POSTER SESSION P8D

PEST, DISEASE AND WEED MANAGEMENT IN ARABLE CROPS

Session Organiser: Martin Lainsbury
The Arable Group, Morley, UK

Poster Papers: P8D-1 to P8D-8

Compatibility of neonicotinoid seed treatments with carbamate granules in sugar beet

L A Haylock, B H Garner, A M Dewar
Broom's Barn Research Station, Higham, Bury St. Edmunds, Suffolk, IP28 6NP, UK
Email: alan.dewar@bbsrc.ac.uk

ABSTRACT

No adverse interactions on plant growth or vigour were recorded between the neonicotinoid seed treatments, imidacloprid (at 90 g a.i./unit), thiamethoxam plus tefluthrin (at 60+8 g a.i./unit) and clothianidin plus betacyfluthrin (at 60+8g a.i./unit), and the carbamate granules aldicarb (at 510 g a.i./ha), benfuracarb (at 600 g a.i./ha), carbosulfan (at 600 g a.i./ha) and oxamyl (at 600 g a.i./ha) applied down the furrow at sowing of sugar beet pelleted seed. None of the neonicotinoid treatments gave any control of free-living nematodes that cause Docking disorder, but all four carbamates gave significant yield increases at one infested site in 2004.

INTRODUCTION

Following the withdrawal of aldicarb (Temik) in 2004 as a result of an EU Review (Pesticides Safety Directorate (PSD) http://www.pesticides.gov.uk/fg_ec.asp?id=648), and its replacement by other carbamates, mainly to control free-living nematodes that cause Docking disorder (Dewar *et al.*, 2004b), concern has been expressed about the compatibility of seed treatment imidacloprid, and the newer neonicotinoid treatments, thiamethoxam and clothianidin, with the remaining carbamate products. These carbamates are less active against aphids than aldicarb was, (Seutin & van Steyvoort, 1976; Dewar, unpublished data) and there is therefore a greater likelihood that growers will use a neonicotinoid seed treatment and a carbamate granule treatment to control nematodes AND aphids; in the past they could rely on aldicarb to control both for up to eight weeks after sowing. This paper describes results from two trials conducted on nematode-infested sites in 2004 to test the compatibility of seed treatments that are already available, or are likely to be commercialized in the near future, and the remaining carbamate products.

MATERIALS AND METHODS

Two trials comparing the three remaining carbamate granules, carbosulfan (Posse from Belchim), oxamyl (Vydate from DowElanco) and benfuracarb (Oncol from NuFarm UK), with the now withdrawn aldicarb (Temik from Bayer CropScience) were conducted in sandy soils infested with free-living nematodes; aldicarb was applied at 510 g a.i./ha, while the other three carbamates were applied at 600 g a.i./ha. The seed treatments included an untreated control, standard imidacloprid at 90 g a.i./unit (Gaucho from Bayer CropScience), the still under development thiamethoxam plus tefluthrin at 60+8 g a.i./unit (from Syngenta Crop Protection), and the recently available clothianidin plus betacyfluthrin at 60+8 g a.i./unit (PonchoBeta from Bayer CropScience). One unit =100000 seeds, and on average 1.15 units/ha are sown in the UK. All seed was treated with Advantage priming treatment, and with the fungicides thiram and hymexazol to control seedling diseases in the seed and soil respectively. Nematode infestation levels had been established from preliminary soil samples taken in February using 25 cm soil augers. Samples were extracted and the nematodes identified at Rothamsted Research.

Emergence and establishment counts and crop vigour scores were carried out on two occasions at each site. Both crops were harvested in the autumn using an Edenhall 422 two-row harvester, taking roots from the four central rows by 9.7 m per plot (19.8 m^2). Root weight, sugar concentration, and levels of impurities were determined in the tarehouse at Broom's Barn.

RESULTS

The weather conditions in April and May in 2004 were very conducive to attack by free-living nematodes – wet and warm. Consequently it was expected that nematodes would have some effect on plant growth. However, although some damage was seen at the site at Cavenham, Suffolk, none was recorded at the other site at Docking, Norfolk. This latter site was therefore regarded as a test of crop safety and compatibility between the seed treatments and granules without the complication of pest attack.

Docking

Sixteen days after sowing, emergence ranged from 44 to 57%.There were significantly fewer plants in plots sown with thiamethoxam plus tefluthrin-treated seed (47%) than with untreated (54%) or the other two neonicotinoid treatments (50-56%) (Table1). This effect disappeared by the end of May when final establishment ranged from 55 to 63%. There were no effects, good or bad, of carbamate granules on emergence or establishment, nor any interaction between seed treatments and granules on either assessment date, although plots treated with oxamyl had lower plant numbers than those treated with other granules. There were some slight interactions between seed treatments and granules in crop vigour scores on 28 May, between aldicarb and thiamethoxam plus tefluthrin, between carbosulfan and imidacloprid and between oxamyl and clothianidin plus betacyfluthrin, but these were not consistent, and disappeared by 11 June.

Root weights and sugar yields were quite high at harvest reflecting the wet summer. There were no adverse or beneficial effects on sugar yield of any seed treatment or granule, nor any interactions between them at harvest (Table 3). There was a slight interaction between treatments on sugar content between benfuracarb and clothianidin plus betacyfluthrin, but again differences were not consistent. There was no effect of granules or seed treatments on levels of K, Na or amino N, nor any interactions between granules and seed treatments (data not shown).

Cavenham

Free-living nematodes, especially *Pratylenchus* spp. were especially active at Cavenham in 2004, and caused substantial damage in untreated plots where only 33% of sown seeds produced plants 22 days after sowing, and final establishment was only 46%. Consequently, all granule treatments, but no seed treatments, gave significant improvements in plant populations (of at least 13%) and crop vigour (Table 2); there were no differences between the granules – all performed equally well. There were no interactions between seed treatments and granules on any assessment date for either plant population or crop vigour.

All granule treatments gave significant increases in root yield of at least 10 t/ha, and increases in sugar yield of at least 1.9 t/ha (Table 3); there were no differences in sugar content or in the levels of K and Na, but the amino N levels in benfuracarb-treated plots was significantly lower than in other treatments (data not shown). There were no differences between the seed treatments, nor any interactions between seed treatments and granules, for any yield parameter.

Table 1. Compatibility between seed treatments and carbamate granules: effects on emergence and crop vigour at Docking, Norfolk in 2004

Granule	Seed treatment	Emergence (%) 27 April 16 DAS	Mean	Emergence (%) 28 May 47 DAS	Mean	Crop Vigour 28 May 47 DAS	Mean	Crop Vigour 11 June 61 DAS	Mean
No granule	Untreated	50.6		61.3		6.0		7.0	
	Imidacloprid	57.5	**56.5**	66.0	**60.6**	7.0	**6.3**	6.3	**6.8**
	Thiam + tef	54.8		56.0		6.3		7.0	
	Cloth + betacyf	63.0		59.1		6.0		7.0	
Aldicarb	Untreated	44.4		66.8		7.3		6.7	
	Imidacloprid	40.0	**43.8**	57.1	**63.4**	6.0	**6.5**	7.7	**6.8**
	Thiam + tef	41.7		63.8		5.7		6.0	
	Cloth + betacyf	49.1		65.8		7.0		6.7	
Carbosulfan	Untreated	61.4		63.2		6.0		7.7	
	Imidacloprid	49.7	**56.9**	69.1	**66.8**	7.0	**6.6**	6.7	**6.9**
	Thiam + tef	54.4		63.7		6.3		6.3	
	Cloth + betacyf	62.1		71.1		7.0		7.0	
Oxamyl	Untreated	53.4		64.0		6.7		6.0	
	Imidacloprid	55.4	**48.2**	51.3	**55.1**	5.7	**6.1**	6.0	**5.9**
	Thiam + tef	39.0		56.7		6.3		5.7	
	Cloth + betacyf	45.0		48.3		5.7		6.0	
Benfuracarb	Untreated	62.1		59.8		6.7		7.0	
	Imidacloprid	45.4	**53.4**	58.3	**61.4**	6.0	**6.4**	6.7	**6.9**
	Thiam + tef	47.2		58.0		6.0		7.0	
	Cloth + betacyf	58.8		69.4		7.0		7.0	
All granules	**Untreated**		**54.4**		**63.0**		**6.5**		**6.9**
	Imidacloprid		**49.6**		**60.3**		**6.3**		**6.7**
	Thiam + tef		**47.4** +		**59.6**		**6.1**		**6.4**
	Cloth + betacyf		**55.6**		**62.8**		**6.5**		**6.7**
LSD seed tr 30 d f		5.63; P=0.017		7.07; NS		0.51; NS		0.61; NS	
LSD granules 8 d f		10.96; NS		10.30; NS		1.08; NS		1.03; NS	
LSD interaction 30 d f		14.62; NS		16.34; NS		1.38; P=0.031		1.48; NS	

NS = not significant; + significantly less than untreated.

Table 2. Compatibility between seed treatments and carbamate granules: effects on emergence and crop vigour at Cavenham, Suffolk in 2004

Granule	Seed treatment	Emergence (%) 22 April 22 DAS	Mean	Emergence (%) 24 May 54 DAS	Mean	Crop Vigour 24 May 54 DAS	Mean	Crop Vigour 9 June 70 DAS	Mean
	Untreated	30.3		38.8		4.0		4.0	
No granule	Imidacloprid	33.8	**32.5**	50.7	**45.7**	4.7	**4.3**	5.3	**4.9**
	Thiam + tef	29.6		44.3		4.3		5.0	
	Cloth + betacyf	36.3		48.8		4.0		5.3	
	Untreated	48.8		60.4		6.0		8.3	
Aldicarb	Imidacloprid	42.0	**44.2***	58.0	**59.0***	6.0	**5.8***	8.0	**8.1***
	Thiam + tef	42.9		58.2		6.0		8.0	
	Cloth + betacyf	43.1		59.3		5.3		8.0	
	Untreated	50.9		61.1		6.0		8.3	
Carbosulfan	Imidacloprid	51.1	**51.9***	65.0	**61.8***	5.7	**5.8***	8.0	**7.9***
	Thiam + tef	49.5		58.6		5.7		8.0	
	Cloth + betacyf	56.3		62.5		5.7		7.3	
	Untreated	54.3		58.8		6.0		8.7	
Oxamyl	Imidacloprid	49.3	**48.0***	64.3	**59.1***	6.0	**5.9***	7.3	**7.9***
	Thiam + tef	44.2		59.1		6.0		7.7	
	Cloth + betacyf	44.3		54.3		5.7		8.0	
	Untreated	57.9		59.1		5.7		8.0	
Benfuracarb	Imidacloprid	45.9	**49.2***	63.2	**61.1***	6.0	**5.8***	8.0	**8.2***
	Thiam + tef	45.9		62.1		6.0		8.3	
	Cloth + betacyf	47.2		60.0		5.7		8.3	
	Untreated		**48.4**		**55.6**		**5.5**		**7.5**
All granules	**Imidacloprid**		**44.4**		**60.3**		**5.7**		**7.3**
	Thiam + tef		**42.4**		**56.5**		**5.6**		**7.4**
	Cloth + betacyf		**45.4**		**57.0**		**5.3**		**7.4**
LSD seed tr 30 d f		5.52; NS		6.00; NS		0.46; NS		0.57; NS	
LSD granules 8 d f		8.94; P=0.007		3.29; P<0.001		0.62; P=0.001		0.90; P<0.001	
LSD interaction 30 d f		13.25; NS		11.93; NS		1.04; NS		1.35; NS	

NS = not significant; * significantly more than untreated; $^{+}$ significantly less than untreated.

Table 3. Compatibility between seed treatments and carbamate granules in 2004: effects on yield and sugar content

Granule	Seed treatment	Docking Sugar Conc'n	Docking Sugar Conc'n Mean	Docking Sugar yield t/ha	Docking Sugar yield Mean	Cavenham Sugar Conc'n	Cavenham Sugar Conc'n Mean	Cavenham Sugar yield t/ha	Cavenham Sugar yield Mean
No granule	Untreated	17.2		12.9		18.7		8.9	
	Imidacloprid	17.2	**17.3**	11.7	**12.2**	18.9	**18.7**	10.1	**9.2**
	Thiam + Tef	17.6		12.8		18.3		8.0	
	Cloth + betacyf	17.3		11.3		18.9		9.7	
Aldicarb	Untreated	17.4		11.8		18.8		12.3	
	Imidacloprid	17.5	**17.4**	12.3	**12.2**	18.8	**18.8**	11.3	**11.7***
	Thiam + Tef	17.2		12.5		18.5		11.2	
	Cloth + betacyf	17.3		12.2		19.0		11.9	
Carbosulfan	Untreated	17.1		13.2		18.6		12.0	
	Imidacloprid	17.4	**17.4**	12.1	**12.4**	19.0	**18.8**	11.8	**11.7***
	Thiam + Tef	17.7		11.4		18.6		11.9	
	Cloth + betacyf	17.6		12.6		19.0		11.2	
Oxamyl	Untreated	17.6		11.2		18.9		11.1	
	Imidacloprid	17.4	**17.5**	10.4	**10.9**	18.8	**18.9**	11.4	**11.1***
	Thiam + Tef	17.7		10.6		18.9		11.0	
	Cloth + betacyf	17.4		11.1		18.8		10.7	
Benfuracarb	Untreated	17.5		12.6		18.8		11.9	
	Imidacloprid	17.5	**17.4**	11.2	**12.3**	18.8	**18.8**	12.0	**12.3***
	Thiam + Tef	17.6		12.4		18.7		12.3	
	Cloth + betacyf	17.0		13.0		18.8		12.9	
All granules	**Untreated**		**17.4**		**12.4**		**18.8**		**11.3**
	Imidacloprid		**17.4**		**11.6**		**18.9**		**11.3**
	Thiam + Tef		**17.5**		**12.0**		**18.6**		**10.9**
	Cloth + betacyf		**17.3**		**12.0**		**18.9**		**11.3**
LSD seed tmts 30 d f		0.18; NS		0.95;NS		0.31; NS		1.03; NS	
LSD granules 8 d f		0.19; NS		1.61; NS		0.46; NS		1.44; P=0.008	
LSD interaction 30 d f		0.38; P=0.044		2.32; NS		0.73; NS		2.35; NS	

NS = not significant; * significantly more than no granule

DISCUSSION

The slowing effect that has been reported before in association with imidacloprid (Dewar *et al.*, 1993; Heatherington and Meredith, 1992) was seen at the Docking trial with thiamethoxam in 2004, although it was only transient. Clothianidin displayed no such slowing effects in either year. This effect may be due to the greater solubility of thiamethoxam compared to both clothianidin and imidacloprid (Dewar *et al.*, 2004a), which allows a greater concentration of chemical to be present in germinating shoots, slowing growth. Often this effect disappears by final establishment.

As expected none of the seed treatments gave any control of free-living nematodes, which only caused damage at the Cavenham site in 2004. Neonicotioids do not have nematicidal activity. There were no adverse interactions between any of the seed treatments and any of the carbamates, so any combination of carbamate and neonicotinoid seed treatment can be used together safely. There were also no significant differences between carbamates in their efficacy against nematodes, although oxamyl in 2004, produced lower yields than the other carbamates in both sites.

ACKNOWLEDGEMENTS

We are grateful to Stephen Goward and the Field Experiments team at Broom's Barn for sowing the trials, to Robert Perowne and Bill Hedgecock for allowing trials on their farms, and to Kath Hudson and Paul May for technical assistance. This work was funded by the British Beet Research Organisation.

REFERENCES

Dewar A M; Read L; Prince J F W; Ecclestone P (1993). Profile on imidacloprid - another new seed treatment for sugar-beet pest control. *British Sugar Beet Review* **61**(3), 5-8.

Dewar A M; Haylock L A; Garner B H (2004a). Which seed treatment? *British Sugar Beet Review* **72(2),** 26-33.

Dewar A M; Haylock L A; Garner B H (2004b). Nematodes in sugar beet: 1. Free-living nematodes. *British Sugar Beet Review* **72(4),** 9-13.

Heatherington P J; Meredith R H (1992). United Kingdom field trials with Gaucho for pest and virus control in sugar beet, 1989-91. *Pflanzenschutz-Nachrichten Bayer* **45(3),** 491-523.

Seutin E; van Steyvoort L (1976). Contribution to the study of new methods of control against the principal entomological pests in beet crops. [FrenchDutch]. *Driemaandelijkse Publikatie, Belgisch Instituut tot Verbeterung van de Biet* **44: 11**, 77-99.

Susceptibility of male sterile wheat varieties to ergot

E A Skorda, P Efthimiadis, T Adamidis
Agricultural University of Athens, Greece

ABSTRACT

Ergot (*Claviceps purpurea* (Fr.) Tul.) is a potential problem in the two phases of hybrid wheat production that utilize a male-sterile parent. This study was undertaken to determine if four wheat cultivars of wheat (*Triticum aestivum* L. em Thell.), which escape the infection of ergot because of their closed glumes, would become infected during hybrid seed production with the use of the chemical pollen suppressant RH 531. The experiment was performed in a field infested naturally with infected plants of *Alopecurus myosuroides*. Therefore the wheat infection was natural. There were high differences in infection between rates of the chemical RH 531 and cultivars. The infection was higher with the higher rate. Following chemical treatment the lowest infection occurred in the cultivar Dio and the highest in cv Vergina. Intermediate infection occurred in cvs Vitsi and Aiges.

INTRODUCTION

The interest in hybrid wheat (*Triticum aestivum* L. em Thell.) has continued with the release of several hybrid wheat lines by private companies because of its potential for increased yield. However ergot caused by *Claviceps purpurea* (Fr.) Tul. may be the primary problem in the production of hybrid wheat seed. Ergot is a potential problem in the two phases of hybrid wheat production that utilize a male-sterile parent, and infection is particularly severe in the humid cold regions. While several measures can be taken for ergot control none is completely effective. Ergot has spread during the past decade and its infection reduces potential seed production. Certain wheat cultivars escape infection mechanically, by having florets that either remain closed or open only for short periods during anthesis. This form of resistance is undesirable in hybrid production, where open flowering is essential in female parents. The flowering pattern may also allow wheat to escape infection.

Protective fungicides have been ineffective in controlling ergot, while some systemic fungicides could offer some hope for chemical control (Shaw, 1988).

Mantle *et al*. (1977) have confirmed the hypothesis that the presence of the weed *Alopecurus myosuroides* increases the risk of high levels of ergot infection in wheat due to its earliness and ease of cross-infection from this grass weed to wheat. *A. myosuroides* is a common arable grass weed susceptible to ergot affecting winter cereals through the world and Greece. Herbicide resistance in this species is a growing problem. Satisfactory weed control is not always achieved and since it is very susceptible to ergot, constitutes a source of inoculum for the wheat plants. Inoculum may also result from *Lolium* spp. that is a significant inoculum source for wheat in Australia (Bretag & Merriman, 1981). Therefore the resistance of wheat cultivars to ergot infection from *A. myosuroides* is essential. Genotype differences are present, and Schmidt (1976) found partial resistance to ergot in some cultivars.

The compound RH 531 has been evaluated in Greece along with other growth regulators in wheat and barley. In these experiments some sterility has been observed even though the application of this compound was made at very early growth stages (Skorda, 1976).

The purpose of this research was to determine the resistance of four chemically male-sterile wheat cultivars to ergot infection from *A. myosuroides*.

MATERIALS AND METHODS

Seeds of two awned and two awnless wheat cultivars were autumn planted in 2.5 m long rows with 30 cm spacing between rows at Ptolemaide Agricultural Research Station, West Macedonia (Greece) during 1989-1990. The field plot arrangement consisted of four rows of each chemically male sterile and 12 rows of fertile cultivars with the fertile rows adjoining the male sterile rows and four replicates. Whole plots of male sterile were cultivars. Subplots were rates of chemical application. The four cultivars were Vergina and Dio awnless and Aiges and Vitsi awned.

The compound RH 531 [sodium-1-(p-chlorophenyl)-1,2-dihydro-4.6-dimethyl-2-oxonicotinate; Rohm and Haas Co.] has been used as a chemical pollen suppressant (CPS). RH 531 rates are expressed in terms of active ingredient. The developmental stage of wheat at the time of chemical application was the early boot, when the flag leaf sheath was exposed from 2 cm to 8 cm.

The female rows were treated with a hand-carried propane sprayer at rates of 1.50 and 2.00 kg a.i./ha. Male rows were shielded from spray drift by holding sheets of plastic between the male and female rows. Total spray volume was 600 litres/ha.

Ten randomly selected spikes were covered with glassine bags as they began to emerge from the flag leaf sheath. Two or three days after the first bagging, ten additional spikes which were just emerging from the boot were bagged. At approximately the soft dough stage ten bagged spikes from each bagging date were harvested, and the numbers of spikelets and seed were counted. To determine the effect of bagging, the seed set was compared on bagged and non-bagged spikes in control plots. Plant height was measured near maturity. After harvest, a total of 700 spikes from each infected and non-infected plot were counted as well as the number of infected and non-infected florets of each spike. Infection percentages were calculated by determining the number of spikes and florets with sclerotia.

The inoculation with ergot was natural by inoculum from infested *Alopecurus myosuroides*. *A. myosuroides* was scattered in the field between wheat plants and more abundant in hedgerows and nearby fields.

RESULTS

The unsprayed control of the four cultivars was completely free from ergot infection (Table 1). There were differences in ergot susceptibility between the four wheat cultivars with Vergina being the most susceptible and Dio the least susceptible at the lower rate of chemical application. At the higher rate the susceptibility of Vergina was higher than that of the three others. The two awned cultivars had similar susceptibility but this was not so for the two unawned cvs. This shows that the awns did not affect susceptibility.

The percentage of infected spikes was higher at the higher rate of RH 531 for all four cvs. The difference in infection between the two rates in cv Vergina was the highest, followed by that in cv Dio, both awnless. cv Dio not only had fewer heads infected than Vergina, but within an infected head fewer florets were infected. In the two other awned cultivars the difference between the two rates tended to be lower and not significant. The most susceptible cultivar had also more infected florets per spike than the other cultivars (table 2).

Table 1. Degree of susceptibility of male sterile wheat varieties to ergot

Cultivar	RH 531 g a.i./ha	Plant height (cm)	Seed weight/ head (g)	Heads infected %
DIO	0	72 ab	0.82 a	0.00e[1]*
	1500	60 eg	0.7 ac	0.32d
	2000	57 fg	0.72 ad	3.44bc
Vergina	0	80 a	0.82 a	0.00 e
	1500	68 cd	0.77 ab	5.61 b
	2000	62 df	0.57 e	16.44 a
Aiges (awned)	0	64 cf	0.65 ce	0.00 e
	1500	58 fg	0.62 de	1.77 cd
	2000	53 g	0.56 e	3.62 bc
Vitsi (awned)	0	81 a	0.76 a	0.00 e
	1500	72 bc	0.74 ac	1.50 cd
	2000	67 ce	0.67 bc	2.94 cd

[1] Based on examination of 700 heads per replicate

Table 2. Frequency of infected florets per spike

Cultivar	RH 531	Number of infected florets per head									
	Rate g/ha	1	2	3	4	5	6	7	8	9	10
DIO	1500	100*	0	0	0	0	0	0	0	0	0
	2000	73	16	7	2	0	0	0	1	0	1
Vergina	1500	70	20	3	6	1	0	0	0	0	0
	2000	64	20	9	4	1	1	1	0	0	0
Aiges	1500	80	17	3	0	0	0	0	0	0	0
	2000	71	16	5	2	3	0	3	0	0	0
Vitsi	1500	76	20	0	4	0	0	0	0	0	0
	2000	69	16	13	2	0	0	0	0	0	0

RH 531 at both rates severely affected plant height of all cultivars, the reduction being proportional to rate. Also RH 531 reduced the length of spike internodes.

DISCUSSION

The use of RH 531 to induce pollen sterility resulted in varying amount of ergot infection in the heads of all four male sterile wheat cultivars. Maximum percentage infection was obtained with the highest rate of RH 531 in all tested cultivars which gave also the maximum reduction in fertility and longer opening of the florets. The awnless cv Vergina not only had the highest percentage of heads infected, but also the highest florets within an infected head.

Therefore awns did not affect the infected spikes and florets percentage. When Puranik & Mathre (1971) clipped the awns the percentage of infected florets varied, probably due to the variation in the number of florets open at the time of inoculation.

Under field conditions plants produce tillers over a considerable length of time, resulting in heads in various stages of development. Thus, the longer the duration of tillering of the plants, the longer would be the over-all period for open florets. A short time after fertilization the plant is immune to ergot (Cunfer *et al.*, 1975).

All untreated fertile cultivars were free from ergot infection. This resistance probably is mechanical and not genetic. The four tested cultivars have morphological resistance to ergot, an exclusion mechanism resulting from the short time the florets are open during flowering.

However, in hybrid production by RH 531, where open flowering in female parents was longer and the physiological or biochemical resistance is crucial, it appeared that cv Vergina was the most susceptible and the three other less susceptible.

Schmidt *et al.* (1976) attributed the increase in ergot infection to increasing divergence of blooming of the male-sterile and pollinator lines and to genotype differences.

At the lower rate of the chemical cv Vergina also was most susceptible of the other cultivars. The flowers were open to receive inoculum of *C. purpurea*. Therefore, no variety was found resistant to use as source of resistance to ergot.

The infection was natural from infected *A. myosuroides* plants. The similarity of alkaloid spectra of ergot sclerotia from *A. myosuroides* and wheat, the ease of cross-infection from *A. myosuroides* to wheat and an association between infection and the occurrence of ergot sclerotia in surveyed wheat crop have confirmed the hypothesis that the presence of this early flowering grass weed increases the risk of high levels of ergot infection in wheat (Mantle *et al*., 1977).

Therefore the resistance of wheat varieties to ergot infection from *A. myosuroides* is essential and the screening of lines and cultivars for resistance to ergot by the method described in this paper is useful. Darlington *et al*. (1977) advise breeders to use mixture of isolates from many different grass hosts in screening germ plasm for resistance to ergot.

It is very difficult to find plants resistant to ergot. *Durum* wheat is more susceptible than bread wheat but some lines of both wheat species are resistant (Platford & Mathre, 1976). The resistance of female parent gives the resistance to progenies. The resistance is maternally controlled (Darlington & Mathre, 1976).

Efficient control of *A. myosuroides* in cereal crops (particularly male sterile wheat), may provide an important means of limiting the development of ergot disease epidemics. The control of *A. myosuroides* in cereal crops is very difficult because of the weed is resistant to many herbicides. Chlorotoluron-resistant *A. myosuroides* was first detected in 1982 and until 1988 was found in 18 other fields. Chlorotoluron-resistant *A. myosuroides* showed cross resistance to at least 15 other herbicides, including isoproturon, terbutryn, pendimethalin and diclofop-methyl. The degree of resistance varied considerably between resistant populations and between herbicides. Resistance, although not absolute, is sufficient to cause substantial reductions in herbicide performance at recommended field doses (Moss, 1990) to ensure in most fields the presence of ergot inoculum.

Control measures are:

a) The use of resistant or tolerant germplasm,
b) The use of a cultivar that produces tillers and open florets at a very short time period,
c) A good pollinator to ensure rapid and complete fertilization,
d) Cultivars that will establish resistance within a few hours after pollination.

REFERENCES

Bretag T W; Merriman P R (1981). Epidemiology and cross infection of *Claviceps purpurea*. *Trans. Br. Mycol. Soc*., **77**, 211-213.

Cunfer B M; Mathre D E; Hockett E A (1975). Factors influencing the susceptibility of male-sterile barley to ergot. *Crop Science* **15**, 194-196.

Darlington L C; Mathre D E (1976). Resistance of male sterile wheat to ergot as related to pollination and host genotype. *Crop Science* **16,** 728-730.

Darlington L.C; Mathre D E; Johnston R H (1977). Variation in pathogenicity between isolates of *Claviceps purpurea*. *Canadian Journal of Plant Science* **57**, 729-733.

Mantle P G; Shaw S; Poling D A (1977). Role of weed grasses in the etiology of ergot disease in wheat. *Ann. Appl. Boil.* **86**, 339-351.

Moss S R (1990). Herbicide cross-resistance in slender foxtail (*Alopecurus myosuroides*). *Weed Science* **38,** 492-496.

Platford R G; Bernier C C (1976). Reaction of cultivated cereals to *Claviceps purpurea. Canadian Journal of Plant Science* **56**, 51-58.

Puranik S B; Mathre D E (1971). Biology and control of Ergot on male sterile wheat and barley. *Phytopathology* **61,** 1075-180

Schmidt H J (1976). Susceptibility of wheat to ergot. M.S. Thesis, North Dakota State Univ., Fargo.

Shaw S (1988). Further evaluation of triadimenol seed treatments for the control of ergot in cereal seed. *Monograph-British Crop Protection Council* **39**, 105-112.

Skorda E A (1976). Response of wheat, barley and oat to seed dressing and foliar applications of three growth regulators. *Scientific Annals of School of Agriculture and Forestry A.U* **18**, 287-314.

Field pansy (*Viola rafinesquii* Greene) control in no-till fields with fall- and spring-applied herbicides

D L Regehr, J N Miller, D E Peterson
Department of Agronomy, Kansas State University, Manhattan, KS 66506, USA
Email: dregehr@oznet.ksu.edu

ABSTRACT

Field pansy is a winter annual that has become a problem weed in no-till fields in the central USA. Some of the common preplant burn down herbicide treatments have given poor or erratic control. Field studies were conducted over three years to evaluate herbicides and application timing. Ahead of maize, the more consistent treatments included atrazine with paraquat, mesotrione, isoxaflutole, or simazine, applied in fall or spring. Ahead of soybean, fall applications with both burn down and soil residual activity were usually more effective than spring applications.

INTRODUCTION

Field pansy is a winter annual violet native to North America. Seed mostly germinates in fall, producing semi-rosettes that over winter. Flowering begins in early spring and continues into late spring and early summer (Baskin and Baskin, 1972). Plants are short in stature, ranging from about 4 to 25 cm in height (Brooks and McGregor, 1986).

No-till crop production now covers about 1.7 million hectares in Kansas, about 21% of total planted cropland (CTIC, 2005). Reasons for adoption include better soil erosion control and soil moisture use, and reduced fuel, machinery and labor costs per hectare. Disadvantages include a greater dependence on herbicides for preplant and in-crop weed management.

Herbicides to remove winter annuals and to create optimum field conditions for spring planting may be applied either in fall or in spring. Because winter is the season of lowest precipitation in the USA Great Plains, there is little potential for herbicide loss in surface water runoff (Regehr *et al.*, 2001; Rector *et al.*, 2003). Thus, atrazine plus 2,4-D may be applied either in fall or in spring on fields to be planted to maize (*Zea mays* L.) (CDMS, 2005). Seedlings of winter annuals are usually more vulnerable to fall-applied herbicides, than are the over-wintered rosettes, to spring-applied herbicides (Regehr & Peterson, 2002).

This research was prompted by reports of poor and inconsistent control of field pansy by atrazine plus 2,4-D applied ahead of maize, and also by metribuzin plus 2,4-D applied ahead of soybean (*Glycine max* (L.) Merr.).

MATERIALS AND METHODS

Field experiments (Tables 1 and 2) were conducted on northeast Kansas no-till fields that were in an annual maize/soybean rotation, on natural populations of field pansy.

Table 1. Application and rating dates for experiments ahead of maize.						
	Hiawatha		Soldier	Manhattan	Perry	
Application date	22-Nov-02	5-Apr-03	2-Apr-04	21-Mar-04	25-Feb-05	28-Mar-05
Air temp. (C)	12	9	17	6	13	22
% R.H.	40	54	31	35	41	24
Soil temp. (C)	5	10	12	5	8	10
Wind velocity (m/s)	3	3	2	1	2	3
Rating dates	3-Jan-03	*	23-Apr-04	15-Apr-04	11-Mar-05	*
	5-Apr-03	*	7-May-04	3-May-04	4-Apr-05	4-Apr-05
	22-Apr-03	22-Apr-03	20-May-04	15-May-04	19-Apr-05	19-Apr-05
					28-Apr-05	28-Apr-05

Table 2. Application and rating dates for experiments ahead of soybeans.				
	Hiawatha [A] (2002-2003)		Hiawatha [B] (2003-2004)	
Application date	22-Nov-02	5-Apr-03	26-Nov-03	9-Mar-04
Air temp. (C)	9	8	9	13
% R.H.	46	60	30	49
Soil temp. (C)	5	7	4	8
Wind velocity (m/s)	2	3	2	3
Rating dates	3-Jan-03	*	6-Jan-04	*
	5-Apr-03	*	9-Mar-04	*
	22-Apr-03	22-Apr-03	6-Apr-04	6-Apr-04
	6-May-03	6-May-03	23-Apr-04	23-Apr-04

Ahead of Maize. A fall-applied by spring-applied factorial experiment was done in 2002/2003 near Hiawatha, on a Marshall & Sharpsburg silt loam (fine-silty, mixed, mesic Typic Hapludoll) with 14% sand, 56% silt, 30% clay, 3.7% organic matter, and a pH of 5.8. In the spring in 2004, randomized complete block experiments were done at Soldier on a Kennebec silt loam (fine-silty, mixed, mesic Cumulic Hapludoll), and at Manhattan on a Kahola silt loam (fine-silty, mixed, mesic Cumulic Hapludoll). The spring, 2005, experiment at Perry was an early spring by late spring factorial, on a Martin silty clay loam (fine, montmorillonitic, mesic Aquic Argiudoll). All experiments had four replications.

Ahead of Soybean. A fall-applied by spring-applied factorial experiment was done in 2002/2003 near Hiawatha [A] on a Grundy silt clay loam (fine, smectitic, mesic Aquertic Argiudoll) with 14% sand, 54% silt, 32% clay, 3.2% organic matter, and a pH of 5.4, and repeated in 2003/2004 at another Hiawatha site [B], on a Muir silt loam (fine-silty, mixed, mesic Cumulic Haplustoll), with 42% sand, 42% silt, 16% clay, 1.9% organic matter and a pH of 5.0

In most experiments, all treatments also contained 560 g ae/ha 2,4-D low-volatile ester and 70 g/ha dicamba, herbicides and rates that have very little effect on field pansy (data not shown), but that help to remove interference from other broadleaf winter annuals. Herbicide treatments contained adjuvants and water conditioners, as appropriate. A non-treated control was included in each experiment but was not included in the analysis. Application and rating dates are shown in Tables 1 and 2.

Table 3. Field pansy control ahead of no-till corn. Only final weed control ratings are shown. Experiments at Hiawatha and Perry, KS were conducted and analyzed as factorials.[a]

		Hiawatha		Soldier	Manhattan	Perry	
Treatment[b,c,d]	Rate	22-Nov-02[e] 151 DAT[f]	05-Apr-03 17 DAT	02-Apr-04 48 DAT	21-Mar-04 55 DAT	25-Feb-05 62 DAT	28-Mar-05 31 DAT
	g ai/ha	% control					
atrazine + COC	1120	97	90	64	60	79	68
atrazine + COC	2240	100	95	63	78	96	96
atrazine + flumetsulam + COC	1120 + 56	100	98	75	78	99	86
atrazine + isoxaflutole + COC	1120 + 79	100	98	95	80	99	99
atrazine + mesotrione + COC	1120 + 140	100	100	99	83	100	100
atrazine + rimsulfuron + thifensulfuron + COC + UAN	1120 + 18 + 9	100	94	86	74	97	93
atrazine + simazine + paraquat + COC	1120 + 1120 + 700	90	100	100	98	99	99
paraquat + NIS	700	85	98	95	95	91	96
atrazine + paraquat + COC	1120 + 700	90	100	92	95	96	98
atrazine + paraquat + COC	2240 + 700	100	98	100	99	99	99
glyphosate + AMS	1120	90	83	88	98	97	93
atrazine + glyphosate + AMS + COC	1120 + 1120	98	89	86	99	90	94
glyphosate + flumiclorac + AMS	1120 + 23	93	93	88	99	93	93
glyphosate + carfentrazone + AMS	1120 + 14	90	95	78	99	91	94
atrazine + dicamba + COC	1030 + 540	*	*	*	88	*	*
glufosinate + atrazine + AMS	347 + 1120	*	*	*	99	*	*
2,4-D + dicamba + NIS	560 + 70	*	*	0	16	6	3
LSD (p=0.05) within columns		7	7	18	16	10	10
LSD (p=0.05) between columns		5		N/A	N/A	7	

[a] Abbreviations: DAT, days after treatment; COC, crop oil concentrate; UAN, 28% urea ammonium nitrate; AMS, ammonium sulfate; NIS, nonionic surfactant, N/A, not applicable.

[b] Treatments contained 560 g ae/ha 2,4-D plus 70 g /ha dicamba.

[c] Surfactant and water conditioner use rates: COC, 1% v/v; UAN, 2.5% v/v; NIS, 0.25% v/v; AMS, 7.7 kg / 378.5 L.

[d] Formulations: glyphosate, isopropylamine salt; 2,4-D, low-volatile ester (LV4).

[e] Application date.

[f] Rating interval. Only final ratings taken in spring are presented.

Table 4. Field pansy control ahead of no-till soybeans from either fall or spring herbicide applications.[a]

		Hiawatha [A] (2002-2003)		Hiawatha [B] (2003-2004)	
Treatment[b,c,d]	Rate	22-Nov-2002[e] 165 DAT[f]	5-Apr-03 31 DAT	26-Nov-03 149 DAT	9-Mar-04 45 DAT
	g ai/ha	% control			
glyphosate + AMS	1120	93	89	93	89
glyphosate + thifensulfuron + AMS + COC	1120 + 26	95	85	93	91
glyphosate + sulfentrazone + chlorimuron + AMS + COC	1120 + 200 + 13	95	78	96	91
glyphosate + thifensulfuron + sulfentrazone + AMS + COC	1120 + 16 + 131	94	81	91	93
glyphosate + flumiclorac + AMS	1120 + 23	94	84	94	79
glyphosate + imazaquin + NIS + AMS	840 + 101	96	84	95	88
sulfentrazone + COC	280	89	46	97	58
sulfentrazone + flumioxazin + COC	280 + 72	94	66	*	*
sulfentrazone + chlorimuron + COC	200 + 13	91	58	88	71
cloransulam + UAN + COC	35	100	90	98	83
cloransulam + flumioxazin + UAN + COC	35 + 72	97	90	97	78
Thifensulfuron + UAN + NIS	26	75	85	86	65
Thifensulfuron + sulfentrazone + COC	16 + 131	88	79	79	79
paraquat + NIS	700	92	64	95	81
2,4-D + dicamba + NIS	560 + 70	*	*	15	3
LSD (p=0.05) within columns		14	14	14	14
LSD (p=0.05) between columns		10		10	

[a] Abbreviations: DAT, days after treatment; COC, crop oil concentrate; UAN, urea ammonium nitrate; AMS, ammonium sulfate; NIS, nonionic surfactant.

[b] Treatments contained 560 g ae/ha 2,4-D plus 70 g/ha dicamba.

[c] Surfactant and water conditioner use rates: COC, 1% v/v; UAN, 2.5% v/v; NIS, 0.25% v/v; AMS, 7.7 kg / 378.5 L.

[d] Formulations: glyphosate, isopropylamine salt; 2,4-D, low-volatile ester (LV4).

[e] Application date.

[f] Rating interval. Only final ratings taken in spring are presented.

Herbicides were broadcast applied in water over 3 m by 7.6 m plots, using a backpack CO_2 sprayer calibrated to deliver 140 l/ha at a pressure of 193 kPa through 11002 turbo tee nozzles (Spray Systems Co., 2004). The spray boom length was 2 m, which left a small-untreated area between plots. Visual ratings for weed control were taken throughout the spring using the scale 0 to 100, with 0 being no control and 100 being complete control.

Data from the factorial experiments was subjected to factorial analysis of variance (ANOVA). Factors subjected to analysis were application timing, herbicide treatment, and the interactions thereof. Separation of appropriate means was based on Fisher's protected LSD at the 5% significance level (p=0.05). Experiments conducted as randomized complete blocks were subjected to ANOVA procedures, and the means were separated using Fisher's protected LSD at the 5% significance level.

RESULTS

Ahead of Maize. The factorial experiment at Hiawatha (Table 3) gave better field pansy control than anticipated. Only paraquat applied in fall, and glyphosate applied in spring, had less than 89% control, when rated in late April just prior to maize planting. Treatments that gave the highest control in both fall and spring were 1120 g/ha atrazine tank mixed with mesotrione, isoxaflutole, or flumetsulam, and 2240 g/ha atrazine plus paraquat. Treatments that performed better when fall-applied were atrazine, atrazine plus rimsulfuron plus thifensulfuron, atrazine plus glyphosate, and glyphosate. Treatments that performed better when spring applied were atrazine plus paraquat, atrazine plus simazine plus paraquat, and paraquat. Tank-mixing flumiclorac or carfentrazone with glyphosate did not increase control when applied in the fall, but did increase control significantly when added to glyphosate in the spring.

The 2004 and 2005 treatments were all spring applied. Atrazine at 1120 g/ha averaged 68% control of field pansy, confirming the generally poor control observed by maize producers. Addition of 700 g/ha paraquat to 1120 and 2240 g/ha rates of atrazine increased control to 95 and 99%, respectively. Several soil residual herbicides have considerable foliar activity, and also increased field pansy control when applied with 1120 g/ha atrazine. The two that were most consistent were 140 g/ha mesotrione and 79 g/ha isoxaflutole. Addition of 17 g/ha rimsulfuron plus 9 g/ha thifensulfuron to atrazine gave somewhat less consistent control. Spring treatments that performed well, but are not atrazine-based, were glyphosate at 1120 g ai/ha, and glyphosate tank mixed with 23 g/ha flumiclorac or 14 g/ha carfentrazone.

Ahead of Soybean. In factorial experiments in 2002-03 and 2003-04, in different fields at Hiawatha, many soybean treatments performed significantly better when applied in fall than in spring (Table 4). This fall advantage was surprising, especially since the fall treatments were applied over heavy maize residues. Treatments showing the biggest fall-over-spring advantage were sulfentrazone, either alone or with flumioxazin or chlorimuron.

Glyphosate at 1120 g ai/ha gave about 90% control of field pansy, applied in either fall or spring. To manage the overall weed complex, however, soybean producers prefer burn down treatments that also have soil residual activity. Therefore, glyphosate is often applied with 200 g/ha sulfentrazone plus 13 g/ha chlorimuron, 131 g/ha sulfentrazone plus 16 g/ha thifensulfuron, or 101 g/ha imazaquin, all of which extend the duration of weed control from the burn down application.

Cloransulam at 35 g/ha was especially active on field pansy after fall application, and held up fairly well applied in spring. Other experiments (not shown) suggest that pansy control decreases significantly when lower rates of cloransulam are used.

ACKNOWLEDGEMENTS

We thank the Kansas Corn Commission, the Kansas State University College of Agriculture, and cooperating maize and soybean producers for their support.

REFERENCES

Baskin J M; Baskin C C (1972). Physiological ecology of germination of *Viola rafinesquii*. *American Journal of Botany* **59**, 981-988.

Brooks R E; McGregor R L (1986). Violaceae Batsch, the Violet Family. In: *Flora of the Great Plains*, ed. Barkley T M. p. 263. University Press of Kansas: Lawrence, KS

[CDMS] Crop Data Management Systems, Inc (2005). www.cdms.net/ldat/ld280019.pdf. accessed June 2005.

[CTIC] Conservation Technology Information Center (2005). www.ctic.purdue.edu/Core4/Core4Main.html accessed June 2005.

Rector R J; Regehr D L; Barnes P L; Loughin T M; Hoobler M A (2003). Application timing impact on runoff losses of atrazine. *Weed Science* **51**, 817-825.

Regehr D L; Barnes P L; Devlin D L; Rector R J; Hoobler M A (2001). Management practices to minimize atrazine loss in surface water runoff. In: *Proceedings of the British Crop Protection Council - Pesticide Behavior in Soils and Water 2001*, ed. Walker A, pp. 373-378. British Crop Protection Council, Farnham.

Regehr D L; Peterson D E (2002). Fall treatments for winter annual weed control in row-crop stubble. *Proceedings of the North Central Weed Science Society annual meeting 2002*. **57**, 189.

Spray Systems Co. (2004). *Mobile systems products*. Wheaton, IL. Catalog 49A.

Indirect weed control in wheat by variety selection and high crop density

E Skorda, P Liakopoulou-Grivakou
Cereal Institute of Thessaloniki, P.O. Box 312, Thermi 57001, Thessaloniki, Greece

A P Efthimiadis
Agricultural University of Athens, Greece

ABSTRACT

The aim of this study was to identify wheat cultivars (sown at different seed rates) which can compete with a mixture of grass and broad-leaved weeds and to determine significant characteristics of the wheat plant that contribute to competitiveness with weeds. Results showed that the lower seed rates of both cultivars had the highest emerged grass weed populations whilst the number of broad-leaved seedlings were about similar at all seed rates. Biomass production of the weed species is also discussed

INTRODUCTION

Modern agriculture is highly dependent on the use of herbicides. Specifically for cereals in Greece, herbicides are the only chemicals used by farmers, except seed dressing fungicides, since the presence of weeds represents one of the major limiting factors to wheat production. Thus herbicides are seen as critical in maintaining economic sustainability for most farmers, and consequently contributing to social sustainability. Nevertheless, the environmental sustainability of the current approach to herbicide use is a matter of contention. In addition, in a global context, it is likely that most farmers could not readily be convinced to dispense with herbicides, at least as part of their armory, if we do not provide them with other methods to control weeds. Furthermore, the world demand for food could not be supplied by organic systems.

Optimizing the efficiency of an integrated weed management program requires the ability to predict the independent and interactive effects of management practices on crop and weed growth and competitive ability. Quantitative understanding is needed to improve predictive ability. Competition between crops and weeds has been studied by numerous authors and by us with most studies concentrating on the effects of single weed species (Skorda & Efthimiadis, 1985, 1989, Richards & Whystock, 1993). However, natural weed infestations usually contain many different species. The combined competitive effects of these infestations are important when considering weed management strategies. Wheat cultivars which are able to tolerate or compete strongly with weeds in combination with increased seed rates would make a significant contribution to productivity and yield stability on farmers fields as was shown from previous research for single weed competition. High vegetative vigor and tall stature were found to be major factors influencing the competitive ability of wheat plants with weeds (Skorda & Efthimiadis, 1985, 1989, Lemerle *et al.*, 1996, Grundy *et al.*, 1993).

The objectives of the present study were to identify wheat cultivars (sown at different seed rate) which can compete with a mixture of weeds, and to determine significant characteristics of the wheat plant that contribute to competitiveness with weeds.

MATERIALS AND METHODS

Two similar field experiments were conducted for two consecutive years. A randomized split-plot design with six replications was used in each experiment. The field was naturally infested with a high population of wild oat (*Avena ludoviciana*), ryegrass (*Lolium rigidum*) and broad-leaved weeds (*Veronica spp.*, *Papaver rhoeas*, *Matricaria chamomilla* and others).

Two wheat cultivars (*Triticum aestivum* L.) were selected based on their different morphological and agronomic traits: Yecora a semi-dwarf cv, and Yupateco, a tall cv. They were studied at five targeted seed rates: 120, 150, 180, 210 and 240 kg ha^{-1}. Cultivars were the main plots, seed rates and weed control treatments were the sub plots. The split-plot consisted of 10 rows, 8.2 m long with 20 cm spacing. Half of each seed rate plot was treated with herbicide and the remaining plot was left for natural infestation by the weeds. Seeding was done by hand in furrows opened by a small tractor. Nitrogen (N) and phosphorous (P_2O_2) were applied before seeding at rates of 100 and 40 kg ha^{-1} respectively, and 60 kg ha^{-1} of nitrogen was applied as top dressing at tillering. On the day of seeding, the plots were rototilled and the fertilizer was broadcasted and incorporated. Dichlofop-methyl was applied at the recommended rate of 800 kg ha^{-1} at the two to three leaf stage to control grass weeds. 2,4D was used later on March to control broad-leaved weeds. A propane-pressurized sprayer with a 2m boom was used to apply the herbicides. Barriers constructed by plastic sheets were inserted at the sides of sprayed plots to prevent spray drift.

Wheat seedlings were counted in two quadrates each 0.5 m^2 placed at random in each replicate. The wild oat and ryegrass seedlings as well as broad-leaved weeds, emerged during winter and early spring, were counted with the same manner. Shortly before the wheat harvest, the number of wheat spikes and plant height were recorded and weed plants were collected from two random quadrates each 0.5 m^2. Samples were separated by species and subsequently fresh and dry weight was recorded.

RESULTS

Wheat established well at the five seed rates even though the second year was unusually dry. The average densities of the seedling populations are presented in Table 1.

Weed seedlings emerged early, over a three-month period, except for some broad-leaved weeds which emerged in spring. The majority of weeds, more than 80%, emerged in autumn together with the wheat. The lower seed rates of both cultivars had the highest emerged grass weed populations whilst the number of broad-leaved seedlings were about similar at all seed rates.

Table 1. Number of wheat, wild oat, ryegrass and broad-leaved weed seedlings per m^2 before herbicide application

Seedrate kg ha^{-1}	cultivar	Wheat	Ryegrass	Wild oat	Broad-leaved
120	Yecora	295	34.8	52.0	27.0
	Yupateco	293	35.3	50.3	29.0
150	Yecora	369	32.3	42.5	26.0
	Yupateco	371	31.3	38.8	23.5
180	Yecora	433	31.8	33.3	27.5
	Yupateco	457	31.3	36.9	25.8
210	Yecora	519	23.5	33.9	23.5
	Yupateco	523	25.3	30.3	25.3
240	Yecora	563	25.8	28.8	18.8
	Yupateco	580	26.8	26.5	20.5

Table 2. Effect of seedrate on dry weight of wild oat (*A. ludoviciana*), ryegrass (*L. rigidum*) and total dry weight of weeds

Year	Cultivar	Treatment	*A. ludoviciana*			*L. rigidum*			Total weight of weeds		
			Seedrate (kg ha^{-1})								
			120	180	240	120	180	240	120	180	240
			Dry weight of weeds (g m^{-2})								
1st	Yecora	Unsprayed	383	228	167	371	206	122	754	434	289
		Sprayed	193	124	116	53	31	33	247	154	149
	Yupateco	Unsprayed	283	202	138	245	207	155	518	393	292
		Sprayed	73	68	64	43	43	36	116	111	101
2nd	Yecora	Usprayed	428	373	234	89	76	65	510	461	315
		Sprayed	264	218	149	27	20	28	291	241	181
	Yupateco	Unsprayed	344	260	285	68	65	37	424	343	333
		Sprayed	236	190	193	28	27	14	268	222	219

Dichlofop-methyl had no effect upon the wheat. This has been verified also in weed – free trials with these cultivars. Herbicide application gave satisfactory control of ryegrass at all seed rates whilst control of wild oat was less satisfactory (Table 2). The wild oat dry weight reduction after chemical control was varied over the range of wheat plant densities studied, from 28% to 50% for cv Yecora and from 48% to 74% for cv Yupateco, in the first year of experiment. In the second year, the recorded reductions were 33-42% and 26-43% for Yecora and Yupateco respectively. The corresponding reduction for ryegrass dry weight was within the ranges 73-86%, 77-82% in the first year and 57-74% and 51-62% in the second year.

With respect to interspecific competition, in the first year of experiment no difference between the biomass of the two grass species was noticed whilst in the second year wild oat gave the highest biomass followed by ryegrass. Broad-leaved weeds gave very low biomass. Wild oat and ryegrass biomass weight was decreased progressively from the lowest wheat plant density to the highest. Calculation of the two-year mean weed weight reveals that for both cultivars the wild oat dry weight was about 50% less at the highest seed rate than at the lowest one. Exception to this trend was observed in the second year of the experiment in which cv Yupateco at the highest seed rate had relatively high weed weights due to lodging.

There were significant differences in weed biomass between varieties. Yupateco had lower weed weights than Yecora. This variety showed rapid vegetative growth (seedling vigor), had large numbers of tillers, and was nearly 20cm higher than Yecora. In the first year Yupateco had lower grass weed weights than Yecora at all seed rates. In contrast Yecora competed with the weeds better at the higher seed rates than at the lower ones.

Specifically the weed dry matter at the highest seed rate was reduced by 62% compared to that at the lowest seed rate. In the second year cv Yupateco has been shown to be again more competitive with the grass weeds, mainly with wild oat, than cv Yecora. Yupateco had significantly lower wild oat dry weight at all seed rates in comparison with Yecora. The only exception was observed at the highest seed rate because of lodging as mentioned above. The total weed biomass was also lower in the plots of Yupateco than in the plots of Yecora. The broad-leaved weeds were extremely suppressed by grass weeds and as a consequence they did not change the overall trends. The difference in the total dry weight of weeds between the two varieties was also clear after chemical weed control. Consequently Yupateco suppressed the growth of the weeds more than Yecora at all seed rates in both years of the experiment.

DISCUSSION

This work investigated the interspecies competition between wheat and multiple weed species. In the first year ryegrass and wild oat gave approximately equal biomass weight whilst in the dry year wild oat biomass was higher. Apparently the wild oat, in combination with the crop susceptibility to drought stress, was more competitive than ryegrass and wheat as the low grain yield of this year reveals. Grass weeds competed very strongly against the broad-leaved weeds, which emerged in relatively high numbers, but their biomass was very low in comparison with that of ryegrass and wild oat.

Both grass weeds emerged early with the crop. Consequently, they may be more competitive compared with those that emerged later (as most broad-leaved weeds did) when the crop was well established (Peters, 1984). The early emergence allowed grass weeds to compete with the wheat crop from the early stages in the growth season. It is noted that grass weeds are particularly aggressive weeds in crops. Yield reduction due to weed mixtures was only slightly lower or equal than that due to single species. Alex (1970) and Skorda & Efthimiadis (1989) reported that the competitive effects of weed species on wheat crop were not fully additive because the effects of one species tended to obscure the effects of the other. With later competing weed species such as *P. rhoeas* predictions based on early spring biomass may produce underestimates in weed competitiveness and consequently incorrect estimation on final yield losses.

The results of this study also confirm the effect of crop density on weed growth expressed as a reduction of the dry matter accumulation. Skorda & Efthimiadis (1985, 1989) and Wilson *et al.*, (1995) reported similar effects caused by dense and more uniform crop canopy. This is confirmed by the case of Yupateco at the 240 kg ha^{-1} seed rate, which caused lodging in the second year leading to high weed biomass. The high weed biomass did not affect grain yield because the lodging occurred late in the season when grain filling had been completed. Early work on the chemical control of *A. ludoviciana* indicated that the level of infestation depended upon crop competition (Skorda, 1974). Higher rates of herbicide were needed in a thin rather than in a dense highly competitive crop to reduce the wild oat population to a given level.

The wheat cultivars tested differed substantially in their ability to suppress weed growth. Yupateco suppressed weeds better than Yecora. The former is characterized by vigorous early growth, high tiller and spike number and is taller than the latter. The early establishment of a closed crop canopy limits the growth of weeds and the late germination of weed seeds.

Tiller production is an important characteristic in many low input situations. Tillering enables the wheat plant to adapt to variable plant population in the crop area, a situation common in the field where plant establishment can be non-uniform. The ability to tiller early facilitates rapid ground cover, while late tillering enables the crop to recover after a late weeding. In our experiments Yecora had less ability to tiller than Yupateco. There was also a negative correlation between weed biomass and spike number during the vegetative stage. Others have suggested that tiller number is not necessarily an important factor in determining competitiveness with weeds (Kawano *et al.*, 1974). Perera *et al.* (1992) suggested that root competition may be more important than shoot competition, particularly in the early stages of the crop.

Many other workers have also reported that the effect of weed competition on grain yield of cereals is mainly through reduction in the number of effective tillers (Walia & Brar, 1996). It is also widely accepted that in cereals yield depends on number of fertile spikes per unit area, on number of kernels per spike and on kernel weight. The factor fertile spikes per plant seems to be of minor significance (Liakopoulou – Grivakou *et al.*, 1990). Further studies are required on root development patterns, growth rate, and possibly on allelopathy to determine the importance of below ground competition with weeds.

The development of cultivars with ability to compete successfully with weeds would significantly enhance plant yield stability under extensive, low input conditions common for sustainable agriculture. To determine an "optimum plant type" for poor weed control conditions, future studies should focus on the major morphological characteristics that determine weed competitiveness and the extent to which yield potential may be sacrificed by the incorporation of weed competitiveness traits.

REFERENCES

Alex J F (1970). Competition of *Saponaria vaccaria* and *Sinapis arvensis* in wheat. *Canadian Journal of Plant Science* **50**, 379-388.

Grundy A C; Froud-Williams R J; Boatman N D (1993). The use of cultivar, crop seed rate and nitrogen level for the suppression of weeds in winter wheat. *Crop Protection Conference-Weeds* Brighton 1993, **3**, 997-1002.

Kawano K; Gonzalez H; Lucena M (1974). Intraspecific competition, competition with weeds and spacing response in rice. *Crop Science* **14**, 841-845.

Lemerle D; Verbleek B; Cousens R D; Coombes N E (1996). The potential for selecting wheat varieties strongly competitive against weeds. *Weed Research* **36**, 505-513.

Liakopoulou-Grivakou P; Kyzeridis N; Kartitsi E (1998). Effect of planting density on durum wheat yield components. *Proc. of 7th National conference of the Hellenic Society of Genetic Plant Breeding*, Crete, Greece.

Perera K K; Ayers P G; Gunasena H P M (1992). Root growth and the relative importance of root and shoot competition in interaction between rice (*Orysa sativa*) and *Echinochloa crus-galli*. *Weed Research*, **32**, 67-76.

Peters N C B (1984). Time of onset of competition and effects of various fractions of an *Avena fatua L*. population on spring barley. *Weed Research* **24**, 305-315.

Richards M C; Whytock G P (1993). Varietal competitiveness with weeds. *Aspects of Applied Biology*, **40**, 345-354.

Skorda E A (1974). Control of wild oat with new chemicals in wheat and barley. *Proc. 12th British Weed Control Conference* **3**, 901-912.

Skorda E A; Efthimiadis P (1985). Effect of wheat seed rate on *Avena ludoviciana* competition 1985. *British Crop Protection Conference-Weed* **2**, 709-714.

Skorda E A; Efthimiadis P (1989). Effect of wheat seed rate on *Lolium rigidum* competition. *Brinhton Crop Protection Conference-Weed* **1**, 399-404.

Walia U S; Brar L S (1996). Performance of new herbicides for controlling wild canary grass (*Phalaris minor*) in wheat. *Indian Journal of Weed Science*. **28**, 69-72.

Wilson B J; Wright K J; Clements M; Stephens E (1995). Predicting the competitive effects of weed and crop density on weed biomass, weed seed production and crop yield in wheat. *Weed Research* **35**, 265-278.

Development of a pheromone trap for monitoring the orange wheat blossom midge (*Sitodiplosis mosellana*)

J N Oakley, G E Talbot
ADAS Rosemaund, Preston Wynne, Hereford, HR1 3PG, UK
Email: Jon.Oakley@adas.co.uk

T J A Bruce, L E Smart, L J Wadhams, A.H. Hooper
Rothamsted Research, Harpenden, Hertfordshire, AL5 2JQ, UK

O T Jones, E D Casagrande, N J Brown
AgriSense BSC Ltd, Unit 1, Taffs Mead Road, Treforest Industrial Estate, Pontypridd, Mid Glamorgan, CF37 5SU, UK

ABSTRACT

An improved pheromone trap has been developed to catch, selectively, male orange wheat blossom midge, *Sitodiplosis mosellana*, and to allow for the quantification of risk in UK agriculture. This paper describes development of the trap and identification of the optimum pheromone formulation, release mechanism and rate. Initial testing of the traps on a farm scale is leading to recommendations for use of these traps to estimate risk.

INTRODUCTION

The orange wheat blossom midge (*Sitodiplosis mosellana*) (owbm) has continued to increase in importance across the wheat growing areas of the Northern Hemisphere. In the UK, outbreaks have caused particular concern, with over 500,000 ha being sprayed against this pest in 2004. Much of this insecticide usage may be unnecessary, or mistimed, due to difficulties in identifying which fields are at risk in time for treatment to be applied. These difficulties arise from local variations in hatch and the timing of flight, with midges migrating into crops in the evening and laying their eggs throughout the night. Forecasting systems in the UK rely on the monitoring of pupation, giving some warning of when hatch may occur (Oakley *et al.* 1998), with field-by-field decision-making relying on direct observation and the use of yellow sticky traps (Oakley & Smart, 2002). The owbm sex pheromone, 2,7-nonadiyl dibutyrate, was identified by Gries *et al.* (2000). This paper describes the development of a trap suitable for monitoring owbm populations in the UK.

MATERIALS AND METHODS

Field experiments

2,7-Nonadiyl dibutyrate was made racemically, using a strategy based on the methodology described by Gries *et al.* (2000). Different formulations of *S. mosellana* sex pheromone were used in field trials conducted at Rothamsted Research, Herts, UK, to determine optimum pheromone loading and formulation. Formulations were tested in AgriSense Delta traps, which contained a removable sticky insert on which owbm were caught. In the first experiment, three contained a removable sticky insert on which owbm were caught. In the first experiment, three different loadings of the pheromone (10mg, 5mg and 1mg) were tested in polyethylene vials (Fisons: WP/5). From these results, the 5mg loading was thereafter used as the standard formulation and was also used in test marketing of the trap in 2004. Feedback data on the efficacy were collected from 137 participating farmers. In a second series of experiments, rubber septa (Aldrich Z10,072-2) formulations (5mg and 1mg loadings), more amenable to commercial production, were also evaluated in comparison with the standard 5mg polyethylene vial. In addition, lures and traps obtained from Phero Tech in Canada were also tested and compared with the standard lure and AgriSense Delta traps under UK conditions.

Farm-scale study

In 2005, as part of a larger calibration study, commercial pheromone traps (1mg rubber septa formulation) were tested at ADAS Boxworth. Two pheromone traps were placed in each of 24 fields alongside two yellow sticky traps with 5 m between each trap. Traps were changed daily, from the first catch of more than 20 owbm to the completion of the susceptible ear emergence stage on all the wheat crops in the study area.

RESULTS

Comparison of 10, 5 and 1mg loadings in polythene vials (Figure 1) showed that there was no significant difference between catches with 10 and 5mg loadings, but that the 1mg loading was too low. Comparison with Phero Tech lures and traps (Figure 2) indicated that the AgriSense Delta trap caught significantly more males than the Phero Tech trap. In addition, comparison of the 5mg loading polyethylene vial with the Phero Tech lure showed the latter to be less effective with either trap. Rubber septum lures were as effective as the standard polythene vials (Figure 3).

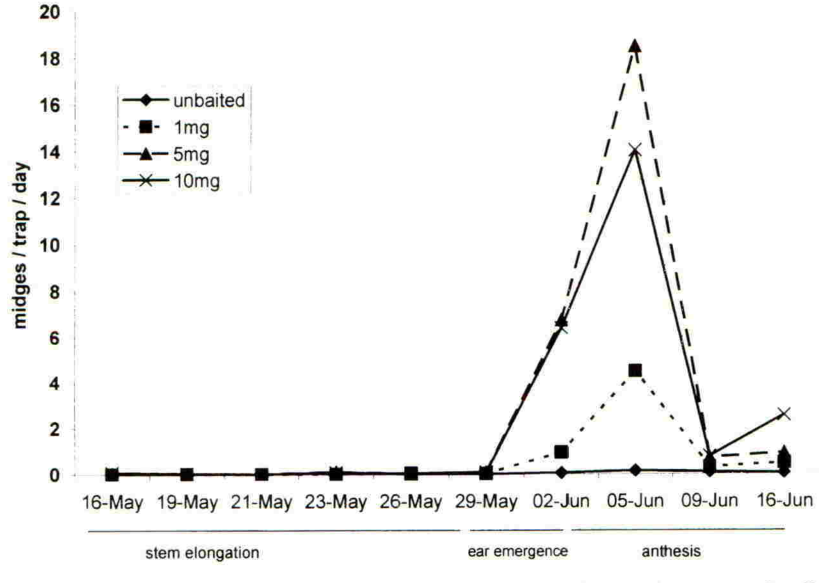


Figure 1. Comparison of polyethylene vials with different pheromone loadings (2003)

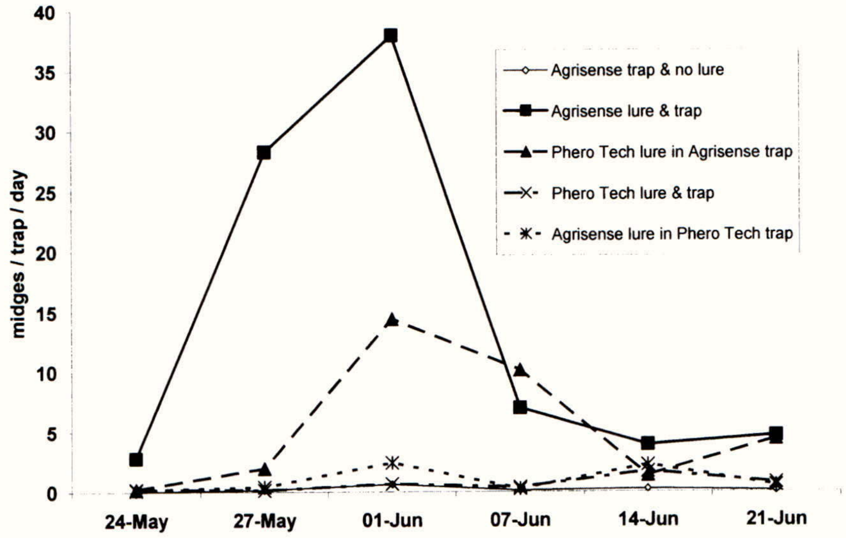


Figure 2. Comparison with Phero Tech traps and lures (2003)

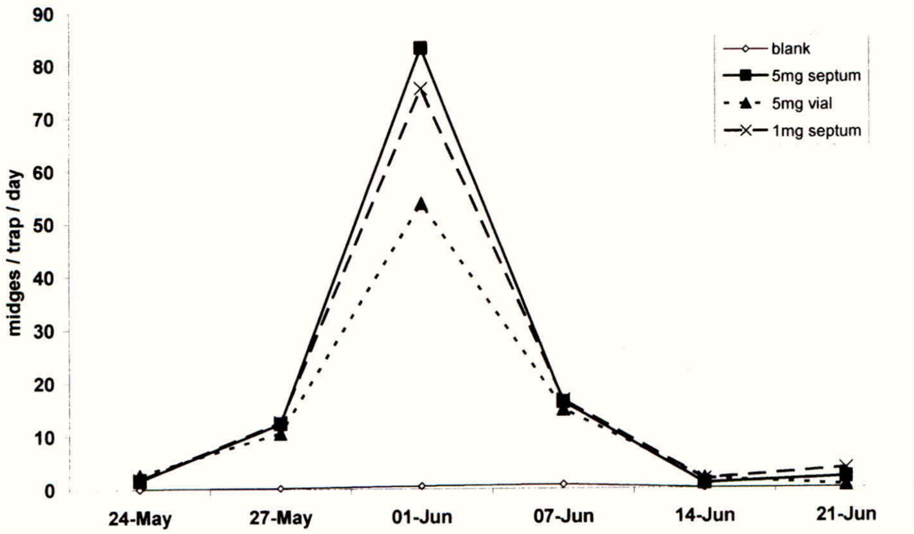


Figure 3. Comparison of polyethylene vial and rubber septum formulations (2004)

In the farm scale study in 2005, pheromone traps caught a higher proportion of emerging male owbm earlier in the season in beans and set-aside than under wheat (Figure 4). These early catches did not result in similar levels of female activity (monitored by yellow sticky traps) in wheat crops, as the weather conditions were unsuitable for migration (Figure 5). The greatest numbers of female owbm were caught on 6 and 9 June, when temperatures at dusk exceeded the flight threshold of 15°C (Pivnik & Labbé, 1993). The maximum catch over two nights, within fields of susceptible wheat varieties, gave a very good prediction of the eventual infestation of percentage attacked grain = 0.512 + (0.0746 x maximum two night catch) (R^2 = 85.1%, p >0.001, 7 d.f.).

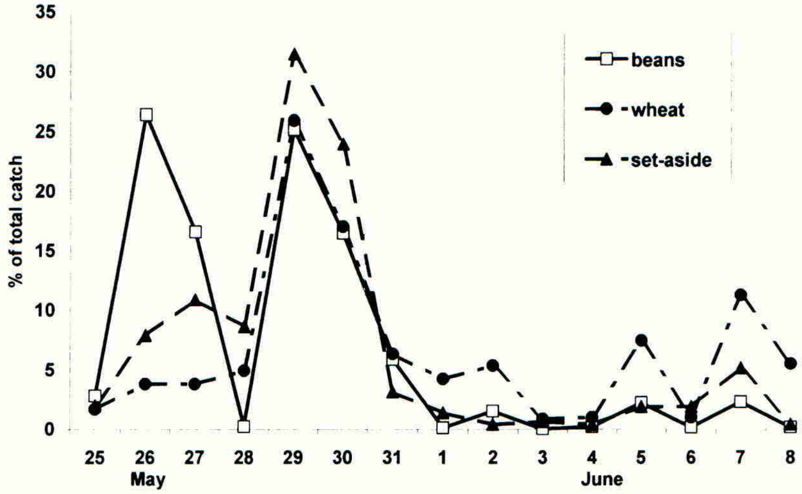


Figure 4. The proportion of the total catch of owbm caught on different days on pheromone traps placed in different crops through the emergence period.

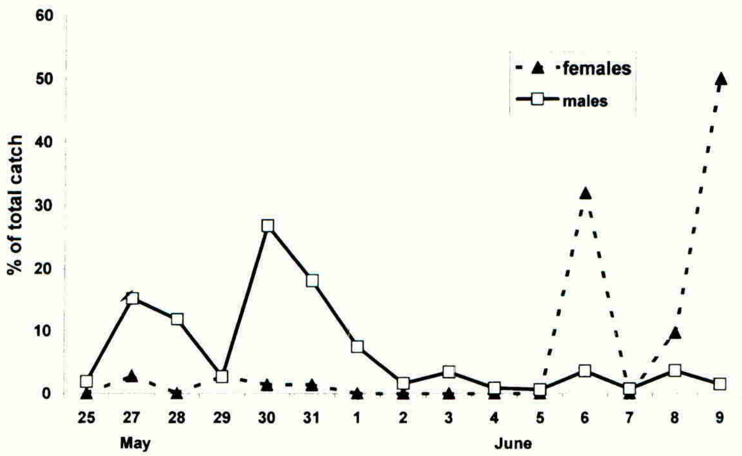


Figure 5. The proportion of male owbm caught on pheromone traps across the Boxworth farm compared to females caught on yellow sticky traps placed in wheat fields

DISCUSSION

Considerable progress has been made towards the development of a monitoring system for male owbm and the optimum pheromone release rate and methodology have been established. The trap is now commercially available and demand for it from UK wheat growers has been high. The pheromone, 2,7-nonadiyl dibutyrate (Gries et al., 2000), performed well for indicating the onset of owbm flight activity in the vicinity of wheat fields. Several different pheromone formulations were tested. The most effective were the 5mg loading in polyethylene vial and the 1mg loading in rubber septum. Release rate from the rubber septum formulation was only 26ng/day. Other formulations with higher release rates did not give more accurate information on the timing of owbm flight activity. As rubber septa are easier to mass produce, this formulation was used for commercial production. For UK agriculture, the higher trap catch achieved with the AgriSense trap/lure provided the necessary sensitivity to assess owmb risk to individual cereal fields. However, it should be noted that, whilst trials in 2004 with these traps, incorporating a brown sticky insert, caught negligible numbers of non-target insects, use of a white insert in 2005 resulted in significant contamination of trap catch. Thus, further work is required to investigate these pheromone visual cue interactions.

The male owbm caught by pheromone traps are flying in search of mates. This flight is relatively short-range and restricted to the emergence site. Following mating, female owbm fly to lay their eggs in host crops on the following five suitable nights. Crops at risk from oviposition are those in the ear emergence stages. Activity may be suspended for several days if the conditions for flight are unsuitable (Pivnik & Labbé, 1993). Short-range egg laying flights can occur under quite marginal conditions for flight, when female owbm resident in the crop are likely to be the sole threat. Numbers may, however, be building in other fields previously cropped with wheat and these insects will fly to the crop if and when conditions become optimal. Should the cultivation and cropping in these fields lead to warmer and/or wetter soil conditions, the hatch in these fields may occur earlier than under the cover of a winter wheat crop (Oakley *et al.*, 1998; 2005).

Ideally, traps would be placed to cover both these risks, with traps located in second wheat crops, to monitor the risk from resident populations, and some in other situations to guard against the risk of migration from earlier, localised hatches. A threshold catch of 20-30 over two nights, has been proposed, which during the ear emergence period within a wheat crop would indicate an immediate risk to that crop. A higher threshold number of 60 owbm over two nights could have been used at Boxworth in 2005, when weather conditions were only marginally suitable for flight and the impact of migrations from other fields was low. Further research is underway to determine the efficiency with which female owbm select susceptible crops, to determine whether a different threshold value should be assigned to catches in adjoining fields and how this should be related to flight conditions.

Due to the complex nature of the biology of the pest, a decision support system is likely to be required taking into account trap catches of male owbm, the suitability of conditions for flight within and between fields, crop growth stage and the inherent susceptibility of different varieties of wheat.

A test marketing exercise was conducted in 2004, with questionnaires returned from 137 users. The response was very positive, with 93 % of users finding the traps a useful aid to decision making. Various useful suggestions were made which were incorporated into the system for the 2005 season. A very positive response has been received following the first commercial year in 2005, with the traps giving farmers and agronomists the confidence to avoid unnecessary treatment and improve the targeting of that which is necessary.

ACKNOWLEDGEMENTS

The work reported here was funded by the Sustainable Arable LINK Programme of Defra and the Home-Grown Cereals Authority. We thank the other partners in the LINK projects, Advanta UK Ltd, Dow AgroScience Ltd, Elsoms Seeds Ltd, John Innes Centre, Nickersons UK Ltd and The Arable Group for their advice and support. Rothamsted receives grant aided support from the BBSRC.

REFERENCES

Gries R; Gries G; Khaskin G; King S; Olfert O; Kaminski L-A; Lamb R; Bennett R (2000) Sex pheromone of orange wheat blossom midge, *Sitodiplosis mosellana*. *Naturwissenschaften*, **87**: 450-454

Oakley J N; Cumbleton P C; Corbett S J; Saunders P; Green D I; Young J E B; Rogers R (1998). Prediction of wheat blossom midge activity and risk of damage. *Crop Protection* **17**, 145-149.

Oakley J N; Smart L E (2002). The use of baited and unbaited traps to monitor the orange wheat blossom midge *Sitodiplosis mosellana* and its parasitoid *Macroglens penetrans*. *The BCPC Conference – Pests and Diseases 2002*, 665-670.

Oakley J N; Talbot G; Dyer C; Self M M; Freer J B S; Angus W J; Barrett J M; Feuerhelm D; Snape J; Sayers L; Bruce T J A; Smart L E; Wadhams L J (2005) *Integrated control of wheat blossom midge: variety choice, use of pheromone traps and treatment thresholds.* Home-Grown Cereals Authority: London.

Pivnick K A; Labbé, E (1993) Daily patterns of activity of the Orange Wheat Blossom Midge, Sitodiplosis-Mosellana (Gehin) (Diptera, Cecidomyiidae). *Canadian Entomologist* **125**: 725-736

Are soil migratory nematode populations increasing? Implications for nematode management in crops

K A Evans
Crop & Soil Research Group, SAC, West Mains Road, Edinburgh EH9 3JG, UK
Email: andy.evans@sac.ac.uk

K Stanley, A Blackwell
APS Advanced Pest Solutions Ltd., Darwin Building, King's Buildings, Edinburgh EH9 3JR, UK

ABSTRACT

Migratory nematodes in soil cause significant damage to a range of crops such as potatoes, carrots, cereals, as well as being vectors of virus diseases such as tobacco rattle virus in potatoes. This paper reviews the changes in Scottish population levels of several plant pathogenic nematode species over the last 11 seasons and how this has impacted on the management of nematodes in several crops. The introduction of a diagnostic test for detecting tobacco rattle virus (the causative agent of spraing in potatoes) in trichodorid nematodes has allowed an initial snapshot to be obtained of the prevalence of the virus in fields used for potato production in Scotland. The implications of virus incidence for the management of spraing in potatoes is discussed, along with current and future management options for other soil migratory nematodes.

INTRODUCTION

Migratory nematodes in soil are a worldwide problem; many are vectors for viruses as well as causing direct damage through their feeding (Whitehead, 1998). All crops are susceptible to feeding damage by nematodes; their impact on yield increasing with the numbers of nematodes present (Whitehead, 1998). However, the role of migratory nematodes as virus vectors is not necessarily reliant on the numbers of nematodes present – low populations of viruliferous nematodes can cause significant problems in crops.

Until recently, it was not possible to routinely test nematodes for their viruliferous state. In the season 2004/2005 SAC introduced a diagnostic test that identifies whether Trichodorid nematodes are carrying tobacco rattle virus (TRV), the cause of the disorder known as 'spraing' in potatoes.

There have been significant changes in the application of insecticides (which may have some activity against nematodes) and nematicides to soil over the last decade. Several soil applied active ingredients such as carbofuran, lindane, carbosulfan, dibromochloropropane, and methyl bromide have been withdrawn or their use severely curtailed, and currently available nematicides such as aldicarb, fosthiazate, oxamyl and ethoprophos are under the spotlight or face restrictions in their future use.

Has the reduction in soil applied pesticides had an impact on the populations of soil migratory nematodes over the last 10 years? The results of nematode population counts from Scottish fields used for potato and carrot growing have been collated for the last eleven seasons to assess whether populations of Trichodorid, Longidorid and Pratylenchid nematodes have altered significantly.

MATERIALS AND METHODS

Nematodes were extracted from Scottish soil samples submitted to SAC by growers, SAC advisers, and independent consultants. Only results from fields tested for potatoes (Longidorid and Trichodorids) and carrots (Longidorids, Trichodorids and Pratylenchids) were included in this survey.

Nematodes were extracted using a Baermann funnel method, where nematode motility is used to separate them from soil samples washed through sieves (Hooper, 1986). Primarily *Trichodorus primitivus, Longidorus elongatus* and *Pratylenchus penetrans* were extracted from soil samples. For ease of analysis, the results are expressed as all Longidorids, Trichodorids and Pratylenchids. Nematode results from 1994/1995 (September-May) to 2004/2005 were collated and expressed as mean numbers of nematodes in 250g soil for each season.

For the 2004/2005 season, growers who requested a test for the presence of TRV, the causative agent of 'spraing' in potatoes, had nematodes tested for the presence of the virus. This test was available with a nematode count (TRV Level 1) or without a nematode count (TRV Level 2). RNA was extracted from individual nematode samples using the Qiagen RNeasy mini kit following the manufacturers' protocol of the isolation of total RNA from animal tissues. Each sample was then tested for the presence of TRV using a one-step Quantitative RT-PCR reaction using a published primer/probe combination specific for TRV (Mumford *et al.*, 2000). This was carried out using the Quantitect Probe RT-PCR kit (Qiagen) following the manufacturers reaction and cycling conditions. Each individual nematode sample was tested in triplicate, against positive control TRV RNA. Presence of TRV was scored on a positive/negative basis as compared to negative control reactions.

RESULTS

Migratory nematode populations

The numbers of soil samples submitted for nematode population counts rose significantly over the last decade:

- From 13 samples for Pratylenchid nematodes in carrots in 1994/95 to a peak of 92 in 1997/1998, with 82 in 2004/2005.

- From 90 samples for Longidorid and Tricodorid nematodes in 1994/1995 to a peak of 607 in 1998/1999, with 456 in 2004/2005.

The mean numbers of nematodes in each sample (expressed as No./250 g soil) for each season from 1994/1995 to 2004/2005 are illustrated in Fig. 1.

Populations of Trichodorid nematodes increase significantly year on year from 1994/1995 to 1998/1999 (Fig. 1). There is a significant drop in Trichodorid populations from 1999/2000 to 2000/2001, with a steady rise again to the present day (Fig. 1).

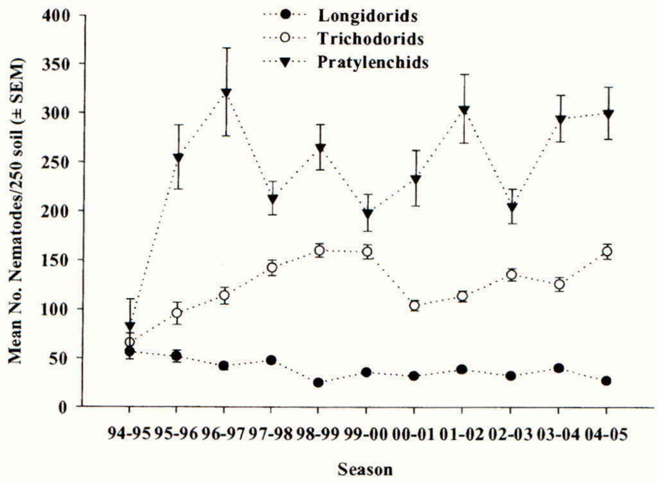


Figure 1. Mean populations (nematodes/250g soil ± SEM) of Longidorid, Trichodorid and Pratylenchid nematodes from 1994/1995 to 2004/2005 seasons

Longidorid populations show a gradual decline over the years from 1994/1995 to the present day (Fig. 1).

Pratylenchid populations have increased significantly since 1994/1995 (Fig. 1), with mean populations following a cyclical increase and decrease every 2-3 years.

In several seasons, there is a significant positive linear correlation between Longidorid, Trichodorid and Pratylenchid populations in individual fields (Table 1). In 4 out of 11 seasons, there is a significant correlation between Longidorid and Pratylenchid populations and Trichodorid and Pratylenchid populations, and in 6 out of 11 seasons a significant correlation between Longidorid and Trichodorid populations (Table 1).

Table 1. Correlation* of Longidorid, Trichodorid and Pratylenchid populations in individual fields from 1994/1995 to 2004/2005

Season	Longidorids x Pratylenchids		Trichodorids x Pratylenchids		Longidorids x Trichodorids	
	R Square	P	R Square	P	R Square	P
1994/1995	**58.4**	**0.002**	0	0.974	0.3	0.607
1995/1996	0.5	0.667	9.2	0.082	**8**	**0.001**
1996/1997	**15.3**	**0.005**	**19.0**	**0.001**	1.3	0.081
1997/1998	0.8	0.407	1.4	0.259	**7.2**	**0.001**
1998/1999	1.4	0.347	2.1	0.255	0.4	0.101
1999/2000	3.1	0.273	**10.3**	**0.019**	**3.6**	**0.001**
2000/2001	2.5	0.384	1.5	0.508	**5.6**	**0.001**
2001/2002	0.9	0.394	**4.7**	**0.049**	0	0.816
2002/2003	0.1	0.783	3.1	0.114	**1.0**	**0.025**
2003/2004	**5.1**	**0.017**	**9.5**	**0.001**	**1.3**	**0.015**
2004/2005	**8.1**	**0.009**	1.8	0.229	0.1	0.464

* Significant correlations are highlighted in bold

The percentage of nematode populations that exceed direct feeding damage thresholds are shown in Table 2.

For Longidorids, populations above 25 nematodes/250g soil are considered to be potentially damaging to root crops such as potatoes and carrots (ADAS, 1990). Between 1994/1995 and 2004/2005 Longidorid populations were potentially damaging in 28-53% of fields sampled (Table 2).

For Trichodorids, populations above 100 nematodes/250g soil are considered to be potentially damaging to root crops such as potatoes and carrots (ADAS, 1990). Between 1994/1995 and 2004/2005 Trichodorid populations were potentially damaging in 21-52% of fields sampled (Table 2).

For Pratylenchids, populations above 100 nematodes/250g soil are considered to be potentially damaging to carrots (ADAS, 1990, Potter and Olthof, 1993). Between 1994/1995 and 2004/2005 Pratylenchid populations were potentially damaging in 23-86% of fields sampled (Table 2).

Table 2. Percentage of nematode populations within 3 population categories

	% of Nematode counts (in 250 g/soil) within each population category								
	Longidorids			**Trichodorids**			**Pratylenchids**		
	Population categories (e.g. 0-24 in 250 g/soil)								
Year	0-24	**25-99***	**100+**	0-99	**100-199**	**>200**	0-99	**100-199**	**>200**
94-95	47	**37**	**16**	79	**10**	**11**	77	**8**	**15**
95-96	56	**28**	**16**	71	**16**	**13**	26	**21**	**53**
96-97	51	**37**	**12**	59	**20**	**21**	29	**14**	**57**
97-98	54	**32**	**14**	58	**17**	**25**	29	**29**	**42**
98-99	72	**22**	**6**	48	**23**	**29**	14	**34**	**52**
99-00	62	**27**	**11**	49	**19**	**32**	23	**45**	**32**
00-01	64	**28**	**8**	62	**21**	**17**	31	**17**	**52**
01-02	63	**26**	**11**	61	**19**	**20**	24	**27**	**49**
02-03	65	**26**	**9**	56	**18**	**26**	33	**21**	**46**
03-04	58	**31**	**11**	61	**17**	**22**	18	**25**	**57**
04-05	69	**24**	**7**	49	**19**	**32**	16	**21**	**63**

* Categories in bold signify percentage of samples with potentially damaging levels of nematodes.

Tobacco rattle virus (TRV)

Of the 311 Scottish soil samples that were tested for TRV in 2004/2005, 92 (29.6%) were positive for the presence of TRV.

DISCUSSION

Trichodorid and Pratylenchid nematode populations have risen significantly over the last 11 years. This is reflected in an increase in the amount of nematicides being applied to Scottish potato and carrots crops over this period (Snowden & Thomas, 2003, Struthers & Snowden, 2004). Whilst nematicide use against migratory nematodes in potatoes is primarily for the protection of the crop from Trichodorid vectored TRV, there is an added benefit in the protection of the crop from the increased threat of direct feeding damage from Trichodorid and Longidorid nematodes (Table 2).

The threat of damage by Pratylenchids to potatoes is not routinely tested for in the UK. Yield loss in potatoes has been noted at population levels as low as 25 nematodes/250g soil (Olthof, 1987), which is a quarter of the lowest mean population level of Pratylenchids seen in Scottish soils (Fig. 1). Whilst these populations of Pratylenchids have been recorded from fields specifically destined for carrots, such high populations could have a significant impact on any potato crops grown in the rotation. In addition, *P. penetrans* interacts synergistically with *Verticillium dahliae* (Verticillium wilt) to further reduce potato growth and yield (Saeed *et al.*, 1998). This synergistic interaction between *P. penetrans and V. dahliae* reduces the density of *P. penetrans* required to cause economic potato yield losses (Wheeler *et al.*, 1992).

Just over a quarter of the Scottish fields tested for TRV came back as positive for the virus. Preventing TRV infection of tubers is the primary use of nematicides (outside of management of potato cyst nematode, *Globodera spp.*) in Scottish potato crops, and many crops may have been receiving nematicides unnecessarily as the definitive detection of TRV presence has only been available for the last year. However, this use of nematicides may well have limited the direct feeding damage caused by Trichodorids, Longidorids and Pratylenchids, as well as the prevalence of verticillium wilt disease in potatoes.

Nematode populations in Scottish soils are a cause for concern, due to the potential damage they can cause in carrots and potatoes. Subsequent impacts on other crops in the rotation are also being noticed; one severely stunted crop of winter wheat in 2005 had Trichodorid counts of 3,200/250g soil and Longidorid counts of 290/250g soil.

ACKNOWLEDGEMENTS

We would like to thank growers, SAC advisers and independent consultants for submitting soil samples to SAC for nematode testing, and SAC technical staff for nematode extraction and identification.

REFERENCES

ADAS (1990). *Treatment Thresholds in Entomology*.

Mumford R A; Walsh K; Barker I; Boonham N (2000). Detection of Potato mop top virus and Tobacco rattle virus using a multiplex real-time fluorescent reverse-transcription polymerase chain reaction assay. *Phytopathology* **90**, 448-453.

Hooper, D J (1986). Extraction of free-living stages from soil. In: *Laboratory Methods for Work with Plant and Soil Nematodes*, ed. J F Southey, pp. 5-30. Reference Book 402. MAFF.

Olthof T H A (1987). Effects of fumigants and systemic pesticides on *Pratylenchus penetrans* and potato yield. *Journal of Nematology* **19**, 424–430.

Saeed, I A M; MacGuidwin A E; Rouse D I (1998). Effect of initial nematode population density on the interaction of *Pratylenchus penetrans* and *Verticillium dahliae* on 'Russet Burbank' potato. *Journal of Nematology* **30**, 100–107.

Snowden, J P; Thomas, L A (2003). *Pesticide Usage in Scotland, Arable Crops 2002*; SEERAD, Edinburgh 2003.

Struthers, G; Snowden, J P (2004). *Pesticide Usage in Scotland, Vegetables for Human Consumption 2003*; SEERAD, Edinburgh 2004.

Wheeler T A; Madden L V; Riedel R M; Rowe R C (1992). Modeling of yield loss in potato early dying caused by *Pratylenchus penetrans* and *Verticillium dahliae*. *Journal of Nematology* **24**, 99–102.

Whitehead A G (1998). *Plant Nematode Control*. CAB International: Wallingford.

Control of *Alternaria* spp. in European potato crops using zoxamide + mancozeb

J Edmonds
Dow AgroSciences Ltd, Latchmore Court, Hitchin, Hertfordshire, SG5 1NH, UK

ABSTRACT

Zoxamide + mancozeb is a well-known fungicide used in Europe to control Late Blight *(Phytophthora infestans)* in potato. In the last few seasons *Alternaria solani* and *Alternaria alternata* has become almost as devastating a disease in some key potato growing regions in Europe as Late Blight. Laboratory and field studies indicate synergy between Zoxamide and Mancozeb showing better than predicted levels of disease control compared to the higher registered rate of Mancozeb alone. The paper is a study of field trials in the last three seasons aimed at identifying the *Alternaria* species present and controlling it in European potato crops, and to investigate various products and control strategies for this disease.

INTRODUCTION

In the last few seasons *Alternaria solani* and *Alternaria alternata* have become almost as devastating a disease in some key potato growing regions in Europe as Potato Late Blight. The range of fungicides used to control Late Blight show varying levels of control of *Alternaria* diseases and there is increasing need for potato fungicides to be effective on both *Alternaria* and *Phytophthora* diseases (Rotem, 1998).

MATERIALS AND METHODS

Field trials were conducted in the most relevant countries from 2001 to 2004 on susceptible potato varieties, normally either in commercial field crops or at research stations. All trials were planned to be carried out to EPPO standard guidelines for efficacy field trials in potato. Where this was not possible then the standard technique employed by that organisation was used to conduct the field trial. The comparison fungicides used in the field trials were commonly used for late blight control. Trial plots were sprayed using standard equipment and operating procedures as in the guidance of the organisation conducting field trial.

RESULTS

The results below are shown as field trial results conducted in various European countries where Alternaria is now a problem in commercial potato crops.

Denmark Efficacy. The data summary below is from one trial conducted by the Danish Institute of Agricultural Science, Denmark. The objective was to compare *Alternaria* control of various potato fungicides used for the control of late blight. The trial was set up in accordance with current DIAS guidelines for Potato Fungicide field trials.

Table 1. The *Alternaria* disease infection from one field trial in Denmark in 2003

Product	Rate	25-7-03	11-8-03	18-8-03	26-8-03	AUDPC
Untreated		0	20	40	NA	NA
Fluazinam	0.4 litre/ha	0	2.2	8.3	NA	NA
Fluazinam plus famoxadone+cymoxanil	0.4 + 0.6	0.03	0.68	3.8	3.8	33.9
Mancozeb	1.6 kg/ha	0	0.5	2.1	2.5	21.7
Zoxamide+mancozeb	1.8 kg/ha	0	0.23	1.5	1.5	13.2

The zoxamide+mancozeb season long treatment gives consistently good control of *Alternaria* and a level of disease control superior to the all the commercial standards including mixtures with strobilurin based products.

Germany Efficacy: The data in Table 2 shows a summary from trials carried out in Germany in 2003, either contracted with Dr. Hans Hausladen at Munich University, or internal DAS field trials. The objective was to generate data with zoxamide + mancozeb compared to other fungicides in the control of *Alternaria*. The applications of the fungicide products were season long. In all trials, zoxamide+mancozeb was consistently superior to fluazinam and equal or better to the range of mancozeb containing competitor products tested. The curative activity seen with fenamidone (QoI mode of action) was considered different to the protectant mode of action known for zoxamide and mancozeb.

Table 2. Summary of the mean efficacy from the final assessment of three field trials against *Alternaria* in Germany in 2003

Treatment	final disease infection
Untreated	39%
Zoxamide+mancozeb	23.7%
Fenamidone+mancozeb	25.7%
Fluazinam	33.3%
Cyazofamid+adjuvant	34.3%

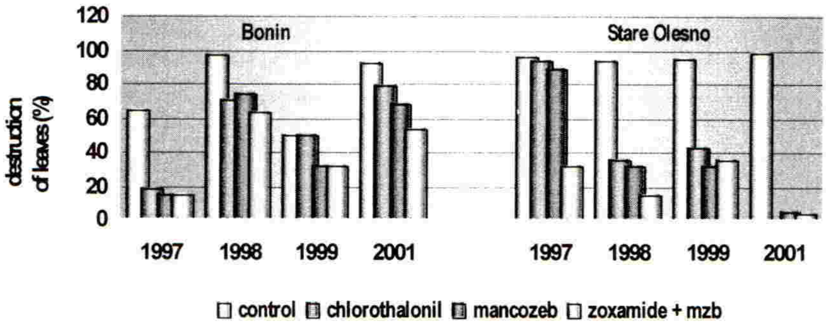
Table 3. The mean foliar infection of ALTESO on potato leaf, calculated as AUDPC (Area Under Disease Progress Curve) Calculation, 15-21 day infection period

Treatment	AUDPC (mean of 2 trials)
Untreated	22
Zoxamide+mancozeb	12
Fluazinam	19
Cyazofamid	19
Dimethomorph+mancozeb	12

Zoxamide + mancozeb and dimethomorph + mancozeb both gave a similar level of control but the other two fungicides gave very little control compared to the untreated levels of disease.

Poland Efficacy:

Table 4. Summary of efficacy from two trial sites in Poland from 1997 to 2001



The data summary above from Poland shows zoxamide + mancozeb consistently gave very good control of *Alternaria*, at least equal to and in most cases superior control compared to the other two commercial fungicides, both of which are registered in Poland for the control of *Alternaria.*

The Netherlands Efficacy: In Table 5 the results are presented of the effect of the fungicides on conidial germination of *A. solani.* It is clear that fluazinam, mancozeb and zoxamide+mancozeb had a strong effect on the germination of the conidia of *A. solani*. Only at 0.1% of the recommended label dose rate mancozeb is not able to restrain the germination of the conidia anymore.

Table 5. Germination of *A. solani* conidia on PDA medium mixed with fungicide concentrations at three assessment dates.

Concentration	100% Label dose rate			10% Label dose rate			1% Label dose rate			0,1% Label dose rate		
Fungicide	11/9	15/9	19/9	11/9	15/9	19/9	11/9	15/9	19/9	11/9	15/9	19/9
Fluazinam	-	-	-	-	-	-	-	-	-	-	-	-
Mancozeb	-	-	-	-	-	-	+/-	+/-	+/-	++	++	++
Zoxamide+mancozeb	-	-	-	-	-	-	-	-	-	+/-	+/-	+
Untreated	+++	+++	+++									

In Table 6 the results are presented of the effect of the fungicides on conidial germination of *A. alternata.* Fluazinam only restrained germination at a 100% label dose rate and to some extent at the 10%, 1% and 0.1% Label dose rate. Mancozeb and zoxamide + mancozeb had even at the 1% Label dose rate full control over the conidial germination of *A. alternata.*

Table 6. Germination of *A. alternata* conidia on PDA medium mixed with fungicide concentrations at three assessment dates.

Concentration	100% Label dose rate			10% Label dose rate			1% Label dose rate			0,1% Label dose rate		
Fungicide	11/9	15/9	19/9	11/9	15/9	19/9	11/9	15/9	19/9	11/9	15/9	19/9
Fluazinam	-	-	-	+/-	+/-	+	+/-	+/-	++	+	+	++
Mancozeb	-	-	-	-	-	-	-	-	-	+++	++	+++
Zoxamide+mancozeb	-	-	-	-	-	-	-	-	-	+++	++	+++
Untreated	++++	++++	++++									

Experiment 2: In Table 7 the results are presented of the effect of the fungicides on the mycelial growth of *A. solani*. Mancozeb and zoxamide + mancozeb fully restrained the growth of mycelium in the medium and on the plug at the 100% and 10% label dose rate. This indicates that this fungicide diffuses into the mycelial plug or that the volatility is high. Fluazinam did not inhibit the growth of the mycelium on the plug, but managed to inhibit the growth on the fungicide-medium even at a label dose rate of 1%.

Table 7. Diameter in mm of the *A. solani* colony (original plug included) grown on PDA medium mixed with fungicide concentrations on three assessment dates.

concentration	100% Label dose rate			10% Label dose rate			1% Label dose rate			0,1% Label dose rate		
Fungicide	15/9	19/9	22/9	15/9	19/9	22/9	15/9	19/9	22/9	15/9	19/9	22/9
Fluazinam	5[1)]	5	5	5	5	8.2	5	5	10.7	5	11.0	16.7
Mancozeb	0[2)]	0	0	0	0	0	5	13.8	21.7	17.5	49.5	74
Zoxamide+mancozeb	0	0	0	0	0	0	5	14.7	24	18.3	47.8	73
Untreated	24.7	66.5	85									
LSD (0.05)	1.3	3.5	3.2									

1) 5 mm = mycelium grows abundantly on the plug, but no growth of mycelium on or in the PDA medium + fungicide
2) 0 mm = no active mycelium on the plug and no growth of mycelium on or in the PDA medium + fungicide

Fluazinam completely inhibited germination of the conidia of *A. solani* at all label dose rates. The restriction of germination of conidia of *A. alternata* is sufficient at the 100% and 10% label dose rate. In general fluazinam allowed some very restrained growth of mycelium of both *Alternaria* species especially with the lower label dose rates. Mancozeb and zoxamide+mancozeb inhibited the germination of the conidia of both *Alternaria* species up to the 1% label dose rate. The effect of mancozeb and zoxamide mancozeb on the mycelial growth is stronger on *A.solani*. It is evident that the mancozeb component in zoxamide+mancozeb accounts for the control of *A. solani* and *A. alternata*. Zoxamide + mancozeb seems slightly better in controlling the conidial germination of A. solani than straight mancozeb at the lower dose rates (maybe due to some synergistic effect of zoxamide + mancozeb).

ACKNOWLEDGEMENTS

Dow AgroSciences LLC would like to thank all the researchers involved in these projects in particular Dr Josefa Kapsa in Poland, Dr Bent Nielsen in Denmark, Dr Hans Hausladen in Munich and Dr Huub Schepers in The Netherlands.

REFERENCES

Rotem, J. (1998). The Genus *Alternaria*: Biology, Epidemiology and Pathogenicity

Interaction of neonicotinoid seed treatments with lenacil herbicide applied to sugar beet

A M Dewar, L A Haylock, B H Garner and M J May
Broom's Barn Research Station, Higham, Bury St. Edmunds, Suffolk IP28 6NP, UK
Email: alan.dewar@bbsrc.ac.uk

ABSTRACT

Lenacil applied pre-emergence at the post-emergence recommended rate of 176 g a.i./ha to plants treated with imidacloprid or thiamethoxam at 90 and 60 g a.i./unit respectively had only a slight effect on crop vigour and no effect on final establishment in 2003. However, both imidacloprid and thiamethoxam, applied at the same rates in 2004, had adverse interactions with lenacil herbicide applied at the much higher pre-emergence recommended rate of 2200 g a.i./ha, resulting in significantly lower plant populations, and poor crop vigour of surviving plants; there was no effect with tefluthrin applied at 10 g a.i./unit. All three seed treatments had good crop safety when treated with other commonly used pre- or post-emergence herbicides. Although lenacil is rarely used as a pre-emergence herbicide in the UK, it is suggested that there should be a label recommendation not to use it pre-emergence with thiamethoxam; this already occurs with Gaucho.

INTRODUCTION

The neonicotinoid seed treatments, imidacloprid (Gaucho from Bayer CropScience) and thiamethoxam (from Syngenta) have shown adverse effects on establishment and growth of sugar beet when used in conjunction with lenacil herbicide applied pre-emergence at the relatively high recommended rate for that timing (1760 g a.i./ha) (Meridith & Morris, 2003); there was no such effect when applied post-emergence at the much lower recommended rate for the later timing. Although lenacil is rarely used pre-emergence in the UK (British Sugar personal comm.), this resulted in a label recommendation not to use lenacil herbicide pre-emergence with Gaucho-treated seed, but post-emergence use was acceptable. However, in a recent trial, a post emergence application of lenacil seemed to cause serious phytotoxicity when applied to plants treated with either imidacloprid or thiamethoxam, but not tefluthrin or clothianidin (Dewar *et al.,* 2004); this was attributed to a pre-emergence effect on a proportion of imidacloprid or thiamethoxam treated seeds that had germinated late in dry soil conditions.

This paper describes results from trials that sought to understand the latter result, especially with regard to thiamethoxam, and to assess if any other pre- or post-emergence herbicides might cause adverse interactions, to minimise risk to growers' crops prior to the registration of this product in the UK.

MATERIALS AND METHODS

In 2003, sugar beet seed cv Stallion treated with imidacloprid at 90 g a.i./unit (1 unit = 100000 seeds; seed rate = 1.15 units/ha), thiamethoxam at 60 g a.i./unit and an untreated control was sown on 25 March. All pelleted seed was treated with the fungicide thiram (at 5g a.i./kg seed) and hymexazol (at 10.5 g a.i./unit) to control the seedling diseases *Aphanomyces* spp. and *Pythium* spp. The herbicide lenacil was applied at post-emergence recommended rate of 176 g a.i./ha to all plots but at different timings - pre-emergence on 26 March, peri-emergence on 16 April, cotyledon stage on 23 April and 2 leaf stage on 6 May - using a one man 3m sprayer delivering 100 l/ha through Lurmark F110-01nozzles.

In 2004, a trial was designed to compare seven pre-emergence (pre-em) herbicide products (some of them mixtures) and five post-emergence (post-em) products (also in mixtures) (Table 1), applied to sugar beet cv Cinderella treated with three insecticide seed treatments - tefluthrin at 10 g a.i./unit (Force; Syngenta Crop Protection), imidacloprid at 90 and thiamethoxam at 60 g a.i./unit. The recommended rate of lenacil used pre-em was much greater (x 12.5) than that used post-em. Seed treatments were sown in 21 x 15 m blocks on 25 April; pre-em sprays were applied on 27 April in sub-plots 3 m wide with the plant rows, while post-em sprays were applied on 19 May, 25 days after sowing, when plants were at the cotyledon stage, at right angles across the plot rows. This matrix design incorporated three replicates for each combination of seed treatment, pre-em and post-em herbicide treatment, involving 315 3 x 3m sub-sub-plots. A second basal post-emergence application of phenmedipham + lenacil + triflusulfuron + oil was applied to all plots on 9 June. Sprays were applied as before using fine spray nozzles delivering 200 l /ha for the pre-em herbicides, and 100 l /ha for the post-em herbicides.

In 2003, the numbers of sugar beet plants in the central four rows by 10m in all plots were counted on five occasions from mid- April, when plants were just coming through the ground to the four leaf stage. The effect of treatments on crop vigour was recorded on three occasions using a 0-10 linear scale, in which 0 = no plants, and 10 = a very healthy crop stand. In 2004 the numbers of sugar beet plants in the central four rows by 2m in all plots were counted on two occasions, in late May 30 days after sowing, and mid June 46 days after sowing. The effect of treatments on crop vigour was recorded on four occasions as before.

RESULTS

In 2003, as the plant population reached its peak in May, there were slightly but significantly fewer plants in thiamethoxam-treated plots on the last three assessment dates (Table 2). Lenacil had only had an adverse effects overall on the emergence and establishment of plants on 8 and 19 May, when fewer plants were recorded in plots sprayed at the cotyledon stage than at other timings. This effect was not significant at the last assessment. There were no significant interactions between seed treatments and the timing of lenacil applications on any assessment date.

There were no adverse effects of seed treatment on plant vigour across the range of lenacil treatments (data not shown). However, there were significant effects of the timing of herbicide sprays on sugar beet plant vigour; by 30 April plots that had been sprayed pre-em on 26 March or at the cotyledon stage on 23 April were less healthy than those that had been sprayed at the peri-emergence stage on 16 April. Similar effects were seen on 9 and 19 May, but not on 27 May. There were no significant interactions between seed treatments and crop vigour throughout the assessment period.

Table 1. Pre- and post-emergence herbicides applied to sugar beet in 2004

Pre emergence herbicides	Product	Dose g a.i./ha
1. Untreated	-	-
2. Chloridazon	Takron	2150
3. Lenacil	Venzar	2200
4. Metamitron	Goltix	2100
5. Quinmerac + chloridazon	Fiesta T	270 + 1620
6. Metamitron + ethofumesate	Torero	700 + 300
7. Metamitron + CIPC	Golmet	1120 +98
Post-emergence herbicides		
A. Untreated	-	-
B. Phenmedipham + lenacil	Betanal Flo + Venzar	272 + 176
C. Phenmedipham + chloridazon	Betanal Flo + Takron	256 + 430
D. Phenmedipham + lenacil + triflusulfuron+ oil	Betanal Flo + Venzar + Debut	112 + 176 +15
E. Phenmed. + desmedipham + ethofumesate	Betanal Expert	93.4 + 31.3 +188.8

In 2004, significantly fewer plants were recorded on 24 May in plots treated with thiamethoxam (TMX) than in those treated with tefluthrin or imidacloprid; there were also significantly fewer plants in plots treated with lenacil than with any other pre-em herbicide, but no effect of post-em herbicides on plant population (Table 3). There was no significant interaction between pre-em herbicides and the three seed treatments on 24 May, although numbers in plots treated with lenacil were lowest in all seed treatments.

By 10 June, establishment was over 84% in the tefluthrin- treated plots, but there were significantly fewer plants overall in thiamethoxam-treated plots (76%). Lenacil again significantly reduced establishment, especially in plots treated with imidacloprid (53%) or thiamethoxam (45%); there was no effect of the other pre-em or post em herbicides on plant number. There were no interactions between seed treatments and post-em herbicides, nor between pre-em and post-em herbicides on either assessment date (data not shown).

The vigour of plants in the experiment closely reflected the results for plant numbers. On 21 May plants treated with tefluthrin were significantly healthier across all herbicide treatments than those treated with thiamethoxam or imidacloprid, but, subsequently, there was no difference between seed treatments (data not shown). There was a highly significant negative effect ($p<0.001$) of lenacil applied pre-emergence on plant vigour on all assessment dates, particularly in plots treated with thiamethoxam or imidacloprid, the latter interactions being significant for both insecticides on 8 and 22 June ($p=0.016$ and 0.048 respectively). There was no effect of post-em treatments on plant vigour across all treatments, nor were there any significant interactions between post-em herbicides and seed treatments or pre- and post-em herbicides at any assessment date.

Table 2. Effect of seed treatments and timing of lenacil application on emergence of sugar beet in 2003

Treatment	Percent plants emerged on 14 April	24 April	8 May	19 May	27 May
Seed treatments across all herbicide timings					
Untreated	40.6	66.8	76.4 a	81.0 a	82.7 a
Imidacloprid	38.8	67.7	76.7 a	81.1 a	82.7 a
Thiamethoxam	36.2	62.9	70.9 b	77.4 b	80.0 b
Lenacil across all seed treatments					
Pre-emergence	**39.2**	**65.5**	**74.6** ab	**80.9** a	**82.3**
Peri-emergence	35.6	**65.4**	**75.6** a	**80.2** a	**81.9**
Cotyledon	38.2	**63.5**	**71.6** b	**76.8** b	**79.9**
2 leaf stage	41.1	68.7	**76.8** a	**81.3** a	**83.3**
LSD seed tr (33 df)	6.92, NS	4.18, NS	2.91, P<0.001	2.62, P=0.011	2.30, P=0.029
LSD herbs (33 df)	7.98, NS	4.82, NS	3.36, P=0.022	3.02, P=0.020	2.65, NS
LSD interac (33 df)	13.83, NS	8.35, NS	5.82, NS	5.23, NS	4.59, NS

NS = not significant; treatments followed by different letters are significantly different
Data in bold denotes after herbicide application

DISCUSSION

In 2003, in the absence of soil pests, thiamethoxam, at the proposed commercial rate of 60 g a.i./unit slowed emergence of beet seedlings and the plant population was reduced by about 3% compared to untreated plots across all herbicide timings. This was largely caused by application of lenacil pre-em and at the cotyledon stage, but not when applied at peri-emergence or later at the two leaf stage. It is difficult to explain why this peri-emergence treatment did not behave the same way as the earlier or later applications of lenacil. One possible explanation is that 6.6 mm of rain fell two days after the treatment at the cotyledon stage, which might have had a disproportionate effect on thiamethoxam-treated plants because of the greater solubility of thiamethoxam (Dewar *et al.*, 2004). The vigour of already emerged plants was also adversely affected. Although there appears to be some slight adverse interaction between thiamethoxam and lenacil, it was not great enough to explain the serious loss of plants in the trial the

Table 3. Effects on emergence (% of plants sown) of interactions between seed treatments and pre- and post-emergence herbicides applied to sugar beet in 2004.

Herbicide treatment	Date of assessment: 24 May, 30 days after sowing				10 June, 47 days after sowing			
	Tef 10	Imid 90	TMX 60	**Mean**	Tef 10	Imid 90	TMX 60	**Mean**
Pre-em herbicides								
Untreated	41.6	43.2	40.7	**41.8**	85.4	87.7	85.8	**86.3**
Chloridazon	39.4	41.9	38.3	**39.9**	83.0	83.2	77.5	**81.3**
Lenacil	37.5	26.7	21.3	**28.5***	77.5	58.3*	47.1*	**61.0***
Metamitron	42.5	40.7	39.1	**40.8**	83.8	83.5	80.0	**82.4**
Quin + Chlor	40.0	40.1	39.3	**39.8**	84.5	83.2	80.0	**82.6**
Meta + Etho	42.9	39.9	30.7	**37.8**	86.8	85.2	73.5	**81.8**
Meta + CIPC	41.4	42.2	43.5	**42.4**	88.4	83.3	89.1	**87.0**
	LSD interact: 8.13, NS		LSD pre herb: 5.04, P<0.001		LSD interact: 11.21. p=0.046		LSD pre herb: 6.77, p<0.001	
Post-em herbicides								
Untreated	43.4	38.0	36.0	**39.1**	85.8	79.7	71.8	**79.1**
Phen + len	39.1	40.9	37.8	**39.3**	81.3	82.0	76.1	**79.8**
Phen + chlor	41.0	38.2	34.5	**37.9**	87.6	83.7	76.2	**82.5**
Phen + len + trif	39.8	42.2	37.1	**39.7**	83.0	81.2	77.1	**80.4**
Phen + des + etho	40.6	36.9	35.3	**37.6**	83.3	76.5	79.5	**79.8**
Mean seed tr	**40.8**	**39.2**	**36.1***		**84.2**	**80.6**	**76.1***	
	LSD seed tr: 2.04, p=0.020; LSD interact: 4.04, NS		LSD postherb: 2.54, NS		LSD seed tr: 6.07, P=0.058; LSD interact: 8.27, NS		LSD post herb: 5.01, NS	

NS= not significant; * significantly less than untreated (herbs) or tefluthrin (seed tr) previous year (2002), despite weather conditions being broadly similar in the two years, namely dry and warm, and the same rate of chemical being applied.

However, the 2004 trial confirmed the previous observations that both thiamethoxam and imidacloprid can have adverse interactions on sugar beet seedlings with lenacil when the latter is applied pre-em, although the rate of application in 2004 was over 12 times that used in 2003, which may explain the lack of effect with the much lower rate in that year. The interaction was manifest in the number of plants that emerged and the vigour of those that survived. That there was no effect with tefluthrin highlights the good crop safety shown by that treatment. There was no adverse effect of lenacil when applied post-em at a much lower rate with phenmedipham, which suggests that the interaction occurs at the point where seedlings containing high concentrations of these two neonicotinoid insecticides in their shoot tips push through soil containing residues of lenacil. There was no adverse effect of any of the other herbicides applied pre- or post-em, on the growth of plants treated with any of the test insecticides. Provided there is a warning on the label for thiamethoxam not to use the product with lenacil applied pre-em, there should be little risk to young sugar beet plants with post-em use. There is certainly no concern based on these studies with any of the other commonly-used herbicide products applied pre- or post em.

Although few farmers are likely to apply lenacil as a pre-em herbicide (it is very expensive at the rates recommended), there may be occasions when emergence of treated seed is delayed due to dry conditions (as happened in the Broom's Barn trial in 2002), resulting in exposure to what would effectively be a pre-em application once moisture levels return to normal. It may be wise to delay application of lenacil post-em until the seedlings are at the 2 leaf stage, to allow late-emerging plants to harden off.

ACKNOWLEDGEMENTS

Thanks are due to Stephen Goward and his field experiments team for drilling and harvesting the trial, and Pippa Cole, Sonia Coupe, Ben Hulme Kath Hudson, Paul May and Anne Perry for technical assistance. This work was funded by Syngenta Crop Protection.

REFERENCES

Dewar A M; Haylock L A; Garner B H (2004). Which seed treatment? *British Sugar Beet Review* **72 (2),** 26-33.

Meredith R H; Morris D B (2003). Clothianidin on sugarbeet: field trial results from Northern Europe. *Pflanzenschutz-Nachrichten Bayer* **56 (1)**, 111-126.