SESSION 2
INSECTICIDAL SEED TREATMENTS

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The impact of thiamethoxam seed treatment on maize storability and laboratory test performance

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ABSTRACT

Maize inbred and hybrid seed was treated with the insecticide thiamethoxam then stored at 10 and 25°C for 24 months with samples removed at six month intervals. The treatment rates ranged from 0 to 200 gms a.i./100 kg seed. Laboratory tests included the standard germination, tray cold test (7 days at 10°C and 7 days at 25°C) and the extended cold test (14 days at 10°C and 7 days at 25°C). Classical declines in vigor tests occur with increased time in storage. These declines are little effected by the addition of the insecticide. The physiological basis for these responses will be discussed.

INTRODUCTION

Volumes of literature exist detailing various aspects of seed storage and deterioration (Roberts, 1972; Justice & Bass, 1978; Bewley & Black,1982; McDonald & Nelson, 1986; Priestley, 1986). One of the most useful concepts to come from all this work is the rule-of-thumb that the sum of the RH and the Fahrenheit temperature should equal less than 100. Using this general guide the seed industry has functioned relatively well for several decades. At the same time seed biologists have struggled to better understand the fundamental processes at work. To a large extent changes in lipids and the membranes they comprise are responsible for deterioration.

The primary biological functions of the seed are to preserve the species and to provide a means of dissemination. In native plant communities and especially weed species this is reflected in the rapid development of the embryo and some storage reserves following fertilization.

Modern plant breeding has produced an abundance of high yielding varieties which exploit an extended period of development to produce high yields. The extension of the reserve deposition phase challenges the natural ontogeny of the seed. However, over the years plant breeders have inadvertently produced lines which lack the ability to produce acceptable seed or seed which deteriorates rapidly.

Recent advances in seed treatment technology have resulted in the introduction of the seed as a delivery system for many materials including systemic insecticides. At the same time maize genetics have become more costly and growers expectations have increased. Because of these factors, seed producers have become much more aware of the potential impact of any seed amendment on seed quality; and since it is necessary to carry over a significant amount of seed for more than one season, the potential for a seed amendment to effect seed deterioration must be investigated. This study was designed to evaluate the impact of the systemic insecticide thiamethoxam on the storability of both inbred and hybrid maize as influenced by storage temperature.

METHODS AND MATERIALS

Seed produced in 1998 of four single cross maize hybrids and four inbreds were treated with thiamethoxam at 0, 30, 50, 100, 125, 200 gm a.i. /100 kg in addition to a base treatment of Maxim XL at 2.5 g 'Maxim' + 1 g 'Apron XL'/100 kg. The treated seed was packaged then stored at 10 or 25°C prior to testing. Seed was tested at 6 month intervals over a two year period.

Tests included: **Warm Germination** using 4 replications of 100 seed each planted on pre-moistened Kimpak substrate. The tray containing the test is placed in a germination cart fitted with a Plexiglas back and held at 25°C for seven days. The tests are evaluated according to the AOSA Rules. The **Tray Cold Test** includes the Kimpak substrate which is moistened the day prior to planting, trays are placed in the germination cart and the cart is held at 10°C overnight. The wet/chilled tray is removed from the cart and 2 replications of 100 seeds are planted then covered with sand. The test is returned to the cold room to be held for 7 days at 10°C then transferred to 25°C for 7 days at which time the germination percentage is determined according to the AOSA Vigor Testing Handbook (similar criteria as the Warm Germ). This test is the most widely used cold test procedure for corn and is used by the industry worldwide. The **Extended Cold Test** is identical to the tray cold test except that the cold period is 14 days prior to the seven days at 25°C. This test is used as a rigorous version of the Tray Test, and is often helpful in separating the performance of seed treatment chemicals.

RESULTS

The warm germination is unaffected by treatment rate, storage temperature or storage period (Table 1). Although genotype differences are present there does not appear to be any significant difference between the inbred and hybrid seed. The differences are related to quality levels in specific seed lots which is confirmed by the lack of significance in the genotype by treatment interaction. There were no significant responses in either the warm germination abnormal percentage or the number of dead seed (data not shown). Changes in these values would be expected if a typical phytotoxicity were present.

Of the available vigor tests for corn, the tray cold test procedure is the most common method used by the seed corn industry in both North and South America. It has a reasonably good correlation with field performance and variation can be reduced to an acceptable level. In this experiment the tray cold test values are high but because of test precision and a large sample number all main treatments are significant although the interactions are not. When compared across storage period, temperature and genotype, nly the 200 g rate exhibited a significant decline. Extending the 10°C period of the cold test by seven days reduced the test values to a similar extent across treatment rates. Thus the performance of the fungicide portion of the treatment was not effected by the increasing rate of thiamethoxam.

Table 1. The effect of thiamethoxam treatment on seed quality averaged across storage period, storage temperature and genotype.

Seed treatment g a.i./100 kg	Warm germ.	Tray cold	Extended cold	Tray minus extended cold
0	96.4ab*	94.2a	91.8a	2.4a
30	96.3ab	93.8a	91.6a	2.2a
50	96.6a	94.0a	91.5ab	2.5a
100	96.3ab	93.6a	90.7bc	2.9a
125	96.3ab	94.0a	91.5ab	2.5a
200	96.2b	92.6b	90.0c	2.6a

* Means in the same column followed by the same letter are not significantly different.

Storage temperature had little if any effect on either the tray or extended cold test over the eighteen month storage period (Table 2). Increased treatment rate had no consistent effect until the 200 gm rate was applied. The lack of significant storage temperature effects is likely the result of low consistently low seed moisture which minimizes the consequences of the elevation in temperature.

Table 2. The effect of thiamethoxam treatment on seed quality averaged across storage period, and genotype.

Seed treatment g a.i./100 kg	Tray cold stored at 10°C	Tray cold stored at 25°C	Extended cold stored at 10°C	Extended cold stored at 25°C
0	94.9a	93.3a	92.8a	90.5a
30	94.7a	92.6ab	92.5a	90.3a
50	95.0a	92.7ab	92.3ab	90.4a
100	93.9a	93.1a	91.6b	89.8ab
125	94.6a	93.3a	92.5a	90.1a
200	93.3b	91.8b	91.2b	88.5b

* Means in the same column followed by the same letter are not significantly different.

A similar response to treatment rate is evident at all storage periods (Table 3). The eighteen month period coincides with storage for two planting seasons. The values obtained would clearly not suggest any biologically significant effect due to thiamethoxam addition. Further, comparison of the rate of decline in vigor in response to storage time was the same regardless of thiamethoxam rate.

Table 3. The effect of storage period and thiamethoxam treatment on tray cold test performance averaged across storage temperature, and genotype.

	Tray cold test			
Seed treatment g a.i/100 kg	0 months storage	6 months storage	12 months storage	18 months storage
0	94.8ab	94.7a	93.8a	93.9a
30	95.7a	94.5a	92.6b	93.4a
50	95.8a	94.3a	93.7a	93.2ab
100	94.3ab	94.0ab	93.2ab	93.4a
125	95.5a	94.5a	92.9b	93.9a
200	93.4b	92.8b	91.8c	92.7c

* Means in the same column followed by the same letter are not significantly different.

Although there was no significant difference between inbred and hybrid seed response to thiamethoxam treatment there are interesting specific seed lot responses. The tray cold test results showed no response to treatment rate in a high quality seed lot, while the low quality seed lot exhibited a gradual decline with increasing treatment rate (Table 4). Extending the cold test resulted in approximately a three percentage point reduction in test values. The statistical significance indicated in the tables may not be of biological significance, and in most cases fall within the tolerance range established by the Rules for Seed Testing (Anon., 1993).

Table 4. The effect of thiamethoxam treatment on high and low quality seed lot performance averaged across storage period, and temperature.

	Tray cold test		Extended cold test	
Seed treatment g ai/100 kg	High quality seed	Low quality seed	High quality seed	Low quality seed
0	97.9a	89.5a	94.4a	85.8a
30	96.9a	88.0b	95.4a	85.8a
50	97.4a	87.5b	94.3ab	84.4ab
100	97.1a	86.4b	93.9b	83.8b
125	97.9a	87.4b	95.0a	83.6b
200	96.9a	84.1c	92.6c	80.9c

* Means in the same column followed by the same letter are not significantly different.

CONCLUSION

It is clear that treatment with thiamethoxam at rates up to 125 g/100 kg has no significant impact on seed quality during normal storage of either hybrid or inbred maize seed. Further, thiamethoxam does not appear to accelerate the deteriorative processes except at the elevated rates of application. The impact of storage temperature was slight and did not influence the effect of the thiamethoxam application.

Seed quality has a significant impact of the thiamethoxam on seed vigor but not on standard germination. Interestingly the impact of increased treatment rate on the decline in vigor was only slightly greater in the low quality seed. Thus the consequence of the reduced quality is important but is not likely to be exacerbated by the seed treatment.

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A new insecticidal seed treatment for oilseed rape

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ABSTRACT

In trials between 1998-2000 a seed treatment containing beta-cyfluthrin + imidacloprid was effective against adult flea beetle (*Psylliodes chrysocephala & Phyllotreta* spp.) attack, cabbage stem flea beetle (*P. chrysocephala*) larval damage, and reduced the incidence of Beet Western Yellows Virus (BWYV), resulting in yield increases. Additional benefits were obtained from a sequential spray application of deltamethrin. This new insecticidal seed treatment provides an effective, safe replacement for gamma HCH on oilseed rape.

INTRODUCTION

Cabbage stem flea beetle (*Psylliodes chrysocephala*) is the most important establishment pest of autumn sown oilseed rape and can be found in most areas where the crop is grown (Lane & Cooper, 1989). The adults can cause damage to emerging seedlings, with particularly serious damage in dry weather when plant growth is slow. A further problem may occur between October and early April as larvae hatch and enter the plants. The larvae can cause extensive damage both to leaf stalks and main stems (Gratwick, 1992).

The cabbage flea beetle (*Phyllotreta* spp.) can also cause damage to oilseed rape crops by eating holes in the cotyledons and stems of seedlings, starting just before cotyledons appear above the ground. Most activity occurs under warmer conditions (Jones & Jones, 1974). Whilst it is mainly a spring rape pest, early autumn sown crops can suffer in warm dry conditions.

For many years, seed treatment with gamma HCH has been the standard method for controlling early damage from adult flea beetles. Since the withdrawal of UK registration for gamma HCH, as a seed treatment, the only control option has been an application of a pyrethroid spray at crop emergence.

A further potential problem with autumn sown oilseed rape crops is Beet Western Yellows Virus (BWYV), which is spread by aphid vectors. This virus is widespread in England and can cause significant loss of yield. (Hill *et al.*, 1989).

This paper reports on 33 autumn sown oilseed rape field trials during 1998-2000 to investigate the effects of seed treatments based on beta-cyfluthrin + imidacloprid against these problems.

METHODS AND MATERIALS

The seed treatments are listed in Table 1. Application was by mini-Rotostat, where 1kg seed lots were treated for 30 seconds. Except for fenpropimorph + gamma HCH + thiram, all seed was additionally treated with thiram against fungal diseases.

All trials were fully replicated using randomised block designs. The sites were mainly drilled using an Oyjord small plot drill, with plot sizes of 3.5 m x 15 m. Pathways were burnt off between plots and replicates, to ease assessments and harvesting. All trials were conducted by Bayer staff throughout the UK.

The seed rates in machine drilled trials followed seed producers' recommendations. Spray treatments of deltamethrin were applied using gas powered knapsack sprayers between GS 10-19 (Meier, 1997) either as leaf pest damage became visible or at a requested growth stage, depending on the protocol.

Trials were assessed for adverse effects of seed treatments by 'crop stand counts' and 'visual crop biomass assessments', where appropriate. Adult flea beetle (*Phyllotreta* spp. and *P. chrysocephala*) damage on emerging plants in the autumn was assessed by counting plants attacked. Attempts were made to trap the active pest for identification and where this was successful, both species were found but with no clear indication of which species was actually causing leaf damage.

Cabbage stem flea beetle (*P. chrysocephala*) damage in the early spring was assessed by counting petiole base entry holes or by dissecting plants and counting larvae in a minimum of ten plants per plot. In early spring, prior to flowering, leaf samples from 20 randomly selected plants per plot were taken from selected treatments and ELISA tested for % BWYV incidence at Central Science Laboratories, York.

After desiccation of the plots small plot combines, with on board weighing facilities, were used to yield trials.

Table 1. Formulations included in trials and rates of application

Product	Active ingredients		Application rate per kg seed	
			ml	g a.i.
UK894	beta-cyfluthrin + imidacloprid (normal rate)	N	20	2.0 + 2.0
UK894	beta-cyfluthrin + imidacloprid (double rate)	2N	40	4.0 + 4.0
'Lindex Plus'	fenpropimorph + gamma-HCH + thiram	N	22	0.95 + 12.0 + 1.6
'Lindex Plus'	fenpropimorph + gamma-HCH + thiram	2N	44	1.9 + 24.0 + 3.2
'Agrichem Flowable Thiram'	thiram		5	3.0
			Application rate per ha	
'Decis'	deltamethrin		250	6.2

RESULTS

The results of trials are summarised in Tables 2 to 7.

Crop stand counts are from trials without adult flea beetle damage. They reflect treatment safety and are given in Table 2. The autumn of 1999 was a very difficult season for oilseed rape crops with dry seedbeds at drilling and flooded soils at some sites post-emergence with associated plant loss and slug damage. Many commercial crops were re-drilled or ploughed up. This led to poor and erratic emergence figures in 1999.

Table 2. Mean % relative crop stand – by year. (Untreated = 100)

Harvest year	1998	1999	2000	
Number of trials	2	8	8*	6
Insecticide				
Untreated level (plants/m²)	(90)	(61)	(51)	(68)
Gamma HCH (N)	82	111	97	106
Gamma HCH (2N)			99	
Beta-cyfluthrin + imidacloprid (N)	100	104	96	98
Beta-cyfluthrin + imidacloprid (2N)			96	

* Safety trials with double rates. These trials received insecticide overall sprays (all plots) from emergence to protect from pest damage.

No symptoms of phytotoxicity, as expressed as RACB (relative aerial crop biomass), were seen with beta-cyfluthrin + imidacloprid treatments over three years (Table 3).

Table 3. Mean relative aerial crop biomass (1998-2000)

Insecticide	RACB	Number of Trials
Gamma HCH (N)	99	35
Gamma HCH (2N)	91	13
Beta-cyfluthrin + imidacloprid (N)	101	40
Beta-cyfluthrin + imidacloprid (2N)	100	13

Beta-cyfluthrin + imidacloprid was the most effective seed treatment at reducing adult flea beetle damage. A follow-up spray of deltamethrin showed no consistent benefit (Table 4).

Table 4. % Reduction in number of adult flea beetle *(Phyllotreta* spp. and *Psylliodes chrysocephala)* damaged plants

Year	1998	1999	1999	1999	2000	2000	2000	
Site	WR-02	ES-01	MR-01	WR-06	ER-04	ES-03	NM-02	
County	Worcs.	Cambs.	Leics.	Hereford	Suffolk	Cambs.	E Yorks	
Cultivar	Express	Express	Pronto	Pronto	Apex	Pronto	Pronto	Mean
GS at spray application	13-14	19	16	12-18	10-14	12-16	14-16	
Untreated level (% plants damaged)	(20)	(20)	(91)	(91)	(58)	(57)	(17)	(50.3)
Gamma HCH					55	19	16	30.0
Gamma HCH followed by deltamethrin	12	14	53	78	49	19	34	37.1
Beta-cyfluthrin + imidacloprid	56	20	36	69	69	36	64	50.0
Beta-cyfluthrin + imidacloprid followed by deltamethrin		28	47	77	72	25	53	50.4

Of the seed treatments alone beta-cyfluthrin + imidacloprid most effectively reduced larval damage; control was substantially increased by a sequential spray of deltamethrin (Table 5).

Table 5. % Reduction of *Psylliodes chrysocephala* larvae numbers in plants

Site	WR-06-99	ES-03-00	MR-01-00	ER-04-00	
County	Hereford	Cambs.	Leics.	Suffolk	
Cultivar	Pronto	Pronto	Apex	Apex	
Drilling date	21.08.98	03.09.99	19.08.99	06.09.99	
Date of spray application	19.10.98	05.10.99	19.10.99	05.10.99	
GS at spray application	12-18	12-16	16	10-14	
Date of assessment	15.02.99	12.01.00	02.02.00	31.01.00	
Days after drilling	178	131	167	147	Mean
Insecticide (all at N rates)					
Untreated (larvae /plant)	(4)	(2)	(5)	(4)	(3.75)
Gamma HCH	0	0	51	55	35.3
Gamma HCH followed by deltamethrin	91	80	97	87	88.8
Beta-cyfluthrin + imidacloprid	67	56	57	88	67.0
Beta-cyfluthrin + imidacloprid followed by deltamethrin	97	93	96	97	95.8

The incidence of BWYV was reduced by beta-cyfluthrin + imidacloprid (Table 6). Trial WR-02-00 was not taken to yield.

Table 6. % Reduction in numbers of Beet Western Yellows Virus infected plants and yields

Site	SR-04-00		ER-04-00		WR-02-00	
County	Kent		Suffolk		Hereford	
Cultivar	Pronto		Apex		Pronto	
Drilling date	26.08.99		06.09.99		20/08.99	
Date of spray application	30.09.99		05.10.99		07.10.99	
GS at spray application	11-16		10-14		14-16	
Date of sampling	30.04.00		30.04.00		30.04.00	
Days after drilling	248		237		254	Mean
		Yield		Yield		BWYV
Untreated level (% infected)	(49)	(4.04 t/ha)	(75)	(3.03 t/ha)	(44)	(56)
Gamma HCH followed by deltamethrin	21	102	48	106	26	32
Beta-cyfluthrin + imidacloprid	56	104	70	116*	40	55
Beta-cyfluthrin + imidacloprid followed by deltamethrin	41	105	93	113*	17	50

* Statistically different from untreated (p = 0.05)

Fourteen trials were yielded over 3 years (Table 7).

Table 7. Relative yield – efficacy trials

Year Number of trials	1998 3	1999 9	2000 2
Untreated level (t/ha)	(2.76)	(4.11)	(3.54)
Gamma HCH			100
Gamma HCH followed by deltamethrin	124	106	104
Beta-cyfluthrin + imidacloprid	102	105	110
Beta-cyfluthrin + imidacloprid followed by deltamethrin		109	109

Safety trials from year 2000 were short term only and were not yielded.

DISCUSSION

The withdrawal of registration for gamma HCH as an oilseed rape seed treatment has left UK growers with no seed treatment option for the control of establishment pests. A beta-cyfluthrin + imidacloprid seed treatment would provide a very effective replacement and give some additional benefits in reducing BWYV.

Beta-cyfluthrin + imidacloprid provided safe crop establishment (Tables 2-3) with early protection against the adult flea beetle complex (Table 4). The levels of *Psylliodes chrysocephala* larvae were usefully reduced by beta-cyfluthrin + imidacloprid seed treatment and further reductions were achieved by a sequential application of a single foliar spray of deltamethrin (Table 5).

BWYV is spread by infected aphids in the autumn in oilseed rape (Hill, 1989). The disease rarely produces visible symptoms in the field and control, with associated yield increases, has not been widely targeted. Beta-cyfluthrin + imidacloprid achieved useful reductions in BWYV incidence; additional control from a sequential application of deltamethrin occurred in one out of three trials (Table 6).

There appears to be some correlation between the level of BWYV infection and yield increases (Table 6 - limited data), however the combination of both pest and virus control probably contributed to overall increased yields (Table 7).

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Novel seed treatments to control aphids and virus yellows in sugar beet

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ABSTRACT

In five field trials conducted in sugar beet between 1997 and 2000, the novel seed treatment, thiamethoxam applied at 60 g a.i./unit, gave excellent control of aphids and virus yellows, and significantly increased sugar yields in two of the trials. Fipronil applied at 50 or 100 g a.i./unit was phytotoxic to young seedlings and had no effect on aphids; as a consequence of lower plant populations virus incidence was increased and yields decreased in three trials. Imidacloprid applied at 60 g a.i./unit gave as good control of aphids, poorer control of virus, but equivalent sugar yields to the commercial 90 g rate. Imidacloprid or thiamethoxam mixed with tefluthrin at 4 g a.i./ha performed as well, occasionally better than either neonicotinoid applied alone, but tefluthrin applied alone had no effect on aphids or virus yellows.

INTRODUCTION

Pest control in sugar beet is now dominated by the pelleted seed treatment, imidacloprid ('Gaucho', Bayer), which was applied to over 70% of crops in the UK in 1999 and 2000 (Dewar & Asher, 2000). Imidacloprid gives excellent control of aphids, especially vectors of virus diseases such as barley yellow dwarf virus in cereals (Schmeer *et al.*, 1990) and virus yellows in beet (Dewar *et al.*, 1996). However, such heavy reliance on one insecticide for control of virus yellows in sugar beet can render the crop vulnerable to the disease if control breaks down, for example, as a result of the development of resistance.

In this paper we report the results from five trials conducted in 1997-2000 to test the efficacy of two new insecticides, fipronil (Aventis) and thiamethoxam (Novartis), and mixtures of these with one or other of the current products (imidacloprid and tefluthrin) at reduced rates, against aphids and the consequent infections of virus yellows in sugar beet.

MATERIALS AND METHODS

Treatments

Sugar beet seed cv Zulu in 1997, Nicola in 1998, Roberta in 1999, and Stallion in 2000 was pelleted and treatments applied by Germain's of King's Lynn in a process similar to their commercial pelleting treatment. All seed was treated with the fungicides thiram and hymexazol to control seedling diseases (Asher & Dewar, 1994). Insecticide treatments were applied as a film-coat to the outer surface of the pellets at rates (expressed as g a.i. per unit of 100,000 seeds) listed in Tables 1-3. An untreated control was compared to treatments containing the neonicotinoid insecticides imidacloprid and thiamethoxam, the pyrethroid tefluthrin, the phenylpyrazole fipronil, or mixtures of some of these. Not all treatments reported here were included in every trial in each year. Seed was sown with a Rallye 590 drill which placed them 18.2 cm apart within rows that were 50 cm apart (approximately 1.1 units/ha). Plots were 12 rows by 12 m and treatments (ten in each year) were replicated four times in randomised blocks. Not all the treatment results are presented here.

Aphid inoculations

In 1997, 1999 and 2000 aphid numbers were not high enough to provide adequate discrimination between treatments. Therefore six plants per plot were inoculated with aphids from an insecticide-susceptible clone of virus-infective *Myzus persicae*, which had been reared on glasshouse cultures of shepherd's purse, *Capsella bursa-pastoris*, infected with beet mild yellowing virus (BMYV). Circa 20 aphids feeding on small pieces of *Capsella*, were placed in the heart leaves of each of six plants per plot when plants were at the 8-10 leaf stage. These plants were located 3 m from each end and in the centre of rows 5 and 8 in each plot. The timing of inoculations was chosen to allow maximum discrimination between treatments, i.e when the activity of some treatments may have been coming to an end 9-12 weeks after sowing.

Aphid assessments

Naturally-colonising aphids were counted on 4 - 10 plants per plot, depending on plant size, on two or three occasions in each trial. In 1997 and 2000, when naturally-occurring aphids were particularly low in number, the number of aphids on the marked inoculated plants was counted instead, within 8 days of inoculation. Dates of sampling in relation to sowing date are presented in Table 1. Aphids were classed as green or black, winged or wingless. The green aphids were either *M. persicae* or *Macrosiphum euphorbiae*, and the black aphids were mostly *Aphis fabae*.

Virus Yellows infection

Virus yellows incidence was assessed visually in the same area that was used to assess establishment and in which the inoculated plants were located, i.e. the central 6 rows x 8 m (24 m^2). Virus assessments were done on at least two occasions at each site, but only the late August/ September data are presented here.

Yield

Sugar beet was harvested by machine, an Edenhall 422 2-row harvester, usually in November, from the four central rows by 9.7 m per plot (19.8 m^2), or by hand from the central four rows by 8m (16m^2). Root weight, sugar concentration, and levels of impurities were determined in the tarehouse at Broom's Barn.

Analyses

Data were analysed by analysis of variance using GENSTAT V. Aphid data were transformed logarithmically ($\log_{10}(n + 1)$) before analysis.

RESULTS

Effect of treatments on aphids

Seed treatments generally have little effect on colonisation of plants by winged aphids, and few, if any, significant effects were seen on them in any of the five trials reported here. Treatment effects were mainly manifest in the subsequent development of wingless aphid colonies on plants. Therefore only data on wingless aphids is presented in Table 1.

In 1997 aphid numbers remained too low (< 0.5 per plant) on uninoculated plants throughout the sampling period to allow adequate analyses. Thus the numbers of aphids present on inoculated plants, two days after inoculation, was assessed. In addition to the green aphids, which were mostly the *M. persicae* that had been placed on the plants, some colonisation by black aphids had also taken place by 6 June. There were no significant differences between treatments in the number of green aphids, but there were significantly more black aphids in plots treated with fipronil at both rates (Table 1). This latter result may have been due to the lower plant population in fipronil-treated plots (Dewar *et al.*, 2000) which would have resulted in greater colonisation per plant by immigrant black aphids. This concentration effect would not have happened with inoculated aphids that were placed on selected plants.

In 1998, natural colonisation by both green and black aphids was much greater than in 1997, and there was no need to inoculate plants. Significant reductions in green aphid numbers (both *M.persicae* and *M. euphorbiae*) in early June were achieved by imidacloprid at all rates tested whether applied alone or in a mixture, although numbers in plots treated with imidacloprid at 15 g plus tefluthrin at 4 g were higher than in those treated with higher rates (Table 1). Neither tefluthrin nor fipronil applied alone had any effect on aphids. Thiamethoxam gave as good control as both rates of imidacloprid applied alone, as did imidacloprid mixed with fipronil. In contrast, only imidacloprid at 45 g and the mixture of tefluthrin and imidacloprid (at 4 and 15 g respectively) gave significant control of black aphids. This latter contradictory result may have been a consequence of the large variability in the between-plant numbers of this species; for example, the coefficient of variation for all samples after transformation of the data was 116% for black wingless aphids compared to only 26% for the green wingless aphids.

In 1999, aphid numbers (mostly *M. persicae*) never exceeded two per plant at either Broom's Barn or Little Wilbraham despite the early migration recorded in the suction trap at Broom's Barn; very few black aphids were seen in that year. At Broom's Barn, all treatments significantly reduced aphid numbers, although tefluthrin and fipronil gave poorest control. At Little Wilbraham, neither tefluthrin nor fipronil gave significant control, but both imidacloprid and thiamethoxam gave excellent control at all rates tested, applied alone or in mixtures (Table 1).

In 2000, numbers of naturally-colonising aphids were again too low to assess the effect of treatments. Assessments done on inoculated plants on 15 June, eight days after inoculation, showed that all rates of imidacloprid and thiamethoxam, and the mixture of the latter with tefluthrin, significantly reduced aphid numbers 84 days (12 weeks) after sowing, but there were no differences between the two products. Neither rate of tefluthrin applied alone or the mixture of tefluthrin at 4 g and imidacloprid at 60 g a.i./unit had any effect on aphids.

Effect of treatments on virus incidence

In all years virus incidence nationally was low (< 2 %). It was thus fortunate that four of the five trials here were inoculated to allow collection of data on the effects of treatments on virus infection. In 1997, virus infection in the untreated plots rose to 24% by the 22 September. Only thiamethoxam at 60 g a.i./unit significantly reduced infection, to 17%. There were no differences between the other treatments (Table 2). In 1998, natural virus infection in the uninoculated untreated plots only reached 3% by September. No treatment significantly reduced virus infection, but virus infection in two treatments, tefluthrin at 10 g and fipronil at 50 g a.i./unit, was significantly above that in the untreated (Table 2). In 1999, virus infection in untreated plots reached almost 60% at Broom's Barn. Imidacloprid at 90 g, the mixture with tefluthrin, and all treatments containing thiamethoxam, gave significant reductions in virus levels. Neither imidacloprid applied alone at 60 g, tefluthrin at 4 g nor the mixture of fipronil and imidacloprid had any effect; fipronil applied alone at 50 g increased virus incidence, probably because their were fewer plants in the plots, leading to a higher proportion becoming infected. At Little Wilbraham, virus infection was 45% in untreated plots. All treatments except tefluthrin applied alone at 4 g and fipronil at 50 g a.i./unit substantially reduced infection; the latter treatment in fact increased infection significantly (Table 2). The lower rate of imidacloprid (60 g) did not give as good control of virus yellows (20%) as the higher rate (12%) or when that lower rate was mixed with tefluthrin (7%). In 2000, virus yellows infection in the untreated plots at Broom's Barn reached 50%. However, only imidacloprid at 90 g, applied alone or mixed with tefluthrin, and both treatments containing thiamethoxam significantly reduced infection (Table 2). Tefluthrin applied alone or mixed with imidacloprid at 60 g, and the latter insecticide applied alone at that rate had no effect.

Effect of treatments on yield

The consequences of the effects of treatments on virus infection and sugar concentration are finally manifest in sugar yield at harvest. In 1997, no effects on yield by any treatments were detected, and in 1998, the only effect found was a significant reduction in yield caused by fipronil at 100 g a.i./ha. However, in 1999, the higher levels of infection, and the greater differences between treatments, produced some significant effects. At Broom's Barn, the only treatment to improve yields, tefluthrin plus thiamethoxam (at 4 + 60 g a.i./unit) (Table 3), was the treatment which gave the greatest reduction in virus infection (Table 2). Fipronil again reduced yield confirming its phytotoxic effect. At Little Wilbraham, most of the treatments containing imidacloprid and thiamethoxam, which had given such good control of virus disease, also increased yields. Neither tefluthrin nor fipronil applied alone had any effect. In 2000, only thiamethoxam at 60 g a.i./unit and the mixture of imidacloprid and tefluthrin at 90 + 4 g a.i./unit produced significant increases in sugar yield; the commercial rate of imidacloprid yielded the same as the untreated, but this may have been partially due to a poor plant population in one block (poor seed bed).

DISCUSSION

The low levels of virus disease recorded in 1998, despite a high forecast (Dewar & Asher, 1998) and early migrations of aphids (Asher & Dewar, 1999), was indicative of the low reservoir of virus yellows in the wider agricultural landscape. Not surprisingly, although good data on control of aphids was obtained from the trial in that year, none of the treatments had any positive effects on virus levels, sugar concentration or yield. The practice of inoculating trials with virus-infective aphids was very effective at stimulating large enough levels of the disease to discriminate between treatments in three of the other four trials reported here. Only in 1997 were differences in virus levels not great enough to cause significant yield losses, and this may have been due to the effect of adverse weather on virus spread after inoculation. It is certainly not due to the time of inoculation after sowing because treatment effects in 2000 were significant even 76 days after sowing compared to 67 days in 1997.

Of the novel treatments tested, thiamethoxam at 60 g a.i./unit gave consistently good control of aphids and virus infection in four of the five trials; in 1997 it was the only treatment to do so. In the later trials, when it was applied at 45 g or mixed with tefluthrin, thiamethoxam continued to give excellent control of both aphids and virus, at least as good as the commercial rate of imidacloprid. In contrast, fipronil was ineffective against aphids and caused serious losses of plants (Dewar *et al.*, 2000), which probably contributed to the increase in percent infection by virus yellows, and certainly caused significant losses in yield. Fipronil performed better when it was mixed with imidacloprid, but not well enough to overcome some phytotoxic effects on young seedlings.

The mixtures of tefluthrin and imidacloprid, while they have given better control of soil pests in other trials where these have been present (Dewar *et al.*, 2000), did not give any added benefits when controlling aphids. Imidacloprid applied alone at 60 g gave as good control of aphids as the 90 g rate, and, although it gave consistently poorer control of virus yellows, sugar yield was lower in one trial but higher in the other where these treatments were tested together. However this was not the case when that rate was applied in the mixture with tefluthrin, when reduction in virus incidence was as good as the commercial rate. Imidacloprid applied at 15 g with tefluthrin did not give effective control of either aphids or virus yellows, largely because it had worn off before plants were inoculated.

ACKNOWLEDGEMENTS

Thanks are due to Germain's of King's Lynn for applying the treatments to pelleted seed, to John Webb and Stephen Goward and the Broom's Barn farm staff for sowing and harvesting the trials, to Andrew Dewar, Neil Kift, Emma Wykes, Emma Heard, Ruth Hudson for technical assistance. This work was funded by the British Beet Research Organisation. IACR is a grant-aided Institute of the Biotechnology and Biological Sciences Research Council.

Table 1. Effect of insecticide seed treatments on the number ($\log_{10}$ (n+1)) aphids colonising sugar beet

Treatment	Rate a.i./unit	Broom's Barn 1997 6 June: 69 DAS		Broom's Barn 1998 8 June: 80 DAS		Broom's Barn 1999 1 June: 59 DAS	L. Wilbraham 1999 25 May: 61 DAS	Broom's Barn 2000 15 June : 84 DAS
Aphid type (wingless)		Green ◆	Black	Green	Black	Green	Green	Green ◆
Untreated		1.236 (16.2)	0.268 (0.9)	1.069 (10.7)	0.434 (1.7)	0.457 (1.9)	0.431 (1.7)	1.094 (11.4)
Imidacloprid	45	1.232 (16.1)	0.175 (0.5)	0.031 (0.1)*	0.075 (0.2)	-	-	-
Imidacloprid	60	-	-	-	-	0.094 (0.2)*	0*	0.612 (3.1)*
Imidacloprid	90	0.925 (7.4)	0.040 (0.1)	0.031 (0.1)*	0.369 (1.3)	0.165 (0.5)*	0.021 (0)*	0.298 (1.0)*
Tefluthrin	4	-	-	-	-	0.276 (0.9)*	0.326 (1.1)	1.022 (9.5)
Tefluthrin	10	1.056 (10.4)	0.278 (0.9)	0.868 (6.4)	0.985 (8.7)	-	-	1.119 (12.2)
Tef + Imid	4 + 15	1.189 (14.5)	0.170 (0.5)	0.708 (4.1)*	0.031 (0.1)*	-	-	-
Tef + Imid	4 + 60	-	-	-	-	0.093 (0.2)*	0.040 (0.1)*	0.791 (5.2)
Tef + Imid	4 + 90	-	-	-	-	-	-	0.603 (3.0)*
Fipronil	50	0.983 (8.6)	0.593 (2.9)+	1.032 (9.8)	1.120 (12.2)+	0.291 (1.0)*	0.607 (3.0)	-
Fipronil	100	1.093 (11.4)	0.482 (2.0)+	1.073 (10.8)	0.243 (0.7)	-	-	-
Fip + Imid	50 + 45	0.978 (8.5)	0.171 (0.5)	0.055 (0.1)*	0.162 (0.5)	-	-	-
Fip + Imid	50 + 60	-	-	-	-	0.113 (0.3)*	0.030 (0.1)*	-
Thiamethoxam	45	-	-	-	-	0.026 (0.1)*	0*	-
Thiamethoxam	60	1.260 (17.2)	0.200 (0.6)	0.087 (0.2)*	0.190 (0.5)	0.037 (0.1)*	0*	0.619 (3.2)*
Tef + Thiam	4 + 60	-	-	-	-	0.083 (0.2)*	0.010 (0)*	0.571 (2.7)*
SED (27df)		0.1591	0.1536	0.0925	0.3009	0.0613	0.0627	0.1740
LSD (5%)		NS	0.3149	0.1896	0.6168	0.1258	0.1287	0.3571

Figures in parentheses are back-transformed minus 1. * significantly less or + significantly more than untreated at $P<0.05$. ◆ data from inoculated plants

Table 2 Effect of insecticide seed treatments on virus yellows incidence (% plants infected) in sugar beet

Treatment	Rate g a.i./unit	B. Barn ◆ 22 Sept 1997	B. Barn 8 Sept 1998	B. Barn ◆ 1 Sept 1999	L. Wil'ham ◆ 31 Aug 1999	B. Barn ◆ 24 Aug 2000
Untreated		23.9	3.2	58.2	44.8	49.6
Imidacloprid	45	23.2	2.8	-	-	-
Imidacloprid	60	-	-	47.6	20.4*	43.9
Imidacloprid	90	20.1	2.3	40.5*	11.9*	37.4*
Tefluthrin	4	-	-	55.5	45.7	49.5
Tefluthrin	10	21.5	7.2+	-	-	52.2
Tef + Imid	4 + 15	21.7	2.0	-	-	-
Tef + Imid	4 + 60	-	-	44.7*	6.9*	41.8
Tef + Imid	4 + 90	-	-	-	-	33.5*
Fipronil	50	27.3	8.1+	74.4+	54.0+	-
Fipronil	100	23.4	4.2	-	-	-
Fip + Imid	50 + 45	24.9	1.9	-	-	-
Fip + Imid	50 + 60	-	-	52.7	11.7*	-
Thiamethoxam	45	-	-	42.4*	8.7*	-
Thiamethoxam	60	17.1*	2.1	41.6*	10.0*	34.3*
Tef + Thiam	4 + 60	-	-	35.4*	6.8*	34.7*
SED (27df)		2.24	1.61	6.00	3.19	3.93
LSD (5%)		4.59	3.30	12.30	6.55	8.06

* significantly less and + significantly more than untreated at $P<0.05$. ◆ data from inoculated plants

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Table 3 Effect of insecticide seed treatments on sugar yield (t/ha) in sugar beet

Treatment	Rate g a.i./unit	Broom's Barn 1997 ◆	Broom's Barn 1998	Broom's Barn 1999 ◆	L. Wilb'ham 1999 ◆	Broom's Barn 2000 ◆
Untreated		9.64	11.19	9.10	14.10	8.85
Imidacloprid	45	9.29	11.03	-	-	-
Imidacloprid	60	-	-	9.88	16.75*	8.74
Imidacloprid	90	9.56	11.90	9.36	17.57*	8.88
Tefluthrin	4	-	-	9.26	14.48	8.67
Tefluthrin	10	9.79	10.58	-	-	8.48
Tef + Imid	4 + 15	9.30	12.10	-	-	-
Tef + Imid	4 + 60	-	-	9.97	17.48*	9.46
Tef + Imid	4 + 90	-	-	-	-	10.25*
Fipronil	50	8.97	10.04	6.46+	10.50+	-
Fipronil	100	9.71	5.80+	-	-	-
Fip + Imid	50 + 45	9.54	10.40	-	-	-
Fip + Imid	50 + 60	-	-	8.27	14.26	-
Thiamethoxam	45	-	-	10.02	17.11*	-
Thiamethoxam	60	10.45	11.55	9.98	17.21*	10.18*
Tef + Thiam	4 + 60	-	-	10.91*	17.75*	9.28
SED (27df)		0.390	0.763	0.794	0.705	0.501
LSD (5%)		NS	1.564	1.630	1.447	1.029

NS = not significant; * = significantly more and + = significantly less than untreated at $P<0.05$; ◆ data from inoculated plots.

Thiamethoxam (CGA 293'343) – a novel insecticide for seed delivered insect control

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ABSTRACT

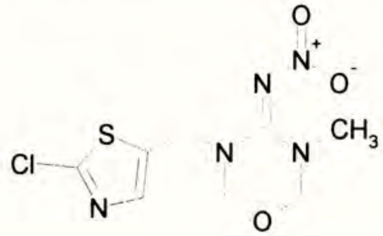
Thiamethoxam (CGA 293'343) is a novel insecticide discovered and currently under world-wide development by Syngenta Crop Protection. Thiamethoxam belongs to a new class of chemistry – the neonicotinoids. It is the first representative of the thianicotinyl subclass – a second generation neonicotinoid characterized by a chlorothiazole ring responsible for the broader activity and higher control potential. A good crop start is ensured by efficient control of all important soil-dwelling and early leaf-feeding and -sucking insects like wireworms, false wireworms, flea beetles, pea weevils, colorado potato beetles, aphids, whiteflies, thrips and different bugs. By controlling sucking insect pests it also prevents the transmission of insect-vectored viruses. The long-lasting and reliable activity of the compound is based on low use rates, systemicity and robustness of performance under different environmental conditions.

INTRODUCTION

Neonicotinoids are a novel and distinct class of insecticides with new mode of action, selective toxicity to insects, and a favourable safety profile (Yamamoto, 1996). Due to these characteristics the neonicotinoids are considered as a suitable substitution of some organophosphate, carbamate, pyrethroid and organochlorine compounds currently used in crop protection, but suffering from high mammalian toxicity, resistance and/or unfavourable environmental properties. Thiamethoxam, a thianicotinyl insecticide, is a compound of second generation of neonicotinoids (Maienfisch *et al.*, 1999). This paper describes the technical properties and latest findings on biological performance of thiamethoxam for seed delivered insect control.

CHEMICAL AND PHYSICAL PROPERTIES

Chemical Structure:



Code Number:	CGA 293'343
Chemical Name:	3-(2-Chloro-thiazol-5-ylmethyl)-5-methyl-[1,3,5]oxadiazinan-4ylidene-N-nitroamine
Empirical Formula:	$C_8H_{10}ClN_5O_3S$
Chemical Class:	Neonicotinoid
Subclass:	Thianicotinyl
Common Name:	Thiamethoxam (ISO draft)
Molecular Weight:	291.72
Physical State at 20° C:	Crystalline powder
Melting Point:	139.1° C
Water Solubility 25° C:	4,100 mg/l
Vapor Pressure 25° C:	6.6×10^{-9} Pa
Partition Coefficient 25° C (log P_{ow}):	-0.13
Formulations	WS70, FS350, FS 600 (FS 5), and combinations with fungicides

MAMMALIAN TOXICOLOGY

Table 1: Acute toxicity of technical thiamethoxam

Acute oral LD_{50}, Rat	1,563 mg/kg
Acute dermal LD_{50}, Rat	> 2,000 mg/kg
Acute inhalation LC_{50} (4h), Rat	> 3,720 mg/m^3
Eye irritation, Rabbit	Non-irritant
Skin irritation, Rabbit	Non-irritant
Skin sensitization, Guinea pig	Non-sensitizing

METHODS AND MATERIALS FOR UPTAKE AND DISTRIBUTION

Cotton seeds were treated with C-14 marked thiamethoxam. The seed loading was determind by combustion. For the autoradiography the plants were freeze-dried and subsequently analysed by a Fuji Bio-Image analyser.

RESULTS

Thiamethoxam has a low molecular weight, low octanol-water partition coefficient and relatively high water solubility, all of which favour rapid and efficient uptake and xylem transport. When applied to the soil or seed, thiamethoxam is rapidly taken up by the roots, or germinating seedlings respectively, and is translocated to the cotyledons and leaves (Figure 1). Thiamethoxam is transported in the xylem in an acropetal direction. This systemic activity protects plant parts situated acropetally from the application site with efficacious levels of thiamethoxam. Degradation of thiamethoxam in the plant is relatively slow, resulting in insect control for an extended period of time.

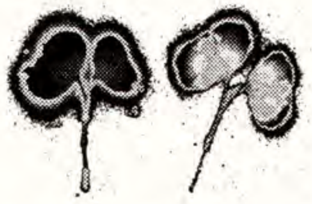


Figure 1: Uptake study of thiamethoxam (left) and imidacloprid (right) in cotton under normal moisture conditions. The darker shading indicates a greater take-up of product. Thiamethoxam is taken up quickly and well distributed throughout the whole leaf where as imidacloprid shows less uptake during the same time period.

METHODS AND MATERIALS FOR FIELD TRIALS

The field trials were laid out in randomized plots with 4 replications. The size of the plots varied from 50 to 300 m². The products were applied as seed treatments before planting. A Hege treater was used to treat the small batches of seeds which were planted with standard equipment. A visual assessment of either number of pests per plant or % of infected or non-infected plants was made either for a specified number of plants per plot or for the whole plot.

RESULTS

Cotton

Resulting from very favourable water solubility, thiamethoxam (Figure 2) performs well under different environmental conditions. Especially in dry soils, the activity is clearly superior to standard treatments. A field study (Figure 2) shows the control of thrips under two different water regimes. One field plot was irrigated and the other was kept dry. Thiamethoxam shows similar control as imidacloprid under normal moisture soil but is clearly superior under dry conditions. Field trials in Brazil confirmed this finding. In one non-irrigated trial it was so dry that even aldicarb was less effective from thiamethoxam against thrips.

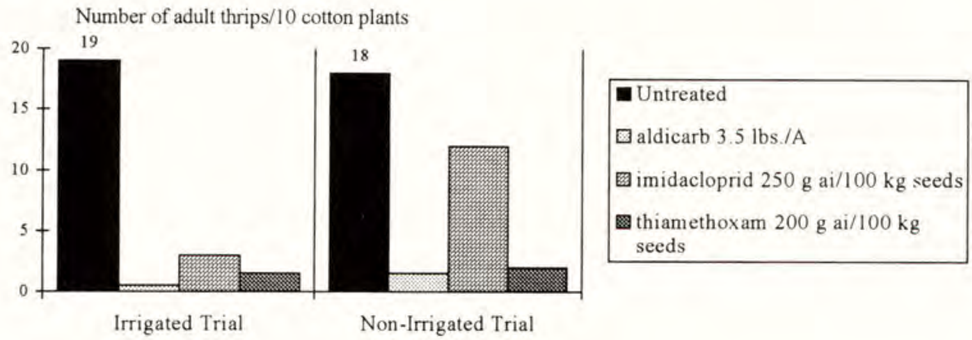


Figure 2. Thrips trial in cotton in USA under irrigated and dry soil conditions.

Maize

In maize, thiamethoxam showed excellent and long lasting activity against different species of wireworms (*Agriotes* spp.) at tested rates between 50 and 315 g a.i. per 100 kg seed in different climatic conditions around the globe (see figure 3).

At rates between 175 to 315 g a.i. per 100 kg seed, early and mid season foliar pests including aphids, jassids, frit fly, black maize beetle, false wireworm and leaf bugs (*Rhopalosiphum* spp., *Zyginidia scutellaris, Oscinella frit, Heteronychus arator, Somaticus* spp., *Dichelops* spp. respectively) were also controlled effectively.

Compared to the standard imidacloprid, control of pests by thiamethoxam was as good in the earlier stages of growth and showed an improvement in damage reduction at the later growth stages. The tested rates and formulations were well tolerated by the different hybrid and inbred lines used in the tests.

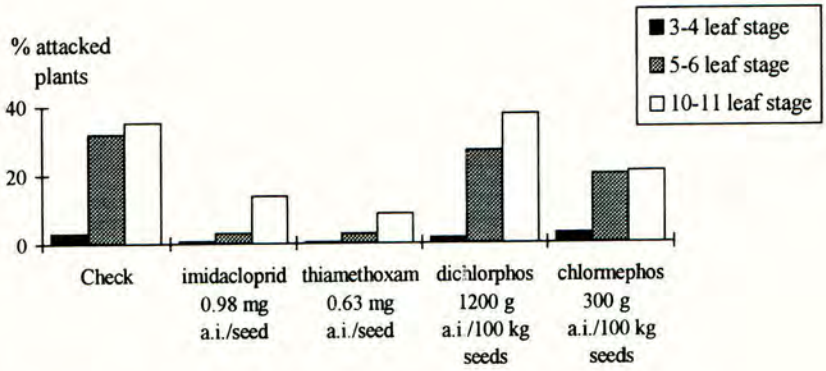


Figure 3: Efficacy of thiamethoxam against *Agriotes* spp. on maize after seed treatment, France, 1997

Cereals

The main reason for applying insecticide seed treatments to cereals is to prevent aphid-vectored virus transmission like barley yellow dwarf virus (BYDV). Thiamethoxam is very active against aphids (*Rhopalosiphum padi*) and a clear effect on virus transmission was observed (Figure 4). In high pressure areas, e.g. occurring in France, 52 to 70 g a.i./100 kg seeds may be needed whereas in low pressure areas, lower rates are sufficient (35 g a.i.). A rate of 35 g a.i./100 kg is also sufficient to control wireworms (*Agriotes* spp.) and ground beetle (e.g. *Zabrus tenebrioides*) in wheat and barley.

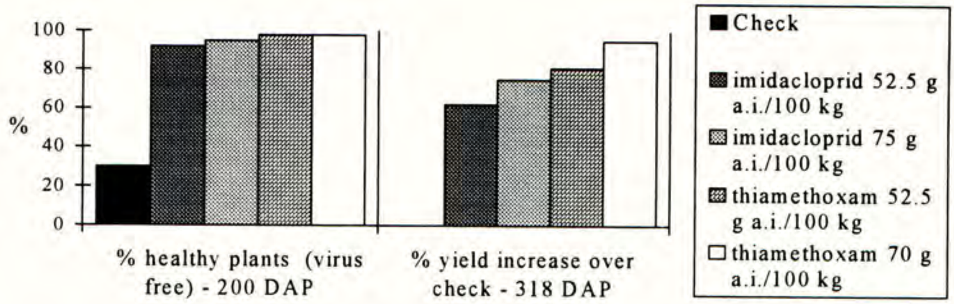


Figure 4: Efficacy of thiamethoxam against barley yellow dwarf virus (BYDV on barley after seed treatment, France, 1997. (Efficacy and yield response).

USE RECOMMENDATION OF THIAMETHOXAM

Crop	Typical Pest	Seed Treatment
Potato	*Leptinotarsa decemlineata* *Myzus persicae* *Macrosiphum euphorbiae* *Empoasca fabae*	4 - 7.5 g a.i./100 kg
Soybean	*Sternechus subsignatus* *Ceretoma arcuata* Termites	17.5 - 150 g a.i./100 kg
Rice	Water weevil Planthoppers *Deois flavopicta* *Elasmopalpus lingnosellus*	50 - 100 g a.i./100 kg
Cotton	*Aphis gossypii* *Empoasca devastans* *Conotrachelus denieri* *Thrips tabaci*, *Frankiniella* *Eutinobothrus* spp. *Agriotes* spp.	70 - 350 g a.i./100 kg
Maize	*Agriotes* spp. *Rhopalosiphum* spp. *Oscinella frit* *Heteronychus arator* *Dichelops* spp.	40 - 315 g a.i./100 kg
Cereals	*Rhopalosiphum padi* *Agriotes spp.* *Zabrus tenebrioides*	35 - 70 g a.i./100 kg

Sugar beet	*Myzus persicae, A. fabae* *Atomaria* spp. *Chaetocnema* spp. *Pegomya betae*	60 g a.i. per unit (unit = 100,000 seeds)
Sorghum	*Rhopalosiphum maidis* *Agriotes spp.* *Schizaphis graminum*	100 - 200 g a.i./100 kg
Oilseed rapes	*Psylliodes chrysocephala* *Phyllotetra* spp. *Brevicoryne brassicae*	400 - 420 g a.i./100 kg
Peas/Beans	*Macrosiphum pisum* *Aphis fabae* *Sitona lineata*	52 g a.i./100 kg
	Bemisia tabaci	70 - 100 g a.i./100 kg
Sunflower	*Anuraphis helichrysi* *Myzus persicae* *Aphis fabae, Agriotes* spp.	350 g a.i./100 kg
Peanuts	*Frankliniella* sp.	150 - 200 g a.i./100 kg

CONCLUSIONS

Thiamethoxam is the first representative of the 2nd generation neonicotinoid compounds with clear advantages, such as lower use rates, higher residual activity and a much broader spectrum. In addition to its uses as a foliar and granular soil treatment, thiamethoxam is about to be introduced into the market as a seed treatment under the brands Cruiser®, Adage™ and Helix™. This product range offers the opportunity to manage crops more efficiently through more sophisticated and integrated crop protection systems. In comparison to other currently marketed neonicotinoid products, thiamethoxam can give an improved performance under different environmental conditions. It can be used in most agricultural crops and controls a wide range of sucking and chewing insects, including some *Lepidoptera* pests. Thiamethoxam is the ideal replacement of older chemistry in this market.

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The influence of seed rate on the efficacy of imidacloprid seed treatment against BYDV in winter cereals

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ABSTRACT

Unless adequately controlled, Barley Yellow Dwarf Virus (BYDV) can have a devastating effect on cereal crops. Imidacloprid seed treatment affords control of the aphid vectors of BYDV, providing protection to the plant from crop emergence. However, with an increasing number of growers looking to drill winter cereal crops earlier and at reduced seed rates, the potential risk of BYDV infection is increased. In addition, the performance of imidacloprid seed treatment can be affected. The need for a programmed approach to BYDV control where early drilling and low seed rates are involved, is discussed.

INTRODUCTION

With growers being under increasing pressure to reduce inputs, there is a tendency for earlier drilling of winter cereals. Earlier drilling allows growers to realise potential yields, spread workloads and use lower seed rates. Seed rates for earlier drilled cereals can be lower than for conventional timings, because individual plants have more time to develop and produce more tillers.

One disease which can be more prevalent in early drilled crops is Barley Yellow Dwarf Virus (BYDV). World-wide, BYDV is recognised as one of the most economically damaging diseases of grass and cereal crops (D'Arcy & Burnett, 1995). In Britain, regions in the South and West and areas within close proximity to coastland or grassland are at a higher risk of infection.

Early drilling using lower seed rates has increased the need for effective and more intensive BYDV control in areas of high disease pressure. In such situations, imidacloprid seed treatment has an important part to play (Schmeer *et al.*, 1990). Imidacloprid is applied at a fixed rate per tonne of seed. This means, for earlier drilled, lower seed rate crops, several factors are at work which could affect efficacy against BYDV. The rate per hectare of imidacloprid is reduced, and therefore the possible uptake of imidacloprid by a seedling from neighbouring seeds, will also be reduced. At the same time, individual plants will grow larger in the increased space and growing period made available by earlier sowing, resulting in a lower concentration of the insecticide in individual plants.

This paper reports on a series of field trials in winter wheat and winter barley during the 1999/2000 season, investigating the impact of seed rate and, to some extent, time of drilling, on the control of BYDV, and suggests the best approach to control of BYDV where seed rate varied from 50 to 150 kg/ha.

MATERIALS AND METHODS

During the 1999/2000 season, a total of five trials were carried out by Bayer plc. Three trials were conducted on winter barley. Trial 1 (Suffolk) was drilled on 27 August, trial 2 (Kent) and trial 3 (Devon) were drilled 16 September. Two winter wheat trials were drilled; trial 4 (Essex) on 10 September and trial 5 (West Sussex) on 7 September.

The trials were drilled using a small plot Wintersteiger drill, with half rate (17.5g a.i./100 kg seed) imidacloprid guard plots between each treated plot to minimise 'edge effects'. The treated plots were 3 m in width by 8-10 m in length. The trials were drilled in a standard four-replicate randomised block design (trial 1 had three-replicates) at three different seed rates (50, 100 and 150 kg/ha). The seed treatments (all flowable formulations), were applied using a Mini-Rotostat laboratory seed treater (Table 1).

Table 1. Experimental treatments.

Crop	Variety	Trade name	Rate of product/ 100 kg seed	Active ingredients and formulation (g/litre)		Rates a.i./ 100 kg seed
W barley	Regina	'Raxil S'	150 ml	tebuconazole	020	3 g
				+ triazoxide	020	3 g
W barley	Regina	'Raxil Secur'	150 ml	tebuconazole	020	3 g
				+ triazoxide	020	3 g
				+ imidacloprid	233	35 g
W wheat	Consort	'Sibutol'	150 ml	bitertanol	375	56.23 g
				+ fuberidazole	023	3.45 g
W wheat	Consort	'Sibutol Secur'	400 ml	bitertanol	140	56.0 g
				+ fuberidazole	008.6	3.44 g
				+ imidacloprid	087.5	35.0 g

Throughout this paper treatments will be referred to as winter barley or winter wheat, with or without imidacloprid seed treatment. All plant growth stages are referred to using the BBCH scale (Meier, 1997). The standard comparison in all trials was a two spray pyrethroid programme. Lambda-cyhalothrin ('Hallmark' 50 g/litre EC) 5.0 g a.i./ha was applied between BBCH 12-24 (three weeks after emergence). The second application was made between BBCH 13-29 (seven weeks after emergence). Spray applications were made using a water volume of 200 l/ha by means of a pressurised knapsack sprayer.

Aphids were assessed by sampling plants and counting the numbers of aphids per plant. BYDV was recorded as the percentage area of the plot infected. Yields were obtained using a Sampo small plot combine harvester and correcting grain yield to 86% dry matter. All assessment data were statistically analysed.

RESULTS

Treatments containing an insecticide component have been compared against the same seed rate for the seed treatments without the insecticide.

Winter barley

Aphid Control

Results for the control of the bird-cherry aphid *(Rhopalosiphum padi)* were obtained from trial 1. Irrespective of seed treatment, the lower the seed rate used, the higher the number of aphids per plant recorded. However, the number of aphids per m² on the plots without imidacloprid treatment, was broadly similar for all seed rates. With the addition of imidacloprid, the number of aphids per plant was substantially reduced (Table 2).

Table 2. Aphid control (*Rhopalosiphum padi*) in winter barley (trial 1).

Drilling rate kg/ha	Imidacloprid g a.i./ha	No. of pyrethroid sprays	Aphids/plant [mean]	Aphids/plant [sq. root trans]	Aphids/m² [mean]	Aphids/m² [sq. root trans]
50	0 g	0	28.6	4.7	2709.5	51.3
50	17 g	0	0.8	1.0	85.3	8.7
100	0 g	0	16.4	3.7	2940.5	53.5
100	35 g	0	0.3	0.9	52.6	7.2
150	0 g	0	12.2	3.1	3085.3	53.9
150	52 g	0	0.1	0.8	24.2	5.0
100	0 g	1	0.7	1.0	126.2	10.4
		S.E. =	-	0.2	-	3.7
		d.f. =	-	30	-	30

Assessed 54 days after drilling at BBCH 29

BYDV Control

BYDV results were obtained from all three winter barley sites, with disease on the plots without imidacloprid treatment, ranging from 12-96% plot area infected across the three trials. In the absence of insecticide treatment, as the seed rate decreased, then the level of BYDV increased (Table 3). All insecticide seed treatments and sprays gave significant reductions in the level of BYDV recorded. In spite of this, the level of control given by the imidacloprid treated seed also decreased as the seed rate was reduced. Seed without imidacloprid followed by two pyrethroid sprays gave similar BYDV control to imidacloprid treated seed followed by one-spray.

Yield

The yield from the earliest drilled trial (trial 1) was, as expected, the most affected by BYDV. The imidacloprid seed treatment gave substantial benefits to yield, but the most effective treatments were imidacloprid treated seed followed by one pyrethroid spray and non-imidacloprid treated seed followed by two pyrethroid sprays.

For both imidacloprid and non-imidacloprid treated seed, the lower the seed rate, the lower the mean yield recorded (Table 4).

Table 3. BYDV infection on winter barley.

Drilling rate kg/ha	Imidacloprid g a.i./ha	No. of pyrethroid sprays	% BYDV/plot (Trial 1)	(Trial 2)	(Trial 3)	Mean infection
50	0	0	95.7	19.8	68.8	61.4
50	17	0	83.3	8.4	22.5	38.1
100	0	0	95.0	20.2	55.0	56.7
100	35	0	70.0	3.7	8.2	27.3
150	0	0	90.7	12.4	52.5	51.9
150	52	0	46.7	2.0	7.2	18.6
100	0	2	12.0	0.0	1.2	4.4
100	35	1	11.0	0.1	0.2	3.8
		S.E. =	2.5	1.4	3.3	
		d.f. =	30	27	27	

Assessed 197-220 days after drilling at BBCH 31-37

Table 4: Yield of winter barley.

Drilling rate kg/ha	Imidacloprid g a.i./ha	No. of pyrethroid sprays	Yield t/ha (Trial 1)	(Trial 2)	(Trial 3)	Mean
50	0	0	1.6	7.9	4.4	4.6
50	17	0	3.8	9.8	5.2	6.3
100	0	0	2.4	8.5	4.7	5.2
100	35	0	3.9	9.6	5.7	6.4
150	0	0	3.4	8.2	4.7	5.4
150	52	0	5.2	8.7	5.6	6.5
100	0	2	6.9	9.3	6.7	7.6
100	35	1	7.3	9.5	6.6	7.8
		S.E. =	0.3	0.3	0.2	
		d.f. =	30	27	27	

Assessed 305-335 days after drilling at BBCH 99

Winter wheat

BYDV control

BYDV results were obtained from both winter wheat sites (Table 5), with disease levels across both trials on the plots without imidacloprid treatment ranging from 4-70% plot area infected. In the absence of insecticide treatment, as the seed rate decreased the level of BYDV increased slightly. Significant reductions in BYDV levels were recorded for all insecticide seed treatments and sprays. The level of control given by the imidacloprid treated seed decreased as the seed rate was reduced. Comparable to the results for winter barley, winter wheat seed without imidacloprid followed by two pyrethroid sprays gave similar BYDV control to imidacloprid treated seed followed by one-spray.

Table 5. BYDV infection and yield of winter wheat.

Drilling rate kg/ha	Imidacloprid g a.i./ha	No. of pyrethroid sprays	% BYDV/plot (Trial 4)	% BYDV/plot (Trial 5)	Mean infection	Yield t/ha (Trial 4)
50	0	0	12.7	70.4	41.6	9.6
50	17	0	4.4	20.3	12.4	10.3
100	0	0	9.5	65.8	37.7	10.4
100	35	0	1.3	19.9	10.6	11.1
150	0	0	4.8	69.6	37.2	10.8
150	52	0	0.3	12.5	6.4	11.0
100	0	2	0.2	0.4	0.3	11.4
100	35	1	0.3	0.2	0.3	11.3
		S.E =	0.6	3.2		0.2
		d.f. =	27	27		27

Assessed 247-266 days after drilling at BBCH 39-59

Yield

Due to significant lodging in one trial, only one yield result for winter wheat is presented in this paper (Table 5). Imidacloprid seed treatment increased yield at all seed rates used. Imidacloprid treated seed followed by one pyrethroid spray gave equivalent yield results to seed without imidacloprid followed by two sprays.

DISCUSSION

The number of aphids flying into an area will remain the same, irrespective of seed rate used. This was borne out at trial 1, where the number of aphids/m^2 was broadly similar across all seed rates.

Therefore, at the lower seed rates individual plants will be infested with a greater number of aphids. This will increase the possibility of an individual plant being infested with a virus bearing aphid, and therefore becoming infected by BYDV.

Early drilling can increase BYDV disease pressure, as there is a greater opportunity for aphids to infect the crop. In this series of trials, this was shown at trial 1, where winter barley was drilled on 27 August. The level of BYDV at this site was very severe, reaching over 95% of the plot infected where non-imidacloprid treated seed was used. Yield increases from the most effective insecticide treatments were up to 4.9 t/ha. On the other later drilled sites (drilled between 7-16 September) the level of infection was lower (12-69% plot infected), and the corresponding yield improvements from treatments were lower. However, yields as a whole were higher. At these later sites, imidacloprid seed treatment followed by one pyrethroid spray gave virtually complete control of BYDV, whilst at the earliest site this treatment gave less than complete control. The yield response in winter wheat was not as great as in winter barley, which was a reflection on the difference in disease severity between these two crops.

Control of BYDV from imidacloprid was seed rate related. At reduced seed rates, the amount of imidacloprid per hectare and per plant is reduced, which has a significant bearing on the level of protection offered. This was more pronounced in the winter barley, where the mean level of infection was much greater. The imidacloprid seed treatment performed similarly on both cereal crops, whereby the higher the seed rate, the lower the level of BYDV recorded.

This series of trials has shown that in areas of high disease pressure and early drilling, crops treated with imidacloprid will require appropriate follow up spray treatment(s). Where imidacloprid treated seed is drilled in the middle two weeks of September and at a minimum of 100 kg/ha, a follow up spray of one well-timed insecticide is likely to be required. With earlier drillings, or at seed rates lower than 100 kg/ha, more than one spray may be required.

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