DISEASE CONTROL WITH HWG 1608 ON CEREALS AND RAPE

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ABSTRACT

(RS)-1-(4 chlorophenyl)-4,4-dimethyl-3-(1H-1,2,4-triazol-1-ylmethyl)pentan-3-ol, code numbered HWG 1608, is a new broad spectrum fungicide. Results from field trials in the UK during the years 1984-87 have shown HWG 1608 at 250-375 g a.i./ha (depending on crop) to give effective control of *Erysiphe graminis*, *Septoria* spp., *Puccinia* spp., *Rhynchosporium secalis*, and *Pryenophora teres* in cereals and *Pyrenopeziza brassicae*, *Mycosphaerella brassicicola*, *Alternaria brassicae* and *Sclerotinia sclerotiorum* in oilseed rape.

INTRODUCTION

(RS)-1-(4-chlorophenyl)-4,4-dimethyl-3-(1H-1,2,4-triazol-1-ylmethyl) pentan-3-ol, code numbered HWG 1608, is a new broad-spectrum fungicide discovered by Bayer AG, West Germany. The physical and chemical properties of HWG 1608 and results of initial trials work have been reported by Reinecke *et al* (1986). This paper summarises the results of field trials on cereals and winter-sown oilseed rape carried out by Bayer UK Limited field staff during the harvest years 1984-1987. Information on *S. sclerotiorum* from 1988 trials has also been included.

MATERIALS AND METHOD

HWG 1608 was formulated as a 250 EC and used as a foliar spray against a range of standard products suited to the disease and crop under test. Standard treatments comprising combinations of active ingredients are shown in this paper as "x + y" for tank mixtures and "x & y" for coformulated products. Trials were largely sited in commercial crops and were of randomised block design consisting of 4 replicates, with plot sizes ranging from 36-60 m^2. Treatments were generally applied to cereals as a single application of HWG 1608 at rates of 250-375 g a.i./ha over a wide range of growth stages and timed to effect optimum disease control. For oilseed rape a two-spray programme of HWG 1608 at 375 g a.i./ha was applied at the pre- and post-flowering stages.

All treatments were applied using carbon dioxide pressurised knapsack sprayers with TeeJet SS8002 or SS8003 flat fan nozzles at 250-300 kPa and at water volumes of between 220-300 l/ha.

Disease assessments were made by sampling 10 cereal tillers or oilseed rape plants per plot and estimating the % cover of disease on the leaves, pods etc, using a 0-9 scale (0=0%, 1=1%, 2=2.5%, 3=5%, 4=7.5%, 5=10%, 6=15%, 7=25%, 8=50%, 9=75% cover). Some whole-plot assessments have also been included where the % cover of disease was estimated on specified parts of plants at several places in the standing crop.

Plots were harvested using a small-plot combine harvester and yields corrected to 86% dry matter for cereals and 92% dry matter for oilseed rape.

Cereal growth stages are described after Zadoks *et al* (1974) and oilseed rape growth stages after Sylvester-Bradley and Makepeace (1984).

RESULTS AND DISCUSSION

Winter barley

HWG 1608 at 250 and 375 g a.i./ha gave good control of *E. graminis, R. secalis, Pyrenophora teres* and *Puccinia hordei* (Table 1). The median % control figures show that control was rate related for all diseases except *E. graminis* where an excellent level of disease control, equal to that of triadimenol & tridemorph, was achieved by both rates. HWG 1608 at 375 g a.i./ha achieved similar or superior disease control in comparison to the various standards used. HWG 1608 proved particularly effective against *P. hordei*.

TABLE 1

Median (range) % control of winter barley foliar diseases 1984-87

		E. graminis	*R. secalis*	*P. teres*	*P. hordei*	
GS at application		18-32	30-45	31-59	47	37
Median % cover top 3 lvs		3	10	1	Trace	1
TREATMENTS	g a.i./ha					
UNTREATED	*% cover*	*18 (6- 33)*	*13 (2-30)*	*21 (5-40)*	*34*	*5*
HWG 1608	250	93 (71- 99)	62 (34-95)	83 (0-90)	81	98
HWG 1608	375	91 (77-100)	75 (32-98)	90 (24-95)	89	99
triadimenol & tridemorph	125 375	87 (74- 99)	-	-	-	86
fenpropimorph	750	-	-	-	-	89
propiconazole & tridemorph	250 250	-	85 (40-98)	89 (36-94)	67	-
No. of trials		8	10	8	1	1

Spring barley

Table 2 shows the results of *E. graminis* control in spring barley in the harvest years 1986-87. The results are similar to those of winter barley with little difference in efficacy between the rates of HWG 1608.

TABLE 2

Median (range) % control of *E. graminis* in spring barley 1986-87

GS at application Median % cover top 3 leaves		30-45 7%
TREATMENTS	g a.i./ha	
UNTREATED	*% cover*	*19 (18-51)*
HWG 1608	250	82 (35-97)
HWG 1608	375	83 (25-99)
triadimenol & tridemorph	125 375	84 (32-97)
No. of trials		11

Winter wheat

Table 3 outlines the disease control results of HWG 1608 on winter wheat. As with the barley results, disease control was rate-related although the improvement in control from 250 to 375 g a.i./ha was generally quite small.

TABLE 3

Median (range) % control of *E. graminis* and *Septoria* spp. in winter wheat 1986-87

		E. graminis	*S. tritici*	*S. nodorum* (leaf)	*S. nodorum* (ear)
GS at application		32-59	32-43	65	65
Median % cover*		1	2	2	3
TREATMENTS	g a.i./ha				
UNTREATED	*% cover*	*10 (3-49)*	*20 (9-48)*	*11*	*21*
HWG 1608	250	76 (47-95)	60 (54-76)	84	81
HWG 1608	375	83 (58-98)	64 (41-92)	90	91
triadimenol & tridemorph + prochloraz	125 375 400	-	60 (51-85)	-	-
triadimenol & tridemorph	125 375	83 (58-98)	-	-	47
propiconazole & tridemorph	250 250	-	-	48	-
No. of trials		10	5	2	

* Top 2 or 3 leaves

Mixed infections of *Septoria* spp. occurred at many of the trial sites but for the purposes of this paper only sites where single infections of either *S. tritici* or *S. nodorum* were identified, have been presented (Table 3).

HWG 1608 at both rates gave useful control of *S. tritici* and was equal to the standard, triadimenol 125 & tridemorph 375 + prochloraz 400 g a.i./ha. The two sites where *S. nodorum* glume blotch occurred, were sprayed after ear emergence when disease levels were low. HWG 1608 gave excellent control at these sites with the lower rate of 250 g/ai/ha far superior to the standards used.

Excellent control of *Puccinia recondita* and *P. striiformis* were given by HWG 1608, irrespective of rate (Table 4). Control of *P. recondita* was achieved when HWG 1608 was applied before or after pustules were present in the crop and confirms the level of efficacy documented by Hanbler and Kuck (1987) who found low dose-rates of HWG 1608 to have good protective, curative and eradicative properties against this disease.

TABLE 4

Control of *P. recondita* and *P. striiformis* in winter wheat

		P. recondita		*P. striiformis*
GS at application		47	50	41-51
% Cover top 3 leaves		1 (1f 4)	0	1
TREATMENTS	g a.i./ha			
UNTREATED	*% cover*	*(33)*	*(6)*	*(10)*
HWG 1608	250	92	100	95
HWG 1608	375	98	100	91
triadimenol & tridemorph	125 375	73	100	88
No. of trials		1	1	1

HWG 1608 tends to be translocated relatively slowly within the plant, but it will generally achieve a very even distribution, affording good protection of the leaves and ear (Kuck and Thielert, 1987). This is reflected in the *E. graminis* results of one trial on wheat where, on initial assessment 10 days after application, HWG 1608 at 375 g a.i./ha was giving 58% control of 6% cover leaf mildew in comparison to 75% control from triadimenol 125 & tridemorph 375 g a.i./ha. At a later assessment of the ear 56 days later, both treatments were giving 58% control of a 20% infection.

Cereal yield

HWG 1608 gave increases in grain yield commensurate with disease control (Table 6). The results were taken from all the trials presented in this paper that were yielded, with the figure for the standard being a mean value of all the various standard treatments used.

TABLE 5

Yield shown as a mean (range) % increase over the untreated (harvest years 1984-87)

Crop		winter barley	spring barley	winter wheat
TREATMENTS	g a.i./ha			
HWG 1608	250	9 (0-32)	16 (7- 31)	10 (0-40)
HWG 1608	375	10 (5-24)	19 (10-41)	10 (0-44)
Standard		12 (0-39)	15 (7-28)	10 (1-29)
No. of trials		14	9	16

Oilseed Rape

HWG 1608 375 g a.i./ha applied twice gave similar control of *A. brassicae* in comparison to the standard treatment (prochloraz 500 g a.i./ha followed by iprodione 500 g a.i./ha) on the pods and superior control of the disease on the leaves. HWG 1608 was also considerably more effective than the standard against the other diseases encountered; *M. brassicicola*, *P. brassicae* (stem and pods) and *S. sclerotiorum* (Tables 6 & 7).

The excellent disease control gave rise to large increases in yield with the mean % increase over the untreated in 10 trials being 23% for the HWG 1608 programme and 14% for the standard.

TABLE 6

Median (range) % control *P. brassicae*, 1986-87

		Leaves	Stem	Pods
TREATMENTS	g a.i./ha			
UNTREATED	*% cover*	*18 (17-19)*	*35 (7-68)*	*53 (7-92)*
1. HWG 1608 2. HWG 1608	375 375	67 (66-67)	72 (64-75)	70 (70-98)
1. prochloraz 2. iprodione	500 500	63 (61-64)	44 (24-63)	47 (39-84)
No. of trials		2	3	3

1. GS at application: 3.4-3.7 2. GS at application: 4.8-6.3

TABLE 7

Median (range) % control of *A. brassicae*, *M. brassicicola* and *S. sclerotiorum* 1986-88

		A. brassicae Leaves	Pods	*M. brassicicola* Leaves	*S. sclerotiorum* Stems
TREATMENTS	g a.i./ha				
UNTREATED	*% cover*	*5*	*5 (5-13)*	*58*	*6*
1. HWG 1608 2. HWG 1608	375 375	66 (47-84)	80 (47-96)	100	63
1. prochloraz 2. iprodione	500 500	48 (0-95)	79 (60-95)	77	29
No. of trials		2	3	1	1

1. GS at application: 3.4-3.7 2. GS at application: 4.8-6.3

CONCLUSIONS

HWG 1608 has proved to be an effective broad spectrum foliar fungicide for cereals and oilseed rape, giving a good level of control over a wide range of diseases.

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CONTROL OF RHIZOCTONIA SOLANI IN POTATOES IN THE UK WITH PENCYCURON

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ABSTRACT

Twenty-one small plot replicated trials and forty-two non-replicated large plot trials conducted in the UK between 1985 - 87 demonstrated that pencycuron was a highly effective fungicide in reducing the development of R. solani in potatoes. The dry seed treatment formulation (DS) of pencycuron in particular was effective in reducing the symptoms of severe stem canker infection, whilst both the DS and suspension concentrate (SC) in-furrow band spray treatments markedly reduced the development of black scurf on progeny tubers. The trials confirmed that 25 g a.i./100 kg seed was the optimum rate of the DS treatment for controlling both black scurf and stem canker although useful suppression of stem canker was achieved in some first-early crops using pencycuron DS at 12.5 g a.i./100 kg seed. The marketable yield of crops from large-plot trials in 1987 was increased by 23% following the use of pencycuron DS, which reduced the proportion of progeny tubers contaminated with commercially unacceptable levels of black scurf.

INTRODUCTION

Rhizoctonia solani Kuhn (the mycelial state of Thanatephorus cucumeris (Frank) Donk) is a fungal pathogen found in potato-growing regions throughout the world. The biology of the fungus was described by Brenchley and Wilcox (1979). In the United Kingdom it is viewed as a pathogen of increasing importance, as it causes several types of damage to the potato crop.

The stem canker phase of the disease results in often severe lesions to the stems and the pruning of stolons which can affect both the size and yield of progeny tubers, especially in first-early crops. The development of black scurf on the progeny tubers can greatly reduce the marketable yield especially for the washed pre-packed ware market, and for the very disease-conscious seed export market. Further aspects of the disease, especially the stem canker phase, were reported by Hide, Read and Sandison (1985a, 1985b).

This paper summarises the results from 63 field trials (21 replicated small-plot, and 42 non-replicated large-plot) initiated by the development staff of Bayer UK Limited between 1985 - 87, to evaluate various formulations of pencycuron. Pencycuron, N-[(4-chlorophenyl)-methyl]-N-cyclopentyl-N'-phenylurea, is a new non-systemic fungicide for the control of R. solani (Bayer AG, 1984), and the 12.5% wt/wt dry seed treatment (DS) was introduced to the UK market in 1988 under the trade name of Monceren DS.

MATERIALS AND METHODS

Trial design

Small-plot trials with plot sizes of 10 m long x 2 row width (in 1987) or x 4 row width (in 1985 and 1986), were planted using a modified Johnson, semi-automatic, manned two row planter. Each trial was arranged in randomised blocks with four replicates.

The non-replicated large-plot trials were planted by farmers using their own machinery, with plot sizes ranging from 0.5 ha to 3.0 ha. In 1986 five large non-replicated trials were planted using a Kramer automatic seed planter, to which an in-furrow band sprayer had been attached. The plot sizes for these trials were 4 rows x the length of the fields.

Varieties

Of the 63 trials planted between 1985 - 87, 46 trials were planted with maincrop varieties, 8 with first-early varieties and 9 with second-early varieties.

Application methods

The application methods used in the small plot trials were described in detail by Rollett et al (1987).

Dry seed treatments

1. Small-plot trials: immediately prior to planting an appropriate amount of chemical was placed with a known weight of seed tubers in a sealed plastic bag which was then rolled for a standard number of times.

2. Large-plot non-replicated trials: depending on the individual farmer's preference, the chemical was applied to the seed tubers either just before or during the loading of the planting machine hoppers. The methods used in decreasing order of frequency were as follows: layering of the chemical in the planting hopper(28); placing the chemical on top of the bulk boxes prior to loading(8); layering of the chemical in the bulk boxes(4); sprinkling chemical onto seed in chitting trays(2). All methods resulted in the distribution of the chemical on the seed to the growers' satisfaction.

In-furrow band spray treatments

Spray treatments of pencycuron SC (suspension concentrate) were applied to open furrows both in the replicated small plot trials and five non-replicated large-plot trials using a single flat fan nozzle giving a 40 cm band spray centred on the row. The nozzle was located on the seed planter directly behind the point of seed placement but in front of the covering discs. The actual rates/ha varied according to row widths, for example with 80 cm row width, the actual rate/ha was 2.5 kg a.i./ha. In 1985 the spray treatments were in fact applied as overall sprays over the open furrow using treatment rates per hectare equivalent to the band spray rates per hectare.

Treatments

Not all treatments were applied in every series of trials. Treatment details are recorded in the 'Results' section.

TABLE 1

Formulation details and treatment rates used in trials 1985 - 87.

Chemical	Formulation	Dose (a.i.)
pencycuron	12.5 DS	12.5 g/100 kg seed
pencycuron	12.5 DS	18.75 g/100 kg seed
pencycuron	12.5 DS	25.0 g/100 kg seed*
pencycuron	12.5 DS	50.0 g/100 kg seed
pencycuron	250 g/l SC	5.0 kg/ha (within spray band)
tolclofos-methyl	10.0 DS	12.5 g/100 kg seed
tolclofos-methyl	10.0 DS	25.0 g/100 kg seed*

* Recommended field rates

Assessments

Stem canker

The stems from 10 plants per plot (small-plot trials) or 50 plants per plot (large-plot trials) were scored using a 0 - 3 scale where:

0 = no infection
1 = 0 - 10% cover of lesions (on underground stem)
2 = >10 - 25% cover of lesions
3 = >25% cover of lesions.

Black scurf

100 tubers per plot (small-plot trials) or 250 tubers per plot (large-plot trials) were stored for between 8 - 12 weeks after harvest, and then assessed for black scurf using a 0 - 6 scale of disease cover on the total tuber skin area where:

0 = healthy, no scurf
1 = >0 - 0.25% cover of scurf
2 = >0.25 - 1.5% cover
3 = >1.50 - 5% cover
4 = >5 - 10% cover
5 = >10 - 20% cover
6 = >20% cover

The results were expressed as a black scurf index:

$$\text{index} = \frac{g_o + g_1 + 2g_2 + 3g_3 + 4g_4 + 5g_5 + 6g_6}{g_o + g_1 + g_2 + g_3 + g_4 + g_5 + g_6} \times \frac{100\%}{6}$$

Where g_n is the number of tubers in grade n.

In the replicated trials, the percentage results were transformed to angles before analysis. Each trial was analysed separately.

RESULTS

Stem canker

Stem canker (Table 2) was recorded in twenty-seven trials. The results are given for the % reduction of the incidence of severe (grade 3) symptoms of canker, since it was the severe expression of the disease that was most likely to affect crop growth and tuber development.

TABLE 2

Stem canker: % reduction of stems severely infected by R. solani

Treatment	Dose (a.i.) Rate/100 kg seed (DS) or Spray rate/ha (SC)	1985 small plot	1986 small plot	1986 large plot	1987 large plot
		Results meaned for individual years and projects			
Untreated (% severely infected stems)		(11.2)	(36.1)	(43.1)	(53.4)
pencycuron DS	12.5 g	-	-	-	64
pencycuron DS	25.0 g	78	65	37	85
pencycuron SC	5.0 kg	65	46	25*	-
tolclofos-methyl DS	12.5 g	-	-	-	74
tolclofos-methyl DS	25.0 g	52	74	26	-
Number of trials		5	9	10	3

(*mean of 3 trials)

When the seed treatments were applied at the full recommended rate of 25 g a.i./100 kg seed, pencycuron DS was more effective in reducing severe stem canker than tolclofos-methyl DS in every series of trials with the exception of the small-plot trial series in 1986. In the replicated trials, there were no significant differences in performance of pencycuron DS and tolclofos-methyl DS (at P = 5%). In 1987 when both pencycuron DS and tolclofos-methyl DS were applied at half the recommended rate (12.5 g a.i./100 kg seed) on first early crops, these treatments were not greatly out-performed by the 25 g a.i./100 kg seed rate of pencycuron DS. In the three series of trials in which the pencycuron SC band sprays were included and severe stem canker developed, this treatment was superior to tolclofos-methyl DS 25 g a.i./100 kg seed in reducing the disease in one series of trials, inferior in another and of equivalent effectiveness in the third.

Black Scurf

Black scurf developed on the progeny tubers from thirty-nine trials. The results are expressed as a disease index, being a function of both incidence and severity of the disease (Table 3).

TABLE 3

Black scurf: % reduction of black scurf index on progeny tubers

Results meaned for individual years and projects

Treatment	Dose (a.i.) Rate/100 kg seed (DS) or Spray rate/ha (SC)	1985 small plot	1986 small plot	1986 large plot	1987 small plot	1987 large plot
Untreated (disease index)		(18.0)	(24.2)	(11.6)	(3.3)	(15.2)
pencycuron DS	12.5 g	-	-	-	38	-
pencycuron DS	18.75 g	-	68	-	-	-
pencycuron DS	25.0 g	64	73	80	95	95
pencycuron DS	50.0 g	72	72	-	-	-
pencycuron SC	5.0 kg	75	70	85*	84	-
tolclofos-methyl DS	25.0 g	59	69	72	87	81*
Number of trials		6	11	12	4	6

(*mean of 5 trials)

During the period 1985 - 87, pencycuron DS was evaluated at four different rates which were respectively a half of full recommended rate (12.5 g a.i./100 kg seed), three quarters of full rate (18.75 g a.i./100 kg seed), full rate (25 g a.i./100 kg seed) and double rate (50 g a.i./ 100 kg seed). The 25 g a.i./100 kg seed rate of pencycuron DS was the most effective DS treatment (with the exception of 1985) in reducing the levels of black scurf developing on progeny tubers. Doubling the rate of pencycuron DS to 50 g a.i./100 kg seed did not improve efficacy whilst reducing the rate saw a marked reduction in efficacy especially at the 12.5 g a.i./100 kg seed rate. Tolclofos-methyl DS (25 g a.i./100 kg seed) was consistently less effective than the equivalent rate of pencycuron DS although in the replicated trials there were no significant differences between the treatments (at P = 5%). The band spray treatments of pencycuron SC proved to be very effective in reducing the development of black scurf, and the results were almost on a par with those of the dry seed treatment formulation of pencycuron (at 25 g a.i./100 kg seed).

Effect on marketable yield

Where stringent quality assessments are applied to tuber samples, the criterion for tuber rejection is often taken as when the scurf levels are obviously visible to the naked eye. In terms of the assessment grades used in these series of trials, unacceptable samples would fall into grade 2 or above (> 0.25% tuber surface infected). The meaned results from the 1987 large plot trials demonstrated how the proportion of 'marketable yield' was increased by fungicide treatments (Table 4).

When assessed in the small-plot trials in 1985 and 1986, the gross yields on maincrop varieties were unaffected by any treatment.

TABLE 4

Black scurf: % tubers in black scurf assessment grades

Meaned results from 6 large-plot trials in 1987			
Treatment	Dose	Grades 0 - 1	Grades 2 - 6
Untreated		75.3	24.7
pencycuron DS	25 g a.i./100 kg seed	98.7	1.3
tolclofos-methyl DS	25 g a.i./100 kg seed	95.0	5.0

DISCUSSION

In summarising a large number of trials conducted over a number of years, individual trials are unable to be discussed and conclusions are drawn from the general trends which developed. This approach is useful because, by the very nature of the pathogen, disease levels at individual sites can be affected by innoculum in the soil and on the seed, soil type, plant resistance, and weather conditions to name but a few. What was of importance was the high level of disease control given by both the dry seed treatment and band spray treatments of pencycuron in all types of trials over three growing seasons. These results give confidence that both the optimum rate for the DS treatment had been identified and that the precise method of application of the DS treatment under farm conditions was not critical, so long as it resulted in even coverage of seed tubers with the material. The feasibility of using the band spraying system under farm conditions is currently under investigation.

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THE ASSESSMENT OF A NEW FORMULATION OF CYPERMETHRIN AS A GRAIN PROTECTANT

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ABSTRACT

A new, micro emulsion formulation of cypermethrin was compared with a standard commercial emulsifiable concentrate of pirimiphos-methyl, as a grain protectant. Batches of grain were treated with 5 concentrations of each pesticide and at 1 day, 2, 4 and 6 months after treatment, 4 insect and 2 mite species were exposed to the treated grain. The insects used were susceptible strains of *Rhyzopertha dominica*, *Sitophilus granarius*, *Oryzaephilus surinamensis* and a resistant strain of *Tribolium castaneum*. The mites were susceptible strains of *Acarus siro* and *Glycyphagus destructor*.

Cypermethrin was more toxic to *R. dominica* than pirimiphos-methyl and was a more effective knockdown agent against *T. castaneum*. Pirimiphos-methyl was more toxic than cypermethrin against the other species including the mite *G. destructor*. Neither compound was effective against *A. siro* at the doses used.

INTRODUCTION

Grain has a relatively short harvest period yet is consumed throughout the year and must be stored for many months between harvests. Fortunately, cereal grains can be stored for long periods without deterioration provided attack by mites, moulds, insects and rodents can be prevented. Damage caused by moulds can be avoided by controlling grain moisture content before storage. Similarly, rodents can be denied access to the grain by good proofing. However, damage caused by mites and particularly insects remains the principal problem associated with the long-term storage of grain throughout the world.

Numerous methods of preventing pest damage to stored grain have been used or proposed but the application of grain protectants directly to cereals as they are put into store appears to be one of the most cost-effective and widely used methods. Not all pesticides are suitable for application to stored grain and the following properties are desirable:- low mammalian toxicity, long-term effectiveness, easy application, cost-effectiveness and activity against a range of pests.

Most pesticides currently used as grain protectants are organophosphorus compounds and, although several are very effective, all suffer from certain actual or potential disadvantages. For example, resistance to organophosphorus compounds has been detected in most species of grain insects

(Dyte 1974). Also these chemicals are generally not very effective against one major pest- Rhyzopertha dominica. It is therefore advantageous, to assess alternative chemicals.

One potential grain protectant is the synthetic pyrethroid cypermethrin and a micro emulsion formulation of this compound has been examined under laboratory conditions against a wide range of grain pests. Pirimiphos-methyl, one of the most widely used grain protectants in the UK, was included as a standard.

MATERIALS AND METHODS

Two pesticides were used:- i) pirimiphos-methyl emulsifiable concentrate containing 260g/l a.i., purchased through normal commercial channels. ii) cypermethrin formulated by NCH Europe as a (W/O) micro emulsion (100g/l a.i.) in which most of the organic solvents had been replaced by water. By formulating the concentrate in this way the flammability is significantly reduced as is the problem of solvent attack on the seals and piping of application equipment. Also when the concentrate is diluted with water it spontaneously inverts ~~to~~ form a micro emulsion possessing several advantages over conventional, solvent based emulsions. These include:-

a) a significant reduction in average particle size coupled with a much narrower distribution of sizes giving more even distribution of a.i. throughout the spray.

b) greatly enhanced physical stability with no tendency for the phases to separate.

The pesticides were applied to English wheat with a moisture content of 14.6% as determined by BS 4317 (Part 3, 1987). Twenty-five kg batches of grain were treated at doses of 0.125, 0.25, 0.5, 1.0 or 2.0 mg/kg with one or other of the pesticides. A batch of grain was also treated with water to provide control material. Each batch of grain was stored in open-topped bins under ambient conditions and samples were removed for assessment as needed. The toxicity of the chemicals was assessed 1 day after application and then after 2, 4 and 6 months, based on a bioassay using test insects and mites from laboratory cultures. Adults, 0-2 weeks old, of the following species were used:- Oryzaephilus surinamensis, Sitophilus granarius and R. dominica, all of which were susceptible to pirimiphos-methyl, and other organophosphates. A strain of Tribolium castaneum was also used which was known to be resistant to many organophosphorus pesticides, including pirimiphos-methyl and to some synthetic pyrethroids. The mites used were laboratory susceptible strains of Acarus siro and Glycyphagus destructor. The insects were assessed after 7 days exposure at 25°C and 70% rh and categorised as unaffected, knockdown or dead. The mites were assessed after 14 days exposure to the treated grain at 17°C and 75% rh and the proportions of live and dead mites were compared using an assessment key of 0 = <10% mortality, 1 = 25% mortality, 2 = 50% mortality, 3 = >75% mortality and 4 = 100% mortality.

Pesticide residues on the grain were determined 1 day after treatment and then after 6 months. Pirimiphos-methyl residues were determined by the method developed by the Committee for Analytical Methods (ANON 1980) and cypermethrin was assessed using a multi-residue procedure

(Bottomley and Baker 1984).

RESULTS

The results of the analysis of the pesticide residues on treated grain show that, except for the lowest dose of cypermethrin, at least 70% of the intended dose of both pesticides was detected on the grain 1 day after treatment and that neither pesticide degraded to a significant extent during the 6-month period of assessment.

The knockdown of the insects after 7 days exposure to the treated grain is summarised in Figs. 1-8. There were considerable differences in the response of the 4 insect species to both pesticides, as follows:-

R. dominica - Cypermethrin was very toxic to this species and gave 98% knockdown of these insects at the lowest dose 1 day after the grain had been treated. This fell to 69% knockdown after 6 months. All other doses gave better than 95% knockdown throughout the trial. The three highest doses of cypermethrin killed more than 90% of the insects throughout the assessment period except at the 2-month assessment when unusually low kills were recorded.

Pirimiphos-methyl gave little knockdown or kill of R. dominica at any of the assessments except 1 day after treatment when the three highest doses produced more than 95% knockdown but less than 5% kill.

T. castaneum - The mortality results with cypermethrin against this species showed little effect, but the highest doses always produced close to 100% knockdown. Pirimiphos-methyl gave 100% knockdown and almost 100% kill with 2 mg/kg at 1 day after treatment but kill and knockdown fell to about 60% by the last assessment.

S. granarius - Pirimiphos-methyl was more effective against this species than cypermethrin. The 1 and 2 mg/kg doses produced more than 90% and often 100% knockdown and kill throughout the trial. By comparison the highest dose of cypermethrin produced between 55 and 85% knockdown and between 35 and 55% kill.

O. surinamensis - The highest dose of cypermethrin always produced more than 90% knockdown and kill of O. surinamensis but the lower doses were less effective. Pirimiphos-methyl appeared to be more active and doses of 0.5 mg/kg or above gave close to 100% knockdown and kill.

A. siro - None of the doses of either pesticide produced a significant level of kill of this mite.

G. destructor - Pirimiphos-methyl was the more active chemical with the two highest doses always giving complete kill. All doses of cypermethrin, except the lowest, gave about 75% kill at the first two assessments, 100% at the 4-month assessment and 75% at the final 6-month assessment.

CONCLUSIONS

The results obtained during this trial represent an initial assessment of cypermethrin as a grain protectant. They suggest that the chemical is effective against some grain pests over a 6-month period and has a particularly high activity against R. dominica for which few alternative measures exist.

There was often a greater difference between levels of knockdown and kill produced by cypermethrin than with pirimiphos-methyl. The phenomena of rapid knockdown and subsequent recovery of insects removed from surfaces treated with synthetic pyrethroids is well documented (White 1984). This can prove to be a serious drawback when using these chemicals to treat the fabric of buildings when insects may fall onto untreated surfaces. However, within a bulk of treated grain any insects affected by a pesticide are likely to remain in contact with the pesticide and so will ultimately die. In this respect the 7 day exposure period used in these experiments may have been too short to have measured the full potential of cypermethrin.

This experiment was not designed to assess differences in formulation but the micro emulsion formulation proved easy to dilute and apply to grain. NCH Europe (Unpublished) have also demonstrated that the characteristics of micro emulsion formulations may include a significant enhancement of biological efficacy.

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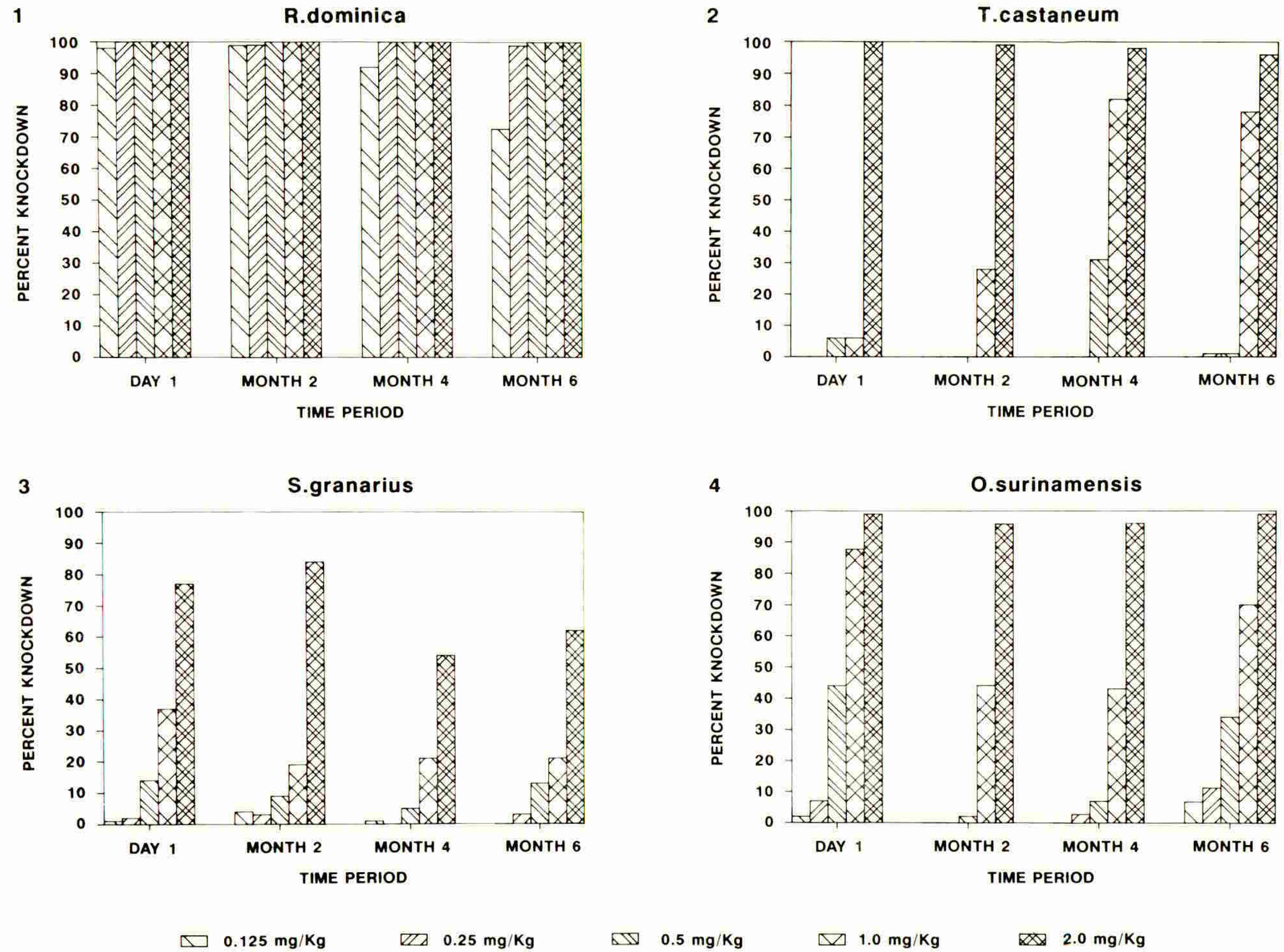
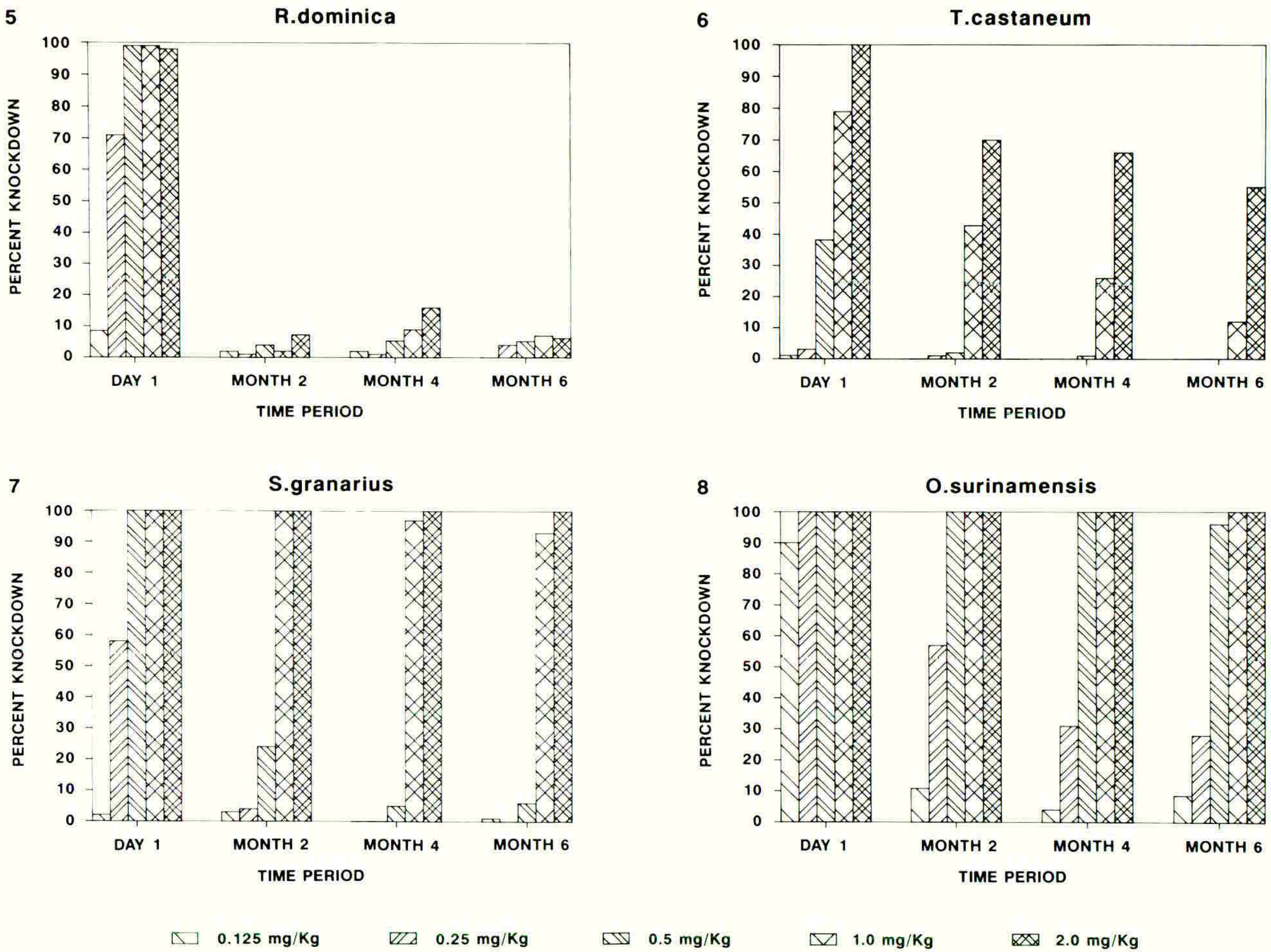


Figures 1-4 The effect of cypermethrin admixed to grain on four species of insect pest.



Figures 5-8 The effect of pirimiphos-methyl admixed to grain on four species of insect pest.

A COMPARISON OF REDUCED DOSES AND STRIP SPRAYING AS SELECTIVE TACTICS FOR PESTICIDE APPLICATION IN CEREALS

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ABSTRACT

Recent experiments on reduced dosage application and strip spraying of aphicides in cereals are summarised. Both techniques offer a degree of control of aphid pests and have potential for the preservation and enhancement of natural enemy activity. Their further development is at present delayed by uncertainties concerning their effects on natural control and their economics in comparison with conventional spraying. Some areas requiring further research are outlined.

INTRODUCTION

The short-term effects of a pesticide on a natural enemy species will be a function of the level of exposure to the chemical and its toxicity (Jepson, 1988); these effects may be ameliorated by the use of selective pesticides or application practices. At present, few pesticides demonstrate genuine physiological selectivity towards natural enemies and the options for obtaining some protection of natural control relate more to decisions about spray timing, rate and targetting that are made just prior to treatment. The use of these tactics may lead to a reduction in natural enemy mortality and consequently, enhanced pest suppression. This may therefore reduce the likelihood of pesticide related problems such as resurgence or secondary pest outbreaks (Metcalf, 1986); these may in turn lead to a treadmill of increased pesticide usage and thus increased selection pressure for pesticide resistance in the pest population (Tabashnik and Croft, 1982; Georghiou and Taylor, 1986).

The options for selective pesticide application include dosage reduction and strip spraying. Dosage reduction may permit the survival of vulnerable and important natural enemies (Kiritani, 1976; Plapp, 1981) and may reduce pest populations sufficiently to benefit the pest/natural enemy ratio (van Emden, 1988; Poehling, 1989). Strip spraying leaves untreated areas in the crop which may act as refuges for natural enemies and maintain populations by providing prey or hosts for pest-specific species.

The results of two trials investigating these techniques are reviewed below to provide a basis for evaluating the potential for implementing selective application practices in UK cereals.

MATERIALS AND METHODS

A reduced dosage trial was undertaken in 1986 (Taye, 1988) in winter wheat, cv. Moulin. Pirimicarb and demeton-S-methyl were applied at full and half recommended field rates to 1 ha plots in a fully randomised design, with four replicates of each treatment and untreated controls. Polyphagous ground active predators were sampled by pitfall trapping. Aphid populations did not develop within the field so to investigate the effectiveness and persistence of the treatments, *Sitobion avenae* from cultures in controlled conditions were introduced to individual cereal ears and enclosed within cellophane sleeves (Smith, 1987). The subsequent population development of the aphids was monitored, with controlled reintroductions to establish populations in the more toxic treatments as their residues declined.

In 1987, a strip-spraying trial was undertaken in winter wheat, cv. Rendezvous Dimethoate was applied at recommended field rate to a square, four hectare plot in 36 m wide sprayed strips. alternating with 18 m wide unsprayed strips. A square four hectare plot was fully sprayed and a third plot remained untreated, as a comparison. Predators and pests were sampled comprehensively by pitfall trapping, D-vac. sweep netting and tiller counts. Parasitoid populations were assessed by dissection of aphids from field collections or the 'rearing-through' of aphid mummies.

Full experimental details of these studies will be presented elsewhere. A summary of trends in pest and natural enemy populations is given below.

RESULTS

The numbers of carabid and staphylinid beetles trapped before and after treatment in the reduced-dose study are given in Table 1. Pirimicarb had less apparent effect on the numbers of predators trapped than demeton-S-methyl; application rate differences emerged only some time following treatment (Taye, 1988). Significant overall variation in natural enemy numbers between treatments was detected ($F = 75.9$. $DF = 4$, $\underline{P} < 0.001$).

Significant variation in natural enemy numbers was also detected in the strip-spraying trial ($\chi^2 = 11.42$, $DF = 4$, $P < 0.05$). Figures 1 and 2 show the mean numbers of carabid and staphylinid beetles trapped per day, before and after treatment. Overall numbers in the strip-sprayed block were intermediate between the fully sprayed and unsprayed treatments.

The population growth rates of _S. avenae_ in the different treatments of the reduced dose trial are given in Table 3 and reveal a significant trend between chemicals and rates with full-rate demeton-S-methyl being the most toxic treatment and half-rate pirimicarb the least. Trends in _S. avenae_ populations in the strip-spraying experiment are given in Figure 3 together with population trends in the untreated and treated sections of the strip-sprayed block as well as overall trends in the block as a whole. Numbers in the strip-sprayed block were intermediate between the fully sprayed and unsprayed blocks.

DISCUSSION

The experiments summarised above and recent work by Poehling (1989) have shown that selective application practices affect both pest and predator populations. The economic consequences of reduced pest mortality are relatively straightforward to estimate. The enhanced contribution made by natural enemies to pest control is much more difficult to estimate and trends of the type produced in the present study do not provide any quantitative information concerning predation rate. Further studies of predator behaviour and feeding in these treatment regimes are required before the precise mechanisms of any effects can be understood. A series of important questions remain to be examined. For example, should the level of dosage reduction be varied as a function of the intrinsic toxicity and persistence of individual compounds? Broad spectrum compounds should perhaps be applied at greater dilutions to obtain similar results to those of selective products. An analysis of laboratory toxicological data for ground active predators for example (C.F.G. Thomas personal communication) combined with data predicting direct exposure from Cilgi, Jepson and Unal (this volume) suggests that a dosage reduction of 50% with dimethoate will have only a small effect on the mortality of the carabid _Pterostichus melanarius_. The effects on beneficials

TABLE 1 a b

Mean numbers of carabid (a) and staphylinid (b) beetles trapped per pitfall trap per day before and after spraying in reduced dose treatment.

a)	Control	Pirimicarb half rate	Pirimicarb full rate	Demeton-S-methyl half rate	Demeton-S-methyl full rate
before treatment	2.41	2.58	2.35	2.40	2.35
after treatment	2.04	1.24	0.85	0.65	0.50
b)					
before treatment	0.50	0.50	0.45	0.58	0.55
after treatment	0.34	0.14	0.12	0.09	0.06

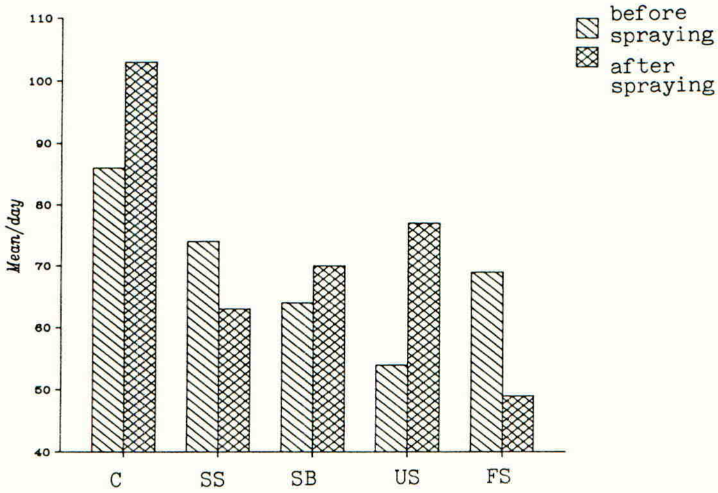
TABLE 2

Increase rates of artificially infested S. avenae populations in the reduced dose rate trial expressed as a simple linear regression coefficient of numbers per tiller against days over period of population increase to peak level in each treatment. (Statistical comparisons by modified t-test, ***, $P < 0.001$, ** $P < 0.01$, n.s. not significant $P > 0.05$).

	Treatment	regression coefficient	r^2	P	treatment number 1	2	3	4	5
1	Control	3.76	98.9	<0.01	-	***	**	***	**
2	Pirimicarb half rate	2.40	99.9	<0.01	-	-	***	***	***
3	Pirimicarb field rate	1.20	94.2	<0.05	-	-	-	n.s.	n.s.
4	Demeton-S-methyl half rate	0.68	82.8	n.s.	-	-	-	-	n.s.
5	Demeton-S-methyl field rate	0.16	11.7	n.s.	-	-	-	-	-

FIGURES 1 and 2

Mean numbers of carabid beetles (1) and staphylinid beetles (2) caught per trap per day in the strip-spraying trial in each treatment. Trap data for the unsprayed and sprayed sections of the strip treatment are also given. (C, control; SS, sprayed strip in strip treatment; SB, overal data for strip sprayed block; US, unsprayed strip in strip treatment; FS, fully sprayed block)



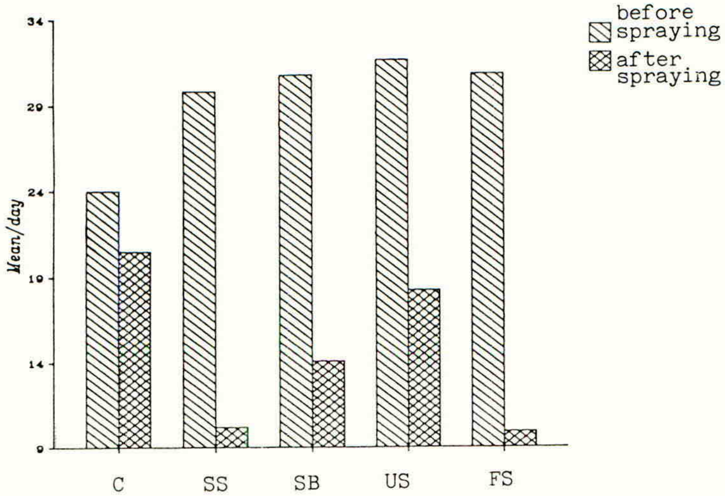
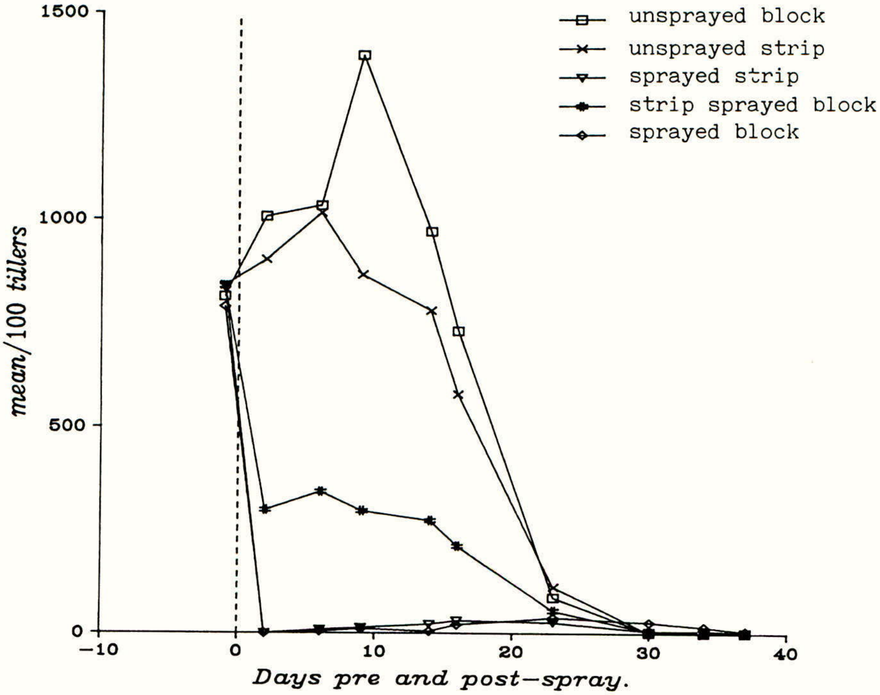


FIGURE 3

Mean numbers of aphids/100 tillers before and after each treatment in the strip spray study. Data for the sprayed and unsprayed sections of the strip sprayed block are also given.



of pirimicarb, a more selective product would be reduced to a far greater extent by this level of dilution.

The level of recommended dilution could also be linked to crop growth stage and the window of changing susceptibility to aphid attack in cereals. Normal field rates may be required at the peak of crop susceptibility for economic reasons however as the season progresses and predator populations increase, the decreasing susceptibility to aphid attack and reduced requirement for persistence may make dosage reduction advisable. Thus by the end of the window of crop susceptibility to aphids, dosages could be considered to be 'corrective', altering pest/natural enemy ratios rather than giving 100% aphid control. The linking of dosage reduction to crop growth stage could also provide a practical basis for the application of this technique.

The economic risks of leaving unsprayed strips in the crop may be more severe since, in years of pest outbreak, yield loss in these strips may offset the benefit of enhanced natural control in the sprayed areas. This raises the problem of equating short-term economic considerations against long-term ecological factors such as reduced pest attack and reduced reliance on pesticides (Pimentel et al., 1979). The width of the untreated strip and selection of appropriate pesticides for this technique requires detailed examination. The detailed mechanism of the effects of strip application on predator behaviour, survival and feeding also need to be understood before the potential of this technique can be fully evaluated.

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A SURVEY OF APHICIDE USE ON WINTER WHEAT IN THE SUMMER OF 1988

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ABSTRACT

A survey of aphicide use in winter wheat was carried out in the summer of 1988. Data from more than 115,000 ha revealed that many crops were sprayed with no reference to ADAS recommended threshold levels, pirimicarb was the insecticide most frequently used and tank-mixes with fungicides were common. Comparison with a similar survey carried out in 1984 showed that several important changes have occurred during the interim period.

INTRODUCTION

In 1976 and 1984, questionnaire surveys were conducted amongst farmers throughout the U.K. concerning the use of aphicides on winter wheat. These surveys revealed considerable variation amongst farmers concerning aphid control, with late spraying being common and some yield losses remaining in many cases (Watt et al. 1984, Wratten et al. 1989).

By 1988, ADAS advice had changed, with the familiar spray threshold for Sitobion avenae (F.) of 5 aphids per ear between flowering and mid milky-ripe being replaced. The advice now is to spray when there are more than 66% of ears infested between flowering and mid milky-ripe (Anon., 1988). This small yet important change allowed farmers to sample aphids more easily, requiring them only to count the proportion of stems infested rather than the number of aphids/stem.

Also, British Telecommunications´s "Farmlink" aphid advisory package (Mann & Wratten 1987) had been running successfully for several years and new legislation was also gradually being introduced to regulate pesticide use in agriculture. In 1988 aphids reached high numbers over much of the U.K.

It was with this background that a third survey was carried out in 1988; this paper describes the results of this survey.

METHOD

A questionnaire was circulated in June and July 1988 to farming subscribers to the Game Conservancy's Cereals and Gamebirds Research Project. The geographical distribution of the farms involved is in general similar to that of arable farms in England, through the area of cereals grown in these surveyed farms is larger than the average. Questionnaires were also sent to members of the Association of Independent Crop Consultants, who were asked to complete the forms for the farms under their stewardship. The questionnaire requested information on the following: area of winter wheat grown and area sprayed with aphicide in the summer; aphicide used, and whether or not in a fungicide "tank-mix"; other compounds in tank-mix; spraying by farm staff/ground contractors/aerial contractors; week in which spraying took place; the aphid level when sprayed; source of advice.

RESULTS

The survey produced data for over 115,000 ha of winter wheat, of which 44,000 ha were from farmers' own returns, with the remainder supplied by consultants. The mean area of winter wheat grown by each farmer was 210 ha. The data for consultants' farms were pooled by them, so areas and other details for each farm could not be calculated. Sixty percent of the area surveyed on individual farms received aphicide, while for consultants' farms the proportion was 51 percent. Percentages for the proportion of the sprayed area receiving the aphicide in a "tank-mix" with fungicide(s) were 83% and 98% respectively. More than 70 different combinations of aphidicide/fungicide active ingredients were applied, with 9 different insecticides being used of which 7 were approved for use in summer cereals (Ivens 1988) (Fig. 1). The group of compounds not approved represented only a small (0.4 percent) proportion of the total sprayed area, however (Fig. 2).

There was a considerable variation in the timing of application of aphicides (with respect to date and crop growth stage), and the aphid population levels were also highly variable (Figs. 3 & 4). Fifty-three percent of farmers and 60% of consultants sprayed outside the spray 'window' recommended by ADAS, with 17% of farmers and 48% of consultants spraying outside the recommended range of growth stages and 15% of farmers and 33% of consultants spraying when aphid numbers were too low.

Comparison of the 1988 spray survey with the 1984 survey reveals that some important changes have occurred over the interim four years particularly in the type of insecticides used and their use in tank-mixes (Table 1).

Fig. 1. Insecticide compounds used in winter wheat in the summer of 1988: proportion of respondents.

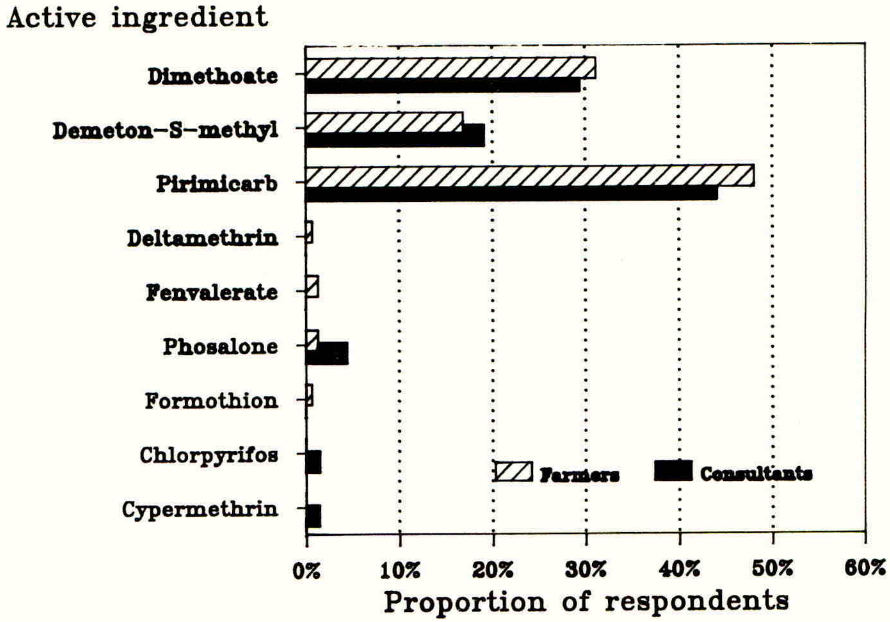

Fig. 2. Insecticide compounds used in winter wheat in the summer of 1988: proportion of sprayed area.

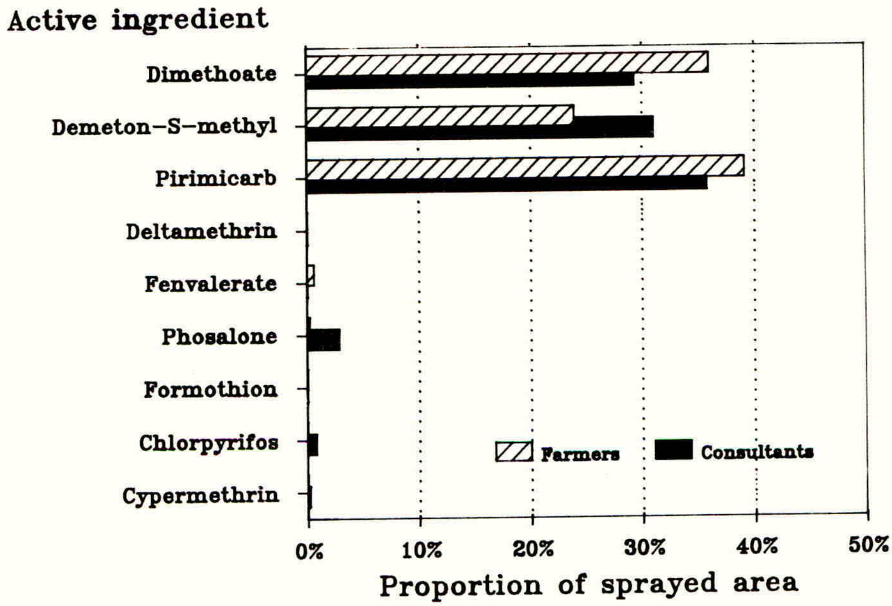

Fig. 3. Timing of spray application in 1988.

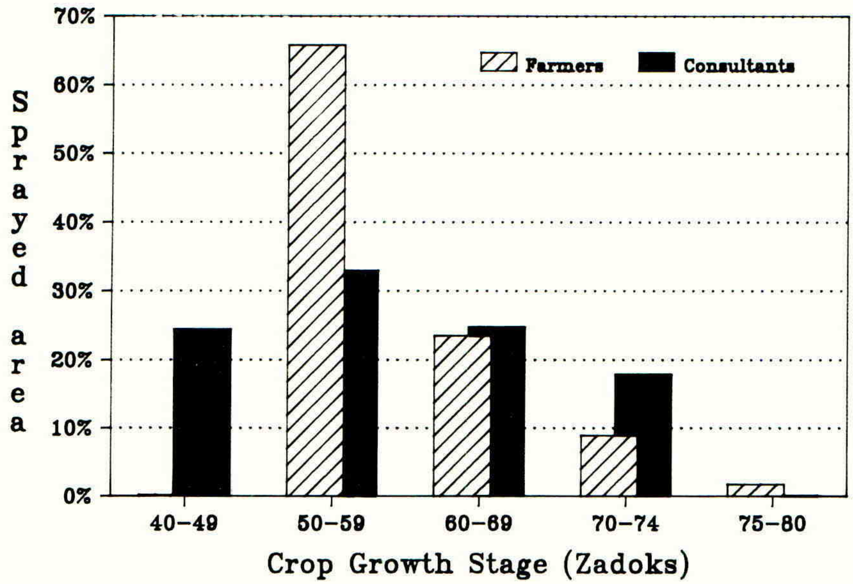

Fig. 4. Aphid infestation when sprayed.

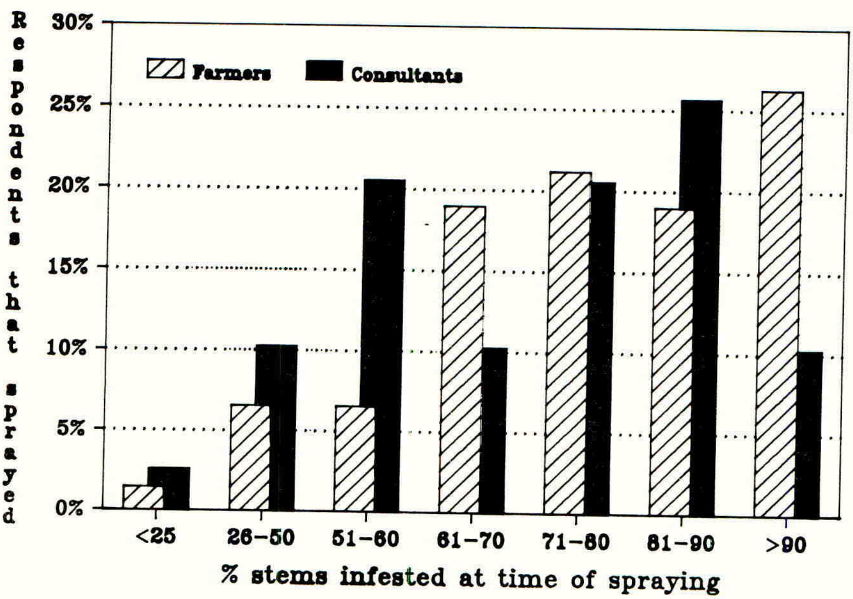

TABLE 1

Comparison of some of the results from the 1984 and 1988 surveys.

	YEAR 1984	1988
Area surveyed (ha)	62670	115711
Area receiving aphicide (%):		
Farmer	74	60
Consultant	86	51
% aphicides as tank-mix:		
Farmer	69	83
Consultant	83	98
Number of tank-mix combinations	>100	>70
Number of insecticides	12	9
Number of approved insecticides	6	7
% of sprayed area sprayed with non-approved insecticides	4	0.4
% of sprayed area sprayed with the insecticides:		
dimethoate	50	31
demeton-S-methyl	16	30
pirimicarb	28	37
others	6	2

DISCUSSION

The surveys carried out in 1976 and 1984 showed that a high proportion of farmers were using insecticides sub-optimally, often spraying too late. Despite improvements in the type of advice available to farmers and changes in ADAS advice, evidence from the 1988 survey again indicates the sub-optimal use of insecticides with, in this case, insecticides being applied before flowering, outside the period of spraying recommended by ADAS. However, detailed analysis of the economics of the decision making, similar to that carried out for the previous surveys, needs to be performed and will be reported elsewhere.

The number of non-approved insecticides used has declined since 1984 from 6 to 2, with decreases in the area sprayed with these from 4% to 0.4%. The number of different ´cocktails´ used in tank-mixes has also decreased, by about one third, although the proportion of the area sprayed with tank-mixes has risen considerably. These changes may be due to a combination of the introduction of new pesticide regulations and the early arrival of high numbers of aphids, perhaps resulting in panic spraying.

A large proportion of the cereal acreage received inputs of broad-spectrum compounds such as dimethoate, which has wide-ranging effects on the "non-target", beneficial arthropod fauna (Vickerman & Sunderland 1977, Vickerman et al. 1987), although the area sprayed with these compounds was smaller in 1988 than in 1984. In 1988, the more specific insecticide pirimicarb, which has fewer effects on some beneficial insects than does dimethoate (Vickerman et al. 1987), proved to be the most popular, being used on 37% of the sprayed area. This proportion could have been greater since some farmers commented that it was unavailable in their area, so forcing them to use other products.

The results from this, the most recent of the three surveys carried out so far, again points towards farmers' using insecticides against cereal aphids inappropriately.

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THE EFFECT OF PYRETHROID AND ORGANOPHOSPHATE INSECTICIDES ON THE FEEDING ACTIVITY OF THE PEACH-POTATO APHID (MYZUS PERSICAE (SULZER))

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ABSTRACT

The feeding activity of insecticide-susceptible peach-potato aphids (*Myzus persicae*) on insecticide-treated Chinese cabbage leaves was recorded using an electronic monitoring system. Leaves were treated with either the pyrethroid insecticide, bifenthrin, or the organophosphate insecticide, demeton-S-methyl. The pyrethroid reduced both the number and the duration of probes. The organophosphate reduced probe number only. The pyrethroid insecticides would therefore be expected to inhibit the spread of non-persistent potato viruses better than the organophosphate insecticides. The mechanism of pyrethroid repellency appears to involve taste.

INTRODUCTION

The spread of non-persistent plant viruses by aphids is too rapid for many insecticides to be effective (Loebenstein & Raccah 1980). Pyrethroid insecticides have been found, however, to restrict the spread of aphid-borne, non-persistent, potato viruses (Gibson *et al*. 1982; Rice *et al*. 1983; Gibson 1983; Bell & Henry 1986). Efficacy was related to the incapacitation (Bell & Henry 1986) or intoxication (Gibson & Campbell 1986) of the aphid vectors.

Pyrethroids are repellent to insects including aphid virus vectors (Highwood 1979). The mechanism of repellency is unknown, but is presumably related to taste, touch or smell or some complex combination of these senses. Taste is the principal sense involved in the aphid feeding process (Edwards & Wratten 1980) which can be monitored directly using an electronic apparatus (McLean & Kinsey 1964; 1965). This paper reports the results obtained while electronically monitoring the feeding activity of the peach-potato aphid (*Myzus persicae* (Sulzer)) on Chinese cabbage (*Brassica pekinensis* (Rupr.)) leaves treated with a pyrethroid insecticide or an organophosphate insecticide.

MATERIALS AND METHODS

Starved fourth-instar apterous nymphs of a standard, insecticide-susceptible clone of the peach-potato aphid (obtained from Rothamsted Experimental Station, Harpenden, England) were used throughout the experiments. They had been reared on glasshouse-grown Chinese cabbage plants, cv Granaat. During the experiments, they were allowed to feed on the fourth leaves of similarly glasshouse-grown chinese cabbage plants of the same cv.

The feeding activity of each aphid was monitored at room temperature and humidity for 20 min using the electronic apparatus of Brown & Holbrook (1976). If the silver wire electrode attached to the back of an aphid became detached or the wire obviously hindered the aphid's movements, the experiment was repeated using another starved aphid.

Five experimental treatments were tested: untreated; pyrethroid insecticide (P) at manufacturer's recommended rate of application (rra) -leaf dip; organophosphate insecticide (OP) at rra - leaf dip; P at 22.4 x rra - leaf dip; and OP at rra - systemic. In order to compare equal doses of the P and OP insecticides, the P was tested as a leaf dip at 22.4 x the manufacturer's recommended rate of application to give equimolar concentrations of the a.i.'s. The P insecticide used was bifenthrin (10% EC, FMC 54800, FMC Corporation) at a rate of 20 g a.i. ha^{-1} and the OP insecticide used was demeton-S-methyl (58% EC, 'Metasystox 55', Bayer) at a rate of 243.6 g a.i. ha^{-1}. For the leaf dip treatments, leaves were detached from the parent plants and the petiole stumps enveloped in damp tissue paper. The leaves were then dipped in the insecticidal solutions for approximately 5s, drained of excess solution and air-dried for half-an-hour. For the systemic treatment, all the leaves of a plant were dipped for approximately 5s each in the OP insecticide solution and drained of excess 24-48h before the experiment. Each experimental treatment was repeated ten times, a different leaf and aphid combination being used each time.

The feeding activity of each aphid was recorded as an ink trace on an oscillograph (Washington 400 MD1 single channel, direct writing oscillograph, Kent ME12 1RZ). The numbers of probes and the angular transformations of the proportions of time spent feeding were analysed by one way analysis of variance. A probe began when the ink trace moved away from the base line and ended when the trace returned to the base line.

RESULTS

The effects of the insecticides on the feeding activity of peach-potato aphids are shown in Table 1.

All treatments significantly (p < 0.05) reduced the numbers of probes. The P treatments only reduced significantly (p < 0.05) the proportions of time spent feeding.

DISCUSSION

The pyrethroid insecticide treatments have been shown to be more repellent to peach-potato aphids than the organophosphate insecticide treatments. The pyrethroid treatments reduced both the number and the duration of probes. A similar result was obtained by Sassen (1983) using permethrin and deltamethrin. The organophosphate treatments reduced probe number only. The data suggest that the organophosphate treatments may increase the duration of probes.

As the transmission of aphid-borne, non-persistent potato viruses like potato virus Y can occur in less than 60s (Hille Ris Lambers 1972), none of the treatments in this study would have inhibited non-persistent virus spread in potatoes because the mean probe durations were not less than 156s long. This conclusion is based on the assumptions that the feeding activity of peach-potato aphids on potato and Chinese cabbage plants treated with the same insecticides and the interaction between these insecticides and the two crop plants are similar. The ranges of probe durations were however quite wide across the different treatments of this study. Ignoring the higher rate of pyrethroid - an experimental nicety rather than a practical reality -and concentrating on the lower

TABLE 1
Mean numbers and durations (including ranges) of probes during feeding by peach-potato aphids on Chinese cabbage leaves treated with pyrethroid (P) and organophosphate (OP) insecticides

Treatments	Probes		
	Number	Duration(s)	Angular transformations of proportions of time spent feeding
P @ rra*- leaf dip	1.6	227.8 (5-1200)	35.0
OP @ rra*- leaf dip	1.5	454.0 (5-1200)	51.8
OP @ rra*- systemic	2.4	360.2 (10-1095)	60.1
P @ 22.4 rra*- leaf dip	1.8	156.4 (10-675)	24.2
untreated	3.7	250.5 (15-1200)	63.3
LSD$\underline{p}$ = 0.05	1.13		18.86

*manufacturer's recommended rate of application

rate of pyrethroid, the recommended rate, 7 of the total number of 16 probes monitored across the 10 experimental aphids for this treatment were less than 60s long. Assuming efficient application in the field, a pyrethroid insecticide might be expected then to be about 44% effective at inhibiting the spread of non-persistent viruses. In the field, pyrethroid insecticides (fenvalerate, permethrin, deltamethrin, cypermethrin) were found by Gibson (1983) to be on average 46% effective at inhibiting the spread of potato virus Y from infected to healthy plants. The same argument which was used with the pyrethroid treatment if applied to the systemically active organophosphate treatment would result in the organophosphate insecticide being expected to be about 25% effective at inhibiting non-persistent virus spread in the field. In a similar field experiment to Gibson (1983), Schepers (1972) found that an organophosphate insecticide (demeton) was on average 11% effective at inhibiting the spread of potato virus A from infected to healthy plants.

All of the insecticide treatments in this study would be expected to control aphid-borne, persistent potato viruses like leaf roll which require some hours for transmission to be successful (Hille Ris Lambers 1972).

As taste is the principal sense involved in the aphid feeding process (Edwards & Wratten 1980), the mechanism of pyrethroid repellency appears to involve taste. Whether taste is the only or principal sense involved in the mechanism of repellency is unknown. The taste chemoreceptors are presumably mainly located at the tip of the aphids' rostrum. The part tarsal receptors play, if any, in pyrethroid repellency is unknown.

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PREVENTION OF BEET WESTERN YELLOWS VIRUS (BWYV) IN WINTER OILSEED RAPE BY CONTROL OF APHID VECTORS WITH DELTAMETHRIN

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ABSTRACT

Trials carried out in the UK between 1985 and 1988 have demonstrated that deltamethrin applied at 6.25 g a.i./ha is a very effective treatment for controlling the aphid vector, and thus reducing the incidence of BWYV in winter oilseed rape (Brassica napus). This paper reports on the results of these trials and discusses the potential threat of BWYV to winter oilseed rape yields.

INTRODUCTION

Oilseed rape is susceptible to several viruses including cauliflower mosaic virus (CaMv) and turnip mosaic virus (TuMv) (Walsh & Tomlinson, 1983, 1985). In the USA beet western yellows virus (BWYV) is commonly found in sugar beet (Beta vulgaris) in the west of the country (Duffus, 1961). The virus also has a wide host range which includes shepherd's purse (Capsella bursa-pastoris), groundsel (Senecio vulgaris), lettuce (Lactuca sativa) and brassica species such as turnip (Brassica rapa) and oilseed rape (Duffus, 1974).

However, in England, Smith and Hinckes (1984 a) have confirmed that in recent years beet mild yellowing virus (BMYV) is the main cause of virus yellows in sugar beet. Although closely related to BWYV, it has a more limited host range, which includes shepherd's purse and lettuce, but not brassica crops.

Duffus and Russell (1970) tested virus isolates in England from shepherd's purse and commercial lettuce crops and identified them as BWYV on the basis of host range and serological relationships, even though the isolates did not infect sugar beet in glasshouse infection tests. There is therefore the situation of beet-infecting strains of BWYV occurring in the USA and non-beet infecting strains being found in England; BMYV occurs in England but not in the USA.

Although BMYV does not infect oilseed rape and BWYV is not important in the sugar beet crop, there was the possibility that autumn-sown rape acted as an over-wintering reservoir of the virus, especially as the area grown has increased rapidly in recent years, particularly in the sugar beet growing regions of England.

This potential link has been investigated at Broom's Barn Experimental Station. An extensive survey of 80 autumn-sown rape crops was conducted in spring 1983 and BWYV was detected at 78 sites, including some as far north as Aberdeen (Smith & Hinckes, 1984 b).

The principal vector of BWYV is known to be the peach-potato aphid (Myzus persicae) (Duffus, 1972) and the transmission of BWYV to oilseed rape crops in the autumn by this species was confirmed by Smith & Hinckes (1984 b). They also determined that the risk to sugar beet from M. persicae transmitting the virus from oilseed rape was very small.

In the course of their work they also found that untreated plots of oilseed rape infected with high levels of BWYV yielded 10% less seed and 13.4% less oil than treated plots (Smith & Hinckes, 1985).

The luteovirus BWYV is in the same group as barley yellow dwarf virus (BYDV), potato leaf roll virus (PLRV) and BMYV. It has been suggested (Hill, 1986) that BWYV is a host-adapted strain of BMYV as they are serologically the same. They are restricted to the phloem of plants and reduce the transport of photosynthetic assimilates. BWYV is usually symptomless in oilseed rape but it can cause reddening, slight stunting and premature ripening in other host species. BWYV is a persistent virus, so prolonged feeding is required for transmission into plants.

BWYV could therefore pose a threat to the potential yield of UK winter oilseed rape crops and this is investigated by the current series of trials.

MATERIALS AND METHODS

Trials were carried out on commercial crops of winter oilseed rape throughout England and the East of Scotland during the harvest years 1986 to 1988. Site locations and application details are shown in Tables 1 and 2, together with the levels of virus infection at application.

Trials in 1986 were unreplicated and plot size was 0.5 ha. Treatments were applied using conventional farm sprayers in 200-300 l/ha water at standard pressures. In 1987 a series of unreplicated trials was also established with a plot size of 0.5 ha. In addition, a series of small plot trials (4 m x 12 m) was laid down. These were fully randomised and replicated 4 times. Treatments were applied in 200 l/ha water with a hand-held Van der Weij 'AZO' small-plot sprayer using Spraying Systems 110015 Teejets at a pressure of 2.5 kpa.

In 1988 unreplicated trials were again laid down (with a 0.5 ha plot size) and applied by farm sprayers. Deltamethrin as Decis (25 g/l EC) was used in all the trials. An early spray was always included (mainly at the cotyledon to 6 leaf stage, GS 1.0-1.6), hopefully prior to virus being introduced into the crop. In the last two trial series a later autumn spray was also applied either as a separate treatment or as part of a two-spray programme.

Samples of leaves were taken at or near the first application timing and these were analysed at Broom's Barn Experimental Station using an ELISA technique to establish the base-level of virus in the autumn. Assessments of cabbage stem flea beetle (CSFB) were also carried out in February/March of each year by counting live larvae in the petioles and stems. Sites with significant infestations of CSFB were discounted as potential yield assessment sites. A further sample of leaves was taken from treated and untreated plots at the end of March when virus spread was assumed to be finished, and these were again analysed for presence of BWYV.

In the harvest year of 1988 yield data was obtained from 5 sites where significant BWYV had developed and good control had been achieved. This was done at 4 sites using a Hege 125B small-plot combine fitted with side knives. A 1.5 m cut was taken from 4 x 40 m lengths in each plot. At the other site (Site 1), the total plots were cut with a John Deere 965 combine fitted with a Claydon Yieldometer.

RESULTS

Data from each trials series are presented separately in Tables 3-6, and yield data in Table 7. No adverse effects on crop vigour were noted from any treatment at any of the sites.

Virus levels detected in the spring varied from season to season and from area to area. However, consistently high figures were seen in certain areas, notably the south-west.

At most of the sites over the three seasons, deltamethrin gave some level of control of BWYV. This was highest where no virus, or only low levels, were detected at application. Where two-spray programmes were used these tended to give higher levels of control, particularly in the 1988 trials.

At one large-scale site (5) harvested with a farmer's combine in 1986, a 6.4% yield response was recorded.

Positive yield responses were achieved at all the sites harvested in 1988. At two of the sites where the two-spray programme gave much better control there was a suggestion that this was reflected in a higher yield response.

DISCUSSION

The calendar timing of sprays appears to play little or no part in the final control of infection of BWYV. The critical factor would appear to be the date when viruliferous aphids infest the crop. This obviously varies dramatically, not only from one part of the country to another, but also on a field-by-field basis. However, in general terms the earlier that sprays are applied, the more likely that the aphids have not become established and that BWYV infection is still low.

In the 1987 trials very high virus levels were recorded up to 4 weeks earlier than in 1986 and this suggests that the aphid migration had been earlier. This was confirmed by the Rothamsted Insect Survey (Tatchell, 1987).

In the 1987/88 season the migration of M. persicae occurred over a much longer period of time and this explains why two-spray programmes gave much better control at some sites.

At the site which was harvested and gave a yield response in 1986, there was also visual evidence of premature senescence in the untreated plot. There was also very obvious stunting of the untreated plants visible at site 16 in the 1986/87 trials. At other sites, no symptoms were seen.

The yield data obtained from the 1987/88 trials confirm that yield responses can be achieved from prevention of BWYV infection. These were

TABLE 1

Site and application details

Site No	Location	Cultivar	Date of autumn ELISA	Date of applic	GS of crop at applic	Virus level in autumn (%)
1986 Harvest Year:						
1.	Newton, Cambs	Bienvenu	04/11/85	27/09/85	1.3	5
2.	Stafford, Staffs	Jet Neuf	12/11/85	08/10/85	1.4	0
3.	Diss, Suffolk	Bienvenu	24/10/85	24/10/85	1.8	12.5
4.	Chichester, West Sussex	Bienvenu	01/11/85	11/11/85	1.10	30
5.	Sleaford, Lincs	Rafal	30/10/85	30/10/85	1.4	2.5
6.	Hingham, Norfolk	Mikado	30/10/85	01/11/85	1.8	20
7.	E Winch, Norfolk	Bienvenu	29/10/85	29/10/85	1.8	12.5
8.	Sidmouth, Devon	Bienvenu	24/10/85	10/10/85	1.4	22.5
9.	Gt Wakering, Essex	Bienvenu	25/10/85	08/11/85	1.10	87.5
10.	Lewes, E Sussex	Jet Neuf	11/11/85	09/11/85	1.5	50
11.	Wantage, Berks	Mikado	26/11/85	23/11/85	1.5	5
12.	Driffield, Yorks	Bienvenu	26/11/85	20/11/85	1.6	5
1987 Harvest Year (unreplicated trials):						
1.	Arundel, W Sussex	Bienvenu	06/10/86	06/10/86	1.4-1.6	12.5
2.	Chichester, W Sussex	Bienvenu	07/10/86	07/10/86	1.4	32.5
3.	Lt Wakering, Essex	Bienvenu	01/10/86	30/09/86	1.0-1.5	0
4.	Lt Wakering, Essex	Bienvenu	01/10/86	01/10/86	1.0-1.5	0
5.	Boroughbridge, Yorks	Bienvenu	06/10386	06/10/86	1.6-1.8	22.5
6.	Escrick, Yorks	Bienvenu	20/10/86	20/10/86	1.3-1.4	20
7.	Scampton, Lincs	Bienvenu	03/10/86	04/11/86	1.8-1.12	32.5
8.	Newark, Notts	Bienvenu	03/10/86	04/11/86	1.2-1.8	17.5
9.	Torpoint, Cornwall	Bienvenu	08/10/86	14/10/86	1.2	97.5
10.	Plympton, Cornwall	Bienvenu	08/10/86	09/10/86	1.2	7.5
11.	Newton Poppleford, Devon	Bienvenu	02/10/86	02/10/86	1.2	75
12.	Upton Magna, Salop	Bienvenu	06/10/86	06/10/86	1.2	40
13.	Danesbury, Cheshire	Bienvenu	24/09/86	24/09/86	1.6	27
14.	Neston, Wilts	Bienvenu	30/09/86	13/10/86	1.2-1.5	27.5
15.	Blandford, Dorset	Bienvenu	06/10/86	16/10/86	1.0-1.3	42.5
16.	Stratford, Worcs	Mikado	30/09/86	30/09/86	1.4	7.5
17.	Oxford, Oxon	Bienvenu	07/10/86	09/10/86	1.3-1.6	60
18.	Cranworth, Norfolk	Bienvenu	06/10/86	31/10/86	1.4-1.6	10
19.	Lewes, E Sussex	Mikado	13/10/86	13/10/86	1.2-1.4	2.5
20.	Banff, Banffshire	Rafal	15/10/86	07/10/86	1.4-1.6	40

however from unreplicated trials and from sites where high levels of virus were present. It is therefore unlikely that routine treatment of all UK winter OSR crops would be advisable. However, in high risk situations such as the south-west of England and where aphids are seen in crops in the autumn, then treatment is likely to be worthwhile.

TABLE 2

Site and application details

Site No	Location	Cultivar	Date of autumn ELISA	Date of early applic	Date of late applic	GS of crop at early applic	Virus level in autumn (%)
<u>1987 Harvest Year (replicated trials):</u>							
1.	Blythborough, Suffolk	Bienvenu	29/09/86	08/09/86	29/10/86	1.4-1.7	2.5
2.	Blythborough, Suffolk	Bienvenu	29/09/86	08/09/86	29/10/86	1.4-1.7	2.5
3.	Winthorpe, Notts	Mikado	02/10/86	02/10/86	04/04/86	1.4-1.6	0
4.	Bishops Frome, Hants	Rafal	03/10/86	03/10/86	20/11/86	1.0-1.3	42.5
5.	Dunbar, East Lothian	Mikado	10/10/86	01/10/86	24/11/86	1.5-1.6	0
6.	Boyndie, Banff	Mikado	13/10/86	13/10/86	29/11/86	1.5-1.6	5
7.	East Winch, Norfolk	Bienvenu	07/10/86	07/10/86	03/11/86	1.4-1.6	52.5
8.	Amesbury, Wilts	Jet Neuf	23/09/86	23/09/86	01/11/86	1.8-1.10	2.5
<u>1988 Harvest Year:</u>							
1.	East Winch, Norfolk	Ariana	29/09/87	26/09/87	06/11/87	1.2-.14	0
2.	Blythborough, Suffolk	Bienvenu	08/10/87	12/10/87	04/04/87	1.2-1.6	4
3.	Corsham, wilts	Jet Neuf	22/09/87	18/09/87	27/10/87	1.1-1.2	5
4.	Sidbury, Devon	Bienvenu	21/10/87	10/10/87	06/11/87	1.6-1.7	14
5.	Ledbury, Herefs	Bienvenu	29/09/87	30/09/87	13/11/87	1.2	7
6.	Newport, Gwent	Bienvenu	29/09/87	30/09/87	25/11/87	1.2	4
7.	Lincoln, Lincs	Bienvenu	29/10/87	18/10/87	08/11/87	1.2	4
8.	Cuminestown, Banff	Bienvenu	11/11/87	14/10/87	13/11/87	1.5-1.7	1

TABLE 3

1985/86 Trials - effects of deltamethrin on control of BWYV

Treatment	Rate g ai/ha	% Control of BWYV Site No 1	2	3	4	5	6	7	8	9	10	11	12
Deltamethrin	6.25	92	71	50	36	26	33	0	0	0	0	67	33
Untreated (% of leaves infected with BWYV in the spring)		30	25.5	35	82.5	47.5	37.5	45	100	97.5	80	15	15

TABLE 4

1986/87 Unreplicated trials - effects of deltamethrin on control of BWYV

Treatment	Rate g ai/ha	% Control of BWYV Site No 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Deltamethrin	6.25	33	87.5	71	100	62.5	33	80	43	100	100	100	14	31	21	75	67	75	47	91	6
Untreated (% of leaves infected with BWYV in the spring)		15	20	17.5	2.5	20	45	12.5	17.5	30	5	55	17.5	32.5	95	30	45	60	42.5	27	82.5

TABLE 5

1986/87 Replicated trials - effects of deltamethrin on control of BWYV

Treatment	Rate g ai/ha	% Control of BWYV Site No 1	2	3	4	5	6	7	8
Deltamethrin (early)	6.25	40	86	67	100	0	0	100	33
Deltamethrin (late)	6.25	40	14	67	83	0	0	0	0
Deltamethrin (early + late)	6.25 + 6.25	80	100	78	100	40	81	100	33
Untreated (% of leaves infected with BWYV in the spring)		12.5	17.5	45	15	25	35	2.5	15

TABLE 6

1987/88 - Effects of deltamethrin on control of BWYV

Treatment	Rate g ai/ha	% Control of BWYV Site No 1	2	3	4	5	6	7	8
Deltamethrin (early)	6.25	32	60	76	73	0	12.5	0	0
Deltamethrin (early + late)	6.25 + 6.25	97	100	87	82	0	88	0	15
Untreated (% of leaves infected with BWYV in the spring)		46.25	6.25	47.5	55	5	60	1.25	67.5

TABLE 7

Effects of deltamethrin on crop yield

Treatment	Rate g ai/ha	Relative Yield (untreated = 100) Site No 1	2	3	4	6	Mean
Deltamethrin (early)	6.25	104	103	108	105	113	106.5
Deltamethrin (early + late)	6.25 + 6.25	106	103	-	105	115	107.9
Untreated (Yield in t/ha)		1.87	2.32	1.54	2.57	2.21	-
S.E.							1.49
LSD (p = 0.05)							4.98%

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IMPROVED CROP ESTABLISHMENT IN SUGAR BEET RESULTING FROM THE USE OF TEFLUTHRIN

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ABSTRACT

Tefluthrin is a novel pyrethroid with physical and chemical properties which make it ideal for use as a soil insecticide. This paper describes large and small-scale field trials where tefluthrin, formulated as a seed treatment and a micro-granule, was tested against against major soil pests of sugar beet.

INTRODUCTION

Tefluthrin is a novel pyrethroid soil insecticide effective against a wide range of soil pests. Its properties and spectrum of activity have been described in detail by Jutsum et al, 1986. It is sufficiently stable in the soil to provide good residual activity. It exhibits sufficient volatility to allow mobility in the vapour phase to protect crops from insect attack even in dry soil conditions. These qualities make tefluthrin particularly well-suited for the control of soil pests in a range of crops. Where crops are drilled to a stand, usually only small plant losses can be tolerated before yield loss occurs. Sugar beet is such a crop where developing seedlings require good protection through to the fully established stage.

Tefluthrin has been tested for more than four years in many European countries. It is formulated as a suspension of slow release micro-capsules for use in seed treatments (Marrs and Gordon, 1987) and as a micro-granule.

The data presented here are the most recently collected from large scale (2 ha) field trials in the UK and from small plot replicated trials in France.

MATERIALS AND METHODS

In the UK a total of thirty seven large scale, split-field trials were carried out in the 1987 and 1988 seasons. Each trial was conducted using farmer drills and granular applicators. Trial sites covered a range of soil types in the main sugar beet areas.

Tefluthrin seed treatment was compared with the standard seed treatment methiocarb. The value of an additional tefluthrin granule treatment was also tested (Table 1).

TABLE 1

Treatment list for split-field trials 1987-1988

Seed Treatment	Rate g a.i./unit +	Granule	Rate g a.i./ha
Methiocarb	2	-	
Methiocarb	2	tefluthrin**	50
Tefluthrin*	10	-	
Tefluthrin	10	tefluthrin	50

* 20% w/v micro-encapsulated formulation as a seed treatment

** 0.5% w/w micro-granules applied at 10 kg product/ha.

+ 1 unit = 100,000 seeds

In France, small-plot replicated trials were targetted against pygmy mangold beetle (*Atomaria linearis*), spotted millipede (*Blaniulus guttulatus*), wireworm (*Agriotes* spp.) and leatherjacket (*Tipula* spp.) Three rates of tefluthrin as a seed treatment were compared with the standard carbofuran seed treatment. A granular carbofuran treatment was included with the low-rate carbofuran seed treatment. A higher-rate carbofuran treatment (45 g a.i./unit) was also included as a more critical comparison of efficacy and crop safety (See table 2).

TABLE 2

Treatment list for small plot replicated trials - France, 1988

Seed Treatment	Rate g a.i./unit	Granule	g a.i./ha
Untreated	-		
Carbofuran	3		
Carbofuran	3	Carbofuran	600
Carbofuran	45		
Tefluthrin	6		
Tefluthrin	8		
Tefluthrin	12		

RESULTS

The predominant soil pest in UK trials in 1987 was the springtail, _Onychiurus armatus_. _B. guttulatus_, _A. linearis_ and _Agriotes_ sp. were found at some sites. Pest incidence was generally low, but root damage and plant death due to pest activity were recorded at all but four sites. In 1988 _O. armatus_ and _A. linearis_ were the most commonly occurring pests. Root damage and plant death were again recorded, but the data were confounded by mouse damage which occurred at over half the sites. The results of cross-trials analyses for both years are shown in Table 3.

TABLE 3

Effects of seed treatments (ST) and granules (GR) on sugar beet establishment. (Analyses over 17 trials in 1987 and 18 trials in 1988)

Treatment	Rate**	% Crop Establishment relative to methiocarb(= 100) 1987	1988
Methiocarb ST	(2)	100 B (38)*	100 (43)*
Methiocarb ST + tefluthrin GR	(2) (50)	108 AB	109
Tefluthrin ST	(10)	110 A	104
Tefluthrin ST + tefluthrin GR	(10) (50)	113 A	105
Crop growth stage		4-6 leaves	4-6 leaves

* Actual mean number of plants per 10 m row.

** Rates are expressed as g a.i./unit for seed treatments and g a.i./ha for granule treatments.

Treatment means with no letter in common are significantly different at the 5% probability level.

The UK data show tefluthrin, applied as a seed treatment or a granule to offer more effective protection to the crop than the standard seed treatment, methiocarb. The benefit was particularly marked at those sites where conditions favoured pest activity eg. Table 4.

Table 4

Effects of seed treatments (ST) and granules (GR) on sugar beet establishment when conditions favour pest activity (Millipedes, UK, 1988)

Treatment	Rate**	% Crop establishment relative to methiocarb (= 100)	
Methiocarb ST	(2)	100	(40)*
Tefluthrin ST	(10)	122	
Methiocarb ST + tefluthrin GR	(2) (50)	127	
Methiocarb + carbofuran	(2) (600)	125	

* Actual mean number of plants per 10 m row

** Rates are expressed as g a.i./unit for seed treatments and g a.i./ha for granule treatments.

Trials in France illustrated both efficacy and crop safety. The data are shown in Table 5.

TABLE 5

Effects of seed treatments (ST) and granules (GR) on sugar beet establishment, France, 1988

Treatment	Rate**	% Crop establishment Site A	Site B	Site C	Site D
Untreated		100 AB (40.2)*	100 (40.9)*	100 C (18.5)*	100 C (17.5)*
Carbofuran ST	(3)	94 BC	105	99 D	192 B
Carbofuran ST + carbofuran GR	(3) (600)	98 AB	nd	179 A	205 B
Carbofuran ST **	(45)	90 C	98	106 CD	207 B
Tefluthrin ST	(6)	106 A	109	135 BC	229 A
Tefluthrin ST	(8)	101 A	110	147 B	230 A
Tefluthrin ST	(12)	100 AB	102	151 AB	234 A
Assessment timing		48DAS	49DAS	36DAS	35DAS
Crop growth stage		4-8 Leaves	8 Leaves	4 Leaves	4 Leaves

nd = no data

* Actual mean number of plants per 10 m row.

** Rates are expressed as g a.i./unit for seed treatments and g a.i./ha for granule treatments

DAS = days after sowing

Treatment means with no letter in common are significantly different at the 5% probability level.

Predominant Pests: Site A - B guttulatus,
Site B - Agriotes & Tipula spp.
Site C - Agriotes sp
Site D - A. linearis

Throughout the trials tefluthrin showed excellent activity and compared favourably with carbofuran treatments. These data further confirm the findings of Painparay & Verrier (1987)

DISCUSSION

The large-scale grower trials conducted in the UK in 1987-1988 confirmed the excellent efficacy and crop safety of tefluthrin that was reported from small-plot replicated trials in UK (Winder 1986; Dewar et al. 1987). The small-plot replicated trials conducted in France illustrate further the protection offered by tefluthrin when pest attack is severe. Reported data indicate that where pest attack is expected to be moderate, the use of tefluthrin as a seed treatment can reduce the need for a granule treatment. Where pest attack is normally severe the use of tefluthrin seed treatment and granules can provide effective crop protection which is not dependent on soil moisture for activity.

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We thank all the experimentalists and co-operators in France and UK for the data on which this paper is based.

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FIELD OBSERVATIONS OF CEREAL APHIDS AND NATURAL ENEMIES

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ABSTRACT

Cereal aphid and natural enemy populations were monitored in 1987 at weekly intervals in twenty winter wheat fields in each of three areas close to Rothamsted Insect Survey suctions traps at Kirton, Littlehampton and Rothamsted. Aphid populations were slowest to develop in the Kirton area where numbers of migrant aphids in June were the smallest. In July however, aphid populations at Kirton did rise to damaging levels in a number of fields whilst aphid populations at Rothamsted and Littlehampton remained small. There were more Carabidae in pitfall traps at Littlehampton than at Rothamsted or Kirton, but numbers of Staphylinidae and spiders found in the three areas were similar. No clear relationship between the numbers of polyphagous predators in a field and peak aphid densities was found.

INTRODUCTION

RISCAMS (Rothamsted Insect Survey Cereal Aphid Monitoring Scheme) was started in 1982 to study the degree of variation in numbers of cereal aphids between winter wheat fields near Rothamsted Insect Survey suction traps and to determine the factors responsible for any such variation (Dewar, 1983). In the first two years of the study, numbers of aphids remained small despite suction trap samples indicating potential outbreaks and it was suggested that natural enemies were the primary cause (Dewar, 1984). The survey was therefore expanded to include studies on natural enemy presence and abundance. This paper discusses results obtained from RISCAMS in 1987.

MATERIALS AND METHODS

Twenty winter wheat fields were surveyed weekly at each of the three sites which were near suction traps at Littlehampton in Sussex, Rothamsted in Hertfordshire, and Kirton in Lincolnshire. Sampling began on 28 May and continued until 24 July. Twenty samples, of five shoots each, were inspected in each field every week. Each shoot was examined for the presence of grain aphid (*Sitobion avenae*), rose-grain aphid (*Metopolophium dirhodum*), bird cherry-oat aphid (*Rhopalosiphum padi*), or any other species of cereal aphid. If the number of any one species of cereal aphid on a shoot or of all the species combined exceeded ten, this was noted separately. The presence of any natural enemies and the numbers of any diseased or parasitised aphid remains on the shoots were also recorded. Calibration curves were used to convert the percentages of shoots infested with aphids into aphid densities. The percentage of shoots with more than ten aphids was used to calculate aphid densities when more than 75% of shoots were infested, as this gives a more accurate estimate (Rabbinge *et al.*, 1980).

Four pitfall traps, containing 50% methanol, were placed at 25 m intervals into each field. The traps were changed every week. The total numbers of Carabidae, Staphylinidae and spiders in each pitfall trap was noted. Common Carabidae and Staphylinidae were identified to species.

RESULTS

Aphid populations

S. avenae and *M. dirhodum* were the only reasonably numerous aphid species in the fields surveyed. In May and June, *S. avenae* and *M. dirhodum* were more numerous in suction trap samples from Rothamsted and Littlehampton than in samples from Kirton (Table 1). Aphid populations were established in the majority of fields at Rothamsted and Littlehampton by the time crop sampling began at the end of May but at Kirton aphids were absent from most fields until mid June. *S. avenae* was the commoner species at all sites. In July, numbers of aphids increased rapidly in fields at Kirton, raising densities to over five aphids per shoot in nine of the twenty fields sampled after the end of flowering (Fig. 1a). In one field, 98% of the shoots inspected were infested. Crop infestations at Kirton reached a peak in mid July, declining after late milky-ripe stage (GS 77; Tottman, 1987). Numbers in suction trap samples from Kirton also increased in July and were higher than those from Rothamsted or Littlehampton where no major population increase occurred in fields in July (Figs. 1a, 1b). Numbers of aphids in fields at Rothamsted and Littlehampton declined early in the month after the early milky-ripe stage (GS 73).

TABLE 1

Numbers of *Sitobion avenae* and *Metopolophium dirhodum* in suction trap samples.

	S. avenae			*M. dirhodum*		
	May	June	July	May	June	July
Kirton	0	32	4164	0	16	998
Rothamsted	4	91	1527	4	36	423
Littlehampton	12	81	1489	5	28	277

Natural enemies

Polyphagous predators were most numerous in pitfall traps from Littlehampton. Numbers of carabids in pitfall traps were markedly greater at Littlehampton than at Rothamsted or Kirton throughout the sampling season (Fig. 2a). *Pterostichus melanarius* was the commonest species, comprising 60-70% of carabids at all three sites. Staphylinids were also more numerous at Littlehampton than at the other two sites in the first sampling week but their numbers subsequently declined (Fig. 2b). The numbers of spiders found in pitfall trap samples from the three sites were similar (Fig. 2c).

Syrphids were the commonest predators observed on crops at Kirton and Littlehampton, and coccinellids the commonest at Rothamsted. Numbers of mummified aphids remained samll at Rothamsted and Littlehampton but at Kirton parasitism rose above 5% in late July to reach 11% by the last week of sampling. Few diseased aphids were found at any of the three sites.

DISCUSSION

In the Kirton area, aphids were not detected at the beginning of the sampling period and numbers of spring migrants were small. Therefore the outbreaks which occurred there cannot be attributed to greater numbers of overwintering aphids or to greater numbers of immigrant alates. The larger aphid populations observed in some of the fields near Kirton must have developed due to higher rates of increase than at other sites. Factors which influence the rate of increase of *S. avenae* include; temperature, rainfall, crop physiology and natural enemy action (Entwistle & Dixon, 1986). Aphid populations were present earlier in crops at Rothamsted and Littlehampton than at Kirton, and it has been suggested that an early presence of aphids in crops gives natural enemies time to increase to numbers sufficient to suppress aphid populations later in the season (Powell *et al.*, 1983). Large predator populations may have been responsible for suppressing numbers of aphids at Littlehampton but numbers of polyphagous predators found at Rothamsted, where aphids were few, were similar to numbers found at Kirton, where aphid outbreaks occurred. This may be because some species are more efficient aphid predators than others, so that individual species should be considered separately (Sunderland & Vickerman, 1980). *P. melanarius* has been found with aphid remains in the gut, even at low aphid densities, before crop flowering and so has the potential to be an important control agent (Sunderland *et al.*, 1987). In the same study however, only very low densities of this predator were found by surface searching and D-vac sampling whereas large numbers were present in pitfall traps. Pitfall trap sampling tends to overestimate the densities of certain species such as large carabids, whilst being inefficient at catching others, e.g. smaller beetles such as *Tachyporus* spp., so a variety of sampling methods is preferable for assessing the relative densities of species (Sunderland & Chambers, 1982).

The rate of increase of aphid populations on crops has been successfully used to provide short term predictions of aphid damage (Entwistle & Dixon, 1987). Long term forecasting is more difficult because, as seen at Kirton, low initial aphid populations are not a reliable indication that peak aphid populations will be low. Dewar and Carter (1984) considered the presence of natural enemies as a factor in the development of a longer term forecasting scheme. They suggested that the presence in early June of polyphagous predators in the centre of fields decreased the likelihood of an aphid outbreak, as did the presence of larvae or eggs of aphid-specific predators in early June, whilst a level of parasitism and disease below 5% in May increased it. At all sites throughout the sampling period, polyphagous predators were present 100 m into fields and aphid-specific predators were found. Parasitism remained low at all three sites. Therefore, such a simple assessment would not have differentiated between the three sites in 1987. If natural enemies are to be included in a forecasting scheme a more accurate measure of their effectiveness needs to be developed.

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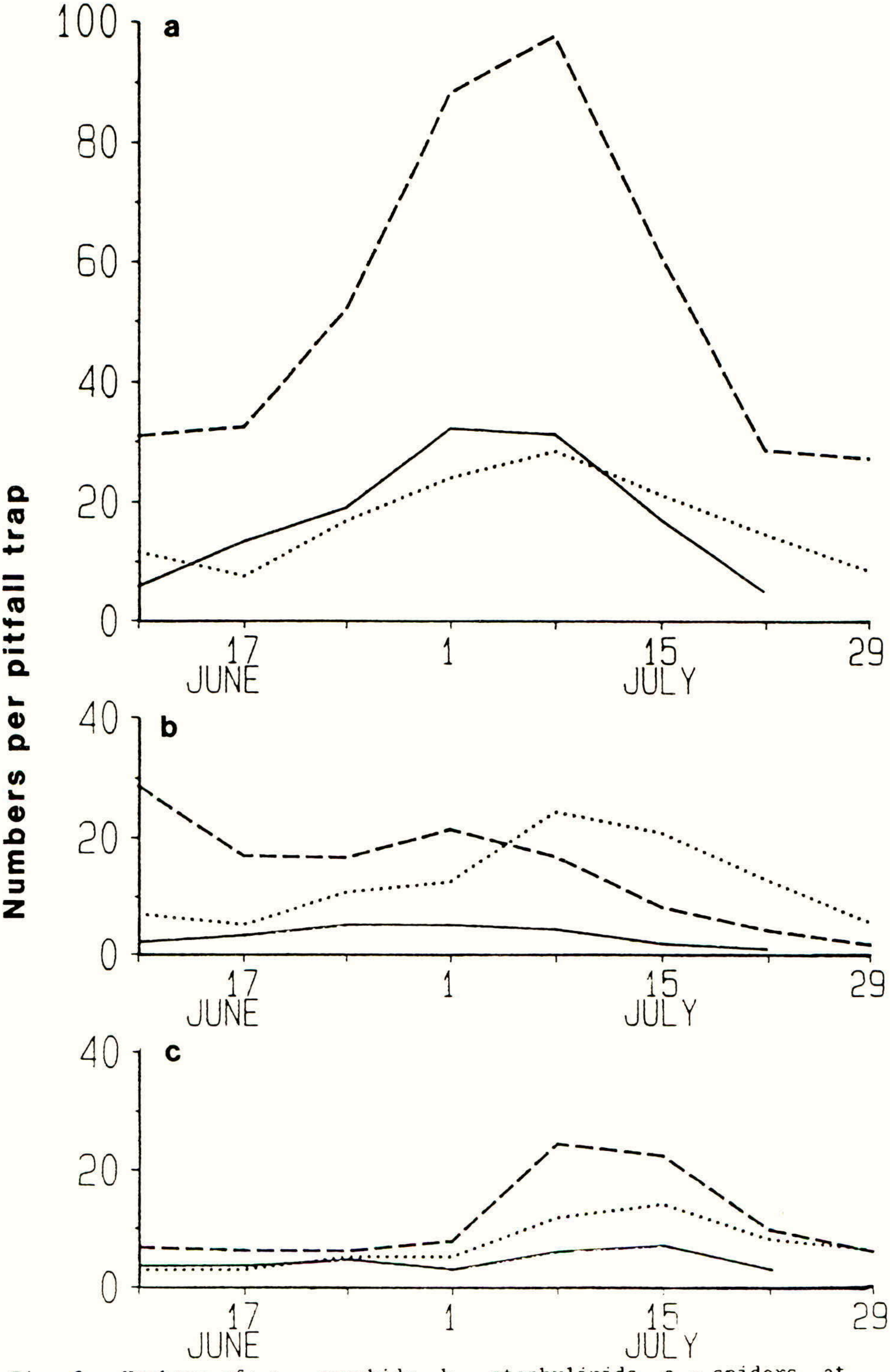

Fig. 2: Numbers of; a - carabids, b - staphylinids, c - spiders, at Kirton (...), Littlehampton (---) and Rothamsted (- -).

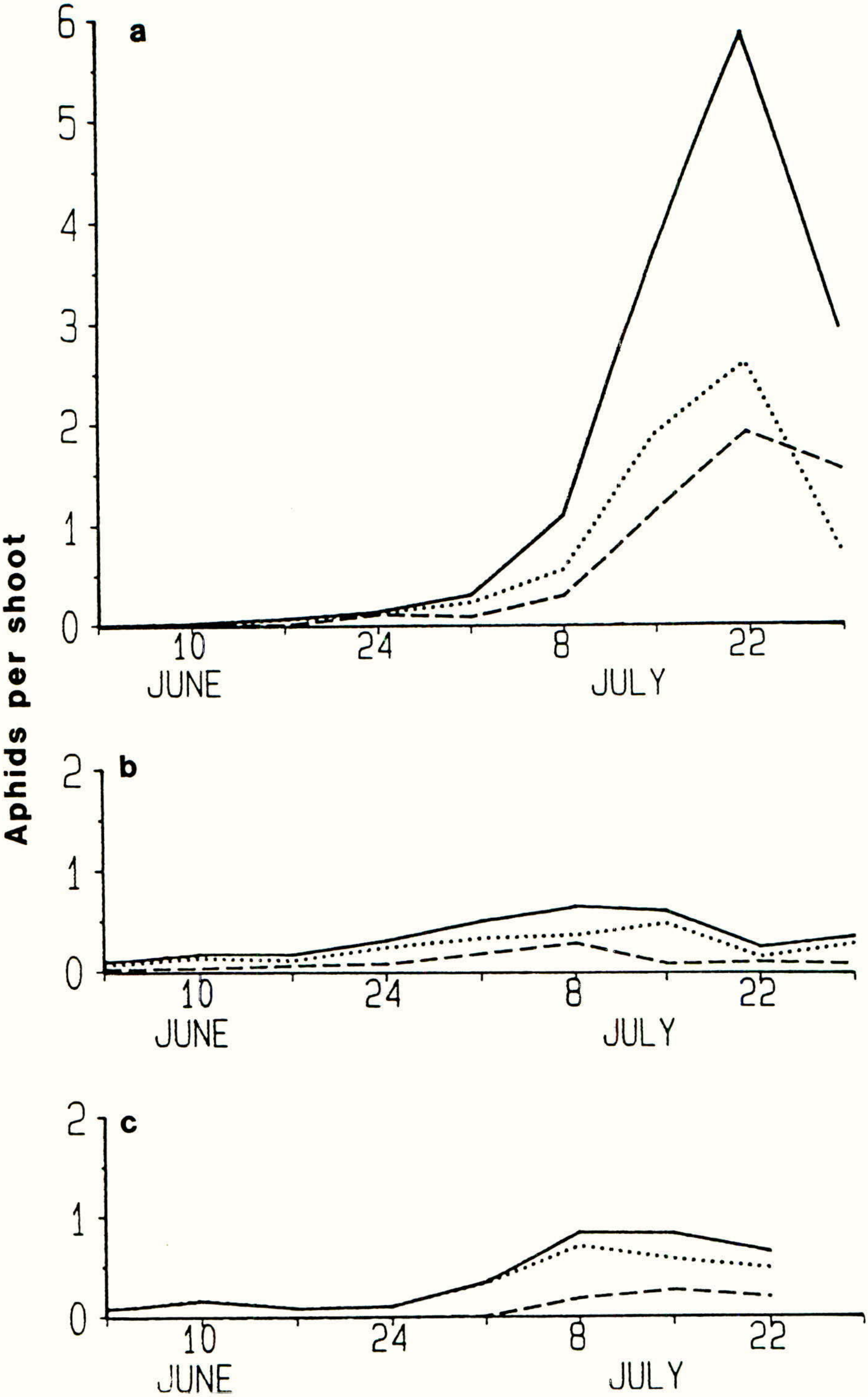

Fig. 1: Numbers of; *S. avenae* (...), *M. dirhodum* (- -), total aphids (---) at a - Kirton, b - Littlehampton, c - Rothamsted.

PEST AND DISEASE MANAGEMENT IN INTEGRATED LOWER INPUT/SUSTAINABLE AGRICULTURE SYSTEMS

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ABSTRACT

The concept of integrated pest management (IPM) has developed a long way from its origins in 1959. However, IPM still concentrates more on separate inputs into individual methods of pest, disease and weed control that minimize use of pesticides, than on integration of these inputs. Fertilizer use, cultivations and rotations all have major impacts upon each other and upon pest disease, and weed incidence. The four main components of crop protection systems are integrated pest, disease and weed management, controlled fertilizer use, appropriate cultivations and suitable crop rotations and combinations. Examples of how these main components impact on individual pest, disease and weed incidence are discussed. The need for integrated farm management systems for pest, disease and weed management and the potential for computer-based farmer operated integrated management systems are reviewed.

INTRODUCTION

The concept of integrated pest management was first suggested by Stern (1959). This emphasized the blending of chemical and biological control measures. It was later broadened (Smith and Reynolds, 1965) to: "a system which uses all suitable methods of pest control in as compatible a manner as possible" and defined by FAO (1967) as: "a pest management or integrated control system which, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains pest population levels below those causing economic injury".

The idea has led to many significant innovations in pest control such as: development of economic injury thresholds, use of selective pesticides, design of pesticide placement techniques, use of pheromones, use of insect pathogens, sterile male release, pest forecasting and breeding of resistant crop varieties. However, the emphasis has been more on development of such techniques independently, than on their integration. Exceptions lie in integrated management of glasshouse, orchard pests and of insects on the cotton crop, but all of these have been confined mainly to management of insect pests.

A major short-fall in the development of integrated pest management in arable crops has been implementation of programs where entomologists, plant pathologists and weed specialists work together with agronomists and plant breeders, to combine efforts in managing insects, diseases and weeds. Only such interdisciplinary efforts can produce a fully-developed and sound integrated crop protection program which should protect crops against animal pests, diseases and weeds, using all available alternative, means, including manipulation of farm practices with minimum possible use of chemical pesticides.

All aspects of insect, disease and weed management interact strongly with each other (Fig. 1).

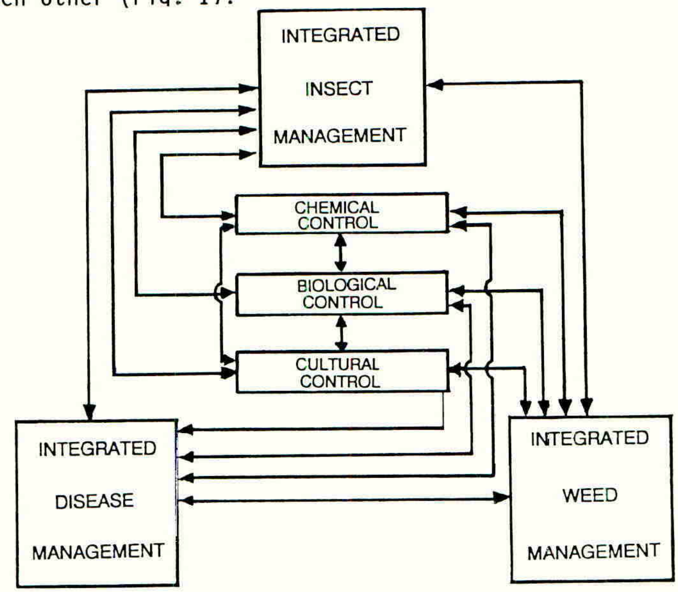

Figure 1. Interactions between insect, disease management in relation to individual control measures.

For this reason, efficient integrated management systems should consider crop protection as only one of the main inputs of a farming system, the others being cultivations, fertilizers (inorganic and organic) and rotations (Fig. 2).

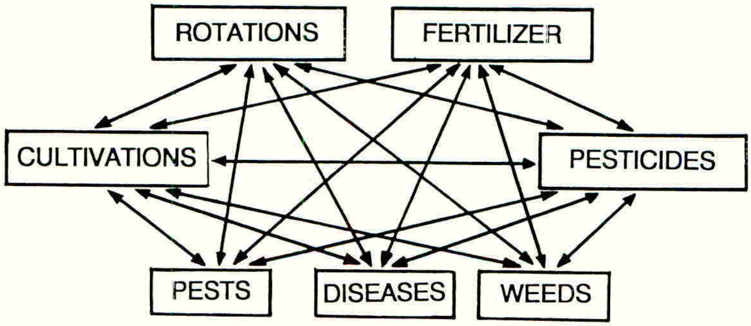

Figure 2. Interactions between inputs into agricultural systems and pests, diseases and weeds.

We therefore propose the concept of integrated farming systems for pest, disease and weed management. This proposal should be considered in the context of the current move towards lower energy-based inputs into farming systems, which will provide a more sustainable agricultural base, both economically, as well as ecologically and environmentally. Such systems were defined by Edwards (1988) as:

> "Integrated systems of agricultural production, less dependent on high inputs of energy and synthetic chemicals, and more management intensive than conventional monocultural systems. These systems maintain or increase net income for the farmer, are ecologically desirable and protect the environment."

The major barrier to development of such systems is our poor knowledge of interactions between the inputs. The aim of this paper is to describe the kind of information needed and to provide illustrations of the value of such data from our work and from the scientific literature.

METHODS - COMPONENTS OF LOWER INPUT FARMING SYSTEMS

1. Cultivations

There has been a progressive move from traditional deep ploughing through shallow ploughing, chisel ploughing, tine and disk cultivation, ridge tillage and other forms of conservation tillage, to no till or direct drilling of crops without cultivation. The assumption has been made that cultivations which involve deep ploughing and inversion of the soil, bury pest disease and weed organisms to a depth where they have little effect on the crop. However, the situation is much more complex than this simple concept, since the soil inversion involves not only the pest organism but many of its natural enemies. Hence incorporating pests deep into soil could actually ensure their survival, since many soil-inhabiting pests are long-lived, and disease spores and weed seeds can survive for long periods in soil.

For instance, we found in eight experiments which compared wheat growth in ploughed plots with that in direct drilled plots (Edwards, 1976) that attacks of wheat by shoot borers (frit complex) were always heavier in the ploughed plots because their natural enemies were buried. Similarly, we found much heavier black cutworm (*Agrotis ipsilon*) attacks and fewer predatory beetles in ploughed plots following soybeans than in no till (direct drill) plots. (Brust *et al*. 1985) (Fig. 3)

2. Rotations and Cropping

Rotations were a traditional means of controlling pests (Edwards and Heath, 1964), diseases (Williams and Schmitthenner, 1962) and weeds (Ross and Elmbi, 1985) before the extensive use of pesticides made monoculture and biculture systems feasible. In a farm management system where pesticide inputs are minimized, rotations become once again an essential component. Additionally, a range of innovative cropping practices have been tested for their potential in influencing the intensity of pest, disease and weed incidence. These include:

Intercropping two crops using alternate drill widths is quite feasible and if the strips are alternated, in succeeding years there is a major effect on the carry-over of pests, diseases and weeds and the activity of natural enemies compared with monoculture (Risch, 1983).

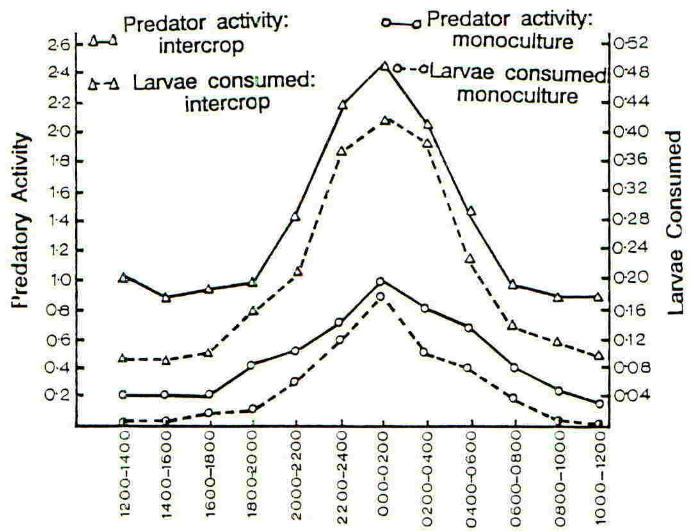

Figure 3. Black cutworm attack in ploughed and direct drilled corn.

For instance, we found predator activity to be much higher in intercropped legume/corn, resulting increased predation on black cutworms (Brust et al., 1986)(Fig. 4).

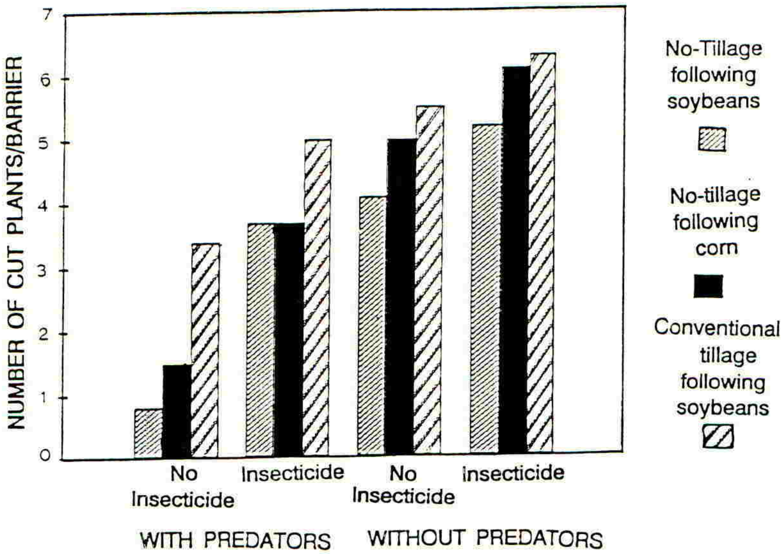

Figure 4. Predator activity and black cutworm predation in intercropped and monoculture corn.

strip-cropping is another new practice combining narrow strips of row and forage crop that can encourage natural enemies. We found phalangids to be 3-4 times more numerous in alfalfa than corn, thereby increasing predatory activity.

trap-crops are an effective way of controlling nematodes and insects (Hill and Mayo, 1974).

living mulches can be effective in controlling weeds (Shelly and Rao, 1981) and greatly increase the diversity and lower the incidence of soil-borne plant pathogens (Rothrock and Hargrove, 1987) and activity of natural enemies (Altieri et al, 1985).

3. Fertilizers

Inorganic fertilizers increase crop yields markedly. However, the readily available nutrients tends to produce abundant, lush plant growth that tends to be more susceptible to attack by insects such as aphids (Kowalski and Visser, 1972) and diseases such as cereal leaf disease (Jenkyn and Finney, 1981). Moreover, fertilizers can grow weeds as well as crops. In drought conditions in 1988, we found that weed growth in corn and soybeans was much greater in conventionally fertilized plots than in those with low nutrient applications.

Organic fertilizers can decrease pest and disease incidence by increasing the diversity of natural enemies and antagonists (Altieri, 1985). For instance, the incidence of nematodes was much less in plots with organic matter than those without, due to multiplication of fungi that attack both adult nematodes and cysts (Kerry,1988).

4. Crop Protection Measures

Pesticides are used as insurance to control pests, diseases and weeds effectively but, their effects on natural enemies and antagonists and the development of resistance, results in continued dependence on and increasing doses and types of pesticides. It is important to minimize pesticide use, by dependence upon economic thresholds, use of accurate placement and low volume techniques, and particularly by choice of pesticides that do not harm natural enemies. This includes minimizing herbicide use since some weed growth is beneficial in maintaining populations of natural enemies (Altieri, 1979). Nor should the pesticides harm organisms such as earthworms (Edwards and Thompson, 1973) or microorganisms (Edwards, 1988).

Biological Control is an essential supplement to decreasing inputs of pesticides in integrated lower input systems. An increasingly impressive battery of biological techniques for controlling pests, diseases and weeds are currently available. Many of these may become even more effective as a result of genetic engineering. Some of the techniques used include: Forecasting of pest and disease populations e.g. Epipré in the Netherlands and the Rothamsted Insect Survey in Europe (Woiwood et al., 1984). Use of resistant varieties of crops that are not susceptible to pests and diseases (Strong et al., 1984). Use of microbial pesticides such as *Bacillus thuringiensis* and *Popilia japonica* to control pests (Riba and Ferron, 1987); biological disease control agents based on *Trichoderma* and *Verticillium* to control disease (Lisansky, 1981); and fungi, termed mycoherbicides to control weeds (TeBeest and Templeton, 1985). Development of semiochemicals that interfere with the attractivity of crops to pests or pheromones that attract pests away from crops (Hummel and Miller, 1984). Promotion of natural enemies by cultural methods (e.g. ecological island in cropping systems) (Altieri, 1984).

CONCLUSIONS AND RESEARCH NEEDS

The pressure for ever-increasing crop yields has led to the development of crop varieties that respond strongly to high chemical inputs and that perform well over relatively long periods of time, although the chemicals used to support them may have adverse ecological and environmental, effects such as soil erosion and ground water pollution. The growing of crops in this way does not depend upon a detailed understanding of agroecosystems, and, although less labor intensive, consume much more energy from non-renewable sources.

However, with over-production of many crops, there is economic pressure to use smaller amounts of less costly chemicals in crop production. Moreover, with increasing pollution of groundwater there is environmental pressure to minimize the use of agrochemicals. This can be answered by the development of: integrated systems of sustainable agriculture. Such systems are much more management intensive and dependent upon an understanding of how the various inputs to farming systems interact with each other. Thus, there is an urgent need for interdisciplinary research into agricultural systems with the aim of integrating inputs to maximize the benefits of natural inputs and minimize the need for chemical inputs.

Once the results of such research are available, there is a need to develop computer-based models to assess the relative importance of the various inputs. The data produced can then be developed to provide computer-based farming advisory systems using those for post control in cereals in the U.K. (Mann et al, 1986) and for horticultural crops in the U.S. (Willson, et al., 1987) as models. These systems would be much more comprehensive than existing models, taking account of all inputs rather than only those associated with pest control.

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CONTROL OF ORANGE WHEAT BLOSSOM MIDGE, SITODIPLOSIS MOSELLANA IN FINLAND.

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ABSTRACT

Six pyrethroids as well as fenitrothion and parathion were found to be effective in controlling ovipositing orange wheat blossom midges. The mean efficacy of one and two applications were 70% and 85%, respectively. Spraying had to be started immediately after midges appeared in the field at the time of ear emergence. Repeated application was necessary if the first application had been done at very early ear emergence and if oviposition was prolonged. Midge larvae aggregated on late-emerging ears. The yield response with one larva per ear was 8 kg/ha, and the control threshold of one midge per 67 plants is proposed in Finnish growing conditions.

INTRODUCTION

In the 1980s, the orange wheat blossom midge, *Sitodiplosis mosellana*, has been the major pest of wheat in Finland. It was economically important particularly in the South Eastern area, in 1983, 1985 and 1987. The highest yield losses, 30 - 40%, occured in 1983, before chemical control was initiated. In this paper, 6 pyrethroids are compared with two organophosphates for midge control. The best spraying time and need for repeated spraying is investigated.

MATERIALS AND METHODS

Two experiments to compare the efficacy of the different pyrethroids were performed by the South Eastern Research Station of the Agricultural Research Centre. The compounds were: bifenthrin 15 g a.i./ha, cyhalothrin 10 g a.i./ha, cypermethrin 50 g a.i./ha, deltamethrin 5 g a.i./ha, fenvalerate 100 g a.i./ha and permethrin 100 g a.i./ha. These were compared with the organophosphorus compound fenitrothion 500 g a.i./ha and parathion 150 g a.i./ha.

The experimental area was formed of four blocks (replicates). Experimental plots, 2 x 12.5 m were randomized across the four blocks. Insecticides were sprayed with a propane-operated knapsack compression sprayer at a pressure of 3 x 10^{-5} Pa. The entire plot was sprayed. The quantity of water was 200 l/ha compounds for pyrethroids and 400 l/ha for the others. The surroundings of the experiments were sprayed except for a 5m border around the plot.

Additional experiments on private farms were organized in the area of the highest midge infestation in the country. Here experimental plots were much larger, from 0.05 to 0.1 hectares. Here, also, the surroundings of the experimental areas were always sprayed. Applications were performed with a normal farm sprayer.

The development stage of the wheat is given according to Zadoks et al. (1974). Midge larvae were counted from 50 ears, randomly taken in the beginning of August, at growth stage 72. All grains were checked, larvae counted and damage recorded. All experiments were harvested with an experimental combine harvester. Yields were dried and sorted. The 1000 grain weight was measured for undamaged and damaged material. The bread-making quality of damaged material is discussed in another paper (Helenius & Kurppa 1989).

RESULTS

Efficacy of pyrethroids in controlling S. mosellana

The efficacy of one application of the six pyrethroids varied between 41 - 78% and of the organophosphorus compounds 74 - 82%. The efficacy of two applications with the pyrethroids varied between 57 - 86%. The organophosphorus compounds (two applications) gave even better results. The effect varied between 94 - 100%. There were, however, no significant differences between the test compounds.

In one experiment the first application was followed by rain, first as a shower after 2 hours and then continuous rain the whole next day. The efficacy of this spraying varied between 25 - 61%.

Correct spraying time and the need for repeated spraying

Midges arrived in most fields before ear emergence of spring wheat. Generally an efficacy of about 70% was obtained if a field was sprayed at the time when first ears emerged (GS51) and the midge oviposition had started (Table 1). In Kadett 1 the effect decreased to 66%, but the spraying of this field was affected by rain. In 1986, midges had finished their oviposition by the time of Kadett 2 ear emergence and an excellent effect was obtained with the earliest possible application at GS 51 of the wheat (Table 1).

Normally, if the midge population was high, a repeated spraying was necessary to cover the ear surface newly-emerged from the sheath. The effect of two applications was about 75 - 85% (Table 1), if the first application had been successful. The third application gave only a small additional effect. If the application was delayed even more, nearer to flowering (stage 61), the effect was nullified (Table 1)

TABLE 1

Control of S.mosellana on private farms in the South-East of Finland: Hinderby, Lapptrask and Tavastby, Perna. Decis EC 25, 0.2 l/ha, was sprayed in 200 l water/ha with a normal tractor compression sprayer. The results of Ulla 2, Kadett 2 and 4 are from 1986, the others from 1987.

Variety/ field no.	Application time (GS)	Effect (%)	Mean no of larvae/ear (untreated)	Lloyd's patch index treated/ untreated
Tapio 1	51	74	9.2	1.3/5.5
Tapio 2	51 + 59	75	16.0	1.2/2.2
Ulla 1	51	73	11.0	1.3/1.3
	51 + 55	81	11.0	/3.8
	51 + 55 + 59	87	11.0	/2.2
Ulla 2	51 + 55	76	5.7	
Kadett	51	66	5.0	1.4/1.4
	51 + 59	72	5.0	/5.3
Kadett 2	51	89	0.9	
Kadett 3	53	59	3.4	1.4/2.3
	55	41	3.4	/1.5
	53 + 57	74	3.4	/2.9
	53 + 57	29	3.4	/1.7
Reno	51 + + 59	85	20.0	1.1/1.7
Tapio 3	58	50	4.0	1.4/1.6
	58 + 60	75	4.0	/2.1
Luja	61	0	4.0	1.7/1.9
Kadett 4	61	0	10.6	

Aggregation of midge larvae among ears in treated areas

Midge larvae were slightly aggregated in certain ears in the pyrethroid plots as well as in the sprayed farm fields. The mean of Lloyd's (1967) patchiness index varied between 1.67 and 2.37 (the index is 1 if distribution is random). A significant difference ($p<0.01$) between the number of applications was found. For example, the mean patchiness index in once-treated areas was 1.96, in twice-treated areas it was 2.84. The most effective pyrethroid, cyhalothrin differed significantly from all other treatments in both experiments. The mean patchiness index in cyhalothrin-treated plots was 1.92 (once treated) and 5.36 twice treated.

The aggregation was normally centered on the late-emerging ears. The larvae were significantly ($p<0.05$) less aggregated in the fenitrothion and parathion treatments than in pyrethroid applicated areas.

Yields

The ear-feeding aphid, Sitobion avenae, infested wheat, in 1987, at the same time as midges and the aphids' effect had to be distinguished. Aphids were controlled by the second treatment, as that was the time when they arrived on the ears. The yield loss cause by aphids was 217 kg/ha and varied between 0 and 14% (Kadett) of the control yield (Table 2).

The yield loss caused by S.mosellana depended on the number of larvae per ear, the number of kernels per ear, plus the weight loss per damaged kernel. In the control experiments the effect of one larva per ear on the yield was calculated to be 97.8 ($\pm$7.0) kg/ha; in other words, 2.4% of the control yield (=4060 kg/ha (4277 kg/ha minus the mean aphid effect, 217 kg/ha)).

TABLE 2

Control of S.mosellana on private farms in the South-East of Finland: Hindersby, Lapptrask and Tavastby, Perna. Decis EC 25, 0.2 l/ha was sprayed in 200 l water/ha. Ulla 1 results are from 1986, the others from 1987.

Variety	Appl.	Mean no of larvae/ ear	Mean no of damaged grains ear	% of damaged grains in ears	Mean yield kg/h	Yield increase %
Ulla 1	Untreated	5.7	4.8	16	3348	
	Treated 2x	1.8	1.8	6	3504	4
Tapio	Untreated	16.0	10.3	34	1243	
	Treated 2x	4.0	3.2	11	1980	29
Ulla 2	Untreated	10.8	7.0	23	2825	
	Treated 1x	3.0	2.4	8	3295	14
	Treated 2x	2.1	1.5	5	3485	23
	Treated 3x	1.7	1.4	5	3235	15
Kadett	Untreated	4.9	3.6	12	3664	
	Treated 1x	1.7	1.6	5	4017	10
	Treated 2x	1.4	1.2	4	4465	22

When damaged grains are not sorted fromm un-damaged grains, the yield loss is composed of the weight loss of damaged grains. Depending on the cultivar, at least 30% of the damaged grains were lost during harvest.

The mean weight of harvested damaged grains varied between 60 and 70% of the mean weight of healthy kernels. Thus the proportional weight loss of the total yield could be roughly estimated to be half of the mean proportion of damaged grains per ear (Table 2, Ulla 1).

DISCUSSION

The efficacy of the tested pyrethroids was good in dry application conditions. If rain interrupted the application, a dry period of two hours seemed not to be enough for pyrethroids, fenitrothion or parathion to be adsorbed to the plant surface. In this case spraying should be repeated.

Observation of midge oviposition and its coincidence with ear emergence is essential when defining the application time. At the time of ear emergence, spraying should be started immediately when ovipositing midges appear and their number can be expected to override the control threshold. Uniform ear emergence throughout a field is essential, so that all ears can be treated at the optimum time. The first application seems to be worth repeating if the midge population is high and most of the ears are in boot during the first treatment. This is important in Finnish conditions because of the injurious effect of damaged grains in the quality of wheat (Helenius and Kurppa 1989).

The yield response, 97 kg/ha/larva, is slightly less than reported from Canada (Olfert _et al_. 1985). The proportional yield loss caused by a certain number of larvae per ear, in Finland, is over two times higher than the effect of the same number of larvae in Central Europe, reported by Lubke & Wetzel (1984). This variation results from the difference in ear size and consequently yield level.

The control threshold is given as the number of ovipositing midges per number of ears and has settled to one midge per three ears in Germany and elsewhere (Lescar 1977). By using this threshold in Finnish conditions the unavoidable yield loss would be as high as 5%, with 6-7% damaged kernels in the yield. A yield of this quality has been reported in some cases to be unacceptable for human consumption (Nijvelt and Bokhorst 1973). If, instead, a damage of 4 - 5% of kernels is accepted, the control threshold should be one midge per 6 - 7 ears, which is the same recommendation, as in Canada (Harvey 1986).

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IMPROVED DIAGNOSIS OF EYESPOT PATHOTYPES: APPLICATION OF A NEW METHOD

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ABSTRACT

Reliable methods for identifying pathogenic fungi are essential when monitoring their populations in crops. W-type and R-type cultures of *Pseudocercosporella herpotrichoides* isolated from cereal eyespot lesions have usually been identified by the different morphologies of their colonies on potato dextrose agar. However, their identification is often hindered by contamination, by mixtures of the two types and by colonies with intermediate appearance. These problems are largely overcome by using a maize-based agar, on which the two types are distinguished by colour produced under near ultra-violet light: W-types produce green-black colour and R-types produce pale brown or pink. The method is being used to study relative survival rates of the types on straws heavily contaminated with *Fusarium* spp.

INTRODUCTION

Populations of the eyespot fungus, *Pseudocercosporella herpotrichoides*, are monitored regularly during farm surveys of wheat and barley crops. In addition to recent changes in sensitivity to fungicides, these surveys have revealed a change during the 1980s from predominantly W (wheat)-type to predominantly R (rye)-type populations in England and Wales (King & Griffin 1985, Hollins *et al.* 1985). The causes and significance of this change are being investigated in field experiments (Bateman *et al.* 1986). Accurate identification of W- and R-types is essential during both surveys and experimental work.

W- and R-types are most commonly identified by isolating them on potato dextrose agar (PDA) and noting the different morphologies of their colonies. The isolates with faster-growing colonies and smooth margins correspond to the W-type, being more pathogenic to wheat than to rye seedlings, whilst those which are slower-growing with feathery-edged colonies correspond to the R-type, being equally pathogenic to wheat and to rye seedlings (Lange-de la Camp 1966, Scott *et al.* 1975, Hollins *et al.* 1985).

However, some isolates do not fulfil the colony morphology criteria, having intermediate appearance on PDA (Hollins *et al.* 1985, Gallimore *et al.* 1987, Maraite *et al.* 1985, Creighton, unpublished). Additionally, the stem bases are often infected by other fungi which obscure the colony margins or retard the growth of *P. herpotrichoides* during isolation. Infection by both W- and R-type can also occur, resulting in the isolation of mixed colonies which are not easily identified on PDA.

Whilst culturing *P. herpotrichoides* on a maize-based agar to induce sporulation (Cavelier & Le Page 1985) it was noticed that W- and R-type isolates produced different colours in the medium when exposed to near ultra-violet light (n.u.v.) for 3 weeks. This led to a procedure for identifying types based on colour production. This method has been compared with other methods during a study of the survival of *P. herpotrichoides* on infected straw, heavily contaminated with *Fusarium* spp. This experiment, a preliminary account of which is presented here, was devised to assess the significance of previous fungicidal treatments (and hence initial populations) on subsequent inoculum levels and to compare the survival rates of pathotypes in the absence of host crops.

MATERIALS AND METHODS

Colour production on maize agar

Maize agar (MA) was made from coarse cornmeal (T.R. Suterwalla & Sons Ltd., Southall, Middx) at 40 g/l and agar (Oxoid Agar Technical) at 20 g/l. Cultures on MA were incubated for 3 weeks under n.u.v. at c. 13°C which encouraged colour production and sporulation. W-type isolates produced a green/black colour and R-type isolates produced a pink or pale brown colour. Isolates with an intermediate colony morphology on PDA were identified as W- or R-type on MA.

Source of infected material

In September 1987 some of the stubble remaining after harvest of a fifth successive wheat crop (cv. Avalon), naturally infected with eyespot, was taken from six plots on a site on the Rothamsted farm. In each of the three preceding seasons two of the plots had been sprayed with prochloraz (Sportak), two with carbendazim (Bavistin) and two had not been treated. Stubble samples from plots of the same treatment were mixed together. In October 1987 the stubble, which had been stored at 2°C, was spread onto 4 m x 5 m plots on fallow ground, with four replicate plots for each treatment. The plots were separated by 3 m of oats. Fifty straws were taken from each plot at intervals of 6 weeks. The first sample was taken immediately and sampling is continuing.

Comparison of methods

Straw bases (c. 1.5 cm of internode) from each plot were surface-sterilised in sodium hypochlorite (1% available chlorine), rinsed twice in sterile distilled water, and left to dry in a sterile air flow. Each straw piece was cut in half longitudinally. One half, containing a lesion if visible, was divided into four pieces. The other half was discarded. One piece of the straw was plated directly onto each of two MA plates and two one-fifth concentration PDA plates (Oxoid PDA at 7.8 g/l, Oxoid Agar Technical at 9.6 g/l). One plate of each medium contained carbendazim at 1 µg/ ml. Both media contained penicillin at 41 µg/ml and streptomycin sulphate at 185 µg/ml. Five straw pieces were placed on each plate and were numbered so that pieces of the same straw could be compared on each medium. The MA plates were incubated under n.u.v. at *c.* 13°C for 3 weeks and the PDA plates were incubated in the dark at 20°C for 2 weeks. As so few colonies from the first sample were positively identified by colony morphology on PDA from directly-plated lesions, the method of Bateman *et al.* (1986) was used for the second sample on PDA. With this method, spore suspensions were made from lesions which had been exposed to n.u.v. light, and spread over two PDA plates, one of which contained carbendazim at 1 µg/ ml. The method of Bateman *et al.* (1986) has been used successfully for monitoring eyespot pouplations in growing crops where contamination with other fungi was not a serious problem (Coşkun *et al.* 1987).

RESULTS

More colonies were positively identified as *P. herpotrichoides* from directly-plated lesions by colour production on MA than by colony morphology on PDA (Fig. 1). After spreading spore suspensions onto PDA a mycelial mat of *P. herpotrichoides* was present on 35 of the 150 plates (results not shown); however, because of contamination only six colonies were finally identified after subculture onto fresh PDA plates (Fig. 1).

In the first sample, straws which had been taken from the plots treated with prochloraz produced fewest isolates. On MA most of these were either W- or R-type isolates sensitive to carbendazim. Straws taken from plots treated with carbendazim yielded isolates which were mostly resistant to carbendazim on both media. More isolates from this treatment on both media and from untreated straws on MA were R-type than W-type. Most isolates on MA from untreated straw were sensitive to carbendazim. Fewer isolates were produced by the second sample, but the proportions of each type were similar to those from the first sample on MA (Fig. 1). Very few isolates were identified from spore suspensions on PDA. *Fusarium* spp. were present on most plates of both media (results not shown).

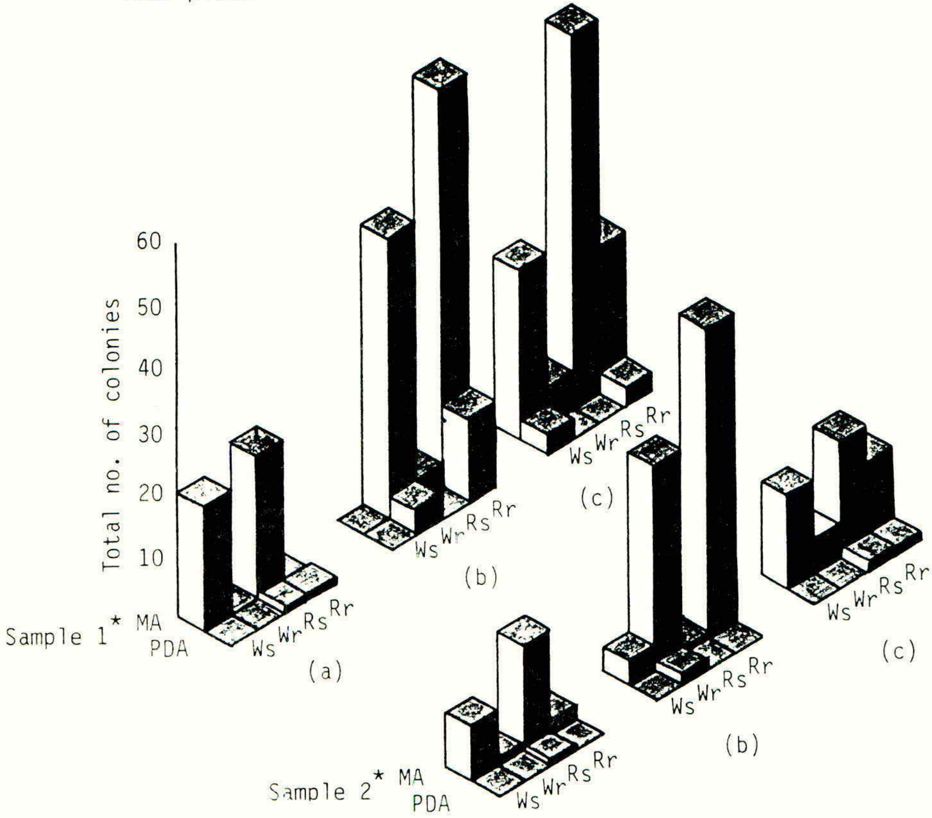
DISCUSSION

Fusarium spp. present on the PDA plates which contained lesions obscured the colony margins and may have retarded the growth of *P. herpotrichoides*. Therefore the eyespot type could not be diagnosed despite colonies being present on the plate. Spreading spore suspensions from n.u.v. irradiated lesions produced a mycelial mat of *P. herpotrichoides* but this fungus could not usually be separated from the *Fusarium* contaminants during subculture.

On MA the *Fusarium* mycelium could be scraped aside, if necessary, to reveal *P. herpotrichoides* colonies. The type was diagnosed from the colour of the colony and the identification confirmed, when necessary, by the presence of conidia. This method does not produce isolates of intermediate appearance, and mixtures of types of *P. herpotrichoides* are recognisable.

The sampling has continued and the proportions of the different types has remained fairly constant over eight months. As suggested by the results in Fig. 1 more isolates have survived from carbendazim-treated straws. This has possible implications for the amount of inoculum available following crops treated with the various fungicides.

Fig. 1. Total number of colonies recovered from 200 straws taken from four plots



Previous fungicidal treatments were (a) prochloraz (b) carbendazim (c) none

* Sample 1 compares directly-plated lesions on MA and PDA

* Sample 2 compares directly-plated lesions on MA and spore suspensions spread onto PDA

Ws = W-type carbendazim-sensitive
Wr = W-type carbendazim-resistant
Rs = R-type carbendazim-sensitive
Rr = R-type carbendazim-resistant

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A PEST INSECT ADAPTS TO THE CULTURAL CONTROL OF CROP ROTATION

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ABSTRACT

Because *Diabrotica barberi* (northern corn rootworm) was univoltine, had a narrow host range, and lacked a dispersal stage at the beginning of a cropping season, crop rotation has controlled it in many fields of *Zea mays* (corn) for over a century. Isolated incidents of damage were attributed to accidental immigration from surrounding fields of continuous corn. By the mid 1980's, reports of damage to first-year corn were frequent enough to re-evaluate the situation. In 1965 Chiang had reported that a small percentage of the *D barberi* population could overwinter for two years. Researchers found sites where 40% of the *D barberi* populations possessed a 2-y diapause. During 1988 a survey of 313 randomly-selected northwestern Iowa cornfields indicated that the extended-diapause variant is generally distributed throughout rotated cornfields, and that there is a need to develop management-decision guidelines to avoid prophylactic use of insecticides.

INTRODUCTION

The corn rootworms, *Diabrotica virgifera* (western corn rootworm) and *D barberi* (northern corn rootworm), are the most serious pests of *Zea mays* (corn) in the Corn Belt of the United States. Eggs are laid in the soil in the fall and hatch the following spring. Larval feeding on the roots of the corn plant in June not only causes physiological yield loss, but also harvesting losses because of plant lodging. Adult emergence from the soil is under way by early July and continues through late summer. Additional crop losses can be caused by the beetles feeding on the female flowers (silks) and soft kernels.

D barberi is believed to have been indigenous to the northern Corn Belt of the United States (Branson & Kryson 1981) It was reported as a new pest of corn by C.V. Riley (1880), who claimed farmers had been experiencing losses from the pest since 1874. The remedies suggested were "rotation of crops, destruction of *Ambrosia trifida* (ragweed) on which the beetles congregate, and the application of lime and ashes around the young corn to ward them off. Within two years, S A Forbes (1882) published a surprisingly complete description of the insect and its damage in his Annual Report. He concluded that there was a relationship between the severity of attack and the number of years corn had been planted in a field. Because the larvae were "scattered and hidden in the soil," Forbes felt they would only be susceptible to local applications of "agents" to the soil, but that this would be impractical except on a very small scale. He felt that "no matter how thickly stocked with eggs the soil may be", there was "no reason to fear injury to any other crop than corn" and that "a single season in grass or any small grain is sufficient to destroy those in the ground." Even though technical advances have made it economically feasible to protect corn roots with insecticides, these sentiments have formed the basis of our preferred corn rootworm control, crop rotation.

Following World War II, technical developments in the areas of synthetic fertilizers and chemical pest control made it possible for farmers to specialize in the production of high-value cash crops. Because of favourable soils and climate and the relatively high market value, farmers in the northcentral region of the United States concentrated on the production of corn. The emphasis on corn production resulted in the concomitant increase in corn rootworm problems, demonstrated by the spread of D.virgifera from the Rocky Mountains, where it was first discovered in the U.S. (LeConte 1868), to the East Coast. It is common throughout the Corn Belt and 78% of the farmers that plant corn after corn treat the soil with an insecticide (Wintersteen & Hartzler 1987).

The introduction of Glycine max (soybeans) and the development of market for its grain offered a crop adapted to the Corn Belt whose cash value rivaled that of corn. Soybeans cannot be grown on highly erodable land, but on land suited for its production, the farmer can realize several advantages by alternating corn and soybean crops: the beans fix nitrogen that can be used by the following corn crop, the rotation between a grass and broadleaf crop and their respective herbicides improves weed control, less tillage is required when corn is planted after soybeans, and soil insecticides have not been needed to control corn rootworms. These attributes increased the popularity of soybeans in Iowa until the amount of land planted to the bean exceeds that of corn planted after corn (7,367,000 & 5,560,000 acres, respectively: Wintersteen & Hartzler 1987).

Since the description of the insect as a pest, there have always been some reports of corn rootworm damage to corn planted after other crops. Forbes (1882) recounted the phenomenon in his early description of D barberi as a pest. He claimed the damage to first-year corn always was located at the edge of the field next to where corn had been grown the previous year and assumed beetles had migrated into the nonhost crop to lay eggs. In 1932 Bigger reported an experimental field where growing corn on alternate years failed to control corn rootworms. More recently Hill & Mayo (1980) reported that, while the western corn rootworm had largely replaced the northern in Nebraska corn the northern "exhibited significant persistency" in the northeast cropping district. They attributed this to the fact that the cropping area grew more corn in short rotation with other crops. The northern was offered a selective advantage because it dispersed into other crops more readily to lay eggs.

It has been proposed that the beetles are attracted to pollen provided by the indeterminate soybeans and late-flowering weeds when corn is senescing. In all soybean fields sampled. Shaw et al. (1978) found beetles and larval damage the following year. The level of damage could not, however, be related to the dgreee of weediness or to the amount of volunteer corn in the bean fields. They did find, though, that 80% of the eggs laid in nonhost crops were D. barberi, even though the northern beetles were no more frequent than D. virgifera. Johnson & Turpin (1985) could not show a relationship between the density of grassy weeds and the number of rootworm eggs laid in corn planted after corn. Gustin (1984) did demonstrate that D. barberi would lay eggs in postharvest oat residue and associated grasses and corn grown in an annual rotation with another crop, usually soybeans, made its third consecutive, dramatic increase. This led farmers to begin to ask Extension Specialists, "What is the likelihood I will experience losses from the variant of D. barberi? Should I apply a prophylactic soil insecticide treatment to my first-year corn? "These questions prompted us to conduct a survey of the extent of the problem during 1988.

TABLE 1

Proportion of 1600 D. barberi eggs with extended diapause from beetles collected in Minnesota (MN) and South Dakota (SD) during 1983 (adapted from Krysan et al. 1986)

Location	Total hatched over 2 years	No. hatched 2nd year	% with extended diapause
Madison, SD	798	374	47
Brookings, SD	669	280	42
Mapleton, MN	534	208	38
Rosemount, MN	779	70	9

METHODS

The area of Iowa at risk was defined as the 35 northwestern counties. A stratified random survey of the area was conducted by grouping the counties into 9 strata of 4 counties each (one county was nearly twice as large as the others and was grouped with only two others, hence 9 strata with 35 counties). One county was randomly selected from each grouping. Under a contract with the Iowa Department of Statistics which maintains a computer listing of all land operators, a random list of farmers' names was chosen from each selected county. The telephone was used to make 50 "positive contacts" from each county, for an initial sample size of 450. A positive contact was an answer by someone who was familiar with the farming practices and was empowered to give permission to survey for the pest insect. The telephone survey yielded 313 farmers who grew corn in annual rotation and gave permission to sample one of their fields for D. barberi, of the 60 initial positive contacts, the number of fields sampled per county ranged from 22 to 46. Very few farmers refused permission to sample their fields; the greatest loss of cooperators was due to the lack of corn grown in rotation.

Sampling for the presence of D. barberi was carried out by three teams of two scientists each. To avoid sampler-by-county confounding, the teams rotated among counties so that each team sampled in each county. The field to be sampled was the cornfield that had been in corn two years previously that was closest to the home address. In this way, the temptation of the cooperator to direct us to a field he felt had a northern corn rootworm problem was avoided. A field was considered to harbor a population of extended-diapausing D. barberi if 1) there were northern beetles present, and 2) roots of the corn plants showed evidence of larval feeding. Because the larval stage cannot disperse, the presence of larval feeding was taken as evidence that beetles present had emerged from that field. 304 of the 313 fields were sampled within 14 working days, beginning on July 18.

RESULTS

The results of the D. barberi survey are presented by county in Table 2. D. barberi adults and larval feeding activity (though light at times) were found in all fields. There were few fields, however, that suffered sufficient larval damage to have warranted an insecticide treatment. This fits the general trend for corn rootworms in Iowa during the droughty 1988 season. Beetles were common (their populations were even high in some fields), but there were few reports of serious larval damage and lodging.

The one-year survey leads me to suspect that the extended-diapause variant of D. barberi is generally distributed throughout the northwestern region of Iowa. Based on the more numerous and the more serious problems of preceding years, I would expect the incidence of economic damage to fluctuate with population cycling. Additional studies need to be conducted to determine the causes of the fluctuations. The fact that fluctuations appear to exist indicates that decision thresholds should offer economic utility and that prophylactic insecticide treatments should be avoided.

TABLE 2

Frequency of fields possessing extended diapausing D. barberi populations in 9 counties representative of the northwestern third of Iowa

	Number of Beetles per Plant				
County	0	0-1	1-2	2-4	>4
northern					
O'Brien	1	0	7	11	13
Dickinson	0	12	9	6	3
Kossuth	3	13	7	9	7
central					
Ida	0	4	1	8	12
Pocahontas	3	10	12	6	1
Humbolt	2	16	7	9	6
southern					
Shelby	2	20	4	2	2
Audubon	2	21	3	1	0
Dallas	2	13	3	1	0
total	15	109	53	51	44

The one-year survey leads me to suspect that the extended-diapause

variant of D. barberi is generally distributed throughout the northwestern region of Iowa. Based on the more numerous and the more serious problems of preceding years, I expect the incidence of economic damage to fluctuate with population cycling. The fact that fluctuations appear to exist and that the level of larval damage was low during 1988 indicate that decision thresholds should offer economic utility and that prophylactic insecticide treatments should be avoided.

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THE COMPARATIVE EPIDEMIOLOGY OF EYESPOT (*PSEUDOCERCOSPORELLA HERPOTRICHOIDES*) TYPES IN WINTER CEREAL CROPS

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ABSTRACT

Plots of barley or wheat, sown at high or low seed rates, were inoculated with W-type or R-type isolates of *Pseudocercosporella herpotrichoides*. The incidence of eyespot on leaf sheaths at GS30/31 was greater at the high seed rate than the low seed rate, but there was little difference in incidence between untreated W-type and untreated R-type plots. By mid-June the incidence of moderate/severe lesions on stems was greater in W-type than in R-type plots, but subsequently lesion development proceeded more rapidly in R-type plots so that there were no differences between W-type and R-type plots in July. W-type colonies were isolated more frequently from diseased leaf sheaths and stems of wheat than were R-type colonies, and R-type colonies were isolated more frequently from barley. Treatment with prochloraz+carbendazim in April or May decreased disease incidence and increased yield, with no effect of treatment date except in some W-type plots, where early treatment was more effective.

INTRODUCTION

Over the last decade the R-type of *Pseudocercosporella herpotrichoides* has replaced the W-type as the predominant type in UK populations (King & Griffin 1985). However, most of the work on the epidemiology of eyespot in cereal crops has been done with the W-type. On potato dextrose agar, R-types, which produce colonies with feathery margins, grow more slowly than W-types, which produce colonies with smooth margins (Hollins *et al.* 1985). In seedling pathogenicity tests, W-type isolates were generally more pathogenic to wheat than R-type isolates in some experiments (Fitt *et al.* 1987, Cavelier *et al.* 1987, Mauler & Fehrmann 1987) but were less pathogenic in others (Hollins *et al.* 1985). However, there is a wide range in pathogenicity among isolates of both types (Fitt *et al.* 1987).

It is not clear how the results of seedling pathogenicity tests relate to rates of disease development in field crops. In controlled environment experiments the relationship between the pathogenicity of isolates to wheat seedlings (assessed on leaf sheaths) and pathogenicity to adult plants (assessed on stems) was poor (Higgins & Fitt 1985). In field trials (Schreiber & Prillwitz 1986) R-type isolates were generally more pathogenic than W-type isolates. Furthermore, field surveys (King & Griffin 1985, Coskun *et al.* 1987) and field experiments (Bateman *et al.* 1986) showed increases in the proportions of R-type isolates between spring and summer samples from the same crop, which may be contributing to the changes which have occurred in UK populations of *P. herpotrichoides*. The survey results of King & Griffin (1985) suggest that another influence on eyespot populations may have been the selection of R-types by winter barley, the area of which has increased greatly in recent years. This paper describes field experiments to investigate the comparative epidemiology of W-types and R-types of *P. herpotrichoides* in winter wheat and winter barley crops.

MATERIALS AND METHODS

Seed of winter wheat (cv Avalon) and winter barley (cv Opera) were sown on 20 September 1986 on a site previously cropped to oats (1985) and potatoes (1986). A high seed rate (wheat 400 seeds/m^2, barley 300 seeds/m^2) was used on half of the plots and a low seed rate (wheat 200/m^2, barley 150 seeds/m^2) was used on the remainder. Plots were inoculated with MBC-sensitive W-type or R-type isolates, or uninoculated. There were two randomised blocks of 24 plots, each split into four sub-plots (8.5 x 3 m). Sub-plots were sprayed in April (wheat - GS30/31, barley - GS32/33), or in May (wheat - GS37/39, barley - GS41/49) with prochloraz plus carbendazim (as Sportak Alpha, 400 g/l emulsifiable concentrate), or unsprayed. The fourth sub-plot was used for detailed epidemiological measurements; samples taken from these sub-plots at intervals between December and July consisted of seven to ten 8 cm row-lengths, depending on the seed rate and cereal variety. The growth stage, numbers of shoots infected and the severity of eyespot lesions were recorded. Before the start of stem extension (GS31), eyespot severity was assessed as the number of leaf sheaths penetrated by the fungus; from GS31 the severity of stem lesions was assessed on the 0-3 scale of Scott & Hollins (1974). All sub-plots except those used for regular sampling were harvested to determine yield and 1000 grain weight.

Isolations were made from diseased tissues at each sample to monitor changes in the pathogen population. Lesions from each plot were surface sterilised in sodium hypochlorite (1% available chlorine) for 45 seconds, rinsed in sterile distilled water, and dried for 0.5 - 1.0 h on sterile filter paper before placing them on one fifth strength potato dextrose agar containing antibiotics. Colonies were characterized as W-type or R-type on the basis of morphology and growth rate after 3 weeks of incubation at 15°C.

RESULTS

Incidence of eyespot

At GS30/31 the incidence of leaf sheath lesions was similar in plots inoculated with W- or R-type isolates of *P. herpotrichoides* (Table 1). In barley, fewer shoots were infected at the low seed rate (76%) than at the high seed rate (90%). However, in wheat seed rate had no effect on the incidence of eyespot lesions. By mid-June the incidence of shoots with moderate or severe lesions was greater in barley (52%) than in wheat (29%). In barley, disease was more severe in W-type plots than in R-type plots, irrespective of seed rate. In wheat, seed rate had little effect on the incidence of moderate or severe lesions in W-type plots, but in plots inoculated with R-type isolates eyespot tended to be more severe at the high seed rate (32%) than at the low seed rate (14%).

In late June there was a marked increase in the severity of eyespot lesions, particularly in R-type plots. In barley, 90% of shoots in W-type plots, and 77% of shoots in R-type plots had moderate or severe lesions. In wheat, 76% of shoots in W-type plots, and 63% of shoots in R-type plots had moderate or severe lesions, irrespective of seed rate. Eyespot continued to increase in severity and by early July there was little difference in the incidence of moderate or severe lesions between barley (90%) and wheat (83%), or between W-type (88%) and R-type (84%) plots.

TABLE 1

Incidence of eyespot on leaf sheaths and stems of winter barley and winter wheat in unsprayed plots inoculated with W-type or R-type isolates of *P. herpotrichoides*.

Cereal	Seed rate	Inoculum	% of shoots with leaf sheath lesions GS30/31[a]	% of stems with moderate or severe lesions 15 June	21 June	3 July
Barley	low	W	72.9	73.6	90.4	90.9
		R	79.3	30.8	77.4	88.9
	high	W	91.5	84.4	89.5	92.5
		R	87.4	21.0	76.2	87.8
Wheat	low	W	96.9	33.6	72.3	83.5
		R	94.2	14.3	58.3	80.2
	high	W	89.0	36.3	79.2	86.4
		R	92.5	31.7	66.8	80.2
SED (12 df)			9.0	13.7	15.7	9.9

[a] Barley sampled 20 April, wheat 29 April.

Characterization of isolates

At GS30/31, equal numbers of W-type and R-type colonies were isolated from eyespot lesions on the leaf sheaths of winter barley (Table 2). However, proportionately more W-type colonies were obtained from the leaf sheaths of winter wheat than from winter barley (χ^2_1 34.80, $P < 0.001$). In later samples, W-type colonies were always isolated more frequently from the stems of winter wheat, whilst R-type colonies were isolated more commonly from the stems of winter barley.

Effects of prochloraz + carbendazim on eyespot and yield

Treatment with prochloraz plus carbendazim in April or May decreased the incidence of moderate or severe lesions on stems of barley and wheat (Table 3). In barley, treatment of W-type plots in April (GS30/31) controlled eyespot better at the low seed rate than treatment in May (GS41/49); both treatments had little effect on the severity of eyespot at the high seed rate. Treatment of R-type plots was equally effective in April or May at both seed rates. In wheat, treatment of W-type plots was equally effective in April (GS30/31) or May (GS33/37) at the low seed rate but not at the high seed rate where eyespot was controlled better by the earlier spray. Control of eyespot in R-type plots tended to be more effective with an early spray at the low seed rate, and with a late spray at the high seed rate.

TABLE 2

Isolation of W- and R-types of *P. herpotrichoides* from leaf sheaths and stems of winter barley and winter wheat in unsprayed plots.

Growth stage	Cereal	% colonies[a] W-type	R-type
30/31	Barley	50.8(33)	49.2(32)
	Wheat	97.1(68)	2.9(2)
83/87	Barley	26.9(28)	73.1(76)
	Wheat	61.9(65)	38.1(40)
Post-harvest	Barley	13.9(15)	86.1(93)
	Wheat	72.5(79)	27.5(30)

[a] Combined data from high and low seed rates (uninoculated plots); numbers of colonies of each type are given in parentheses.

Fungicide treatments, on average, increased the yield of wheat and barley from 7.4 to 8.0 t/ha (Table 3). The largest effects were observed in W-type plots. Treatment in May increased the mean yield of R-type plots (wheat and barley) 6% more than treatment in April. No interaction between yield and fungicide timing was observed in W-type plots.

TABLE 3

Effects of treatment with prochloraz plus carbendazim on the incidence of eyespot in winter barley and winter wheat inoculated with W-type or R-type isolates of *P. herpotrichoides*.

Cereal	Seed rate, inoculum	Spray	% stems with moderate or severe lesions[a] Nil	April	May[b]	Yield (t/ha) Nil	April	May
Barley	low							
	W		92.9	35.4	80.1	7.3	7.9	7.5
	R		94.3	51.2	64.5	7.4	8.0	7.6
	high							
	W		95.6	81.0	83.7	5.8	8.1	7.8
	R		96.1	62.9	66.8	7.5	8.0	8.0
Wheat	low							
	W		69.5	50.1	53.0	7.2	7.9	7.8
	R		89.5	64.7	83.1	8.0	7.7	8.6
	high							
	W		96.1	30.2	77.6	7.4	8.2	8.2
	R		94.4	46.2	28.1	8.0	7.5	8.5
SED (35 df)				14.0			0.4	

[a] Data for three main stems on each plant at GS83/87; barley sampled 3 July, wheat 24 July.
[b] See text for further details.

DISCUSSION

These results show that there are epidemiological differences between W-type and R-type isolates of *P. herpotrichoides* in winter wheat and winter barley crops. However, these differences were not apparent in the sample taken at GS30/31 when there was little difference in eyespot incidence between W-type and R-type plots (Table 1), confirming the results of the previous year (Goulds *et al.* 1987). Differences were greatest in the period of stem lesion establishment, which is a crucial stage in the development of eyespot epidemics (Fitt & White 1988) when the fungus is spreading from the innermost leaf sheaths on to the stem. At this stage growth of W-types was apparently more rapid than that of R-types. However, growth of R-types was more rapid later, since there was little difference between the types in the incidence of eyespot at the end of the season. This late development of R-type lesions fits with the observed increase in the proportion of R-types later in the season in field surveys (King & Griffin 1985, Coskun *et al.* 1987) and field experiments (Bateman *et al.* 1986), suggesting that the two types respond differently to some crop or environmental factors. The isolation of high proportions of R-types from winter barley and of W-types from winter wheat, supports the suggestion that the increasing area of winter barley has been a contributory factor in the increase in the proportion of R-types in UK populations of *P. herpotrichoides* (King & Griffin 1985). However, the increased use of fungicides, including prochloraz, which appears to select for R-types (Bateman *et al.* 1986), has probably contributed to altering the balance between types of *P. herpotrichoides*.

The epidemiological differences between R-types and W-types during the stem lesion establishment phase suggest that accurate forecasts of eyespot severity and yield loss cannot be obtained from measurements of eyespot incidence on leaf sheaths at GS30/31, when spray treatments are traditionally applied against eyespot (Anon. 1984). Even when UK populations were predominantly composed of W-type isolates, such GS30/31 forecasts were inaccurate (Scott & Hollins 1978). Now that populations are predominantly composed of R-type isolates the inaccuracies will be greater since R-type epidemics develop later (Table 1). Thus, wherever possible, treatments for control of eyespot should be based on later disease assessments, perhaps at GS32/33, when more accurate forecasts of eyespot severity can be made. Furthermore, where eyespot epidemics are caused by R-type isolates, the resulting delay in application of treatments may improve control of eyespot and increase yield.

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HIGHLY ACTIVE ANTIFEEDANTS AGAINST COLEOPTERAN PESTS

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ABSTRACT

New analytical techniques which employ a Plasmaspray/Thermospray interface between HPLC and MS have been developed for separating and identifying antifeedants from complex plant extracts. Fractions isolated from the labiate *Ajuga remota* were bioassayed against several different types of insect. The clerodane components ajugarin I, and to a lesser extent ajugarin II, showed very high activity against the coleopteran pest *Phaedon cochleariae*.

INTRODUCTION

There is considerable interest (van Beek & de Groot, 1986) in developing chemicals that interfere with insect feeding for use in crop protection strategies, because these materials show promise for controlling pests without damaging the environment and could be used in situations where insecticide resistance is a problem. Indeed, both synthetic and naturally derived antifeedants have already been used successfully in field trials against aphids (Dawson *et al*., 1986, 1988). However, most work on insect antifeedants has concentrated on activity against lepidopteran insects. There is a need for antifeedants that are also effective against other orders of insect, e.g. Coleoptera, which comprise the main pests of certain crops such as oilseed rape.

Many plant-derived insect antifeedants are polar, involatile and thermally unstable and thus not amenable to analysis by gas chromatography-mass spectrometry (GC-MS). Conventional high performance liquid chromatography (HPLC) using ultra-violet (UV) detection, followed by electron impact (EI) mass spectrometry, are also unsuitable for two reasons. Firstly, many of these compounds do not have strong UV absorption and so cannot be readily detected. Secondly, plant extracts often contain many active compounds which are structurally similar and which show no molecular ions and few diagnostic ions in their EI mass spectra.

The new technique of HPLC-Plasmaspray analysis overcomes these problems because even compounds with no UV absorption are detected and their Plasmaspray mass spectra often show high intensity molecular ions and characteristic fragment ions that can be used to identify them. HPLC-Plasmaspray analysis has been applied to the separation of clerodane antifeedants from the labiate plant *Ajuga remota*, known to be a source of several feeding deterrents (Kubo *et al*., 1976) and the activity of pure compounds has been assessed against a coleopteran insect (the mustard beetle, *Phaedon cochleariae*), an aphid (*Myzus persicae*) and a member of the Lepidoptera (the larval stage of *Plutella xylostella*).

METHODS

Seeds of A. remota were germinated in moist vermiculite, transferred to "Eff" potting compost and grown in a glasshouse at 23°. Extracts were prepared by grinding fresh leaves in liquid nitrogen and extracting the powdered material with ethanol, or methanol-water (60:40) for HPLC.

Conventional HPLC analyses were performed with Gilson 303 pumps with a 250 x 4.6 mm Spherisorb ODS2 (5 micron) column (Anachem) using methanol-water (60:40, 1.5 ml min^{-1}) as the eluent, with UV detection at 213 nm. The HPLC-Plasmaspray analyses were performed with a Thermospray/Plasmaspray source (VG Analytical) in a VG70-250 mass spectrometer with a source temperature of 250°C, probe temperature 220° and a 450v discharge voltage. HPLC conditions were as described above, except that an LDC/Milton Roy Constametrics IIIG pump was used.

All bioassays were choice tests in which the insects were presented with equal areas of treated and untreated plant surfaces on which to settle and feed. Ethanolic solutions of plant extracts or pure compounds were painted on to one half of a Chinese cabbage leaf, with ethanol alone on the other side as a control. After 24 or 48 hours, the area or weight of leaf eaten on each side was assessed (for larvae of P. xylostella and adults of P. cochleariae) or the number of settled insects was counted (M. persicae). Results of individual tests were subjected to analysis of variance and the results of the dose-response tests were analysed by regression analysis.

RESULTS AND DISCUSSION

Conventional HPLC using UV detection, followed by examination of the EI mass spectra of the separated components, was unsatisfactory for analysing extracts of A. remota as they contained many compounds such as ajugarin I and II (Fig. 1) which are structurally very similar. For example, the EI mass spectrum of the lower molecular weight compound, ajugarin II, was very similar to the lower regions of the mass spectrum of ajugarin I (Fig. 2), so it was difficult to analyse mixtures and to ensure that samples for bioassay were pure.

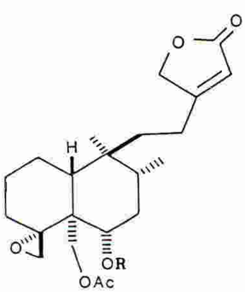

Figure 1 Structures of ajugarin I (R = Ac) and ajugarin II (R = H)

In the HPLC-Plasmaspray technique, components separated by HPLC enter the mass spectrometer in a heated solvent spray. Positive ions formed in the plasma from solvent molecules are accelerated back towards the HPLC probe inlet by the potential difference applied between the source block (anode) and the probe (cathode), where they ionise incoming components.

Chemical ionisation spectra can be obtained, the degree of fragmentation depending mainly upon the probe temperature and the structure of the molecule.

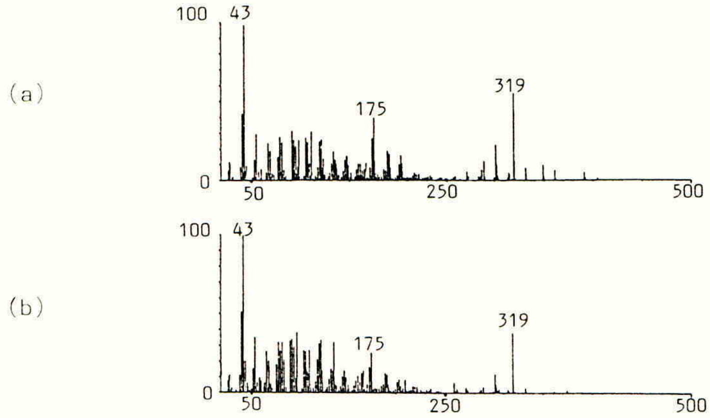

Figure 2 Electron impact mass spectra of ajugarin I (a) and ajugarin II (b)

In contrast to the EI spectra of ajugarin I and II, which exhibited no molecular ions, the Plasmaspray spectra (Fig. 3) showed strong, protonated molecular ions (M+H at 435 and 393 respectively) with diagnostic fragment ions corresponding to the loss of the two acetoxy groups from ajugarin I (m/z 375 and 315) and the loss of the hydroxyl and acetoxy groups from ajugarin II (m/z 375 and 333). It is interesting to note that a sample of ajugarin I which fulfilled purity criteria available from published m.p and EI mass spectra was shown to have co-crystallised with a small amount of ajugarin II .

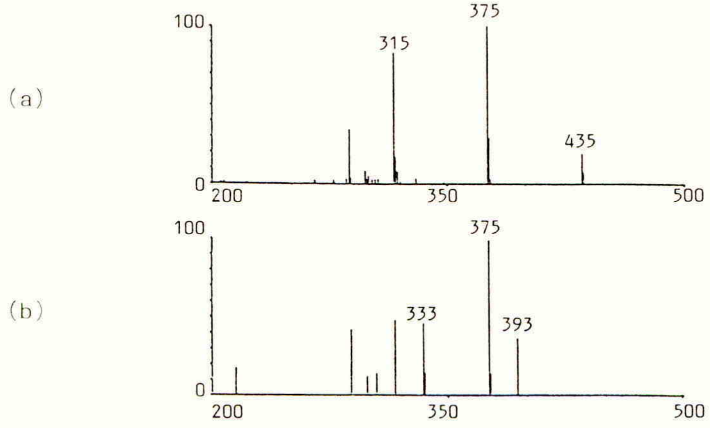

Figure 3 Plasmaspray mass spectra of ajugarin I (a) and ajugarin II (b)

Furthermore, comparison of the HPLC analyses of A. remota extracts using conventional UV detection and the Plasmaspray technique (Fig. 4) showed that many more compounds are detectable with the new method.

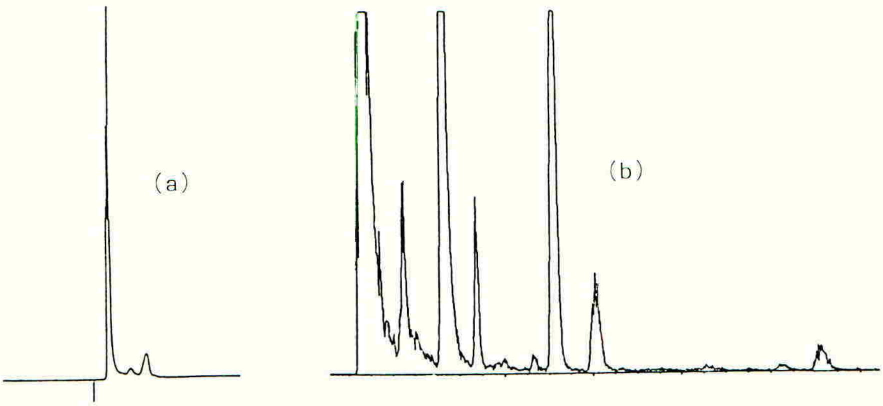

Figure 4 A. remota extracts analysed by HPLC-UV (a) and HPLC-Plasmaspray (b)

Thus, the Plasmaspray technique provides a sensitive tool for the analysis of complex plant extracts. It is clearly very important to be certain that no other active ingredients are present in the samples used for bioassay, and by monitoring the purity using this method, it was possible to ensure that pure samples were available for quantitative antifeedant bioassays.

TABLE 1

Effect of extracts of A. remota on feeding

Species	% Wet wt.	% Leaf area eaten Treated	Control	Significance
P. cochleariae adults (48 h)	5	1	74	<0.001
	0.5	9	79	<0.001
	0.05	32	72	<0.001
	0.005	21	28	Not sig.
P. xylostella larvae (24 h)	5	1	77	<0.001
	0.5	17	83	<0.001
	0.05	39	74	<0.01
	0.005	41	53	Not sig.

Extracts of A. remota were found to be active against P.cochleariae and larvae of P. xylostella at 0.05% weight of wet material (Table 1), and against M. persicae at 5% (Table 2). Fractionation of the extracts by HPLC and subsequent bioassay suggested that the majority of the activity against Coleoptera was associated with a fraction corresponding to ajugarin I.

TABLE 2
Effect of extracts of A. remota on aphid settling

Species	% Wet wt.	No. of aphids settled Treated	Control	Significance
M. persicae (24 h)	50	5	13	<0.001
	5	7	10	<0.05

TABLE 3
Effect of ajugarin I on feeding

Species	%	% Leaf area eaten Treated	Control	Significance
P. cochleariae adults (48 h)	0.1	0	21	<0.01
	0.01	0	64	<0.001
	0.001	1	79	<0.001
	0.0001	19	52	<0.05
	0.00001	32	46	<0.05
P.xylostella larvae (24 h)	0.1	7	90	<0.001
	0.01	39	68	<0.01
	0.001	53	66	Not sig.

Pure ajugarin I, separated by the methods described above, was active against feeding of P. cochleariae, even down to 0.00001% of the compound, and was also active against P. xylostella larvae at 0.01% (Table 3).

TABLE 4
Effect of ajugarin II on feeding

Species	%	% Leaf area eaten Treated	Control	Significance
P. cochleariae adults (48 h)	0.01	21	76	<0.001
	0.001	54	63	<0.05
	0.0001	42	38	Not sig.
P. xylostella larvae (24 h)	0.1	23	63	<0.01
	0.01	15	36	Not sig.

TABLE 5
Effect of ajugarin I and II on aphid settling (M.persicae)

Compound	%	No. of aphids settled Treated	Control	Significance
Ajugarin I	1.0	7	9	Not sig.
Ajugarin II	0.1	8	7	Not sig.

Ajugarin II was less active against both species than was ajugarin I (Table 4). This suggests that the acetoxy group at C6 is an important requirement for antifeedant activity against these pests. Kubo et al (1976) showed similar levels of activity against Lepidoptera (0.01% for Spodoptera exempta and 0.03% for S. littoralis) but did not demonstrate a difference between the two compounds. Against M.persicae , neither ajugarin I nor ajugarin II showed any activity (Table 5).

Finally, the activity of serial dilutions of pure ajugarin I against P.cochleariae was compared with that of a series of dilutions from an extract of A. remota , judged on the basis of the chemical analysis to contain corresponding levels of ajugarin I.

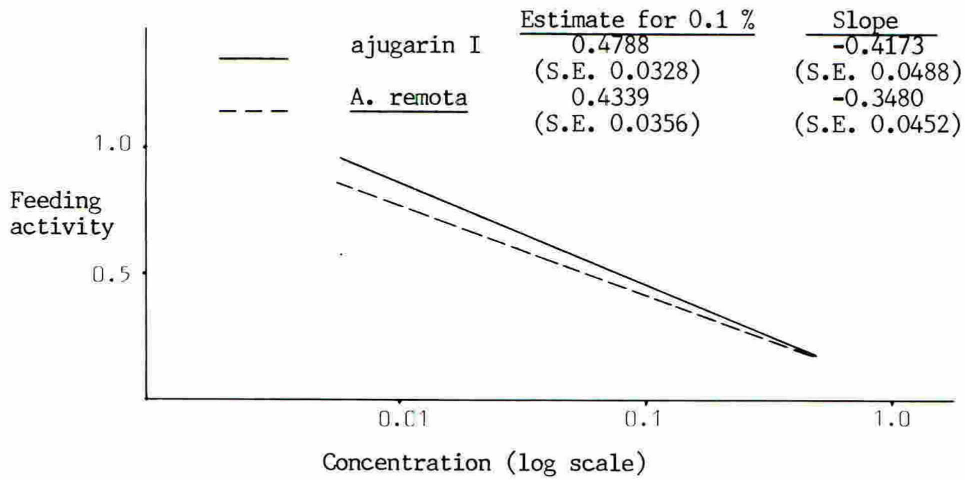

Fig 5. P. cochleariae at 48 h. Feeding activity expressed as proportionate change of leaf weight for treated / control.

Although some variation occurred between replicates, the dose-response curves, obtained by fitting linear regressions from 0.005 to 0.5 %, were similar (Fig 5), demonstrating that ajugarin I accounts for the majority of the activity of A. remota extracts against this species. Thus, ajugarin I shows promise for field testing against coleopteran pests.

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VIDEO RECORDING OF APHID PREDATION BY CARABIDAE IN A WHEAT CROP

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ABSTRACT

Time-lapse video equipment was used to compare the response of Bembidion spp. to areas of high and low aphid densities in a winter wheat field in June 1988. The number of entries into the high aphid infestation area was significantly greater than that for the low aphid infestation, and a large proportion of the time spent in the high infestation area was spent feeding; these results show that non-climbing predators may be an important mortality agent for cereal aphids, given that large numbers of the latter occur on the soil surface.

INTRODUCTION

The two aims of integrated pest management (IPM) are firstly to direct pesticide use towards optimised selective use, combining the various components of IPM in order to guide decision-making and achieve an economically justifiable outcome. Secondly, the environmental side-effects of pest control should be minimised by reducing pesticide input and maximising the use of natural control agents (Burn *et al*. 1987). In order to identify the candidate species for use in an IPM programme a series of criteria needs to be used. One of these criteria concerns the response of the natural enemies to prey spatial heterogeneity. The ability of a predator to control a prey population partly depends on the extent to which it can aggregate in areas of high prey densities. Bryan and Wratten (1984) used pitfall traps and demonstrated that some carabid and staphylinid species responded strongly to aphid aggregations in a winter wheat crop. This work, though, did not identify the behavioural basis of the aggregation and there remains the possibility that the predators were responding to honeydew, exuviae or saprophytic fungi growing on the honeydew. The aims of the present work, therefore, were to identify those species responding to prey aggregations in the field and to evaluate the relative strength of the response between species. Time-lapse video techniques were used to compare the responses of polyphagous predators to areas of high and low aphid densities on a winter wheat field in June 1988. In this paper data for the small carabids *Bembidion lampros* (Herbst), *Bembidion obtusum* (Serville) and *Trechus quadristriatus* (Schrank) are given as an illustration of the potential of the techniques used.

MATERIALS AND METHODS

The work was carried out in a winter wheat (c.v. Mission) field on the Leckford Estate, Stockbridge, Hampshire. An area of high aphid density was created by artificially infesting a caged area of the crop. *Sitobion avenae* (F.) and *Metopolophium dirhodum* (Wlk.), obtained from a natural infestation in another field, were introduced into a 2 x 2 x 2 m field cage on alternate days, starting from the middle of May. Two video cameras were positioned approximately 5 m from a hedgerow and 7 m apart, in the crop. Each of these was focused on a patch of moistened silver sand measuring 9 cm x 11 cm. The activity of soil-surface predators was monitored over a three-week recording period using a time-lapse video recorder set in the 48 h time lapse record mode. The equipment was a JVC 9000 U time-lapse video cassette recorder, a JVC VM-14 psn(G) video monitor, two JVC TKN10 U monochrome Newvicon video cameras, two 8.5 mm fixed-focus auto iris lenses, 2 JVC TK U800 U remote control units, a modified JVC SW 108E sequential switcher and an RM-G90 U remote control unit. The switcher was set to give alternate recordings every five minutes from each of the cameras. Illumination for the night-time recording was provided by the two 100 watt infra-red light sources, one for each camera. A 1200X Honda generator was used to power all the equipment.

The experiment was divided into two ten-day recording periods. For the first period, from 6 to 16 June (experiment 1), both of the cameras were postioned in non-infested areas of the crop. One of the cameras was focused on a grid of 49 dead *S. avenae* (killed by decapitation). From 20 to 30 June (experiment 2) the netting was removed from the artificially-infested area and a grid of 49 *S. avenae* was placed on a 9 cm x 11 cm patch in the centre of the infestation; one of the cameras was positioned above it. The aphid grid was replenished every day at 0900 h and 2100 h.

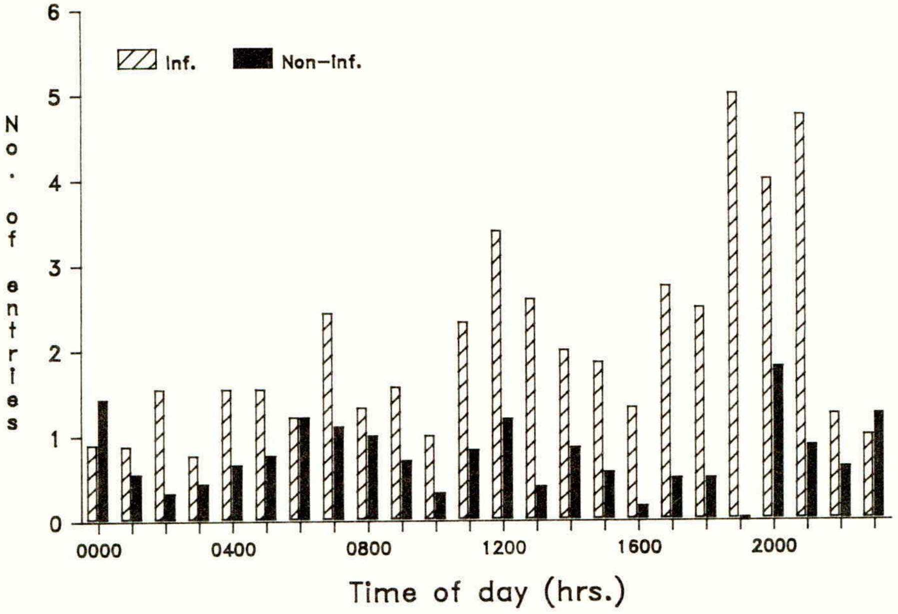
Aphid counts were made on plants in the uninfested and infested areas on alternate days from the time of the removal of the netting. The aphid numbers on 50 stems in each area were recorded. A t-test was used to compare the aphid numbers in each of the areas. Also a regression of aphid fall-off rate with on-plant density (Winder, pers. comm.) was used to estimate the number of aphids that fell to the ground each day. The temperature was recorded hourly, both at the base of the crop and on the areas of silver sand, using a Grant temperature recorder.

Information extracted from the video tapes included; a) species entering the fields of view; b) frequency of entry of the individual species per hour; c) time of day and duration of each visit; d) number of aphids taken per visit; and e) time spent feeding.

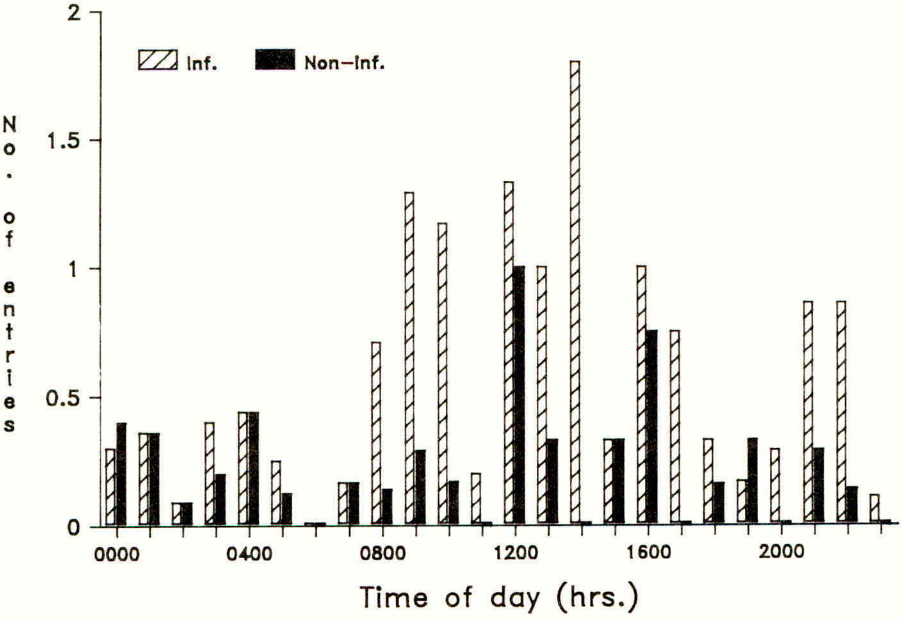
A Chi-squared test, incorporating Yates' correction (Bailey, 1981), was used to determine whether there were differences in the number of entries per hour into the different areas.

RESULTS

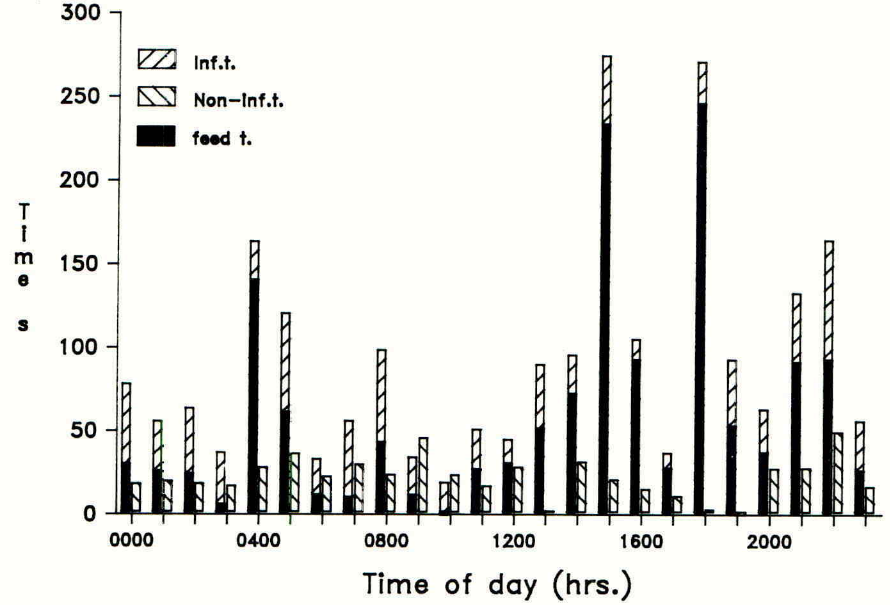
B. lampros, *B. obtusum* and *T. quadristriatus* were grouped together for the purpose of this study. This was because these species are similar in size (< 6 mm, Luff (1978)) and shape, this making it difficult to distinguish between them from the video images.



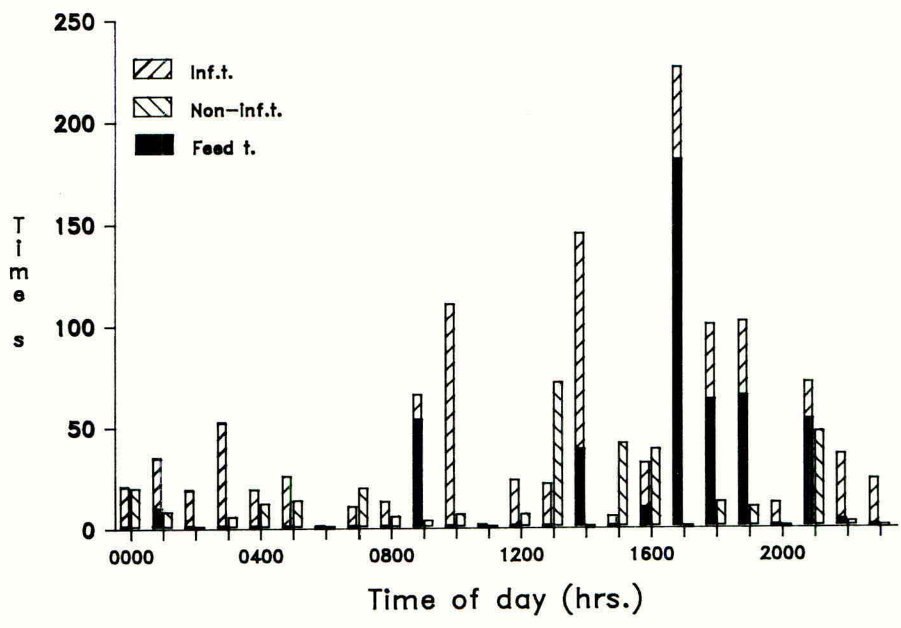
Figs. 1 and 2 show the mean numbers of entries per hour for experiments 1 (June 6 to 16) and 2 (June 20 to 30) respectively. There was a substantially greater level of activity in the former.



The peaks of activity differed between the two experiments, occuring from 1900 to 2100 h in experiment 1 and 1200 to 1400 h in experiment 2. For both experiments the total number of hours with 1+ and 2+ entries differed significantly between the infested and non-infested areas ($P<0.001$ in each case), there being a greater number of entries into the infested area.



Figs. 3 and 4 show the mean number of hours spent in the infested and non-infested areas, together with the mean time spent feeding in the infested area. The overall mean times spent were greater for experiment 1 than for experiment 2.



DISCUSSION

B. lampros is almost exclusively dirunal whereas *B. obtusum* and *T. quadristriatus* are mainly nocturnal, exhibiting a fair degree of diurnal activity (Luff, 1978). The peak of activity in experiment 1 occuring between 1900 and 2100 hrs could have represented the movements of *B. obtusum* and *T. quadristriatus*. According to Mitchell (1963) *T. quadristriatus* is an autumn breeder and therefore emerges as adults in June and July; *B. lampros* is a spring breeder and so the adults are coming to the end of their lives by June and July. The Bryan and Wratten (1984) study substantiates the findings for *B. lampros*, there being a decrease in the overall numbers of the species from early to mid June; the same also applied to *B. obtusum*. The numbers of *T. quadristriatus* from the Bryan and Wratten work were too low for any conclusions to be drawn. Therefore, it appears that *T. quadristriatus* was the main active species during the first recording period. If this was the case, then similar activity levels would be expected for the second recording period, (experiment 2). This was not the case, however. The activity peak corresponded with the diel pattern obtained for *B. lampros* in the Luff (1978) work. And, due to the fact that *B. lampros* is one of the more abundant carabid species in cereal crops, whereas *B. obtusum* and *T. quadristriatus* are only occasionally abundant (Bryan and Wratten, 1984; Mitchell, 1963; Potts and Vickerman, 1974; Sunderland, 1975; Sunderland and Vickerman, 1980; Wratten *et al*. 1984) it would follow that the majority of entries into the patches in experiment 1 would be by *B. lampros* (during the day) and *B. obtusum* (during the night); the much reduced activity in experiment 2 would be due to the decline in the numbers of the *Bembidion* spp. adults.

Current laboratory feeding studies have demonstrated that *B. lampros* has a preference for live aphids rather than dead ones. So, the fact that there was so much feeding activity in the experiments, the aphids being dead and assuming that the predominant species was *B. lampros*, was an unexpected result. However, although Mitchell (1963) found *B. lampros* to feed predominantly on live rather than dead food material, if the dead food was damaged then the beetles did show a strong feeding response, possibly caused by chemical stimulus. The fact that the aphids used in the present study were decapitated provides a possible explanation.

The behavioural components governing the aggregation response of the beetles in the prey patch are yet to be extracted from the video tapes. These include the speeds of movement and angles turned before and after feeding, and the rate of prey capture by the differing species. These details will be published elsewhere. Large numbers of aphids fall to the ground each day, as shown by Sunderland *et al*. (1986) who demonstrated that up to 30% of aphid populations fall off the plants each day, with *M. dirhodum* falling more readily than *S. avenae*. Sopp *et al*. (1987) and Winder (pers. comm.) have independently produced relationships between aphid numbers/stem and the corresponding fall-off rates. The role of the non-climbing epigeal fauna, therefore, may have been undervalued as the current data show that they can readily exploit the high densities of aphids on the soil surface in cereal crops; the aphids are likely to return to the plants in the absence of predation. B. lampros, in particular, which preferentially feeds on live aphids, is present in cereal crops in high densities, and has been shown by this study to aggregate in areas of high aphid density, so would be a key species in the prevention of an early aphid outbreak. It would also be worthy of greater research into its usefulness as a component of an IPM programme.

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