the root was deduced to be as the parent thioether rather than the more polar sulphoxide because in separate tests little of the polar 3-methylsulphonyl phenylurea was accumulated by or translocated from roots bathed in a solution. These results are analogous to those previously reported (*Rothamsted Report for 1979*, Part 1, 124–125) for uptake by earthworms of aldicarb, which readily penetrates and then is rapidly metabolised to its polar sulphoxide. The latter does not penetrate from external solutions. (Briggs and Evans)

Fate and behaviour of pesticides in soils

Microbial degradation. Permethrin was degraded by various soils in the laboratory, the rate depending on the soil type and its previous manurial treatment. Unexpectedly, soils from the Broadbalk FYM plot degraded permethrin more slowly than soils from either the full minerals or nil fertiliser plots. Degradation of permethrin was inhibited by sodium azide, heat treatment and lack of oxygen and so appeared to be microbial but we have not succeeded in isolating any degrading organisms. However, bacteria were isolated which degraded 3-phenoxybenzyl alcohol, a hydrolysis product of permethrin. Repeated treatment of soil with permethrin did not accelerate its degrada-

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tion, perhaps because poor water solubility, <1 ppm, limits the availability of permethrin to microbes. In agitated suspensions of 2 g soil in 100 ml of water permethrin was degraded more rapidly than in moist soil, presumably because more rapid redistribution between soil and water improves availability of the chemical to degrading organisms as noted earlier for the degradation of diazinon (water solubility 40 ppm) (*Rothamsted Report for 1978*, Part 1, 150). (Lord, McKinley and Walker)

Computer simulation. Development of the computer model (*Rothamsted Report for 1978*, Part 1, 149) has continued with its application to a structured clay soil at Compton Beauchamp using information from experiments in both summer and winter (*Rothamsted Reports for 1979*, Part 1, 124, and *for 1980*, Part 1, 129).

Accurate assessment of water movement through soils is essential for modelling pesticide behaviour in soil. Using climatic data and soil–water relationships, the model successfully described water movement in the soil as assessed from the measured soil water contents. However, this required values of hydraulic conductivities somewhat less than those directly measured; this may reflect the difficulties of accurately measuring hydraulic conductivities in the field.

Leaching of aldicarb sulphone, an oximecarbamate weakly absorbed by soil, was consistently overestimated by the model. One reason for this may be that equilibration of solute between the mobile and stagnant phases is incomplete because water drains through cracks between the aggregates of soil. Degradation was estimated by a modification of the procedure of Walker (*Journal of Environmental Quality* (1974) **3**, 396). Aldicarb sulphone decomposed in the field approximately twice as fast as predicted from laboratory incubations, this may be due to changes in the soil induced by air-drying and rewetting before adding chemical in the laboratory tests. (Bromilow and Freeman, with Nicholls, Insecticides and Fungicides Department)

Other projects

As well as work already noted, collaboration as follows is listed in other sections of the *Rothamsted Report*:

Plant Pathology Department

Cayley, with Hide—fungicide control of potato tuber pathogens.
Cayley, with Rawlinson—control of oilseed rape diseases.
Cayley, with Bainbridge—control of chocolate spot of field beans.
Cayley and Lord, with Lacey—hay preservatives.

Nematology Department

Bromilow, with Whitehead—chemical control of nematodes.

Staff of the Department and the Chemical Liaison Unit

Rothamsted Experimental Station was greatly honoured again this year by a Queen's Award for Technological Achievement. The present award for developing more photostable synthetic pyrethroid insecticides complements an Award in 1976 for an earlier series of pyrethroids, also highly active insecticides, but less stable.

Norman Walker, a respected colleague, retired in December after a distinguished career of 31 years at Rothamsted, first in the Soil Microbiology Department, latterly with the Chemical Liaison Unit.

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Dr Liu Xun, a chemist from the Institute of Zoology, Peking, came to spend 2 years working on synthetic aspects of behaviour controlling compounds; Mr Paul B. Hughes returned to the Biological and Chemical Research Institute, Rydalmere, New South Wales. Dr J. Sula of the Czechoslovak Academy of Sciences, Prague, studied aspects of insecticide resistance in *Myzus persicae* and Mlle S. Jusseame, University of Rennes, France, the monitoring of resistance. Dr Thomas Rausch, of the Botanisches Institut, Frankfurt, returned for further work on control of clubroot disease.

Miss A. Abdalla from Sudan and S. Nwokocha from Nigeria joined the Chemical Liaison Unit for training, supported respectively by IAEA and the Inter-University Council.

A. I. Denholm was appointed to work on the development of strategies to counter resistance and R. L. Elliott on synthetic pyrethroids with support from the Leverhulme Trust Fund and NRDC, respectively. Jennifer A. Butters was appointed to the Department and Mavis Davies to the Chemical Liaison Unit. Janine Mills, Sheffield University, worked as a CASE student. M. A. H. Freeman resigned from the Chemical Liaison Unit.

At the request of Roussel Uclaf, M. Elliott organised with Professor J. E. Casida, University of California at Berkeley, a 'Table Ronde' on 'Pyrethroid Insecticides: Chemistry and Action' in Paris, 6–7 March, 1980, at which he, N. F. Janes and R. M, Sawicki lectured. M. Elliott contributed to a scientific Working Group on the 'Use of Naturally Occurring Plant Products in Pest and Disease Control' convened by the International Centre of Insect Physiology and Ecology, Nairobi, Kenya (12–15 May, 1980); he also visited research centres of the Pyrethrum Board of Kenya, Celamerck AG, Ingelheim am Rhein, West Germany, and Bayer AG, Wuppertal, West Germany. R. M. Sawicki visited Oman as consultant to FAO on problems of insect resistance (May–June) and research centres of the United States of America to discuss resistance to pyrethroid insecticides (December); he lectured to the XVI International Congress of Entomology in Kyoto (August). By invitation, J. H. Stevenson acted as rapporteur to the International Commission of Bee Botany Symposium on harmonisation of methods for testing the toxicity of pesticides for bees, Wageningen (22–25 September). A. J. Arnold and B. J. Pye demonstrated the APE 80 electostatic spraying system at Fisons Sprayers-in-Action Show, Peterborough (June).

R. H. Bromilow (January–February) and K. A. Lord (August) continued collaboration on pesticides in soil at the Radioisotopes Centre, Sao Paulo. Brazil, and K. A. Lord discussed the behaviour of pesticide residues at Bayer, Leverkusen (April). N. Walker lectured on and discussed nitrifying bacteria and microbial degradation of insecticides in the University of Granada (October). G. G. Briggs contributed to the ADAS Soil Scientists Conference on Pesticide Residues and organised a session on 'weeds' at the Crop Protection Conference (November).

Publications

General Papers

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CHEMICAL LIAISON UNIT

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