CEREAL-CLOVER BICROPPING, COULD IT AFFECT OUR FUNGICIDE DEPENDENCY?

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ABSTRACT

Field experiments were conducted during the 1993/94 and 1994/95 growing seasons to assess the impact of cereal-clover bicrops on the levels of wheat diseases in the growing crop. Results indicated that the severity of *Septoria* at growth stage 45 was reduced in bicrops relative to the disease level in monocrops, although this effect was not evident either earlier or later in the season. The inoculum level of both *Pseudocercosporella herpotrichoides* and pathogenic *Fusarium* was higher within the bicropping system where more fungal spores were produced on stubble under the clover canopy than on stubble within a direct drilled wheat monocrop. The number of colony forming units of *P. herpotrichoides* in soil was higher within bicropped plots relative to soil under direct drilled monocrops. The incidence of *Fusarium* was significantly lower in bicrops than in monocrops especially at conventional input levels. The incidence of eyespot showed no significant differences between bicrops and monocrops sown following ploughing although both treatments had a higher disease level than the direct drilled monocrops.

INTRODUCTION

Following implementation of major changes resulting from EC reforms of the Common Agricultural Policy, methods of crop production which use lower inputs require evaluation for their potential in reducing fertiliser and other agrochemical applications. A cereal bicropping system which utilises white clover (*Trifolium repens*) as a permanant understorey, has previously been shown to have considerable potential for growing winter cereals with greatly reduced inputs of agrochemicals (Jones & Clements, 1993).

The benefits of nitrogen released from white clover and made available to other crops either through a rotation system or through the grazing or cutting of crops have long been recognised (Cowling, 1982). However within a conventional arable system legume residues must first decompose and be mineralised before the nitrogen can become available (Ladd & Amato, 1986). Recent results however have shown that where a winter wheat crop is drilled directly into an established clover sward the response of successive cereal crops to nitrogen applications is diminished, implying a build-up of available soil nitrogen (Jones & Clements, 1993).

An additional benefit of the bicropping system is that clover survives through successive cereal crops and can be grazed before being redrilled with winter wheat (Jones & Clements, 1993). Furthermore, the bicropping system has been shown to reduce the level of attack by some important major cereal pests, such as aphids and slugs (Jones & Clements, 1991). However, little is known of the effects of cereal-clover bicropping on the incidence of the major cereal diseases, especially those caused by splash dispersed pathogens where an altered canopy structure might have a significant effect on spore dispersal and epidemic

development through an altered microenvironment. This study aimed to evaluate the impact of cereal-clover bicropping, at conventional and reduced levels of agrochemical inputs, on the incidence and severity of *Septoria*, pathogenic *Fusarium* species and eyespot (*Pseudocercosporella herpotrichoides*).

MATERIALS AND METHODS

In an experiment at the Institute of Arable Crops Research, Long Ashton, a fine, firm seed-bed was prepared incorporating 75 kg/ha of P and K fertiliser respectively, but no N. White clover seed was sown at 10 kg seed/ha on 10 June 1993. The clover cv. Donna was established over most of the field, but the cv. Milkanova was established for areas destined for treatments 3 and 4. The developing swards of clover were cut for silage in August and early October. In late October of 1993 and 1994, plots (13 x 60 m) were marked out for each of the treatments (Table 1) in three replicate blocks. For treatments 7 and 8 plots were ploughed and sown with winter wheat cv. Hereward. Plots for other treatments were left unploughed and winter wheat cv. Hereward was direct drilled into the clover understorey (treatments 1-4) or directly into the soil, using a Hunter Rotaseeder, following chemical removal of the clover.

TABLE 1. Summary of treatments used to evaluate the effect of cereal-clover bicropping on disease severity on winter wheat cv. Hereward

Treatment	Clover cv.	Ploughed or not	Input level
1	Donna	No	Conventional
2	Donna	No	Reduced
3	Milkanova	No	Conventional
4	Milkanova	No	Reduced
5	None	No	Conventional
6	None	No	Reduced
7	None	Yes	Conventional
8	None	Yes	Reduced

During the growing season conventional input plots received a standard farm management regime of 140 kg N fertiliser, the growth regulators fluroxypyr, chlormequat and choline chloride, the herbicides chloridazon, ethofumesate and triclopyr, the fungicides tebuconazole, chlorothalonil, propiconazole and cyproconazole and the insecticide pirimicarb. The low input plots received no N fertiliser, no herbicides, no growth regulators, only one fungicide (propiconazole at 0.25 the recommended rate) and the insecticide primicarb (Clements *et al.*, 1994)

From November to the time of harvest plant samples were taken from one metre lengths of crop rows sited at random within each of the plots. From these samples mean tiller number and shoot dry weights were calculated. For disease assessments during the 1993/94 growing season 20 plants were taken at random from a diagonal transect of each plot. Cereal growth stage (Zadoks *et al.*, 1974) was noted and for each leaf the percentage area affected by *Septoria* was assessed using a disease leaf area key. Samples of infected leaf tissue were plated onto Czapek (Dox) agar to confirm pathogen identity. During the 1993/94 season stem base segments were surface sterilised in 10% sodium hypochlorite and placed onto PDA to allow *Fusarium* isolation and enumeration. During the 1994/95 season half of the stem base segments, collected, as during the 1993/94 season, were placed onto PDA, the other half placed onto a copper sulphate isolation medium (Sumino *et al.*, 1991) which allowed an accurate assessment of *P. herpotrichoides*

incidence. Representative fungal isolates were sent to the International Mycological Institute for confirmation of identity. All wheat stem bases were also assessed visually for the severity of eyespot lesioning using the method of Scott & Hollins (1974).

During the 1994/95 season trash remaining on the surface of the three replicate reduced input direct drilled wheat monocrop plots (treatment 6) and the three replicate reduced input bicropped plots (clover cv. Donna, treatment 2) was collected and 10g of stubble was washed in 100 ml sterile distilled water containing a small amount of surfactant to aid spore removal. The numbers of *P. herpotrichoides* spores per g stubble (based on 3 replicated counts from each replicate plot) was calculated for each of the two treatments. Soil samples (10g) were collected from the same plots and were dilution plated on PDA. Following incubation at 15°C the number of *P. herpotrichoides* colony forming units was assessed.

RESULTS

Tiller counts and shoot dry weights of wheat per metre length of crop row on each sampling occasion during the 1993/94 growing season are shown in Table 2. There were no significant treatment effects on crop growth until May and June 1994, when the wheat in low input plots had fewer tillers and less dry weight per unit area than the crop in high input plots. There were only small, non-significant differences in tiller number and shoot dry weights between monocropped and bicropped wheat plants at the same input level.

TABLE 2. Tiller counts and shoot dry weight (g) of wheat (cv. Hereward), grown as monoculture or bicropped with white clover, per metre length of crop row on six sample dates (mean of three replicates)

	Sample date											
	Nov 93		Dec 93		Jan 94		Mar 94		May 94		Jun 94	
Treatment[1]	SN[2]	DW[3]	SN	DW	SN	DW	SN	DW	SN	DW	SN	DW
Conventional input												
1	66	1.2	78	1.2	146	3.4	149	7.6	127	208.0	129	385.0
3	60	1.1	74	1.2	137	3.3	150	6.7	109	187.0	123	343.0
5	74	1.4	88	1.5	174	4.0	206	10.7	139	266.0	110	386.0
7	66	1.0	85	1.3	167	3.7	157	9.3	130	218.0	116	439.0
Reduced input												
2	86	1.6	85	1.5	171	3.8	157	8.4	93	133.0	84	244.0
4	64	1.2	76	1.4	168	3.5	172	9.3	79	127.0	90	241.0
6	72	1.3	90	1.5	185	3.1	224	11.0	119	224.0	96	287.0
8	85	1.4	100	1.6	148	3.0	161	8.0	111	194.0	84	266.0

[1]: Treatments as in Table 1, [2]: Shoot number, [3]: Shoot dry weight (g).

The principal species of *Septoria* causing disease during the 1993/94 growing season was *S. tritici*. Mean *Septoria* severity on the upper leaves and heads for each treatment on each sampling date in the

1993/94 season is shown in Table 3. For all treatments on all sampling occasions the severity of disease was progressively lower on leaves higher up the plant. For the 9 June 1994 assessment, during stem elongation (growth stage 37, Zadoks *et al.*, 1974) the level of disease on corresponding leaves in different treatments did not differ significantly (Table 3). For the assessment on 1 July (growth stage 45) in the conventional input plots, bicrop treatments (1 and 3, Table 2) consistently had a lower severity of *Septoria*. This was significant ($P < 0.05$) on leaf 4 for both clover treatments compared with both monocrop treatments; on leaf 2 for clover cv. Milkanova (treatment 3) compared with the plough treatment, and on the flag leaf for both clover treatments compared with the ploughed plot. In the reduced input plots, bicrop treatments (2 and 4, Table 3) likewise showed consistently lower *Septoria* disease severities with significant differences on leaf 4, 3 and 2 for both clover treatments compared with the direct drilled plots and for the flag leaf for clover treatment cv. Milkanova (treatment 4) compared with the wheat crop grown on ploughed plots.

TABLE 3. Severity of *Septoria* on winter wheat cv. Hereward grown as monoculture or bicropped with white clover (mean of three replicates)

Treatment[1]	Disease severity (%) on leaves and ears									
	June 9				July 1				July 18	
	L2[2]	L3	L4	L5	Flag	L2	L3	L4	Ear	Flag
Conventional input										
1	1.5	4.2	7.4	17.5	1.6	9.0	23.3	40.0	10.0	15.7
3	0.3	2.7	5.9	11.0	1.7	7.7	23.3	40.0	10.7	12.7
5	1.3	3.7	8.0	18.4	5.0	10.0	36.7	60.0	12.0	17.3
7	0.3	2.1	4.9	14.1	7.3	16.7	33.3	61.7	9.0	19.7
Reduced input										
2	0.5	3.1	6.9	18.6	4.3	9.7	20.0	35.0	10.7	16.3
4	1.1	4.0	7.3	14.1	3.0	11.0	21.7	38.3	7.3	11.7
6	0.4	2.5	5.4	13.0	7.3	20.0	38.3	61.7	13.7	25.0
8	1.1	3.6	7.1	16.6	6.0	15.0	31.7	48.3	5.7	17.7
$LSD_{0.05}$	1.3	2.0	3.3	9.5	3.4	8.8	14.1	17.0	6.4	10.2

[1]: Treatments as in Table 1. [2]: L2 - Leaf 2 (first leaf below the flag leaf); L3 - Leaf 3; L4 - Leaf 4; L5 - Leaf 5.

On 18 July, in the plots with conventional input levels, less disease was evident on the heads and flag leaves of the bicropped treatments (treatments 1 and 3, Table 3) although these differences were not significant. At reduced input levels the direct drilled wheat monocrop (treatment 6, Table 3) had higher *Septoria* levels ($P < 0.05$) on the ears and flag leaf than the bicrop with clover cv. Milkanova (treatment 4, Table 3).

The incidence of eyespot was assessed during the 1994/95 season on 16 June (Table 4). Direct drilling had a significant and reducing effect on disease incidence in monocrops (treatments 5 and 6) compared with conventional cultivations (treatments 7 and 8). The effect of bicropping was to increase eyespot incidence relative to the direct drilled treatment, although differences were not significant between bicropped plots and plots which had been conventionally cultivated. In monocrop treatments the level of input had no effect on the incidence of eyespot. An analysis of the severity of eyespot infection (assessed using the method

of Scott & Hollins, 1974) showed that treatments 7 and 8 (conventional input and reduced input wheat monocrops sown following ploughing) had the greatest proportion of severe lesions, the treatments with the lowest numbers of severe lesions were 5 and 6 (conventional input and reduced input, direct drilled wheat monocrops).

TABLE 4. Incidence of eyespot on winter wheat cv. Hereward grown as monocrop and bicropped with white clover (mean of three replicates)

Treatment[1]	Eyespot incidence	Eyespot severity class[2] (bracketed figures are percent of total eyespot lesions)			
		0	1	2	3
Conventional input					
5	28.3	58	3(8)	20(48)	18(44)
7	46.7	60	2(4)	17(42)	22(54)
Reduced input					
2	41.7	72	7(23)	12(42)	10(36)
4	40.0	78	2(8)	12(54)	8(38)
6	21.7	47	8(16)	22(40)	23(44)
8	46.7	53	5(11)	18(39)	23(50)

[1]: Treatments as in Table 1; [2]: 0-no stem lesion, 1-slight lesions occupying less than half the stem, 2-moderate lesions occupying more than half the stem, 3-severe, stem girdled by lesion with tissue softened (Scott & Hollins, 1974).

An analysis of *P. herpotrichoides* spore production on trash showed that spore availability within the reduced input bicrop was 10 times greater than that within the reduced input direct drilled monocrop. Furthermore the *P. herpotrichoides* inoculum potential in soil from bicropped plots was significantly greater than that in monocropped plots at the two corresponding input levels (Table 5).

During the 1993/94 trial there was an increasing incidence of *Fusarium* in all plots during the course of the growing season. The majority of *Fusarium* isolates obtained from infected wheat stem tissue were of *F. avenaceum*. Expressed in terms of the area under the disease progress curve the highest disease levels were in treatments 5 and 7 (conventional input monocrops, both ploughed and directly drilled), disease levels in bicropped plots at the same input levels were significantly lower (Table 6). There were no significant differences in disease levels between monocropped and bicropped treatments at reduced input levels (Table 6).

DISCUSSION

The primary cause of *Septoria* infection on the wheat crop during the 1993/94 season was *S. tritici*. No significant differences were observed in *Septoria* severities between direct drilled and conventionally drilled wheat crops, between corresponding crops at contrasting input levels or between wheat crops above

different clover varieties (Table 3). The most significant factor accounting for differences in disease levels between plots was the presence or absence of clover as an understorey. The presence of clover clearly reduced the severity of *Septoria* compared with the wheat monocrop treatment, although this effect was observed only at growth stage 45. The presence of the clover understorey did not significantly reduce the wheat shoot population (Table 2) and so differences in *Septoria* severities at growth stage 45 cannot be explained in terms of a reduced canopy density.

TABLE 5. Number of *P. herpotrichoides* colony forming units in soil samples taken from plots of winter wheat cv. Hereward grown as a direct drilled monocrop and bicropped with white clover at conventional and reduced input levels (mean of three replicates)

Treatment[1]	*P. herpotrichoides* colony forming units per g. soil
Conventional input	
1	52
5	3
Reduced input	
2	55
6	17

[1]: Treatments as in Table 1

Septoria is a typically splash-dispersed cereal pathogen where pycnidiospores produced from cirrhi by pycnidia on the leaf surface are dispersed by rain splash droplets to initiate new infections. Royle *et al.* (1986) suggested that the vertical movement of pycnidiospores from basal to upper leaves might be a limiting factor in the development of some *Septoria* epidemics. Royle *et al.* (1986) also suggested that because of the rapid emergence of new leaves during stem extension, in most cases initial infections on successively produced upper leaves are likely to have originated from inoculum on diseased leaves lower down on the plant. The severity of *Septoria* attack is dependant on the amount of inoculum on the lower leaves at the start of stem extension (growth stage 30-31), the suitability of weather for allowing infection, and the occurrence of rainfall heavy enough to move inoculum up through the crop (Royle *et al.*, 1986). The presence of a clover understorey at the base of the wheat crop might have acted to reduce the upward movement of spores and therefore disease in the present experiment. This effect could have been brought about by one or both of two mechanisms. Firstly, the clover may have prevented raindrops penetrating to those basal leaves from which most later infections originate, and secondly the clover canopy may have deflected or intercepted spore-carrying splash droplets on their upward path to the newly emerging foliage. In either case, the suggestion that fewer spores were being redistributed from *Septoria* cirrhi in the presence of the companion clover crop appears to be borne out by results from recent experiments conducted in controlled environment conditions (Cooke, B M & Bannon F, personal communication).

The results from the eyespot evaluations indicated that direct drilled monocrops suffered less disease than crops sown following ploughing. These results are broadly similar to those of Herrman & Wiese (1985) who found that a reduced tillage regime lessened eyespot by 50% compared with a conventional cultivation; no-tillage treatments were reduced by a further 50%. Herrman & Wiese (1985) suggest that

the decrease in the level of disease under reduced and no-tillage treatments could be due to straw at the soil line separating the plant's lower stem from the pathogen located below in the soil. However results from the current study indicate that straw supports significant levels of spore production, this level being significantly increased in the presence of a clover canopy where the environmental conditions are likely to be more conducive to spore development. Although, as stated above, rainfall penetration to infected straw at the canopy base is likely to be reduced in the presence of clover, it would appear however that sufficient spores were being transferred to host tissue with the result that similar levels of disease occurred in bicropped plots as in ploughed, monocropped plots.

TABLE 6. Relative area under the disease progress curves for the incidence of *Fusarium* on winter wheat (cv. Hereward), grown as monoculture or bicropped with white clover (mean of three replicates)

Treatment[1]	Relative area under disease progress curve
Conventional input	
1	72*
3	73*
5	100
7	98
Reduced input	
2	62*
4	64*
6	50*
8	53*

[1]: Treatments as in Table 1, * Treatments differing significantly from treatment 5 at $P < 0.05$.

The altered canopy structure may also have had an effect on the levels of *Fusarium* observed during the 1993/94 growing season. However the disease measures as indicated by the areas under the disease progress curves also appear to indicate that the level of nitrogen has an important effect as in both monocrops and bicrops those plots receiving higher levels of nitrogen had greater levels of disease. It is also worth noting that the *Fusarium avenaceum*, the species most frequently isolated from the wheat stems is also pathogenic on clover and was frequently isolated from clover stem tissue collected from the bicropped plots. The degree of cross infection between clover and wheat is uncertain and so the extent to which clover could act as a reservoir for *Fusarium* infections requires further investigation.

ACKNOWLEDGEMENTS

The work reported was conducted in collaboration with a project commisioned by the Ministry of Agriculture, Fisheries and Food, and was carried out whilst M.J. Soleimani was in receipt of an Iranian Government, Ministry of Higher Education and Culture Scholarship.

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AN EVALUATION OF A CHITIN BASED FERTILISER AGAINST POTATO CYST NEMATODE, CABBAGE ROOT FLY AND RHIZOCTONIA SOLANI

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ABSTRACT

Three pot trials were established to investigate the control of wirestem on cauliflowers, caused by the fungus *Rhizoctonia solani,* cabbage root fly (*Delia brassicae*) on cauliflowers, and the white potato cyst nematode (*Globodera rostochiensis*) on potatoes. The relative efficacy of a chitin based fertiliser, at the recommended and three times recommended rate (270 and 810 g/m^2), incorporated up to 12 weeks before and/or applied on the day of inoculation with the pest or pathogen, was compared with tolclofos-methyl, aldicarb 10G and chlorpyrifos. The effectiveness of the test products against wirestem was assessed in terms of seedling emergence and presence of disease symptoms. Control of potato cyst nematode was measured in numbers of cysts per g of soil and control of cabbage root fly was assessed in terms of larval/pupal numbers and root damage.

All synthetic pesticides gave significantly better control of the test organisms than the chitin fertiliser. However, there was evidence that the fertiliser gave some control of potato cyst nematode, wirestem and cabbage root fly.

The potential for a chitin based fertiliser as a component of an integrated control strategy is discussed and suggestions are made for future research.

INTRODUCTION

Actinomycetes growing on chitin in oyster shell powder have been shown to control *Sclerotinia sclerotiorum* in vegetables (Lin *et al.*, 1990) and adding crustacean chitin to soil reduced cyst numbers of the soya bean cyst nematode (*Heterodera glycine*) (Rodriguez-Kabana *et al.*, 1984). As crab shell chitin is a major constituent of the fertiliser Ocean Supermix, it is possible that it may provide some control of soil pests and diseases, by stimulating the development of antagonistic micro-organisms. The present work was designed to evaluate the efficacy of this product against wirestem, caused by the common soil fungus *Rhizoctonia solani* (Telemorph = *Thanatephorus cucurmeris*), cabbage root fly (*Delia radicum*) and the white potato cyst nematode (*Globodera pallida*).

MATERIALS AND METHODS

In all experiments, the rates of fertiliser studied were 270 and 810 g/m², this being the recommended and three times the recommended dose rate. All test crops were grown in a sandy loam soil (Wigton Moor soil association, Quorndon Series). Fertiliser application was made at range of timings before and on the day of planting or sowing of the test crop and inoculation with the pest or disease. Incorporation of fertiliser before pest/disease inoculation was included to determine whether chitinolytic microbes could be stimulated prior to introduction of the test organism and so improve control.

Experiment 1: *Rhizoctonia solani*

Hand incorporation of the fertiliser, at 270 or 810 g/m², was undertaken 45, 31 or 17 days prior to sowing of ten viable non-fungicide treated cauliflower seeds (cv. Dok Elgon) per pot. Tolclofos-methyl as 'Basilex' was used as the standard fungicide in comparison with the fertiliser. An untreated control treatment with no fungicide or fertiliser was also included. Each treatment was replicated six times to provide 48 pots (9 cm diameter) in total. Soil known to be infected with *R. solani* was baited with cauliflower seedlings to provide a pure culture of the fungus. Isolates were prepared from the infested seedlings and cultured in a mixture of vermiculite and maize meal for seven days at ambient room temperature. Equal sized pot doses were prepared by subdividing this medium and these were inoculated 17 days before sowing the cauliflower seed. The fungicide was prepared as a 2 g/l suspension and 6.4 ml applied to the surface of the soil in each pot with a syringe. Pots were maintained in a glasshouse in a randomised block design at 20°C and watered as necessary. Fourteen days after sowing the numbers of emerged seedlings were counted.

Experiment 2: Potato cyst nematode

The fertiliser was incorporated by hand at 270 or 810 g/m² either 28, 14, or 0 days before inoculation with cysts of potato cyst nematode. Aldicarb, as 'Temik' was used as the standard nematicide in comparison with the fertiliser. Individual pot doses of this (0.002 g AI/pot equivalent to 3.36 g AI/m², the standard rate for maincrop potatoes) were prepared and mixed thoroughly with pot soil. An untreated control was also included and each of the eight treatments replicated six times to give a total of 48 pots (9 cm diameter). Soil known to be infested with the white potato cyst nematode was used to provide cysts of the pest and twenty of these were inoculated per pot. Each pot was planted with a single potato sprout (cv. Desiree) and then buried to just below its rim in a larger 18 cm-diameter pot containing general purpose potting compost. This gave an additional area into which potato roots could grow and obtain moisture (Cotten, 1967). Pots were then arranged in a randomised block design in an outdoor insectary. Twelve weeks later the 9 cm diameter pots were assessed for numbers of cysts of potato cyst nematode using a Fenwick can technique (Fenwick, 1948).

Experiment 3: Cabbage root fly

Fertiliser at 270 and 810 g/m² was incorporated by hand either once, twelve weeks before planting or twice, 12 weeks before and at planting. The double application was investigated to determine whether it would enhance pest control. This was compared with the insecticide chlorpyrifos, 'Dursban 4', made up as a solution of one ml in one litre of water, the rate approved as a drench treatment in the field. An untreated control was also included. There were six replicates of each treatment giving 36 pots (9 cm diameter) in total. A cauliflower plant (at the four leaf stage) was planted in each pot. Cabbage root fly eggs were extracted from soil samples taken from around the base of field brassica plants using a Fenwick can technique (Fenwick, 1948) and 10 of these were inoculated around the base of each cauliflower plant. A syringe was then used to apply the chlorpyrifos treatment with 70 ml of the insecticide solution used per plant. Pots were arranged in a randomised block design in a glasshouse at ambient temperature and watered as necessary. After six weeks the numbers of cabbage root fly larvae or pupae in each pot were recorded following flotation of the compost in concentrated magnesium sulphate solution.

RESULTS

Experiment 1

Seedling emergence was significantly greater in pots treated with tolclofos-methyl than in those receiving the fertiliser or in the control ($P<0.005$, Table 1). There was no significant difference between fertiliser treatments but all had significantly more seedlings than the control ($P<0.05$).

TABLE 1. Emergence of cauliflower seedlings after treatment with a chitin fertiliser or tolclofos-methyl

Treatment	Application rate (g/m²)	Days before sowing treatment incorporated	Seedling emergence (mean numbers)
1. Untreated control	-	0	1.8 a
2. Tolclofos-methyl	6.4 mg AI/pot	0	9.3 c
3. Fertiliser	270	17	4.8 b
4. Fertiliser	270	31	4.2 b
5. Fertiliser	270	45	4.8 b
6. Fertiliser	810	17	4.3 b
7. Fertiliser	810	31	5.3 b
8. Fertiliser	810	45	5.0 b

SED (35 df) = 0.88

a, b and c are Duncan's Multiple Range Test indices, values followed by the same letter are not significantly different, $P<0.05$.

Experiment 2

Aldicarb gave good control of potato cyst nematode and significantly fewer cysts were recovered from pots which received this product than from all other treatments ($P<0.05$, Table 2). In general, pots treated with fertiliser had fewer cysts than the untreated control but this difference was only significant ($P<0.05$) where 810 g/m² was incorporated 14 days before pest inoculation.

Table 2. Mean numbers of cysts of potato cyst nematode after treatment with a chitin fertiliser and aldicarb

Treatment	Application rate (g/m²)	Days before planting treatment incorporated	Mean cyst numbers/g soil
1. Untreated control	-	0	2.54 c
2. Aldicarb	3.36g AI/pot	0	0.15 a
3. Fertiliser	270	0	1.65 bc
4. Fertiliser	270	14	1.87 bc
5. Fertiliser	270	28	2.25 bc
6. Fertiliser	810	0	2.23 bc
7. Fertiliser	810	14	1.42 b
8. Fertiliser	810	28	2.31 bc

SED (33 df) = 0.403

a, b and c are Duncan's Multiple Range Test indices, values followed by the same letter are not significantly different, $P<0.05$.

Experiment 3

Significantly fewer cabbage root fly larvae were found in pots treated with chlorpyrifos than in the untreated control or where the fertiliser was incorporated at 270 g/m², 12 weeks before pest inoculation ($P<0.05$, Table 3). Fertiliser incorporation at 810 g/m 12 weeks before and on the day of pest inoculation also resulted in significantly smaller numbers of larvae in comparison with 270 g/m² incorporated 12 weeks pre pest inoculation ($P<0.05$).

TABLE 3. Mean number of cabbage root fly larvae ($\sqrt{(x + 0.5}$ values) following treatment with a chitin fertiliser and chlorpyrifos. Values in brackets are back-transformed data.

Treatment	Application rate g/m²	Days before planting treatment incorporated	Numbers of larvae	
1. Untreated control	-	-	1.53 bc	(1.84)
2. Chlorpyrifos	0.34g AI/plant	0	0.71 a	(0)
3. Fertiliser	270	84	1.75 c	(2.56)
4. Fertiliser	270	84 and 0	1.41 abc	(1.49)
5. Fertiliser	810	84	1.37 abc	(1.38)
6. Fertiliser	810	84 and 0	0.90 a	(0.31)

SED (25 df) = 0.314

a, b and c are Duncan's Multiple Range Test indices, values followed by the same letter are not signficantly different, $P<0.05$.

DISCUSSION

In all experiments the standard pesticide treatment was more effective at controlling *Rhizoctonia solani*, cabbage root fly and potato cyst nematode than the chitin based fertiliser. However, there was evidence that the fertiliser gave some suppression of all test organisms.

Other studies with *R. solani* (Ellis *et al.*, 1993a) have shown that the fertiliser is less effective when incorporated with the fungus at sowing. Therefore it is possible that inoculation of the fertiliser with the fungus, as in the present experiment, allows antagonistic micro-organsims to develop and start to control the pathogen so that its virulence is reduced.

Although the fertiliser appeared to give some control of potato cyst nematode, results were inconclusive. Development of the antagonistic microflora may not be rapid enough to influence cyst production. However, as chitin is a component of nematode egg shells it is possible that the new generation of cysts would be less viable and contain low numbers of eggs. Ellis *et al* (1993b) showed that egg numbers per cyst were lower where a chitin fertiliser was applied in comparison with aldicarb although the differences were not statistically significant.

In general, fewer cabbage root fly larvae were recorded where 810 g/m² of fertiliser was used as opposed to 270 g/m² and also where two applications were made compared with one. A high level of substrate is likely to result in a high population of chitinolytic microbes. Also, where repeat applications are made it is possible that antagonistic organisms develop more rapidly. Such a situation has evolved through continued use of carbamate insecticides to control insect pests in field vegetables. Some soils now show enhanced degradation (Suett, 1990) such that carbamate

pesticides are rapidly broken down by the soul microflora. Continued use of a chitin based fertiliser may also enhance the development of populations of chitinolytic micro-organisms and pest/disease control.

In summary, results suggest that a chitin based fertiliser may be effective as part of an integrated strategy incorporating a range of cultural or biological methods of control of plant pathogens. In this situation the pest/disease pressure is likely to be considerably less than experienced in the current studies.

ACKNOWLEDGEMENTS

We thank Royal Sluis Ltd, for providing the cauliflower seed.

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