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TRIALS ON INTEGRATED PEST MANAGEMENT IN ENGLISH APPLE ORCHARDS

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Summary An integrated pest management system, involving monitoring and the use of selective pesticides, was compared on four 0.5 ha plots with a routine broad-spectrum spray programme. Biological control of spider mite, Panonychus ulmi, by Typhlodromus pyri and predacious insects occurred as early as the second season. Insect and disease control were largely satisfactory, with a reduced number of insecticide applications, but damage to fruit by lepidopterous larvae, including Operophtera brumata and tortricid spp., was above commercially acceptable levels on some plots. The improvements required include better monitoring methods for these pests and for rosy apple aphid, Dysaphis plantaginea, selective control of certain 'minor' pests, and a selective chemical thinning agent to replace carbaryl.

Résumé On a comparé un système de la lutte intégrée, comportant des contrôles périodiques et de l'usage des pesticides sélectifs, avec la lutte chimique classique. Dès la deuxième saison, Typhlodromus pyri et certaines mirides ont commencé a réguler les nombres de Panonychus ulmi. Avec un nombre réduit d'applications d'insecticide pour la lutte contre les autres ravageurs et les maladies cryptogamiques on avait eu un résultat assez satisfaisant, mais la pourcentage de fruits endommagés par les chenilles et les tordeuses avait été plus élevé en lutte intégrée. Cela nécessite un peu d'amélioration sur les méthodes de contrôle, ainsi pour le puceron cendre, Dysaphis plantaginea. On a besoin de la lutte sélectif contre quelques ravageurs secondaires, et une replacement sélectif pour le carbaryl, agent chimique pour démarier les fruits.

INTRODUCTION

The most cogent reason for an integrated approach to pest and disease control in apple orchards is the continuing development of resistance of pests to pesticides, especially in fruit tree red spider mite (Panonychus ulmi (Koch) (Cranham, 1973)). Other important considerations are the increasing costs of pesticides and concern over environmental pollution. In the last decade or so, several developments have enhanced the feasibility of integrating a substantial contribution from natural enemies with chemical control of diseases and most pests. New pesticides have become available that are harmless to phytoseiids, and evidence that these predatory mites can regulate spider mite numbers has accumulated in many countries. Novel methods of controlling apple scab, *Venturia inaequalis*, and powdery mildew, *Podosphaera leucotricha*, in the overwintering stages have been developed (Burchill,1972; Burchill *et al*,1979). Also, the introduction of supervised control to commercial orchards (Carden, 1977) has greatly improved confidence in monitoring methods and the use of spray treatment thresholds; in this, pheromone traps for codling moth and some tortricids are a valuable component.

In 1977, orchard trials were started at East Malling Research Station to compare an integrated pest management system, involving use of the available selective pesticides in a monitored system, with a routine "calendar" broad-spectrum spray programme. These are envisaged as long-term trials to study the integration of biological control of spider mites (and it is hoped certain insect pests) with chemical control of diseases and most insect pests. This paper summarises experience during the first two seasons.

METHODS AND MATERIALS

Trials commenced in 1977 to compare the two systems on four replicate pairs of adjacent plots, *c*. 0.5 ha in size, in three mature apple orchards at East Malling Research Station. Table 1 shows the pesticides used.

Table 1

Pesticides used in comparison of IPM and 'routine' spray programmes

Target	Routine	IPM
Aphids Apple sucker Winter moth	chlorpyrifos or fenitrothion	pirimicarb endosulfan diflubenzuron
Apple sawfly	γ BHC	diflubenzuron
Fruit tree red spider mite	cyhexatin	cyhexatin ($\frac{1}{2}$ standard rate) or tetradifon
Codling moth Tortrix moths	azinphos-methyl	diflubenzuron
Apple powdery mildew	binapacryl	bupirimate
Apple scab	captan or thiophanate-methyl	captan

On the integrated pest management (IPM) plots the choice of insecticides was restricted to those of low toxicity to the predacious phytoseiid mite *Typhlodromus pyri* and predacious insects. These selective insecticides were applied only when monitoring indicated the need. On the 'routine' plots, conventional broad-spectrum insecticides were applied on an 'insurance' basis.

To assess the numbers of insect pests and predators, plots were monitored by visual and beating methods on six occasions from 'green-cluster' to mid-August. Methods and treatment thresholds were similar to those used by Carden (1977). Pheromone traps were used to monitor codling moth, Laspeyresia pomonella, and the tortricids Archips podana and Adoxophyes orana. Numbers of phytophagous and predacious mites were assessed by removing them from leaves with a mite-brushing machine and counting on varnished card discs.

In both systems fungicides were used routinely but with observance of Mills periods for decisions on scab control. Bupirimate, harmless to T. pyri, was used for mildew control on IPM plots instead of binapacryl which is harmful. Mildew levels were monitored as described by Butt (1979); this provided data on the control achieved and aided decisions on the dosage rate and frequency of spraying required.

At harvest, 100 fruits from each of 20 trees per plot were inspected for insect damage and minor blemishes, skin russet, scab, etc. The total yield of fruit from these trees was also recorded.

RESULTS

Population levels of pests and predators

Table 2 shows the pests that exceeded their control thresholds in the first two years of the trial. Rosy apple aphid (Dysaphis plantaginea) exceeded its threshold (3/50 trees infested) on all the IPM plots in both years. In 1977 a low

Table 2

Pests that exceeded control thresholds on IPM plots

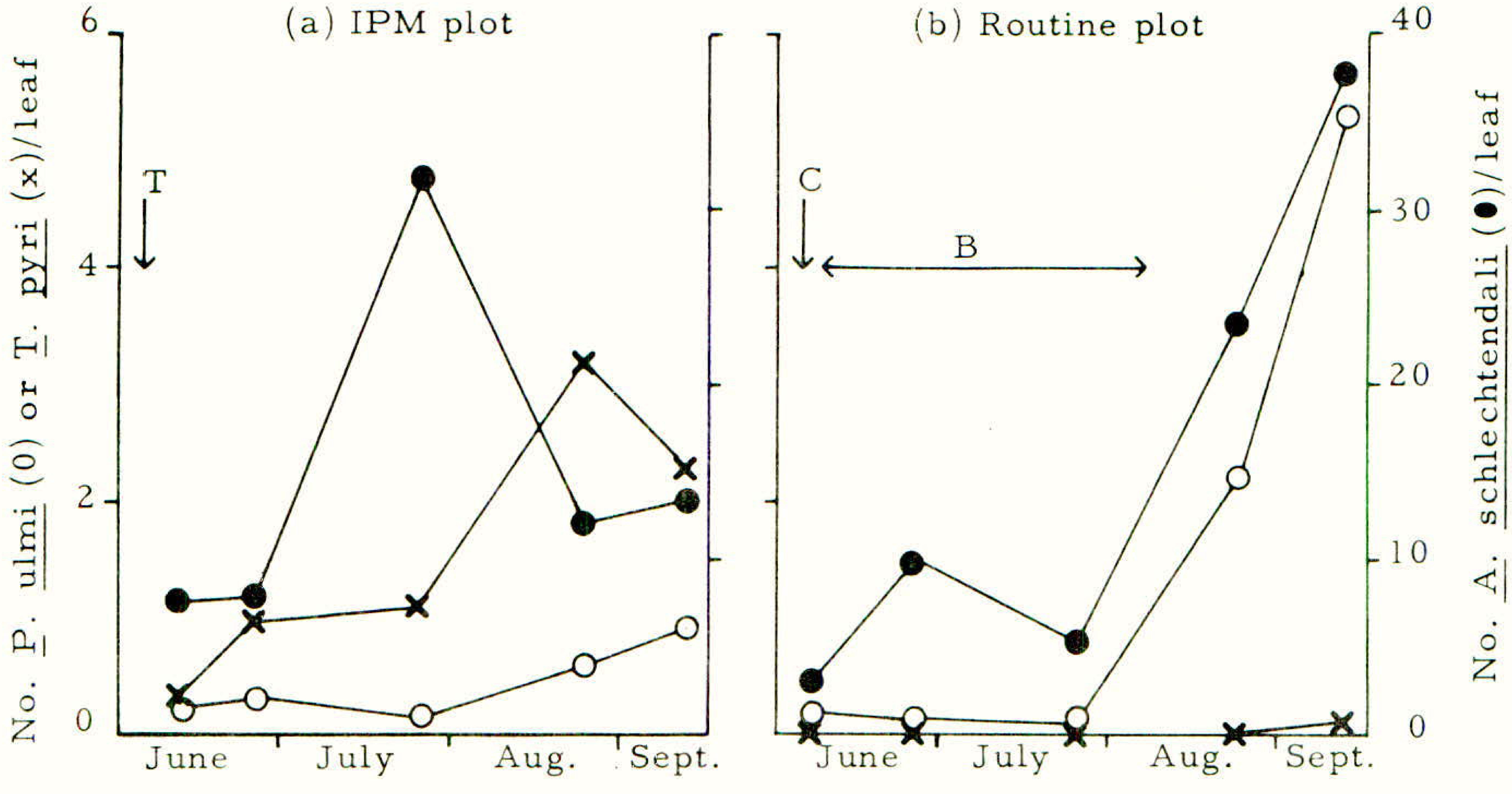
		1977 IPM plot				1978 IPM plot			
Time	Pest	1	2	3	4	1	2	3	4
Green cluster	Fruit tree red spider mite				+	+	+	+	+
	Winter moth							+	
Late blossom	Winter moth			+	+			+	+
	Rosy apple aphid	+	+	+					
Early June	Fruit tree red spider mite	+	+						
	Rosy apple aphid				+	+	+		
Late June	Rosy apple aphid	+	+		+			+	+
	Codling moth	+	+	+	+				
	Fruit tree tortrix				+				
Early August	Rosy apple aphid			+					
	Green apple aphid			+					

rate of pirimicarb (250 g Pirimor/ha) failed to give adequate control. When the threshold was again exceeded later in the summer 375 or 500 g Pirimor/ha gave good control of D. plantaginea and of Aphis pomi. Good control was also achieved with these rates in 1978.

Winter moth (Operophtera brumata) also often exceeded its threshold by mid-blossom (3 larvae per 100 clusters). In most cases damaging levels were not detected until it was too late to apply a pre-blossom spray. In 1978, diflubenzuron (1 kg Dimilin/ha) was applied on half of IPM plot 3 at 'petal fall' stage but this was too late to reduce damage to fruit.

Codling moth (Laspeyresia pomonella) exceeded its threshold (5 moths per trap/wk for two wk) on all IPM plots in 1977 but was well controlled by two sprays of diflubenzuron. In 1978, catches of codling moth, Archips podana, and Adoxophyes orana in pheromone traps were below thresholds and no sprays were applied against these pests.

Fig. 1. Mite populations on an IPM plot and a routine plot in 1978



T, tetradifon; C, cyhexatin; B, weekly binapacryl

In 1977, few predators of fruit tree red spider mite were present on IPM plots as a result of the broad-spectrum spray programme used previously on these orchards. Cyhexatin at a low rate (500 g Plictran/ha) was applied on three of the plots to reduce mite numbers after thresholds were exceeded early in the season. Although spider mite numbers increased again late in 1977 few predators were found. The numbers of spider mite winter eggs were very high so tetradifon was applied at petal fall in 1978 to reduce spider mite numbers. This acaricide allows the survival of T. pyri, which increased rapidly on all IPM plots and kept spider mite below its threshold for the rest of the season. Mite population levels for one IPM plot are shown in Fig. 1a, other IPM plots were similar. At these low spider mite levels, T. pyri exploited apple rust mite, Aculus schlechtendali, as an alternative food source, as indicated by the decrease in rust mite numbers in August.

On the routine plots spider mite numbers, which were reduced by the cyhexatin at petal fall and suppressed by the weekly binapacryl applications until August, then increased in the virtual absence of predators (Fig. 1b).

Numbers of predacious insects on IPM plots also increased in 1978. The first to appear were anthocorids, probably in response to the large numbers of apple-grass aphid (Rhopalosiphum insertum) present. In combination with mortality due to parasitism and fungus disease, they greatly reduced the numbers of this aphid, but failed to prevent the later increase in numbers of rosy apple aphid. Numbers of predacious mirids, such as Blepharidopterus angulatus, Atractotomus mali, and Pilophorus perplexus also increased later in the season.

Fruit blemish

Table 3

Percentage of fruit with blemish due to insects: comparison of integrated pest management (IPM) and routine broad-spectrum (R) programmes

1977

Pest	Cultivar / Plot	Worcester† IPM1 & 2*	Worcester† R1 & 2*	Worcester† IPM3	Worcester† R3	Lambourne† IPM4	Lambourne† R4
'Caterpillar'		0.7	1.7	0.8	1.8	0.3	0
Rosy apple aphid		4.6	0.4	3.4	0.5	0	0
Codling moth		0.8	0.9	0.6	0.1	1.1	0.5
'Tortrix'		0.7	0.2	0.4	0.02	9.2	0.1

1978

Pest	Cultivar / Plot	Cox IPM1 & 2*	Cox R1 & 2*	Cox IPM3	Cox R3	Cox IPM4	Cox R4
'Caterpillar'		2.7	0.7	1.9	3.1	5.6	1.9
Rosy apple aphid		0.6	0	0.3	0.1	0.1	0
Codling moth		0.2	0	0	0.1	0.2	0
'Tortrix'		1.0	0.4	1.2	0.2	8.2	0.9

* Mean of two plots in same orchard; † there was no crop on Cox in 1977. Damage by apple sawfly or earwigs or mussel scale was up to c. 1% on certain plots.

Insects which caused damage to more than 1% of fruit on some plots were the larvae of tortricid and closely related moths ('tortrix') and winter moth ('caterpillar') (Table 3). Most 'caterpillar' damage was due to winter moth as few noctuid larvae (Orthosia spp.), which cause similar damage, were found. 'Tortrix' and 'caterpillar' damage was particularly high on IPM plot 4; this is adjacent to mixed woodland which was probably a source of infestation. Much of the 'tortrix' damage was caused shortly before harvest by a species not yet identified.

Damage by rosy apple aphid was high in 1977, but this could have been avoided by using the higher rates of pirimicarb which prevented damage in 1978. Codling moth caused little damage, even in 1978 when no sprays were applied against it on IPM plots.

It must be stressed that the results in Table 3 include all fruit blemish caused by insects, however slight, and many of the fruits would not be down-graded in a commercial grading system. For example, much of the 'tortrix' damage consisted of one or two 'pinholes', < 0.5 mm in diameter, which were very difficult to see.

Other records

Control of apple powdery mildew was at least as good on the IPM plots as on the routine plots, and there were no significant differences between the programmes in the amount of russet on the fruit.

DISCUSSION

Biological control of spider mite was established as quickly as the second season after changing to selective pesticides in three different mature apple orchards. A similarly rapid increase of *T. pyri* numbers was shown by Solomon (1975). This contrasts markedly with experience of selective programmes in the Netherlands where phytoseiids did not establish themselves for four years and had to be introduced (Gruys, 1975). It is possible that in our trials *T. pyri* increased from very low endemic numbers which survived the broad-spectrum sprays used for many years before trials started. The speed and uniformity of the increase throughout plots suggest this, rather than immigration from outside sources.

Predacious insects on IPM plots also reached high numbers in the second season. Solomon (1975) showed that windbreaks of alder, *Alnus* spp., which are common on East Malling Research Station, are an important source of these insects.

By monitoring it was possible to reduce the number of insecticide applications. None were applied pre-blossom in either year, and codling/tortrix sprays were avoided in 1978. However, experience so far indicates certain limitations in the current monitoring schedule. Levels of winter moth and rosy apple aphid which became damaging post-blossom were not detected early enough to spray pre-blossom. By the 'petal-fall' stage it was too late to prevent some damage to fruitlets by winter moth larvae. Rosy apple aphid is more readily detected post-blossom; very prompt action is then needed because of the high potential for increase. The large numbers of anthocorids that developed early in 1978, feeding mainly on apple grass aphid, evidently did not adequately control rosy apple aphid. Possible reasons, which are under investigation, are that the anthocorids find this aphid species unpalatable or that they were deterred by ants attendant on the aphids.

Problems have already been experienced with species that seldom reach pest status under broad-spectrum programmes. It is notable that, as in trials in the Netherlands (Gruys, 1975) tortricid larvae caused commercially unacceptable surface damage to fruit. Most of the damage was by species currently not included in the monitoring schedule. Another 'minor' pest which increased on two of the IPM plots was mussel scale (Lepidosaphes ulmi).

It may prove possible to control these 'minor' pests by applying a selective pesticide at the right time. Another approach being investigated involves the introduction of a strain of T. pyri from New Zealand which is resistant to organophosphates, thus permitting the use of these insecticides for insect control. A further problem in developing a commercially-acceptable IPM system is the present use of carbaryl as a fruit-thinning agent; carbaryl is harmful to predacious mites and insects. Work on alternative thinning agents, and on ways of minimising the disruptive effects of carbaryl is being pursued.

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THE DEVELOPMENT OF DIFLUBENZURON IN THE UK FOR THE CONTROL OF LEPIDOPTEROUS PESTS IN APPLE AND PEAR

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Summary Diflubenzuron, a selective insecticide which interferes with the deposition of insect chitin, has been shown to provide effective control of most of the lepidopterous pests of apples and pears with minimum adverse effects on several important predators and parasites of orchard pests. In large-scale orchard trials in 1977, a single post-blossom spray at 250 g a.i./ha provided a high level of control of codling moth (*Laspeyresia pomonella*), demonstrating the persistence of diflubenzuron and the potential for a reduction in the number of sprays. In 1978, a single pre-blossom and two post-blossom sprays at 150 g a.i./ha provided control of winter moth (*Operophtera brumata*) and of codling at least as good as that given by single pre- and post-blossom sprays at 250 g a.i./ha. Although diflubenzuron shows strong ovicidal activity on codling, the results indicate that normal spray timing should be employed.

Résumé Le diflubenzuron, insecticide sélectif qui perturbe la formation de la chitine des insectes, a montré un contrôle efficace de la plupart des lépidoptères nuisibles aux pommiers et poiriers avec un minimum d'effets nocifs sur plusieurs prédateurs et parasites importants des insectes nuisibles aux vergers. Dans des essais à grande échelle en verger en 1977, un seul traitement en postfloraiston à 250 g m.a./ha a donné un contrôle élevé du carpocapse (*Laspeyresia pomonella*), démontrant ainsi la persistance du diflubenzuron et la possibilité de réduire le nombre des applications. En 1978 un traitement avant floraison et deux après floraison à 150 g m.a./ha ont donné d'aussi bons résultats sur cheimatobie (*Operophtera brumata*) et carpocapse qu'un seul traitement en préfloraison suivi d'un traitement en post-floraison, tous deux à 250 g m.a./ha. Bien que le diflubenzuron montre une forte activité ovicide contre le carpocapse, les résultats obtenus montrent que l'on doit respecter les périodes d' application normales.

INTRODUCTION

Diflubenzuron, discovered by Philips-Duphar B.V., is one of a new group of highly active insecticidal compounds. Diflubenzuron interferes with the deposition of insect chitin and disrupts moulting in the larval or pupal stages of susceptible species (e.g. many Lepidoptera, Coleoptera and Diptera). The mode of action can also result in ovicidal activity (Grosscurt, 1977) by interfering with chitin deposition of the developing larva within the egg. Adult insects are not affected.

Diflubenzuron acts mainly as a stomach poison (Mulder and Gijswijt, 1973) and therefore has to be ingested by larvae. It has no plant-systemic action and does not penetrate into plant tissue; consequently, sucking insects are generally unaffected. These characteristics form the basis of a distinct selectivity. Diflubenzuron is of very low toxicity to mammals and birds, and to fish.

Although diflubenzuron has good stability on the aerial parts of plants, so providing excellent persistence, it is quickly degraded in the soil. Studies on soil fauna undertaken by Rothamsted Experimental Station (Edwards and Lofty, 1976) showed that diflubenzuron had a negligible effect on earthworms (Lumbricus and Allolobophora), soil mites (Acarina), centipedes and millepedes (Myriapoda).

This inherent selectivity and safety to most non-target organisms has prompted the development and subsequent registration of diflubenzuron for pest control in environmentally sensitive areas such as forestry, parks and gardens, and water. In addition, its novel mode of action has made it an obvious candidate in crops where resistance to conventional insecticides is causing problems in pest control. A consideration in its use for cotton boll weevil (Anthonomus grandis) control is the indirect biological control of bollworms by predators, which are unaffected by diflubenzuron.

In top fruit, the growers' reliance on broad-spectrum insecticides has resulted in the fruit tree red spider mite (Panonychus ulmi) becoming a major pest owing to the destruction of its natural enemies. The subsequent resistance of spider mites to many acaricides has focussed attention on the desirability of using selective insecticides in orchard spray programmes. Gruys (1975) found that in orchards that had received only diflubenzuron, white oil and pirimicarb as insecticides, phytoseiid mites (predators of spider mites) were numerous and two key parasites were unaffected: Chrysocharis prodice (parasite of the miner Stigmella malella) and Colpoclypeus florus (parasite of summer fruit tortrix, Adoxophyes orana). Other trials have shown that Aphelinus mali (parasite of woolly aphid, Trichogramma cacoeciae), and the predators Stethorus punctillum and Chrysopa perla are unaffected by diflubenzuron. Trials at the Zoology and Biological Control Station, Antibes (Lyon, 1975) showed diflubenzuron to have little or no adverse effect on Aphelinus, Stethorus and Chrysopa, and only a slight effect on the aphid predator hover fly, Epistrophe balteata. Cranham (1978) found no reduction in the red spider predatory mite, Typhlodromus pyri, from diflubenzuron at 500 ppm.

In addition to the desirability of maintaining predators and parasites in the orchard, pollination is of paramount importance. Work by Emmett and Archer (1979) showed diflubenzuron, when applied experimentally in full blossom, had no adverse effects on foraging honeybees or their brood. Since diflubenzuron is non-toxic to adult insects, many other species of pollinating insects should also be unaffected.

If predators and parasites are to play any part in pest control in orchards and thus reduce our total reliance on pesticides, it is imperative that pesticides should be not only selective but also highly effective. Trials in Holland, France and Italy (Philips-Duphar, 1974-77) showed that control of codling moth (*Laspeyresia pomonella*) with diflubenzuron was superior to that with azinphos-methyl and, in particular, its persistence allowed a reduction in the number of sprays. Cranham (1978) likewise showed that a single spray of diflubenzuron at a concentration as low as 100 ppm (applied HV to run-off) provided codling control at least equivalent to that from two sprays of azinphos-methyl at standard rate. He also found that two sprays of diflubenzuron at 50 ppm provided a similar level of control to that from one application at 100 ppm.

To obtain further data on codling, and also fruit tree tortrix (*Archips podana*) and winter moth (*Operophtera brumata*), small replicated trials were conducted in 1975 by the author, but unfortunately these pests occurred on the trials only at very low levels. Since work both in England (Cranham, 1978) and Europe indicated that the activity on codling was mainly ovicidal, it was decided in 1977 to compare a programme with diflubenzuron applied earlier and with fewer sprays with conventional usage of OPs and Carbaryl.

In 1978 a further programme was conducted to examine the efficacy of further reduction in dosage rate for the control of winter, codling, and tortrix moths.

METHOD AND MATERIALS

The trials, ten in 1977 and eleven in 1978, were sited in the South East, in East Anglia and the West Midlands. Large plots (0.5-1.0 ha) were sprayed with a commercial orchard mist-blower and where orchard size permitted, treatments were duplicated. Untreated controls were included on sixteen sites where the growers agreed to them. For the control of winter moth, treatments were applied at late green cluster to early pink bud. Spray timing for codling and tortrix was based on ADAS regional warnings and pheromone trap numbers at each site. Diflubenzuron as 'Dimilin', a 25% w.p., was used throughout. Dosage rates are expressed as grams active ingredient (a.i.) per hectare.

Winter and tortrix moth damage was assessed at petal-fall on 100 blossom trusses per plot; leaf and blossom damage and where possible the number of live caterpillars was assessed. The fruits which dropped before harvest ('drops') were regularly gathered from each plot until harvest and assessed for codling damage. The total number of drops varied somewhat but averaged between 1200 to 1500 fruits per plot. Fruit was assessed at harvest for tortrix damage.

RESULTS

a) Winter and Early Tortrix Moth Control

Only on two sites did winter moth reach assessable levels in 1977. Moderate levels occurred on a site in Kent (A) cv. Jonathan and a severe infestation on perry pears in Somerset (B). The pears were assessed for defoliation as their height precluded a truss assessment. Diflubenzuron and carbaryl (grower's standard) were applied at early pink bud on trial A, and diflubenzuron at white bud on trial B when there was already 5% damage, whilst fenitrothion (grower's standard) was applied 2 weeks later. At both sites diflubenzuron at 250 g provided an extremely high level of caterpillar control, superior to both the standards used (Table 1).

Table 1

Winter moth control, 1977

		Trial A		Trial B	
		Caterpillars /100 trusses	% Control	% Defoliation	% Control
untreated		63		93	
diflubenzuron	250 g	0	100.0	10	89.2
carbaryl	1700 g	8	87.3	-	-
fenitrothion	700 g	-	-	69	25.8

In 1978, winter moth and/or tortrix occurred at reasonable levels on 9 sites. Table 2 shows that on six trials (J-O), a single pre-blossom spray of diflubenzuron at 150 g provided control equal to that from 250 g (92.6% caterpillar mortality), but that control from 100 g was somewhat inferior (81.5%).

On three trials (P,Q,R) it was not possible to assess for caterpillar survival, but results in terms of truss damage indicate a similar result.

Table 2

Winter and tortrix moth control, 1978

Truss damage and live caterpillars per 100 blossom trusses

			DIFLUBENZURON		
Trials		Untreated	100 g	150 g	250 g
J-O (Mean of 6)	Damage	21.3	14.5	12.3	14.2
	Winter moth	3.2	0.5	0.2	0.2
	Tortrix	2.2	0.5	0.2	0.2
P-R (Mean of 3)	Damage	-	26.3	24.7	24.3

b) Codling Control

It was decided in 1977 that as diflubenzuron shows strong ovicidal activity against codling, treatment would be made as soon as moth numbers peaked or reached 5 moths per pheromone trap per week, i.e. 7 - 10 days earlier than the timing recommended by ADAS for conventional insecticides. A second spray would be applied one month later on sites where the total number of moths caught exceeded 100.

In retrospect, this earlier timing was shown to be incorrect on two counts. Work in 1977 by Cranham (1978) showed that in spite of its ovicidal activity, codling control by diflubenzuron applied at conventional timing equalled that from earlier treatment. Secondly, determination of spray timing by pheromone trap catches alone, without reference to the accumulated heat sum, proved unreliable, especially in cool, wet seasons such as 1977. It is now evident that diflubenzuron was applied 3 - 4 weeks earlier than the optimum and even allowing for its greater persistence, this must have reduced the level of control that was achieved. However, results on five sites where there was moderate to heavy codling pressure and which received only one early spray of diflubenzuron (compared to two sprays of a standard insecticide applied at normal timing) show that although slightly inferior to the standard programme, diflubenzuron nevertheless provided a high level of control (Table 3). Experience in relating the level of codling damage in dropped fruit to the total crop, and damage levels resulting from known trap catches, suggests that the level of overall control provided was of the order of 93% from diflubenzuron and 97% from the standard programmes.

Table 3

Percentage codling damage (dropped fruit) 1977

Trial	Diflubenzuron 1 x 250 g	Standard x 2	Total moths (no.)
C	7.3	3.1	181
D	0.0	0.0	105
E	6.7	0.1	90
F	4.0	4.9	61
G	0.0	0.0	85
Mean	3.6	1.6	104

In 1978 two sprays at 100 and 150 g diflubenzuron were compared with one of 250 g. These treatments were applied at normal timing, as for conventional insecticides and according to trap catches at each site, but also taking account of local ADAS spray warnings based on trap catches and accumulated heat sum. Table 4 shows that the two sprays at 150 g provided somewhat better control (88%) than one spray at 250 g (80%). Control by two sprays at 100 g was inferior (51%). The actual level of codling control achieved was probably considerably higher than that shown, since the level of damage on the untreated controls (especially trials M and Q) was less than expected from the number of moths caught. Untreated control plots had to be small in size and therefore were not perhaps truly representative of the whole trial area. In two trials (S and T), where it was not possible to include untreated plots, control by the three rates of diflubenzuron showed a similar pattern to trials L-Q, similar also to the results given in Table 2. On two trials where standard insecticide programmes were included in the trial area, two sprays of dialifos on trial M, and two of chlorpyrifos on trial P, provided inferior control to that from diflubenzuron at 1 x 250 g and 2 x 150 g.

Table 4

Percentage codling damage (dropped fruit) 1978

Trial	Untreated	Diflubenzuron 2 x 100 g	Diflubenzuron 2 x 150 g	Diflubenzuron 1 x 250 g	Total moths (no.)
L	4.54	0.99	0.94	1.52	55
M	0.97	0.55	0.06	0.00	107
O	2.75	3.16	0.00	0.19	109
P	0.94	0.00	0.00	0.00	50
Q	0.58	0.09	0.16	0.29	205
Mean L-Q	1.96	0.96	0.23	0.40	105
S	-	1.68	0.78	0.60	45
T	-	2.16	1.32	1.65	133

c) Fruit Tree Tortrix Control

Tortrix catches were low on all trials in both years and exceeded the economic threshold on only two sites in 1978. No fruit damage occurred with any treatment. Gruys (1977) has reported that in addition to fruit tree tortrix, fruitlet mining tortrix (*Pammene rhediella*), eye-spotted bud moth (*Spilonota ocellana*), clouded drab moth (*Orthosia incerta*) and *Hedya nubiferana* are all very susceptible to diflubenzuron.

DISCUSSION

The results of trials presented in this paper show that diflubenzuron provides effective control of winter, codling and fruit tree tortrix caterpillars in apples and pears. The level of control provided by a single post-blossom spray at 250 g a.i./ha demonstrates its persistence on leaves and fruit, and indicates the possibility of reducing the number of post-blossom insecticidal sprays. However, the difficulty of determining the optimum timing of codling and tortrix sprays in some seasons suggests that two sprays at 150 g a.i./ha may prove a more reliable programme for the commercial grower. A single pre-blossom spray followed by two post-blossom at 150 g a.i./ha should provide caterpillar control at least as good as that by those broad spectrum insecticides which are currently most effective.

The inherent selectivity of diflubenzuron also offers the opportunity of reducing reliance on pesticides for the control of certain other difficult pests such as red spider. In addition to the obvious economic advantages, biological control of spider mites is the one certain solution to the problem of red spider resistance to acaricides. The overall safety of diflubenzuron provides the fruit grower with a number of very desirable side benefits, of which the minimising of adverse effects to soil fauna and to pollinating insects, and reducing the hazard to the operator and other mammals, to birds, fish and other wild life, must rate very highly. In the trials under discussion diflubenzuron was tank-mixed with a comprehensive range of other pesticides and foliar nutrients without any resultant incompatibility problems or any adverse effects on fruit skin finish.

A further programme of field trials is being conducted in 1979 to confirm the efficacy of diflubenzuron at 150 g a.i./ha on winter, codling and tortrix moths under commercial conditions. Trials for the control of plum fruit moth (*Laspeyresia funebrana*) and pear sucker (*Psylla pyricola*) are also planned.

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