CONTROL OF CEREAL DISEASES WITH FENPROPIMORPH AND FENPROPIMORPH MIXTURES IN THE UNITED KINGDOM

J.C. Atkin and R.G. Parsons
May & Baker Ltd., Ongar Research Station, Ongar, Essex.
C.E. Rieley and S. Waterhouse
BASF United Kingdom Ltd., Hadleigh, Suffolk.
H. Siegle
Dr. R. Maag Ltd., Dielsdorf, Switzerland.

Summary Small plot replicated and large plot farmer usage trials confirmed the efficacy of fenpropimorph against rusts and powdery mildew on wheat and barley, and showed that leaf blotch on barley is also well controlled.

Mixtures of fenpropimorph with thiophanate-methyl or carbendazim gave good control of eyespot and excellent control of leaf blotch. Addition of fenpropimorph to chlorothalonil led to improved control of *Septoria* on wheat in situations where other leaf diseases were also present. The addition of carbendazim to this mixture slightly improved *Septoria* control and gave higher yields.

Fenpropimorph has been shown to be equal to or better than the standard triazole treatments and thus, because it almost certainly has a different mode of action, presents an attractive alternative for broad spectrum cereal disease control.

Resumé Les essais de détail avec répétitions ainsi que les essais pratiques en grande surface ont confirmés l'efficacité du fenpropimorph contre les rouilles, l'oïdium et la rhynchosporiose sur blé et orge.

Les mélanges de fenpropimorph avec thiophanate-methyl ou carbendazim démontrent un bon contrôle du pietin-verse et un excellent contrôle de la rhychosporoise. L'addition du fenpropimorph au chlorothalonil a révélé une amélioration du contrôle de la septoriose sur blé, particulièrement lorsque d'autres maladies des feuilles étaient preséntes. L'addition du carbendazim à ce mélange renforcé l'efficacité sur septoriose un par et le rendement était supérieur.

Fenpropimorph s'est révélé égal ou supérieur aux standards à base de triazoles. Il représente, grâce au fait qu'il possède un mode d'action probablement tout à fait différent, une alternative très intéressante comme instrument de contrôle à large spectre des maladies des céréales.

INTRODUCTION

Fenpropimorph is a broad-spectrum fungicide active against a wide range of cereal diseases (Bohnen *et al*, 1979). The mode of action of the morpholine group, to which fenpropimorph belongs, is known to be similar to that of the triazoles, both causing C-14 demethylation in the ergosterol biosynthetic pathway

(Kerkenaar, et al, 1979). However, studies with tridemorph, another morpholine, have shown that the specific point of activity in the pathway is dissimilar for these two groups of compounds (Leroux, 1981). This and other work (Fisher, 1974) therefore indicates that cross resistance between the morpholines and the triazoles is unlikely to be of importance in the field.

During initial development of fenpropimorph (Bohnen et al, 1979) the compound was shown to be active against powdery mildew (Erysiphe graminis) and several rust diseases (Puccinia striiformis, P. recondita and P. hordei) of cereals. This paper reports further work with fenpropimorph alone for the control of mildew, rusts and barley leaf blotch (Rhynchosporium secalis), and in mixtures with methyl-benzimidazole-carbamate generating compounds and chlorothalonil for the control of eyespot (Pseudocercosporella herpotrichoides) and Septoria (S. nodorum).

MATERIALS AND METHODS

Small plot replicated and large plot farmer usage trials were carried out on wheat and barley throughout the United Kingdom. In small plot trials, treatments were applied using knapsack sprayers or purpose built motorised sprayers, in 200-300 litres of water per hectare at 2-2.5 kg/cm^2 pressure. Plots were $50m^2$ and were arranged in four randomised blocks. Treatments in farmer usage trials were applied using farm sprayers in 200-300 litres of water per hectare. Plots were 1-2 hectares and unreplicated.

The fungicide treatments are listed in Table 1 but other details for individual trials are given in the results tables. Cereal growth stages were recorded using the decimal code of Zadoks et al (1974). Leaf diseases were assessed using Ministry of Agriculture keys, and eyespot using the Scott and Hollins key (Scott and Hollins, 1974).

Table 1

Fungicide treatments

(a) Mildew, rust, leaf blotch and eyespot trials

Chemical name and formulation		Dose (kg ai/ha)
Fenpropimorph	ec	0.75
Thiophanate-methyl	sc	0.50
Carbendazim	sc	0.25
Triadimefon	wp	0.125
Triadimefon/ Carbendazim	wp	0.125/ 0.25
Propiconazole	ec	0.125
Prochloraz	ec	0.40

(b) Septoria trials

Chemical name and formulation		Dose (kg ai/ha)
Chlorothalonil	sc	1.0
Fenpropimorph +	ec	0.75
Chlorothalonil	sc	1.0
Fenpropimorph +[a]	ec	0.75
Carbendazim +	sc	0.15
Chlorothalonil	sc	1.0
Fenpropimorph +[b]	ec	0.56
Carbendazim +	sc	0.15
Chlorothalonil	sc	0.75
Triadimefon/ Captafol	wp	0.125/ 1.3

Notes: sc = suspension concentrate
a = This treatment denoted in Table 5 as the low rate mixture.
b = This treatment denoted in Table 5 as the high rate mixture.

Yields were taken from small plots using either a Claas Columbus (1.8 metre cut) or a Claas Compact 25 (2.1 metre cut) combine harvester. A strip was cut from each plot and the weight of grain recorded and corrected to 15% moisture. Yields are shown in brackets in the tables as a percentage of the mean yield from untreated plots. Statistical significance is denoted by asterisks (* = significantly different from the untreated at the 5% level, ** at the 1% level and *** at the 0.1% level). Where no asterisks are shown the results are not significantly different from the untreated.

RESULTS

Powdery Mildew

Trials on a range of winter wheat and winter and spring barley cultivars under conditions of differing disease intensity confirmed that fenpropimorph gives very good control of powdery mildew (Table 2). Results were very similar to those obtained with the standard treatments triadimefon and propiconazole, with good control persisting, at some sites, until 45 days after single applications in the spring. Fenpropimorph alone and in a mixture with thiophanate-methyl applied in the winter remained effective for up to 57 days after treatment.

Yields, where measured, were consistently increased compared to untreated controls but not always significantly.

Yellow and Brown Rust

Single applications of fenpropimorph gave similar results to the standard treatments triadimefon and propiconazole in approximately half of the trials, but in the remainder large differences in performance were recorded (Table 3a sites 4, 5 and 7; Table 3b sites 4, 5 and 6) with fenpropimorph being generally superior to the standards. These differences in performance were not apparently associated with particular crops or differences in the intensity of disease present.

At site 6 (Table 3b) the efficacy of fenpropimorph mixtures was tested because although the trial was initially established for the control of Septoria, brown rust subsequently became the predominant disease.

Leaf Blotch

All but one of the leaf blotch trials were on winter barley. Fenpropimorph showed good activity against this disease giving generally better control than the standard treatment triadimefon (Table 4). This was particularly evident at sites 1, 3, 4 and 8 where later assessments were made (between 34 and 42 days after treatment). However, the best results were obtained with mixtures of fenpropimorph plus thiophanate-methyl and triadimefon plus carbendazim, both treatments giving in excess of 90% control at most sites. Their superior activity against this disease in reflected in the higher yield responses given by these mixtures.

Table 2

Control of mildew on barley and wheat

Site/ cultivar	Spray date/ crop GS	Assessment: Days after spraying	Assessment: Leaf No. or ear	Mean % area infected in untreated (yield t/ha)	% control: Fenpropimorph	% control: Standard triadimefon	% control: Other materials
1. Lincs Athos (SB)	19.5.80 31	14	4	34.0 (4.61)	87 (106)	85 (104)	82[a] (104)
2. Midlothion G. Promise (SB)	26.5.79 32	14	4,5 & 6	4.8 (5.96)	93 (108)	90 (107)	92[b] (104)
3. Worcs Georgie (SB)	30.5.79 32	28	3 & 4	6.2 (6.60)	100 (105)	100 (105)	100[a] (101)
4. Essex G. Promise (SB)	1.6.81 32	14	2 & 3	6.5	99	58	93[a]
5. Fife Igri (WB)	23.5.79 69	7 40	1 1	4.8 15.0 (5.34)	94 99 (122)***	75 97 (117)**	
6. Cambs M. Otter (WB)	25.11.80 23	43	3	32.8 (5.20)	98[c] (108)	97[b] (113)	
7. Essex M. Otter (WB)	15.4.81 31	45	2	5.1	78 82[c]	82[b]	
8. Fife M. Otter (WB)	29.10.79 22-23 2.4.80 30	14 40	1 & 2 1 & 2	22.2 37.0 (5.85)	89 86 (115)*	100 97 (110)	
9. Essex Hobbit (WW)	8.1.81 24	57	3	5.4	100 100[c]	100	
10. Essex Armada (WW)	18.2.81 25	47	2	57.1	86[c]	87[b]	
11. Yorks M. Huntsman (WW)	18.6.79 56	12	2	4.0 (7.34)	100 (102)	100 (96)	
12. Hereford Flanders (WW)	16.6.79 70	27	Ear 1	12.5 12.6	94 83	90 88	

Notes: Other materials: a = Propiconazole; b = Triadimefon + carbendazim; c = Fenpropimorph + thiophanate-methyl

SB = Spring barley
WB = Winter barley
WW = Winter wheat

Table 3

(a) Control of yellow rust on barley and wheat

Site/ cultivar	Spray date/ crop GS	Assessed: Days after spraying	Assessed: Leaf No. or Ear	Mean % area infected in untreated (yield t/ha)	% Disease control: Fenpropimorph	% Disease control: Triadimefon
1. Worcs Mazurka (SB)	6.7.78 50-58	28	Ear[b]	14.7 (5.68)	72 (109)**	90 (110)**
2. Yorks Mazurka (SB)	11.7.78 71-75	10	1 & 2	4.2	68	70
3. Norfolk Sonja (WB)	10.6.80 64	10	1	2.8	72	72
4. Worcs Athene (WB)	12.6.80 75	14	1 & 2	6.0	98	25
		28	Ear	33.0	57	30
5. Lincs Kador (WW)	9.6.80 45	10	3	14.0	93	64
		52	2	72.0[c]	93	80
6. Worcs Virtue (WW)	13.6.80 49-50	38	1	17.0	100	100[d]
		48	1	28.7	100	100[d]
7. Cambs Vuka (WW)	15.6.80 58	28	1	5.0	98	40
			2	17.0	23	23

(b) Control of brown rust

Site/ cultivar	Spray date/ crop GS	Assessed: Days after spraying	Assessed: Leaf No.	Mean % area infected in untreated	% Disease control: Fenpropimorph	% Disease control: Triadimefon
1. Essex G. Promise (SB)	1.6.81 35	14	1	25.5	95	93 96[d]
2. Essex M. Otter (WB)	11.6.79 50-64	21	2	38.0	83	96
3. Cambs Igri (WB)	6.5.81 37	50	1	4.4	70	76
4. Lincs FU Armada (WW)	18.6.80 58	21	1 & 2	14.0	99	75
5. Somerset M. Huntsman (WW)	21.6.81 65	10	2	21.7	67	52 68[d]
6. Somerset M. Huntsman (WW)	10.6.81 51-58	11	1 & 2	16.1	61[a]	37[d]
		30	1	25.0	84[a]	58[d]

Notes:- a = Fenpropimorph 0.75 kg ai/ha + chlorothalonil 1.0 kg ai/ha + carbendazim 0.15 kg ai/ha as a tank mix.
b = Percent number of glumes infected per plot.
c = Figure includes associated dead tissue.
d = Propiconazole.
SB = Spring barley; WB = Winter barley; WW = Winter wheat.
FU = Farmer usage trial.

Table 4

Control of Leaf Blotch

Site/ cultivar	Spray date/ crop GS	Assessed: Days after spray- ing	Assessed: Leaf No.	Mean % area infected in untreated (yield t/ha)	% control: Fenprop- imorph	% control: Triadim- efon	% control: Triadim- efon + carbend- azim
1. Fife	5.5.79	35	2	6.2	52	11	95
M. Otter (WB)	30		3	55.0	84	50	91
				(6.24)	(97)	(99)	(106)
2. Devon FU	8.5.79	23	1	23.2	57	67	
Athene (WB)	36		2 & 3	67.8	41	48	
3. Devon FU	9.5.79	23	1	6.2	97	48	
Athene (WB)	37		2 & 3	39.7	40	36	
		34	1	22.6	97	8	
			2	44.4	70	12	
4. Worcs	9.5.79	28	3	4.7	68	47	64
M. Otter (WB)	31	42	1	2.6	38	12	54
			2	13.5	33	32	56
				(5.51)	(103)	(107)*	(114)**
5. Yorks	26.5.79	10	3	3.4	88	71	99
M. Otter (WB)	31-32		4	12.5	72	64	86
				(4.81)	(108)*	(105)	(111)*
6. Essex	14.2.80	35	1	6.4	53	-	91
M. Otter (WB)	23,	after		(5.0)	(100)		(109)
	and	2nd					
	23.4.80	applic-			92[a]		
	30	ation			(111)		
7. Essex	16.4.80	36	3	10.4	86	-	97
M. Otter (WB)	30			(6.9)	(103)		(106)*
					99[a]		
					(109)*		
8. Humberside FU	1.5.80	35	3 & 4	1.4	79	0	
Sonja (WB)	30						
9. Suffolk	18.5.81	24	3	1.1	72	74	
Goldmarker(SB)	30				94[a]		
10. Suffolk	2.5.81	35	3	15.3	94[a]	96	
M. Otter (WB)	36						

Notes: a = Fenpropimorph + thiophanate-methyl
WB = Winter barley
SB = Spring barley
FU = Farmer usage trial

Table 5

Control of Septoria

Site/ cultivar	Spray Date and crop GS	Assessed: Days after spraying	Assessed: Leaf No. or ear	Mean % area infected in untreated (yield t/ha)	% Disease control: Chloro- thalonil	Fenpropimorph + chlorothalonil	3-way mix low rate	3-way mix high rate	Triadimefon + captafol
1. Glos.	25.6.80	29	1 & 2	48.1	29	34	40	47	
Mardler (WW)	68	40	Ear	20.0	15	17	20	20	
				(8.02)	(107)*	(105)	(109)***	(108)**	
2. Somerset	4.6.80	29	2	18.5	18	42	40		16
Hobbit (WW)	68	48	1	43.7	73	79	73		48
				(8.07)	(112)	(115)*	(115)*		(120)*
3. Somerset	3.6.80	49	1	27.0	41	91	85	93	79
Armada (WW)	58			(6.16)	(111)	(118)***	(119)***	(123)***	(121)***
4. Glos.	8.6.81	42	1	28.5			61		60
Bounty (WW)	53			(8.13)			(103)		(105)
5. Glos.	8.6.81	42	1	56.5			55		58
Bounty (WW)	53			(7.77)			(103)		(106)*
6. Glos.	18.6.81	39	1	29.8			58		54
Hustler (WW)	50								

At sites 2 and 3 other foliar diseases infected the plot after Septoria:

Disease	Leaf No.	Days after treatment	Mean % area infected in untreated: Site 2	Site 3
Mildew	2	29-30	15.5	9.2
Brown rust	2	49	0.0	16.2

Table 6

Control of eyespot

Site/ cultivar	Spray date/ crop GS	GS at assess- ment	% stems severely infected (yield t/ha)	% control: Fenprop- imorph	% control: Fenprop- imorph + carbend- azim	% control: Fenprop- imorph + thio- phanate- methyl	% control: Other standard
1. Cambs Armada (WW)	1.4.80 30-31	85	14.0 (7.18)	-	100 (114)**		93[b] (106)**
2. Yorks M. Huntsman (WW)	2.5.80 30-31	75	6.0 (6.82)	-	100 (123)**		100[b] (92)
3. Suffolk Hobbit (WW)	12.2.81 30	73	52.0	-		100	85[a]
4. Hants M. Huntsman (WW)	16.4.81 31	65	31.6	-		95	95[a]
5. Hants Igri (WB)	7.4.81 30	77	93.0	0		61	72[a]
6. Essex M. Templar (WW)	10.4.81 31	69	51.0	0		57	73[a]

Notes: a = Triadimefon + carbendazim WW = Winter wheat
b = Prochloraz WB = Winter barley

Septoria

At site 1 (Table 5) where Septoria was the only disease present, fenpropimorph did not significantly add to the effect of chlorothalonil. By contrast, at sites which subsequently became infected with other foliar diseases, the control of Septoria by chlorothalonil was markedly improved upon by the addition of fenpropimorph (sites 2 and 3). The addition of carbendazim to fenpropimorph plus chlorothalonil gave a small improvement in Septoria control and the high rate of this mixture gave greater yields at sites 1 and 3.

In terms of disease control the 2 and 3-way fenpropimorph mixtures were superior to the standard triadimefon plus captafol in 1980 trials, although there was little difference between these treatments in the 1981 trials.

Eyespot

Mixtures of fenpropimorph plus thiophanate-methyl and fenpropimorph plus carbendazim gave good control of eyespot over a wide range of disease severities (Table 6). The results were similar to those obtained with the standards, prochloraz and triadimefon plus carbendazim. Where yields were measured, increases obtained with fenpropimorph plus carbendazim were superior to those obtained with the standard prochloraz.

DISCUSSION

The trials reported here confirm the activity of fenpropimorph against powdery mildew and rust diseases previously reported (Bohnen et al, 1979) and show that leaf blotch is also well controlled. However, fenpropimorph alone was shown to have little effect against eyespot or Septoria.

The methyl-benzimidazole-carbamate generating compounds, thiophanate-methyl and carbendazim have been previously shown to control eyespot (Jenkyn and Prew, 1973; Taylor and Waterhouse, 1975) and our trials confirmed that both compounds controlled eyespot when applied in mixtures with fenpropimorph. Additionally, a mixture of fenpropimorph and thiophanate-methyl gave excellent control of leaf blotch. Mixtures of fenpropimorph with MBC are therefore particularly suited to application at GS 30-31 for eyespot control, if mildew and leaf blotch are also present.

Chlorothalonil is known to be active against Septoria (Pauwels and Schauer, 1976). In the trials reported, mixtures of chlorothalonil plus fenpropimorph showed no benefit over chlorothalonil alone where Septoria was the only disease present. The value of this mixture, however, was shown at sites where other diseases subsequently developed. At these sites an improvement in Septoria control was recorded, in addition to control of the secondary diseases. The MBC-generating compounds also have some activity against Septoria (Melville and Jemmett, 1971) and the addition of carbendazim to the chlorothalonil plus fenpropimorph mixture gave slightly better control of Septoria in these trials and higher yields. This 3-way mixture is particularly suited to applications at ear emergence in wheat, when crops are often subjected to attack by Septoria and other foliar diseases either together or sequentially.

The carbendazim component of the mixture, as well as contributing to the control of foliar diseases, may well have other benefits when applied at this time because MBC-generating compounds have previously been reported to give some control of late eyespot (Rule, 1975), and are known to give a 'tonic' effect to crops resulting in consistent improvements in yield (Allison et al, 1975).

These trials clearly demonstrated the benefits of fenpropimorph as the basis of cereal disease control programmes, whether used alone for the specific control of mildew, leaf blotch or rusts, or as a component of mixtures for comprehensive disease control. Fenpropimorph represents an attractive alternative to the triazole group of compounds, especially in the light of recent information highlighting the possible adverse consequences resulting from the widespread use of products with the same mode of action (Holloman, 1981).

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EVALUATION OF FUNGICIDES AS SEED DRESSINGS AGAINST NEW STRAINS OF WHEAT BUNT IN GREECE

Elpis A. Skorda
Cereal Institute, Thessaloniki, Greece

Summary One or more hexachlorobenzene insensitive strains of common bunt (*Tilletia foetida*) on wheat in Greece have been shown to be spread all over the country. Therefore screening of used or new seed treatment fungicides for their effectiveness against the new strains was considered to be essential. In field trials, seed treatment chemicals against the new strains of the fungus were tested at different rates, and at four sites over a period of two years. Methfuroxam (in 1979) and nuarimol (in 1978) at the low rate of 10 g a.i. per 100 kg of seed as well as mixtures of these two chemicals with other chemicals were very effective against artificially inoculated bunt of wheat. RH-2161, carbendazim and zinc omadine at a rate of 60 g a.i. per 100 kg of seed, had a similar level of efficacy as the above two compounds. Thiophanate-methyl + maneb, manganese/zinc dithiocarbamate, mancozeb + carbendazim, chlorothalonil + thiophanate-methyl and carboxin + thiram at higher rates also gave good results. Fenfuram, mixtures of guzatine with fenfuram and imazalil, mixtures of thiophanate-methyl with imazalil, thiabendazole + imazalil and triadimenol gave less control on the new strains of common bunt. Yields were increased by all compounds relative to untreated controls, almost directly related to effectiveness against the fungus, as was shown by the correlation coefficient.

INTRODUCTION

High levels of wheat bunt in Greece in 1975-77 were found to be caused by new strain(s) of *Tilletia foetida* insensitive to hexachlorobenzene and other compounds (Skorda 1977). At the time a serious outbreak of wheat bunt developed in the whole country as a result of the continued growing of susceptible varieties and the use by farmers of ineffective seed dressing treatments.

A survey in 1977 and 1978 showed that the new hexachlorobenzene insensitive strain(s) of the *Tilletia* pathogen were present in all 156 samples examined. The insensitive strain competes well with the sensitive ones, and has become dominant in the pathogen population. Most of the wheat varieties grown in the country are susceptible to this strain (Skorda 1979). Therefore the evaluation of used or new fungicides for their effectiveness against the new strain of the fungus was considered to be essential.

The performance of seed treatment fungicides at one or more rates in field trials from 1978 to 1979 against wheat bunt is covered by this report.

METHODS AND MATERIALS

The experiments were carried out in 1977-78 and 1978-79 seasons on samples of bunt collected from farmers fields in 1977 and 1978, respectively, (Skorda 1979).

All trials were laid down in Northern Greece at four sites each year covering a range of soil types.

In all cases, a mixture of two inoculum types were used: spores apparently insensitive to hexachlorobenzene and spores collected from different regions all over the country. The wheat used throughout was cv. Generoso, a commercial semidwarf cultivar susceptible to bunt.

Artificial inoculation of wheat seed was carried out prior to fungicidal treatment. Seed of wheat was inoculated by ball-milling it for a standard time in glass jars with 0.5 percent by weight of bunt teleutospores. Inoculated seed was also treated in the same way with the fungicides at rates given in tables I and II. Also a treatment was included of non-infected seed and without any chemical. Most of the fungicides were applied dry and adhered very well. The slurry and liquid formulations were smeared around the sides of the jar, the seed added and the jar shaken vigorously. In all cases a visual assessment showed coverage to be highly acceptable.

Each year two trials were laid down in randomized blocks with six replications and a further three trials with one replication at each of three sites making three replications in all. The seeds were sown in plots of 2 x 15 m in early to late November, which is near the normal date of sowing.

Disease assessments were made in the laboratory on 100 mature ears per plot, as percentage diseased heads per plot. Also in four trials the fungicide efficiency was judged on the increase in yield.

The fungicide formulations used were as follows: organomercury 1.6% w.p. (equivalent to 1% mercury; Agrosan GM*); thiophanate-methyl + imazalil sulphate 30% + 1.75% w.p. and 30% + 2.5% w.p.; methfuroxam 5%, 7.5% and 10% w.p.; methfuroxam 10% + maneb 50% w.p.; methfuroxam 10% + mancozeb 50% w.p.; methfuroxam 10% + imazalil 2.5% w.p.; chlorothalonil 50% + thiophanate-methyl 20% w.p.; carboxin 20% + thiram 40% w.p.; thiophanate-methyl 14% + maneb 60% w.p. (Frumidor*); manganese/zinc dithiocarbamate 79% w.p. (Vondozeb*); mancozeb 64% + carbendazim 10% w.p. (Vondocarb*); quintozene 23.5% + etridiazole 5.8% (Terra-coat SD-205*); nuarimol 10% w.p.; nuarimol 10% + maneb 40% w.p.; nuarimol 15% + maneb 60% w.p.; nuarimol 20% + imazalil 2% w.p.; nuarimol 10% + maneb 40% + lindane 25% w.p.; fenfuram 75% w.p.; guazatine 60% + fenfuram 20% w.p.; guazatine 60% + imazalil 4% w.p.; guazatine 60% + fenfuram 20% + imazalil 4% w.p.; carbendazim 60% w.p.; zinc dimethyl dithiocarbamate bis (dimethyl) dithio-carbamoyl ethylenediamine 80% w.p. (Monox); zinc 1-hydroxy-2-pyridine thione 95% w.p. (zinc omadine); sodium 1-hydroxy-2-pyridine thione 40% a.c. (sodium omadine); thiabendazole 10% + imazalil 2.5% w.p. (Lirotectim*) n-butyl-phenyl-1H-imidazole-1-propanenitrile (RH 2161); triadimenol 10% and 15% w.p.

* Trade name

TABLE I

Effect of seed treatment with fungicides against common bunt in field trials

Treatment	Rate g a.i./ 100 kg seed	Bunted spikes % 1978		Bunted spikes % 1979		Grain yield % of control 1978	Grain yield % of control 1979
						(3245)	(2683)
Control	-	66.5*	42.5a**	11.0*	33.5a**	100d**	100e**
Organomercury	3.2	-	-	1.0	2.7de	-	148a
Thiophanate-methyl + imazalil sulphate	60 + 3.5	12.5	12.5b	3.6	25.2b	126ac	115d
ditto	75 + 4.4	21.0	10.7b	3.3	19.2c	126ac	127c
ditto	85.2 + 5	23.0	8.3bd	5.0	16.0c	124ac	131c
Thiophanate-methyl + imazalil sulphate	60 + 5	22.5	13.0b	8.0	14.7c	122ac	132c
ditto	74 + 6.2	26.0	7.5bd	9.6	15.5c	126ac	132c
ditto	89 + 7.5	23.0	12.8b	3.3	14.0c	118bc	132c
Methfuroxam	10.0	-	-	4.0	3.8d	-	144ab
ditto	15.0	-	-	1.0	1.8dg	-	148a
ditto	20.0	0.5	0.0e	0.3	0.8eg	135a	144ab
Methfuroxam + maneb	20 + 100	1.0	0.0e	0.6	1.0eg	133a	144ab
Methfuroxam + mancozeb	20 + 100	1.0	0.0e	0.3	0.2g	130ab	148a
Methfuroxam + imazalil	20 + 5	3.0	0.5e	0.6	0.3fg	130ab	144ab
Chlorothalonil + thiophanate-methyl	50 + 20	8.0	8.0bc	7.0	3.7d	115c	135bc
ditto	100 + 40	5.5	1.3e	1.3	3.5d	130ab	144ab
ditto	150 + 60	4.0	0.8e	0.3	2.7df	131ab	145ab
ditto	200 + 80	0.5	2.5de	0.3	1.5dg	132a	147a
Carboxin + thiram	40 + 80	3.0	3.0ce	-	-	127ac	-
ditto	50 + 100	2.5	0.8e	-	-	130ab	-

Figures suffixed by the same letter (a, b, c, d, ...) are not significantly different at the 5% level

* Mean of three sites with one replication each
** Mean of six replications in one location

TABLE II

Effect of seed treatment with fungicides against common bunt in field trials

Treatment	Rate g a.i./ 100 kg seed	Bunted spikes %				Grain yield % of control	
		1978		1979		1978	1979
						(3181)	(3152)
Control infected	-	66.5*	43.0a**	7.6*	29.5a**	100f**	100e**
Control non infected	-	-	1.5de	0.0	2.3fg	139ab	134ac
Organomercury	3.2	9.5	2.0de	-	2.7dg	134ad	142a
Thiophanate-methyl + maneb	28 + 120	4.0	0.7e	-	-	131ad	-
Manganese/zinc dithiocarbamate	197.0	4.5	0.2e	-	-	136ac	-
Mancozeb + carbendazim	160 + 25	6.5	0.0e	-	-	130bd	-
Quintozene + etridiazole	60.2 + 14.8	28.5	-	5.2	-	-	-
Nuarimol	10.0	10.0	2.0de	-	-	138ab	-
ditto	15.0	7.0	0.5e	-	-	140a	-
ditto	20.0	-	-	2.0	2.7dg	-	139a
Nuarimol + maneb	10 + 40	5.5	2.5de	-	-	134ad	-
ditto	15+ 60	1.5	0.0e	-	-	133ad	-
Nuarimol + imazalil	20 + 2	-	-	3.0	5.2cf	-	134ac
Nuarimol + maneb + lindane	20 + 80 + 50	-	-	0.3	0.5g	-	142A
Fenfuram	150.0	39.5	8.0c	-	-	126de	-
Guazatine + fenfuram	60 + 20	54.5	17.2b	-	-	121e	-
Guazatine + imazalil	60 + 4	24.5	5.5cd	-	-	125de	-
Guazatine + fenfuram + imazalil	60 + 20 + 4	35.0	8.2c	-	-	125de	-
Carbendazim	60.0	7.5	1.0e	-	-	136ac	-
ditto	120.0	3.0	0.2e	-	-	134ad	-
Monox	160.0	10.0	1.2e	2.0	9.2c	130bd	127cd
Zinc omadine	48.0	-	-	1.0	-	-	-
ditto	60.0	-	-	0.0	0.5g	-	139a
ditto	142.5	-	-	0.3	0.7g	-	139a
Sodium omadine	40.0	-	-	8.0	-	-	-
ditto	80.0	-	-	2.0	-	-	-
Thiabendazole + imazalil	20 + 5	-	-	2.0	5.7ce	-	126cd
RH2161	20.0	-	-	4.3	14.3b	-	122d
ditto	40.0	-	-	2.0	6.2cd	-	125cd
ditto	60.0	-	-	1.0	0.3g	-	137ab
ditto	80.0	-	-	0.6	2.0eg	-	138a
Triadimenol	7.5	-	-	2.0	5.0cf	-	127cd
ditto	11.2	-	-	2.3	5.7ce	-	127cd
ditto	15.0	-	-	1.6	5.2ce	-	126cd
ditto	20.0	-	-	1.0	5.5cd	-	127cd
ditto	30.0	-	-	0.6	4.3df	-	134ac

Figures suffixed by the same letter are not significantly different at the 5% level

* Mean of three sites with one replication each

** Mean of six replications in one location

RESULTS

Control of common bunt. Bunt infection was higher in the first year of test and lower in the second. Tables I and II show that most of the seed treatment chemicals tested significantly reduced the indicence of bunt compared with the control. Methfuroxam and nuarimol at the low rate of 10 g a.i. per 100 kg of seed as well as mixtures of either with maneb or imazalil, or mancozeb with the former were very effective against artificial inoculation of common bunt of wheat. RH2161, carbendazim and zinc omadine at a rate of 60 g a.i. per 100 kg of seed, had the same level of effectiveness as the above two compounds. Thiophanate-methyl + maneb, manganese/zinc dithiocarbamate, mancozeb + carbendazim, chlorothalonil + thiophanate-methyl, carboxin + thiram and also monox in the first year at high rates gave good results. On the contrary, fenfuram, mixtures of guazatine with fenfuram and imazalil, thiophanate-methyl with imazalil, thiabendazole + imazalil and triademenol gave less control of common bunt.

Grain yield. In both 1978 and 1979 all effective fungicide treatments gave significantly higher yield than the non-treated bunt infected controls. The more effective fungicide treatments tended to give higher yield increases than the less effective with yield increases almost directly related to effectiveness against the fungus, shown by the correlation coefficient (Fig 1). There were some exceptions, probably due to control by some fungicides of other seed or soil-borne diseases in addition to bunt.

Crop safety. No retardation or reduction in emergence or vigour of wheat was noticed with any treatment. Similarly the rates used have been shown to be safe in standard germination tests both before and after 12 months storage of treated seed.

DISCUSSION

The results of trials described indicate that methfuroxam at the low rate of 10 g a.i. per 100 kg of seed was effective against artificial inoculation of common bunt of wheat; this activity has also been observed by Alcock (1978) in Australia where were also found strains of bunt insensitive to hexachlorobenzene (Kuiper, 1965).

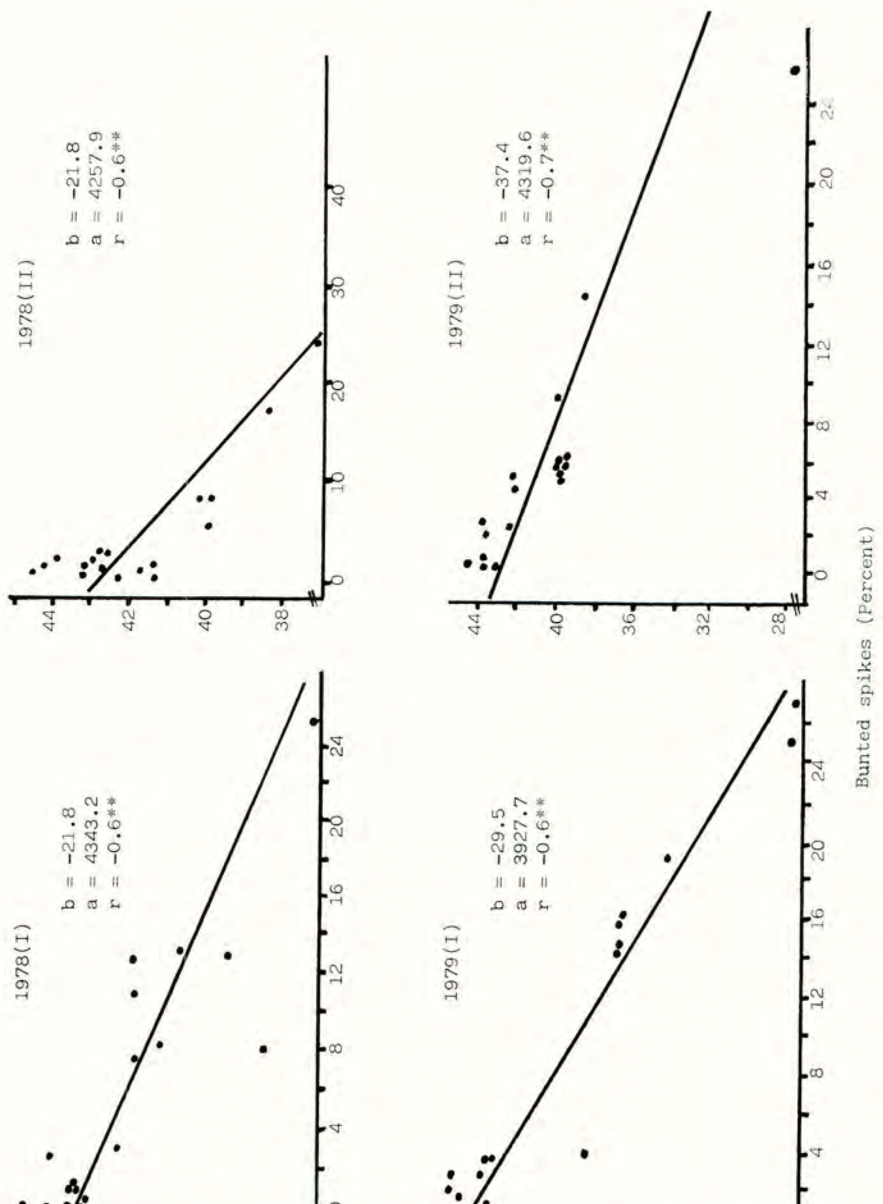
Nuarimol at low rate was also highly active against this strain of bunt. Casanova *et al* (1977) reported that nuarimol gave insufficient control of *Tilletia caries* on wheat and they suggested combination with other products to improve the activity against this fungus. In these trials nuarimol mixtures with maneb or imazalil and methfuroxam with the same chemicals as well as mancozeb were almost as effective as nuarimol or methfuroxam alone.

Zinc omadine at a rate of 60 to 142 g a.i. per 100 kg of seed, sodium omadine at 80 g a.i. rate and RH2161 at 60 g were also very effective. Ballinger (1978) reported almost the same results for *Tilletia foetida* in Australia.

High effectiveness against bunt was also observed with the composite products thiophanate-methyl + maneb, manganese/zinc dithiocarbamate, mancozeb + carbendazim, chlorothalonil + thiophanate-methyl and carboxin + thiram but only at the higher rates tested.

Fenfuram and mixtures with guazatine and imazalil as well as guazatine with imazalil were less effective than in trials in 1977. The inoculum used in 1978-1979 was a mixture from more districts of the country in which insensitive strain(s) of *Tilletia foetida* were observed (Skorda 1977). Monox also gave satisfactory results in 1978 but in 1979 proved insufficient.

FIG 1 REGRESSIONS OF YIELD ON BUNTED SPIKES



Quintozene + etridiazole was the least effective chemical as previously found in 1976 and 1977. These results confirm the fact that the insensitive strain(s) of *Tilletia foetida* in Greece compete well with the sensitive strains, are stable and become dominant in the pathogen population although the application of chemicals ineffective to this strain has now ceased.

Control of bunt produced a large increase in yield over the control and is correlated with amounts of disease (Fig. 1). The development of an insensitive strain can therefore have serious economic consequences both for growers and for fungicide manufacturers.

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SESSION 5B

PEST AND DISEASE CONTROL IN FIELD CROPS (I)

Proceedings 1981 British Crop Protection Conference - Pests and Diseases

EXPERIMENTS FOR THE CONTROL OF PEA AND BEAN WEEVIL (SITONA LINEATUS) IN PEAS, USING GRANULAR AND LIQUID INSECTICIDES

J.M. King

Processors & Growers Research Organisation, Thornhaugh, Peterborough PE8 6HJ

Summary The results are presented of three replicated experiments studying the effects of pea and bean weevil (Sitona lineatus) on peas, in which a range of granular and liquid insecticides were evaluated for its control over a three year period between 1979 and 1981. Phorate granules at 2.24 kg ai/ha or aldicarb granules at 1.00 kg ai/ha gave good control of leaf feeding by adult Sitona and prevented serious nodule damage by larvae, and resulted in increased yields in one of the three experiments. The significance of this is discussed. Foliar sprays of permethrin at 0.10 and 0.05 kg ai/ha and triazophos at 0.34 kg ai/ha, applied as soon as leaf feeding became obvious, gave good control of adult Sitona, but were less effective in preventing larval damage to the root nodules and did not give significant yield increases.

Résumé On a présenté les résultats de trois expériences identiques qui montrent l'effet des Sitona lineatus sur les pois. Dans cettes expériences, quelques insecticides étaient évalues pour l'efficacité pendant une période de trois ans (1979-81). Les granules de phorate à 2.24 kg ai/ha ou granules d'aldicarb à 1.00 kg ai/ha ont été efficaces contre Sitona (adultes) qui mangent le feuillage. Les granules ont empêché d'avarier sérieusement des nodules par les larves, et dans une des trois expériences les rendements meilleurs ont été observé. La signification de ces résultats est discutée. Sur le feuillage, les pulvérisations de permethrin a 0.10 et 0.05 kg ai/ha et de triazophos a 0.34 kg ai/ha étaient appliquées immédiatement quand il etait évident que les Sitona (adultes) mangassent le feuillage. Cependant les pulvérisations étaient moins éfficaces contre l'avarie aux nodules des racines par les larves et les rendements n'étaient pas augmentés.

INTRODUCTION

Pea and bean weevil (Sitona lineatus) is a common pest of both green vining and dried combining pea crops, the adults emerge from hibernation and move into pea fields in the spring and feed on the young seedlings. Large numbers of adults may be found after warm sunny days in late March and April which encourage the beetles to fly into the crops. Egg laying can commence almost immediately, usually around or on the base of the plant, and the larvae which emerge make their way underground and feed on the nitrogen-fixing nodules on the root system. A number of experiments were carried out by PGRO during the period 1952 to 1958 (Home Grown Threshed Peas Joint Committee (1952-53), Home Grown Threshed Peas Joint Committee (1954), Pea Growing Research Organisation (1956), Pea Growing Research Organisation 1957, Pea Growing Research Organisation (1958)), during which several insecticides were evaluated as seed treatments, granular or liquid applications. The work showed that control of the adult and larvae was possible, but the data on the effects of this control on final yield was inconclusive. The results of tests with twenty-one insecticides applied to the foliage or the soil and the effects on larval numbers in the root nodules were reported by Bardner et al (1979). In 1979 PGRO decided after consultation with entomologists at Rothamsted to carry out further experiments to quantify yield losses from Sitona on dried peas, and at the same time to evaluate a range of chemical treatments.

METHODS AND MATERIALS

The experiments were carried out on the Thornhaugh trial ground, different fields being used each year. Latin square layouts were employed, in 1979 there were four treatments, in 1980 five treatments and in 1981 six treatments. Plots were 4m x 5m and were divided down the middle to give a 2m x 5m sub-plot for plant sampling and a 2m x 5m plot for harvesting. The plots were drilled with a 2m Nordsted Ceres drill at seed rates calculated to give 100 plants/m^2. The cultivar was Vedette, an early-maturing combining pea. The granule treatments were applied to the previously worked seedbed immediately before drilling, using a small hand-operated granule applicator, and incorporated using a rotovator set to work approximately 7.5m deep. In 1981 the post-drilling granule treatment was applied using the same equipment when the plants had 1-1½ expanded leaves. The foliar sprays were applied with a van der Weij plot sprayer in 560 l/ha as soon as weevil activity occurred and leaf notching could be found on the seedlings. In 1979 the seedlings had four expanded leaves, in 1980 one to two expanded leaves and in 1981 two expanded leaves. Plant counts were made when the crop was fully emerged. The degree of leaf notching present was determined by counting the number of notches on a representative sample of ten plants per plot, the counts being carried out before the foliar sprays had been applied and again approximately two weeks later. When the crops had reached full flower twenty soil cores per plot were taken by Rothamsted entomologists using a 5cm corer to a depth of 15cm. After washing the roots and nodules were examined for the presence of larvae. The plots were harvested when the crop had reached full maturity, but before it was fully dry, to ensure that shelling out had not occurred. The plants were cut by hand and threshed using a plot viner.

RESULTS

The results of counts of notches on the leaves of the young plants are shown in Table 1. The first assessments indicate control of adult Sitona feeding given by the granular treatments applied before drilling, and the second assessments show the effects of all the treatments. All the treatments reduced leaf feeding, but the granular treatments appeared to give slightly better control than the foliar sprays, while there was significantly less notching on the permethrin treated plots, at the second assessment in 1980, than on those treated with triazophos.

Table 1

Leaf notching assessments - notches per plant

Material	Rate kg ai/ha	1979 ≠ Before foliar sprays	1979 ≠ After foliar sprays	1980 Before foliar sprays	1980 After foliar sprays	1981 ≠ Before foliar sprays	1981 ≠ After foliar sprays
Phorate (granules) incorp.	2.24	1.10	0.03	0.26	25.9	1.3	0.22
" " surface	2.24	-	-	-	-	1.2	0.32
Aldicarb (granules) incorp.	1.00	-	-	0.20	10.2	1.1	0.02
Permethrin (spray)	0.10	-	0.01	-	14.2	-	-
" "	0.05	-	-	-	-	-	0.50
Triazophos (spray)	0.34	-	0.05	-	31.5	-	0.36
Untreated	-	2.20	0.58	0.32	41.6	2.0	1.02
Significance @ P = 0.05		-	SD	SD	SD	SD	SD
LSD @ P = 0.05		-	0.16	0.07	7.3	0.7	0.47
SE as % of gen. mean		-	32.8	17.6	21.6	50.6	98.7

Key: ≠ Notches on the upper two expanded leaves only.

The number of larvae recorded in the nodules and roots washed from the soil cores are shown in Table 2.

Table 2

Larvae per root or per core determined from twenty soil cores per plot

Material	Rate kg ai/ha	1979 Larvae/root Log 10 (+1)	1980 Larvae/root Log 10 (+1)	1981 Larvae/core Log 10 (+1)
Phorate (granules) incorp.	2.24	0.15	0.43	0.39
" " surface	2.24	-	-	0.59
Aldicarb (granules) incorp.	1.00	-	0.27	0.66
Permethrin (spray)	0.10	0.70	0.45	-
" "	0.05	-	-	1.04
Triazophos (spray)	0.03	0.74	0.50	0.93
Untreated	-	0.81	0.53	1.07
Significance @ P = 0.05		SD	NS	NS
LSD @ P = 0.05		0.12	-	-
SE as % of gen. mean		9.4	12.3	52.1

In 1979 phorate granules incorporated into the seedbed prior to drilling significantly reduced the number of larvae in the roots, but in 1980 none of the treatments appeared to have any great effect on larval numbers. In 1981 although the numbers of larvae per core on the granule treated plots were lower than the untreated, there was high variation between samples, and the differences were not significant.

The yield data for the three experiments is presented in Table 3. The experiments in 1979 and 1980 were harvested before the crop had fully dried out in the field to avoid shelling out losses, while in 1981 the plots were split and one sub-plot was harvested at this stage and the second at a much dryer stage.

There were no significant differences in yield between any of the treatments in the 1979 and 1980 experiments or when the 1981 experiment was harvested before the crop was dry. At the later harvest stage, however, both the phorate treatments and the aldicarb treatment gave significantly higher yields than the untreated control, the yield increases from the two foliar sprays were not statistically significant.

Table 3

Yield of peas expressed as a percentage of the untreated control 1979-1981

Material	Rate kg ai/ha	1979	1980	1981 Early stage	1981 Dry stage
Phorate (granules) incorp.	2.24	105	103	102	118
" " surface	2.24	-	-	100	111
Aldicarb (granules) incorp.	1.00	-	107	105	119
Permethrin (spray)	0.10	102	105	-	-
" "	0.05	-	-	100	109
Triazophos (spray)	0.34	105	99	102	106
Untreated	-	100	100	100	100
Yield of untreated tonnes/ha		4.7	5.6	7.2	5.4
Significance @ P = 0.05		NS	NS	NS	SD
LSD @ P = 0.05		-	-	-	9.8
SE as % of gen. mean		4.3	4.3	6.7	8.6

DISCUSSION

The results of assessments for the adult leaf feeding, and the presence of larvae in the root nodules, indicated that phorate granules applied before drilling and worked into the seedbed can give good control of adult Sitona, thus reducing egg-laying and subsequent larval attack. In 1981 a surface treatment of phorate granules applied before the adults moved into the crop also proved successful. Aldicarb granules incorporated before drilling proved promising, significantly reducing leaf notching in the two years in which it was tested and reducing the number of larvae per root. As might be expected the spray treatments were less effective than the soil-applied granule treatments. Although both permethrin and triazophos reduced leaf feeding when applied at the start of the adult Sitona infestation, the assessments on larval numbers in the nodules showed that they were less effective against this stage of the pest. Presumably the materials were not applied soon enough to prevent egg-laying taking place, and they cannot have been particularly successful in preventing hatching and invasion of the root system by the larvae. Permethrin was used at higher than normal rates in 1979 and 1980 and appeared to be slightly more effective than the standard triazophos. In 1981 it was applied at the standard dose rate and still compared very favourably with the standard.

None of the treatments adversely affected the crop, plant counts (not presented) showed that the pre-drilling granule treatments did not significantly affect seedling numbers. In all three years the crop made excellent growth and yields were high. It is generally accepted that the leaf feeding by the adult Sitona does not affect subsequent growth and yield and it is the larval damage to the root nodules which is important. It is not surprising therefore that none of the treatments increased yields compared to the untreated control in 1980, where the results of assessments on the soil cores showed no effects from the treatments on larval number. In 1979 the phorate granules did considerably reduce larval number but again the early harvest yields were not significantly increased compared to the untreated control, in spite of quite high numbers of larvae being present in the root nodules on the untreated plots. In 1981 the granule treatments gave good control of the larval stage and when the crop was harvested at the dry stage the yields from these treatments were significantly higher than the untreated controls. The yield data in 1981 appeared to be correlated with larval numbers, the yield for the permethrin spray only just failing to reach statistical significance. A late aphid attack occurred in 1981, approximately two weeks before the final harvest, but assessments showed that none of the treatments had reduced aphid numbers and the infestation was generally distributed over the experimental area and thus it was unlikely that this could account for the yield difference recorded.

Pea and bean weevil is a common pest of dried peas and in 1980 soil cores were taken from a random fourteen commercial crops being grown in Essex and Suffolk. These were assessed at Rothamsted for the presence of larvae or adult weevil in the root system and the mean number was 3.2 *Sitona* per root, with a maximum of 6.2 and a minimum of 0.8. *Sitona* was found in all fourteen crops. Although some growers apply foliar sprays many of these treatments are probably too late to prevent egg-laying and are unlikely to reduce larval numbers or significantly increase yield. The 1981 results do suggest, however, that well-timed spray treatments might give some yield increase and in view of the relatively low cost of such treatments it is estimated that a 5% yield increase would more than cover the cost of the material and application. Granular insecticides are not generally used for *Sitona* control at present, although the use of aldicarb granules is recommended for control of free-living nematodes on sandy soils to prevent the uptake by the crpp of pea early browning virus (PEBV). Granules are more expensive than foliar sprays and are applied before the severity of the pest problem can be determined. In spite of this they are very effective in reducing *Sitona* damage and it has been shown that they can result in considerable yield increases under some conditions.

Increases in yield in the order of 18%, as recorded in 1981, would certainly justify the use of granule treatments, and assuming the average yield increase over the three years to be only half this figure they would probably still be economically justified on all but the lowest yielding crops.

Acknowledgements

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NOTES

ALDICARB - ITS DEVELOPMENT AND POTENTIAL USES IN FIELD PEAS

R. Joice and F. J. Breslin

Union Carbide U.K. Limited, Agricultural Chemicals Division, Princes House, Princes Square, Harrogate HG1 1LW

Summary Aldicarb has been tested in both vining and dried pea crops for activity against the nematode vectors of pea early browning virus. Where the virus was prevalent a mean reduction of 63% of disease incidence was recorded together with a yield improvement of 25%. Additional benefits included the suppression of *Sitona spp* damage, more than 50% reduction in cabbage thrip numbers and good or partial control of aphids up to harvest. No phytotoxic symptoms were observed and crop establishment was unaffected.

Résumé L'aldicarbe a été testé sur des petits pois de conserve et à graine quant à son efficacité pour la protection de ces cultures contre les nématodes vecteurs du virus du brunissement hâtif des pois. Là où cette maladie était répandue, son incidence a été réduite en moyenne de 63% et le rendement correspondant fut supérieur de 25%. De plus les avantages suivants ont été notes: la suppression des dégâts causés par les sitones (*Sitona spp*), plus de 50% de réduction de la population des thrips (*T. Angusticeps*) et une suppression partielle ou quasi totale des pucerons jusqu'à la récolte. Aucun symptôme de phytotoxicité n'a été observé et l'établissement des cultures n'a pas été perturbé.

INTRODUCTION

In the major pea growing areas of Eastern England the yields have been depressed in the presence of free living (FL) nematodes, particularly *Trichodorus spp* which is a vector for pea early browning virus (PEBV). In preliminary investigations in liaison with Unilever Ltd aldicarb treatment resulted in significant yield increases at certain trial sites. The data indicated that this response often occurred on light soil types. Free living nematodes commonly occur on such soils and it was suggested that control of these pests could be a contributory factor to the yield increases (Ensor 1977). Limited trials carried out in 1978 by Union Carbide indicated a correlation between free living nematode control with aldicarb and yield response. The optimum dosage was aldicarb at 1kg ai per ha. In all the preliminary work it was noted that tenderometer values at harvest were lower in the crop from treated areas. This, together with increased vigour, suggested that crop growth was being maintained over a longer period and yield benefits could therefore be anticipated. In view of these early indications a more extensive trials programme was initiated in 1979 on both vining and dried pea crops using aldicarb at 1kg ai/ha.

(a) Replicated Trials

Trial site details are given in Table 1.

The results of three years work are reported.

Table 1

Site Details

Year	Location	Cultivar	Soil Type
(1979)			
Trial 1	Whickham Market,Suffolk	Avola (Vining)	Loamy Coarse Sand pH7.1 O.M.1.6%
" 2	Raveningham, Norfolk	Avola (")	Loamy Sand pH7.0 O.M.1.5%
" 3	Little Glenham,Suffolk	Avola (")	Sandy Loam pH7.6O.M.1.8%
" 4	Henham, Suffolk	Avola (")	Loamy Sand pH7.3 O.M.1.3%
(1980)			
Trial 5	Diss, Norfolk	- (")	Sandy Loam pH7.7
" 6	Lound, Norfolk	- (")	Sandy Loam pH7.5
" 7	Marr,Doncaster,SYorks	Marrowfat (Dried)	Loamy fine sand pH6.8 O.M.2.6%
" 8	Beltoft,S Humberside	Marrowfat (")	V.Fine Sandy Loam pH7.2 O.M.1.9%
" 9	Elkesley, Notts	Marrowfat (")	Fine Sandy Loam pH7.5 O.M.7.5%
" 10	Low Sandon,S Humberside	Avola (Vining)	Loamy Fine Sand pH7.4 O.M.1.5%
" 11	Wold Newton, Lincs	Sprite (")	Silty Loam pH8.2 O.M3.4%
" 12	Sancton, N Humberside	Avola (")	Fine Sandy Loam pH7.6 O.M.2.6%
" 13	Sancton, N Humberside	Avola (")	Loamy Fine Sand pH.6.7 O.M.2.6%
" 14	Scawby, S Humberside	Sparkle(")	Fine Sandy Loam pH.7.6. O.M.2.1%
" 15	High Hunsley,N Humberside	Sparkle(")	Silty Loam pH.8.0 O.M.3.5%
" 16	Newbald,N Humberside	Perfection(")	Silty Loam pH.8.1. O.M.3.7%
(1981)			
Trial 17	Scawby, S Humberside	Avola (Vining)	Loamy fine sand pH7.6 O.M.1.1%
" 18	Redbourne, Lincs	Avola (")	Fine Sandy Loam pH7.6. O.M.2.8%
" 19	Mkt Weighton,N Humberside	Avola (")	Fine Sandy Loam pH7.5 O.M.2.1%
" 20	Shiptonthorpe,N Humberside	Avola (")	Fine Sandy Loam pH7.4 O.M.1.5%
" 21	Barton-upon-Humber South Humberside	Avola (")	Fine Sandy Loam pH7.6 O.M.2.2%
" 22	Sancton, N Humberside	Avola (")	Fine Sandy Loam pHp.1 O.M.2.4%
" 23	High Hunsley,N Humberside	Sparkle(")	Silty Loam pH7.5 O.M.3.6%
" 24	Keelby, S Humberside	Tri-Star(")	Sandy Loam pH8.0 O.M.1.8%
" 25	Marr,Doncaster,S Yorks	MaroCZ (Dried)	Silty Loam pH7.5 O.M.2.8%
" 26	Beltoft,S Humberside	Marrofat (")	Fine Sandy Loam pH6.0 O.M.1.8%

Sites were selected on light, sandy soil types likely to have infestations of free-living nematodes. Actual nematode infestations are recorded in Tables 2, 3 and 4. Treatments were applied broadcast overall using a Horstine Farmery 'Rickshaw' applicator fitted with 'fishtails'. The aldicarb granules were then incorporated using a variety of types of harrow, including reciprocating harrows, to a depth of 2 - 8 cms. Peas were then drilled within 48 hours followed by a light harrowing.

Table 2

1979 Spring Pre-cropping Nematode Numbers Per Litre of Soil

Eastern Region (Vining Peas)

Nematode/Trial No.	1	2	3	4
Trichodorids	95	100	40	70
Longidorids	40	35	35	0
Heterodea larvae	145	175	200	380
Tylenchorhynchus	1460	3650	1310	1200
Pratylenchus	550	580	1500	1980
Others	70	30	180	110

At all sites, plot size was 2.5 - 3.0 m x 10 - 15 m, and treatments were replicated in four randomised blocks. A single aldicarb dose rate of 1.0 kg a.i./ha was employed. Crop-emergence was evaluated in May by counting seedling numbers in each of 5 x 1 m lengths of row per plot.

Aphid (Acyrthosiphon pisum) infestations were evaluated by random counts, which were made on 20 leaves per plot. Cabbage thrip (Thrips angusticeps) were counted on 50 seedlings per plot. Crop vigour was assessed at intervals throughout the season, based on a 0 - 10 finite scale where 0 = no crop and 10 = excellent crop. In 1980, pea and bean weevil (Sitona lineatus) damage was assessed by weighing root nodules taken from 10 plants per plot. In 1981, damage was expressed as a 0 - 10 finite score of nodulation on 5 plants per plot where 0 = nodules absent, 10 = many healthy nodules. Pea Early Browning Virus was present at four sites and a 0 - 10 finite scale was used to indicate the overall virus infection per plot. A plot receiving a score of 10 was considered to be free of virus symptoms and a score of 0 indicated all plants infected. Crop yield was assessed at all vining pea sites by hand-harvesting 5 - 8 m x 2 m of crop per plot. Harvested vines were then processed through a small viner. Peas were weighed and 2 to 4 tenderometer readings obtained per sample. Dried crops were combined using a Hege small-plot machine.

Allowance was made for the presence of less mature crop in treated areas by the addition of 1.5% of yield per one tenderometer reading point below that obtained for untreated crop.

Data obtained were subjected to two-way Analysis of Variance and F-Test and T-Test giving Co-efficient of Variance, Standard Error and Least Significant Difference for (p = 0.05).

(b) Field-Scale Trials (1979 only)

Four of the seven sites were situated alongside the previously described replicated trials.

Table 3

1980 Spring Pre Cropping Nematode Numbers Per Litre of Soil

	Eastern Region (Vining Peas)		Northern Region (Dried Peas)				Northern Region (Vining Peas)				(Vining Peas)	
Nematode/Trial No.	5	6	7	8	9	10	11	12	13	14	15	16
Trichodorids	480	0	0	0	0	210	0	145	1950	0	0	1260
Longidorids	0	0	0	0	55	0	0	0	10	15	0	0
Heterodera larvae	0	0	55	150	10	30	35	0	0	10	25	795
Tylenchorhynchus	400	2400	495	285	435	835	215	1335	3215	305	235	290
Pratylenchus	3000	0	1075	330	450	1315	75	1055	910	110	165	575
Paratylenchus	1800	0	0	0	0	10	0	480	850	0	0	20
Hemicriconemoides	0	0	0	0	0	0	0	0	95	0	0	0
Hemicycliophora	0	0	0	0	0	20	0	0	145	0	0	30
Spirals	0	0	980	15	305	10	315	0	105	20	145	0
Others	0	0	0	0	0	0	0	0	0	0	0	6120

Table 4

1981 Nematode Numbers Per Litre of Soil

Northern Region

Nematode/Trial No.	17	Vining Peas 18	19	20	21	22	23	24	Dried Peas 25	26
Trichodorids	175	5	390	805	355	205	0	10	10	755
Longidorids	0	0	5	0	0	0	0	0	10	0
Heterodera larvae	505	10	120	10	15	0	0	50	335	90
Tylenchorhynchus	340	295	1155	815	2485	510	505	575	2105	755
Pratylenchus	445	300	1140	985	1680	765	655	335	1285	145
Paratylenchus	35	0	145	95	285	0	20	0	35	0
Hemicriconemoides	0	0	0	0	25	0	0	0	0	0
Hemicycliophora	40	0	0	0	40	0	0	0	0	0
Spirals	0	20	0	0	0	0	310	50	240	0

Each trial consisted of a 2.5 hectare treated area in an otherwise untreated field. Aldicarb was applied at the rate of 1.0 kg a.i./ha using a Horstine Farmery TMA2 air-assisted applicator on the prepared seedbed and either lightly harrowed in prior to drilling or drilled through directly with light harrowing behind the drill. Crop emergence was recorded from counts made on 6 x 1 sq. m. quadrats per area.

A severe infestation of pea and bean weevil occurred at two sites and slugs at one site. Visual observations were made of the degree of control obtained. Aphid infestations were present at four sites and observations made on the percentage of vines infested.

Pea Early Browning Virus was recorded as percentage of plants infected at three sites.

Crop yields were evaluated using commercial machines, and tenderometer readings obtained.

Data were not analysed since treatments were unreplicated.

RESULTS

The results of field trial programmes from three seasons have been considered under three main headings:

Crop safety

Relationship between occurrence of free-living nematodes, PEBV control and yield

Effects on other pests

Crop Safety

No phytotoxic symptoms were observed in any of the trials. The data in Table 5 shows that crop establishment was not affected by aldicarb treatment.

Table 5

Mean Number of Crop Seedlings per m^2 and expressed as % of untreated control for 1979/81

Treatment	1979(4) No.	1979(4) %	1980(10) No.	1980(10) %	1981(10) No.	1981(10) %	Mean No.	Mean %
Untreated-control	78	(100)	68	(100)	82	(100)	76	(100)
Aldicarb 1 kg a.i./ha	79	(100)	66	97	83	101	76	100

Statistical analysis of data from each trial showed that there were no significant differences.

Relationship between occurrence of free-living nematodes, PEBV control and yield

PEBV occurred at three sites in 1979 (Trial nos 1, 3 and 4) and one site in East Anglia (Trial no 5) in 1980. The trials in 1981 were located entirely in N. Lincs and Humberside. The disease was not present at any site. Control of PEBV and the yield data are given in Tables 6 and 7 respectively.

Table 6

Crop Vigour Score Post-Flowering and % Reduction of PEBV

Treatment	Trial Number 1(21) Vig.	1(21) %	3(44) Vig.	3(44) %	4(52) Vig.	4(52) %	5(20) Vig.	5(20) %	Mean Vig.	Mean %
Untreated control	7.0		7.3		5.4		0		6.6	
Aldicarb 1 kg a.i./ha	8.2	67	8.2	37	7.6	56	0	90	8.0	6.3

% area affected with PEBV in untreated-control in brackets.

Table 7

Yield as a % of untreated-control and tenderometer values

Treatment/Trial No.	Yield 1	Yield 3	Yield 4	Yield 5	Yield Mean	Tenderometer values 1	Tenderometer values 3	Tenderometer values 4	Tenderometer values 5	Tenderometer values Mean
Untreated control	(100)	(100)	(100)	(100)	(100)	109.7	126.4	129.5	126.3	123.0
	*(5.7)	(3.6)	(4.9)	(4.9)	0					
Aldicarb	119.4	123.6	126.2	131.3	125.1	106.0	119.4	122.5	117.3	116.3
C.V.%	17.15	11.92	8.25	18.51		3.79	3.71	8.23		
S.E.±	0.73	0.23	0.31	0.26		2.04	2.28	1.78		
LSD ($p = 0.05$)	* 2.23	0.89	1.06	1.18		6.20	8.94	6.16		

* (t/ha)

In a programme of seven grower trials carried out in 1979 vine length and pod numbers were increased by 13% and 35% respectively. Virus expression was reduced by 79% and the yield was increased by a mean of 21%. Tenderometer readings indicated continued growth of treated crop.

Effects on other pests

During the course of the trials programme, complete or partial control of other pests were observed. Assessments were carried out as appropriate.

Cabbage Thrip

This pest was present at two sites in 1980 (Trials numbers 11 and 15). Thrip numbers were reduced in the treated plots by 61% and 54% respectively.

Pea and Bean Weevil

At two sites (Trial numbers 7 and 26) marked crop vigour improvement on treated plots was found to be the result of a reduction of larvae feeding damage on root nodules. The data is summarised in Table 8.

Table 8

Effect of aldicarb on Pea and Bean Weevil

	Trial 7			Trial 26		
Treatment	Crop Vig.	Nodule w/t plant (g)	Yield (t/ha)	Crop Vig.	Nodule* Score	Yield (t/ha)
Untreated-control	8.75	2.03	2.67	5.5	1.42	2.70
Aldicarb	10.00	12.10	2.74	8.0	5.08	3.18
CV		57.82%	6.01%			8.34%
SE		2.03	0.08			0.12
LSD (p = 0.05)		7.04	0.28			0.39

* 0 = no nodules   10 = many healthy nodules

Aphids

Aphids were present in substantial numbers at three sites (Trial numbers 3, 19 and 22) in 1979 and 1981. Table 9 presents the data obtained from counts.

Table 9

% Control of aphids

	1979 3 (July 3)	1981 19 (June 30)	1981 22 (June 30)
Aldicarb	88	53	27

In 1979 the number of plants infested with aphids were counted at four of the grower trials. Results were excellent and at all locations control exceeded 90% in late June and early July.

DISCUSSION

Aldicarb is a long established pesticide used to control FL nematodes in a range of crops. The incidence of PEBV in pea crops particularly in the East of England was associated with FL nematode infestations. Thus aldicarb was considered to be of potential value.

The trials carried out have confirmed that aldicarb was capable of reducing levels of PEBV where it occurred. As a result the crop was more vigorous, senescence delayed and yields considerably improved. Trials in the North of England where the disease is not prevalent did not demonstrate similar beneficial responses.

In addition the use of aldicarb gave some control of cabbage thrip, pea and bean weevil and aphids. Control of aphids was good and sometimes persisted into the harvest period. Excessive leaching of active ingredient probably reduced this persistence in 1981. It is possible that the use of aldicarb may eliminate the need for a separate aphicide application.

From the grower trials there have been indications of satisfactory control of other pests e.g. slugs and leaf miner. Further work in replicated trials would be required to confirm these observations. Evaluation of crop establishment and seedling vigour showed that aldicarb was safe to the pea crop at the rates employed.

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THE USE OF METALAXYL SEED TREATMENTS TO CONTROL PEA DOWNY MILDEW

M. W. Miller and C. V. de Whalley

Ciba-Geigy Agrochemicals, Whittlesford, Cambridge

Summary Primary downy mildew infection of pea seedlings was virtually eliminated by metalaxyl seed treatments. Some subsequent reduction in secondary leaf and pod infection was achieved, although the level of control was variable. The number of mature plants with systemic infections was substantially reduced.

Metalaxyl seed treatments increased plant establishment when compared to conventional standards and improved plant vigour in some fields. This was attributed to protection against downy mildew combined with a possible effect against *Pythium* damping off.

Résumé L'infection primaire de mildiou sur plantules de pois fut pratiquement éliminée par traitement des semences au métalaxyl. On obtenait par la suite une réduction de l'infection secondaire sur feuille et cosse, bien que le niveau de contrôle fut variable. Le nombre de plantes adultes atteintes d'infections systémiques fut ultérieurement réduit.

Les traitements de semence au métalaxyl augmentent l'établissement de la culture si on les compare aux standards classiques et améliorent la vigueur des plantes dans quelques champs. Ceci fut attribué a la meilleure protection contre le mildiou associé à un effet possible sur *Pythium* (agent de fonte de semis)

INTRODUCTION

Pea downy mildew (*Peronospora viciae*) is the most common foliar disease of peas in the U.K. affecting plants at most stages in their development (King, 1979). The incidence of the disease is higher in wet seasons and is particularly associated with the early sowings. In South East Scotland and coastal areas of Eastern England the disease can be a significant limiting factor in pea production (King, personal communication; Brockenshire, 1981).

Primary infection of seedlings by soil borne oospores can cause poor establishment because of seedling death. Infected seedlings are stunted, paler in colour and the underside of the leaves are covered by a mass of purple spores; survival is rare. As the season progresses, secondary spread by wind blown spores results in localised leaf lesions, systemic infections of plant tops and pod infections. This can lead to a loss in yield (Olafsson, 1966; Pegg and Mence, 1972) and occasionally rejection of a vining crop by the processor because of discoloured seed (King, 1979).

Attempts in the U.K. to control the disease with fungicides have in the past been very disappointing (King and Gane, 1965; Ryan, 1966). Effective control of many of the Phycomycete fungi, however has been achieved with the systemic fungicide metalaxyl (Schwinn *et al* 1977; Smith 1979).

A metalaxyl seed treatment has successfully been used for the control of downy mildews in Maize, Sorgham, Millet and Sunflower (Safeeulla and Venugopal, 1978; Lal et al 1979; Ilescu, 1980; Williams and Singh, 1980). This treatment also gives protection against damping off diseases caused by Pythium and Phytophthora spp. (Locke et al 1979; Papavizas et al 1979). An investigation into the use of a metalaxyl seed treatment for peas in the U.K. was therefore undertaken.

METHODS AND MATERIALS

Seed treatments were tested for efficacy against pea downy mildew in replicated small plot trials and in non replicated grower trials. Trials in Scotland, Berwickshire, 1980, were undertaken by the East of Scotland College of Agriculture

1) Small plot trials. Seed treatments were applied to untreated pea seed using a hand operated rotary drum applicator. Metalaxyl was formulated as a 35% ST and 200g product were applied as a slurry in 1 l. of water per 100 kg of seed. Drazoxolon was applied as a liquid, Mil-col® 30 (167 mls + 83.5 mls of water per 100kg of seed). Foliar sprays of metalaxyl + mancozeb (formulated as Fubol® 58 WP) were applied in 200 l/ha of water with 0.1% Agral wetting agent. Treatments were replicated four times using plot sizes of 7 x 2.5m (England) and 20 x 3.4m (Scotland). All the seed was drilled at a rate of 280 kg/ha using the cultivar Sprite. In 1980, there were two trials in England (S. Lincolnshire/Norfolk) and one trial in Scotland (Berwickshire).

The number of plants per metre of row and the percentage of primary mildew infected plants were determined 7 to 14 days after full emergence. Results are expressed as a mean of 5 counts per plot. Secondary leaf symptoms were assessed at intervals throughout the season: i) as percentage leaf area infected or ii) on a 0-5 scale; 0 = no visible infection, 1 = $<$ 10% leaf area infected, 2 = 11-20%, 3 = 21-50%, 4 = 51-75%, 5 = $>$75% leaf area infected. The percentage of plants with systemic infections were recorded together with the percentage of infected pods. Plots were harvested by hand and vined to give a yield of fresh peas.

2) Grower trials. Blocks of metalaxyl treated seed (1 to 4 ha) were drilled along side seed treated with a commercial standard. Seed from the same seed batch was always used. Three metalaxyl seed treatments were examined.

i) 1980 trial (Scotland, Berwickshire). Metalaxyl (35% ST) was applied to untreated seed. One trial.

ii) 1980 trials (England, S. Lincolnshire/Norfolk). Metalaxyl (35% ST) was applied as an overdressing to captan treated seed. Two trials.

iii) 1981 trials (England, Lincolnshire; Scotland, Berwickshire). A specially formulated mixture (SL 233) of 24% metalaxyl + 24% captan was applied using 290g product per 100 kg seed. Nine trials.

All treatments were applied as slurries using a commercial dresser.

The number of plants per metre of row, the percentage of primary infected plants and the level of secondary disease were recorded. Results are expressed as a mean from a minimum of 10 sub samples per treatment area. Yields were assessed by a commercial viner from a 1 ha block per treatment.

RESULTS

Establishment. In the 1980 small plot trials in England metalaxyl seed treatments significantly increased plant establishment when compared to untreated controls (Table 1). A similar increase was given by dazoxolon.

In Grower trials (1980) metalaxyl seed treatments gave increases in plant stand in excess of 30% over the standard captan treatments (Tables 4, 5). These plots appeared greener, standing a few centimetres above the surrounding crop. In nine grower trials (1981) metalaxyl + captan seed treatments gave an average increase in plant stand of 13.3% when compared to the standard captan treatments (Table 6). Increases in the fresh weight of 100 plants of 33% and 50% over the standard were recorded at two grower sites, 3581 (2 June) and 3574 (8 May), respectively.

Primary mildew. Metalaxyl seed treatments virtually eliminated low levels of primary mildew infection in all trials. Some reduction in infection levels were also observed with drazoxolon when used in small plot trials (Tables 1-5, 7).

Secondary mildew (non-systemic). Little reduction in secondary mildew was achieved by metalaxyl seed treatments, although levels were generally too low for a realistic appraisal. However, at one grower trial where leaf infection was in excess of 20% metalaxyl kept infection levels below 10% for the duration of the season (Table 3). In an adjacent small plot trial control was not maintained (Table 2).

Systemic infection. In all trials, where measured, systemic infections of mature plants were considerably reduced by metalaxyl seed treatments (Tables 2-5, 7).

Pod infection. In the majority of trials some, although variable, control of pod infection was achieved by metalaxyl seed treatments. Levels of infection were generally low, however (Tables 2-5, 7).

Yield. Where increases in yield were obtained these could be correlated with increases in plant establishment and in some cases a reduction of systemic mildew in mature plants (Tables 1, 3, 4, 7).

DISCUSSION

Seed treatments based on metalaxyl dramatically reduced a relatively low incidence of primary mildew. Similar results were obtained whether metalaxyl was used alone, in combination with captan or when applied as an overdressing to previously treated seed.

The control of the secondary mildew stages was less clearly defined. Small plot trials were inconclusive. Results from grower trials, where much larger areas of treated seed were used, were more encouraging. Some reduction in secondary leaf and pod infection was achieved, although the degree of control was variable. Significantly, however, the numbers of mature plants with systemic infections were clearly reduced. These infections can directly influence yield by destroying growing points and can presumably spread infection to surrounding plants and developing pods by producing large numbers of spores. A single foliar spray of metalaxyl + mancozeb applied after a seed treatment gave no significant reduction in disease levels, although a second application improved control in the 1980 small plot trial in Berwickshire.

Small plot trials indicated the need for protecting seeds against seedling diseases, since emergence from untreated seed was considerably reduced compared to that of metalaxyl or drazoxolon treatments. In grower trials metalaxyl seed treatments markedly increased plant establishment when compared to the standard. This was also accompanied by increased plant vigour in some cases. Superior control of Pythium damping off may be a contributory factor here since plant stand increases were often achieved when levels of primary downy mildew infection were low.

However, pre-emergence seedling death by downy mildew may be greater than infection levels above ground would suggest. Eradication of latent infections of downy mildew in apparently healthy seedlings by metalaxyl may have contributed to increases in plant vigour. Further research into the epidemiology of the disease is clearly required.

The commercial introduction of a seed treatment for peas based on a mixture of metalaxyl + captan, under the trade name APRON 70 SD, is planned for 1982.

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Table 1 The effect of metalaxyl and standard seed treatments on plant establishment and downy mildew infection (1980)

seed treatment g ai/ 100 kg seed	foliar spray g ai/ha	131 80 (Holbeach) Plant Stand: % of un-treated 29 April	Primary Mildew: No. plants infected/ plot 29 April	Secondary Mildew: % leaf area infected/ plot 30 June	Yield: % of un-treated 4 July	132 80 (Boston) Plant Stand: % of un-treated 14 May	Primary Mildew: No. plants infected/ plot 14 May	Secondary Mildew: % leaf area infected/ plot 2 July	Yield: % of un-treated 8 July
untreated		(19.6 m.row)	3.3	4.1	(2.6 tonnes/ha)	(18.9 m.row)	8.3	1.8	3.3 tonnes/ha
drazoxolon 50	-	129*	1.5	4.0	155*	149*	1.8	2.8	139*
metalaxyl 70	-	133*	0.0*	4.7	145*	146*	0.3*	3.6	147*
metalaxyl + drazoxolon 70 + 50	-	126*	0.0*	3.9	134*	150*	0.5*	2.0	153*
metalaxyl	metalaxyl + mancozeb 200+960	146*	0.0*	2.9	150*	148*	0.3*	2.1	149*
-	metalaxyl + mancozeb 200+960	113	5.0	2.0*	105	117	9.5	1.4	103
LSD (P = 0.05)		25	1.9	1.7	26	23	5.2	2.5	15

131 80 (Holbeach): Drilled 5 March. Foliar spray 6 June

132 80 (Boston): Drilled 25 March. Foliar spray 6 June

* Significantly different from untreated (P = 0.05)

Table 2 The effect of metalaxyl and standard seed treatments on plant establishment and downy mildew infection (Berwickshire, 1980) [1]

Fungicide: seed treatment g ai/ 100 kg seed	Fungicide: foliar spray g ai/ha	No. plants/ m. row 7 June	Primary Mildew % plants infected 7 June	Secondary Mildew Disease Score 0 - 5 12 June	Secondary Mildew Disease Score 0 - 5 24 July	Systemic Mildew % plants infected 4 July	Pod Mildew % infected 24 July		Yield kg/plot 29 July
Captan 105	-	14.4	1.7	2.5	2.0	15.0	58.7	(32.5)*	25.7
metalaxyl 70	-	16.6	0.0	1.3	2.3	6.7	62.5	(29.7)*	24.4
metalaxyl 70	metalaxyl + mancozeb 200 + 960 (x 1)	18.1	0.0	0.8	1.8	4.5	61.9	(32.1)*	25.7
Captan	metalaxyl + mancozeb 200 + 960 (x 2)	17.0	2.5	1.3	2.0	1.7	47.3	(20.9)*	28.9
LSD (P = 0.05)		3.6	0.8	1.0	0.8	9.0	13.5	(15.4)*	3.6

Trial drilled 15 April Foliar sprays applied 29 May, 12 June
( )* % severely diseased

[1] Trial adjacent to a grower trial - Table 3

Table 3 The control of pea downy mildew using a metalaxyl seed treatment : Grower trial (Berwickshire, 1980)

Captan 105	21.2	1.9	3	2	25	66.8 (21)*	6.37
metalaxyl	25.5	0	Trace	1	1	63.6 (10.1)*	6.75

Trial drilled 15 April cv Sprite
( )* % severely diseased

Table 4 The control of pea downy mildew using a metalaxyl seed treatment : Grower trial (Holbeach, 1980)

g ai/ 100 kg seed	No. Plants/m² 14 May	Primary Mildew % plants infected 14 May	Secondary Mildew % leaf area infected 4 June	2 July	Systemic Mildew % plants infected 4 June	Pod Mildew % infected 2 July	tonnes/ha
Captan 105	97	0.7	0.9	1.4	12.5	0.7	2.80
Captan + metalaxyl 105 + 70	136	0	0.6	1.4	0	0.5	3.37

Trial drilled 24 March cv Avola. Metalaxyl applied as an overdressing to captan treated seed

Table 5 The control of pea downy mildew using a metalaxyl seed treatment : Grower trial (Boston, 1980)

	7 May	7 May	4 June	2 July	4 June	2 July	
Captan 105	81	5.2	8.5	3.5	8.9	3.6	2.80
Captan + metalaxyl 105 + 70	106	0	8	3.1	0	2.9	2.98

Trial drilled 26 March cv Avola. Metalaxyl applied as an overdressing to captan treated seed

Table 6 The effect of a metalaxyl seed treatment (SL 233) on plant establishment : Grower trials, 1981

g ai/ 100 kg seed	Site No: 3595	3596	3622	3486	3515	3519	3520	3521	3574	Mean (% of standard)
	No. plants/m row (mean of 20 counts)									
Captan 105	17.0	18.0	10.8	12.1	13.8	20.6*	16.9	16.0	17.2	15.8 (100)
SL 233 140	19.8	17.6	12.8	16.0	17.4	23.5	18.6	17.0	18.4	17.9 (113.3)

All sites were cv Avola

* drazoxolon used as standard, not captan

Table 7 The control of pea downy mildew using a metalaxyl seed treatment : Grower trials, 1981

Site No.	g ai/ 100 kg seed	Primary Mildew % plants infected 7-22 May	Secondary Mildew % leaf area infected 6 July	Systemic Mildew % plants infected 6 July	Pod Mildew % infected 6 July	Yield tonnes/ha
3486	Captan 105	0.4	0.8	20.0	2.8	-
	SL 233 140	0	0.4	2.7	1.4	
3515	Captan 105	0.5	0.8	20.3	12.0	3.71
	SL 233 140	0	0.9	2.3	2.0	4.94
3520	Captan 105	0	0.4	1.6	2.7	-
	SL 233 140	0	0.2	1.1	1.6	
3521	Captan 105	2.4	0.9	22.3	3.1	-
	SL 233 140	0	0.6	4.3	2.4	
3574	Captan 105	0	0.9	23.3	11.7	3.36
	SL 233 140	0	0.6	4.3	4.6	3.53
Mean	Captan 105	0.7	0.8	17.5	6.5	-
	SL 233 140	0	0.5	2.9	2.4	

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CONTROL OF CLADOSPORIUM LEAF SPOT IN SPRING-SOWN AND OVERWINTERED BULB ONIONS

E. W. Ryan : J. A. Doyle
The Agricultural Institute, Kinsealy Research Centre, Malahide Road, Dublin 5
T. B. O'Donnell
ACOT Centre, Farranlea Road, Cork

Summary Fungicidal control was sought for Cladosporium leaf spot of onions, prevalent in Britain and Ireland since 1978. Initial screening tests identified the most promising materials as fentin acetate with maneb, chlorothalonil, triadimefon, mancozeb and iprodione. Combinations of two fungicides proved most effective especially those containing chlorothalonil or fentin acetate with maneb. The fungicides were effective at normally recommended rates. It was found that spray intervals should not exceed 2 weeks and that applications late in the season were most effective.

Résumé On utilise des fongicides pour tenter de contrôler le Cladosporium, maladie des feuilles de l'oignon, généralisé en Grande Bretagne et en Irlande depuis 1978. Des tests préliminaires de sélection ont identifié certains éléments à potentiel excellent, tels que fentin acetate avec maneb, chlorothalonil, triadimefon, mancozeb, iprodione. Une combinaison de deux éléments fongicides s'est révélée particulièrement efficace surtout lorsqu'il s'agissait de chlorothalonil ou fentin acetate avec maneb. Les fongicides étaient efficaces aux doses normales recommandées. Il a été découvert que les pulvérisations devraient être effectuées à moins de deux semaines les unes des autres et qu'une application tard dans la saison était particulièrement efficace.

INTRODUCTION

Cladosporium leaf spot or leaf blotch (*Cladosporium allii-cepae*) has become a serious disease of onions in Great Britain and Ireland. The causal fungus, previously known as *Heterosporium allii-cepae*, occurred occasionally on onions in Britain during the 1930's and 1940's as reported by Moore (1946), but was apparently of little consequence. In 1978, the disease seriously affected onions in Ireland (Ryan 1978) and has continued to affect crops in Britain and Ireland.

Prior to 1978, it was considered that beyond ensuring good growing conditions and spraying for blast and mildew, direct measures were unnecessary for control of Cladosporium leaf spot (Chupp & Sherf, 1960). Trials were therefore initiated to identify efficient fungicidal methods of control, and the results are presented in this paper.

METHODS AND MATERIALS

Trials were carried out in commercial onion crops in County Cork, where infection was most prevalent, and also at Kinsealy Research Centre and at the Peatland Research Station at Lullymore. Natural infection was relied on in all trials. All trials were on bulb onions including autumn-sown and spring-sown cultivars. Fungicides were applied by knapsack sprayer at the rate of 800 l/ha and a non-ionic wetter was included in all preparations. Individual plots were 5 x 2 m minimum with 3 or 4 replications of all treatments. Sprays were applied at 2-week intervals unless specified otherwise. The number and timing of applications are specified in each trial. Disease assessments were generally made at 2-week intervals from the onset of disease but only the final assessments before harvest are included in the tables. In most instances, yields were recorded but are shown in detail only where statistical differences occur. The fungicides tested and the rates of active ingredient are indicated in the tables of results.

RESULTS

Comparisons of 19 fungicides at 3 locations on overwintered onions (1978 - 79) are shown in Table 1. At locations A and B spraying commenced before the onset of disease. At A, where disease was severe, control was obtained with fentin acetate with maneb, mancozeb plus iprodione, triadimefon, chlorothalonil, captafol and mancozeb plus vinclozolin. At B, where disease levels were generally lower, 50% of the treatments gave significant control. At C, the disease was already well established before spraying commenced, and poor control was obtained generally. However, fentin acetate with maneb and chlorothalonil had significant effects.

Yields were recorded only at location A where fentin acetate with maneb, mancozeb plus iprodione, triadimefon, iprodione and copper oxychloride gave increased yields of bulbs. Dodine showed obvious symptoms of phytotoxicity and resulted in yield reduction. Fentin acetate with maneb and captafol were slightly phytotoxic but did not reduce yield.

Some of the more promising fungicides were again tested, alone or in combination, at normal and twice normal rates on spring-sown onions in 1979 (Table 2). At normal and twice normal rates, fentin acetate with maneb, mancozeb plus iprodione, mancozeb plus fentin acetate with maneb, chlorothalonil, and mancozeb plus triadimefon gave significant control of disease. Mancozeb was effective at the double rate while triadimefon and iprodione were not effective at either rate. None of the treatments had a significant effect on yield.

In 1980, five fungicides, singly and combined in pairs, were tested in three trials (Table 3). All combinations containing chlorothalonil or fentin acetate with maneb gave significant control at all locations. In addition, triadimefon plus mancozeb, iprodione plus mancozeb, chlorothalonil, and fentin acetate with maneb were effective at one location. Yields were recorded at locations A and B but differences between treatments were not significant.

In a further trial on overwintered onions at location B, 2-week and 4-week intervals between applications were tested (Table 4). At 2-week intervals, all combined treatments as well as chlorothalonil and fentin acetate with maneb were effective. At 4-week intervals, none of the treatments gave significant control. Yields were not affected by any of the treatments.

The effects of varying numbers and timings of fungicide applications on overwintered onions at two locations are shown in Table 5. Neither the number of applications nor the date of commencement of spraying had a significant effect. The timing of the last sprays was significant, control being obtained only when applications were made on the final two (June) dates of the spraying schedule.

Table 1

Comparison of 19 fungicides for control of Cladosporium leaf spot in autumn-sown onions (1978 - 79) at 3 locations

Fungicides	Rate kg a.i./ha	Disease index[1] A[2]	Disease index[1] B	Disease index[1] C	Yield (kg/plot) Location A only
Fentin acetate with maneb	0.34	1.1	1.0	2.7	27.7
Mancozeb + iprodione	2.7 + 0.84	1.4	-	3.4	27.9
Triadimefon	0.14	1.5	1.3	4.1	26.1
Chlorothalonil	0.84	2.1	2.0	2.9	24.2
Captafol	3.4	2.4	1.3	4.7	24.4
Mancozeb + vinclozolin	2.7 + 0.84	2.5	-	3.4	24.3
Triforine	0.34	3.1	1.7	3.7	23.7
Dithianon	0.90	3.2	0.7	4.1	24.6
Fenarimol	0.13	3.2	1.3	4.1	23.1
Mancozeb	2.7	3.3	0.7	3.9	23.6
Iprodione	0.84	3.5	1.0	4.4	26.3
Vinclozolin	0.84	3.7	1.7	4.2	22.4
Copper oxychloride	2.2	3.8	1.7	4.0	27.3
Dichlofluanid	1.4	4.4	2.0	3.9	25.3
Benomyl	0.56	4.4	2.3	4.8	23.9
Biloxazol	0.14	4.5	-	3.8	22.5
Zineb	1.6	4.6	1.3	4.2	21.2
Metalaxyl	0.28	4.8	3.0	4.9	20.5
Dodine	0.56	5.0	3.0	5.0	15.6
Control (unsprayed)	-	4.9	3.2	4.8	20.9
LSD 5%		2.03	1.64	1.55	4.72

[1] Based on scale 0 = no disease; 5 = very severe disease

[2] Location A Commercial farm, Co. Cork; Ten applications from mid February
B Peatland Experiment Station; Nine applications from early March
C Commercial farm, Co. Cork; Three applications from May 28; disease already severe.

Table 2

Comparison of eight fungicidal treatments at normal and at twice normal rates of application for control of Cladosporium leaf spot in spring-sown onions 1979

Fungicide[1]	Normal rate (N) kg a.i./ha	Disease index[2] N	Disease index[2] 2N
Fentin acetate with maneb	0.34	1.6	1.4
Mancozeb + iprodione	2.7 + 0.84	1.9	1.7
Mancozeb	2.7	2.7	1.6
Mancozeb + fentin acetate with maneb	2.7 + 0.34	1.3	1.6
Chlorothalonil	0.84	1.9	1.4
Mancozeb + triadimefon	2.7 + 0.14	1.8	1.7
Triadimefon	0.14	3.1	3.3
Iprodione	0.84	3.3	3.1
Control (unsprayed)	-	4.4	
LSD 5%		1.92	

[1] Six applications from June 15

[2] Scale: 0 = no disease to 5 = very severe disease

Table 3

Comparison of five fungicides, applied singly and combined in pairs, for control of Cladosporium leaf spot in autumn-sown onions at 2 locations and in spring-sown onions, 1980

Fungicide	Rate (kg/a.i./ha)	Disease index[1] Autumn-sown A[2]	Autumn-sown B	Spring-sown C
Chlorothalonil + mancozeb	0.84 + 2.7	1.1	1.9	1.3
" + iprodione	0.84 + 0.84	1.1	2.0	1.1
" + triadimefon	0.84 + 0.14	1.3	2.0	1.0
" + fentin acetate with maneb	0.84 + 0.34	1.5	2.2	1.0
Fentin acetate with maneb + mancozeb	0.34 + 2.7	1.2	1.9	1.9
" + iprodione	0.34 + 0.84	1.2	2.1	1.8
" + triadimefon	0.34 + 0.14	1.6	1.8	1.6
Triadimefon + mancozeb	0.14 + 2.7	1.5	2.0	2.0
" + iprodione	0.14 + 0.84	1.7	2.7	2.3
Iprodione + mancozeb	0.84 + 2.7	1.6	2.7	2.2
Chlorothalonil	0.84	1.3	2.8	2.0
Fentin acetate with maneb	0.34	1.5	2.3	1.9
Triadimefon	0.14	2.2	2.7	3.0
Iprodione	0.84	2.1	3.0	2.1
Mancozeb	2.7	2.2	2.9	3.2
Control (unsprayed)	-	3.4	4.2	3.6
LSD 5%		1.72	1.98	1.63

[1] Based on scale: 0 = no disease; 5 = very severe disease

[2] At A and B, nine applications from early March; at C, four applications from early August

Table 4

Comparison of 2-week and 4-week intervals between applications of 15 fungicide treatments on autumn-sown onions, 1980

Fungicide	Rate (kg a.i./ha)	Disease index[1] 2-week[2]	4-week[3]
Chlorothalonil + mancozeb	0.84 + 2.7	1.8	3.0
" + iprodione	0.84 + 0.84	1.9	3.3
" + triadimefon	0.84 + 0.14	1.5	2.7
" + fentin acetate with maneb	0.84 + 0.34	1.7	2.6
Fentin acetate with maneb + mancozeb	0.34 + 2.7	1.8	2.5
" + iprodione	0.34 + 0.84	2.1	2.9
" + triadimefon	0.34 + 0.14	2.1	2.8
Triadimefon + mancozeb	0.14 + 2.7	2.0	3.3
" + iprodione	0.14 + 0.84	2.4	2.9
Iprodione + mancozeb	0.84 + 2.7	2.3	3.3
Chlorothalonil	0.84	2.3	3.0
Fentin acetate with maneb	0.34	1.9	3.0
Triadimefon	0.14	2.5	2.9
Iprodione	0.84	2.7	3.7
Mancozeb	2.7	2.8	3.1
Control (unsprayed)	-	4.0	
LSD 5%		1.65	

[1] Based on scale: 0 = no disease; 5 = very severe disease

[2] Nine applications from March 5   [3] Five applications from March 5

Table 5

Effect of number and timing of applications of mancozeb plus iprodione on Cladosporium control in overwintered onions at two locations, 1980

Number of applications	Dates of application: March 4	March 18	April 1	April 15	April 30	May 14	May 27	June 10	June 25	Disease index[1] A[2]	B
9	x	x	x	x	x	x	x	x	x	1.7	1.4
7			x	x	x	x	x	x	x	2.1	1.7
5					x	x	x	x	x	2.4	1.6
3							x	x	x	2.3	1.8
7	x	x	x	x	x	x	x			3.2	2.9
5	x	x	x	x	x					3.6	2.8
3	x	x	x							4.0	3.4
3			x	x	x					4.1	3.1
3					x	x	x			3.5	3.0
0										4.5	3.7
LSD 5%										1.68	1.27

[1] Scale: 0 = no disease; 5 = very severe disease

[2] Onset of disease: mid March at A, early May at B

DISCUSSION

When assessing disease levels a marked reduction in sporulation was noticeable in fentin-sprayed plots. This effect may account to some extent for the effectiveness of this product particularly where severe infection occurs prior to spraying. Also noticeable was the vigour and green colour of plots sprayed with mancozeb-containing preparations. Such plots often showed extensive lesions but appeared to be resistant to the severe blighting effect of the disease. Similar effects were obtained by late topdressings of nitrogen. It appears that the aggressive stage of the disease is triggered by the onset of senescence in the foliage. Certainly, Cladosporium lesions may be found on onion leaves at any stage of growth but severe blighting seldom occurs before the initiation of bulbing. This phenomenon tends to explain why a few but frequent fungicide applications late in the season give best control of disease. The generally late development of severe blight probably accounts also for the relatively few occasions on which yield reductions could be demonstrated.

It is suggested that losses due to Cladosporium leaf spot can be minimised by maintaining vigour with sufficient nitrogen and by the application of effective fungicides, starting at the initiation of bulbing.

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COMPARISON OF THE FUNGICIDES THIABENDAZOLE AND 2-AMINOBUTANE USED FOR THE CONTROL OF GANGRENE AND SKIN SPOT ON POTATOES GROWN UNDER SCOTTISH CONDITIONS

G.A. Hamilton, D.A. Lindsay, C.E. Quinn and A.D. Ruthven

Department of Agriculture and Fisheries for Scotland (DAFS),Agricultural Scientific Services, East Craigs, Edinburgh, EH12 8NJ

P.J. Shipton and W.J. Gray

North of Scotland College of Agriculture (NOSCA), 581 King Street, Aberdeen, AB9 1UD

Summary Fungicides have been tested for many years by DAFS and NOSCA for the control of gangrene and skin spot on potatoes in store. Of the more widely used chemicals 2-aminobutane (2-AB) has regularly given good control but thiabendazole (TBZ) has generally been less effective when tested under trial conditions. Because the potatoes used for some of the trials may not have been typical of those grown further north, the work reported here was done in a main seed potato raising area in Grampian Region. The TBZ treatments were done by the farmers using their own commercial equipment. Residue analyses were done to assess the competence of the chemical applications. The results reported here show 2-AB gave good control of gangrene and skin spot but TBZ was much less effective. Various conditions such as weather, lateness of lifting may have mitigated against the effectiveness of TBZ.

Resumé Depuis de nombreuses années, DAFS et NOSCA téstent des fongicides destinés a maîtriser la nécrose et les taches apparaissant sur les pommes de terre conservées en entrepôt. Parmi les produits chimiques les plus utilisés à-Aminobutan (2-AB) a régulîerement donné de bons résultats alors que le thiabendazole (TBZ) a dans l'ensemble été moins efficace lors des essais expérimentaux. Parce que les pommes de terre utilisées pour certains des essais n'êtaient peut-être pas typiques de celles cultivées plus au Nord, le travail dont il est rendu compte ici fut effectué dans une grande région de production de pommes de terre a'semence de la province des Grampians. Les traitements au TBZ furent donnés par les fermiers utilisant leur propre équipement commercial. Des analyses de residues furent faites pour évaluer la compétence des applications chimiques. Les résultats dont nous rendons compte ici montrent que 2-AB a donné une bonne maitrîse de la nécrose et des taches mais que TBZ a été moins efficace. Il se pent qu'un concours de circonstancestelles que le temps, un arrachage tardif de pommes de terre, ait diminué l'efficacité de TBZ.

INTRODUCTION

Over a number of years various fungicides have been evaluated by the DAFS at East Craigs, Edinburgh, for control of potato storage diseases. The use of 2-aminobutane (sec-butylamine) (2-AB) was described in the early 1970s (Graham et al 1970, 1973a and b, 1975) and has since been widely used in commercial practice. A number of other materials have been evaluated (Graham et al 1981). For example, thiabendazole (TBZ) has been reported by many workers to control gangrene (*Phoma exigua* var. *foveata*), skin spot (*Polyscytalum pustulans*) and dry rot (*Fusarium coeruleum*) (Hide et al 1969 and 1980; Logan et al 1975 and 1978 and Henriksen 1978) and has been introduced widely into commercial practice. In the trials done at East Craigs whilst good control of gangrene and skin spot was obtained when using 2-AB less effective control resulted from the use of TBZ. Many of the stocks used in these experiments, particularly in recent years, may not have been typical of those grown in the main seed potato growing areas further north in Grampian and Highland Regions where these diseases can be troublesome. In an attempt to compare the results obtained at East Craigs with those observed in commercial practice, it was decided to examine the levels of disease following fungicide treatment on potatoes harvested, treated and stored on farms in the Banff and Buchan District of Grampian Region in two simultaneous investigations carried out by the DAFS and the NOSCA.

The NOSCA co-authors of this report were already engaged in a separate detailed study which involved the control of these diseases with TBZ and 2-AB under regimes of good and bad storage management, part of which has already been published (Shipton and Gray 1980).

METHODS AND MATERIALS

It was decided for reasons of handling and cost to fumigate tubers with 2-AB in 0.25 tonne capacity boxes (open-sided) on those farms visited by DAFS. On the NOSCA-supervised farms all the potatoes were kept in standard commercial 1 tonne boxes for storage or fumigation, where applicable. In other respects the trial conditions were similar, so that the results could be combined.

The 2-AB fumigations were done in a commercial brick-built chamber designed for treating potatoes in 1 tonne boxes on a farm situated close to the experimental farms. The potatoes were fumigated in the boxes in which they were stored. Immediately after fumigation the potatoes were returned to the farm stores.

There are several different methods of treating potatoes with TBZ, according to the type of sprayer or applicator and its location, and the interval between harvest and treatment. The two types of sprayer most widely in commercial use, the Mantis Mafex and the Delavan can be mounted on the harvester, on the elevator in the farm store or on the roller table on the grading machinery. Examples of each were included in the trial. The treatments were done on the farm using the farmer's own standard commercial equipment operated by himself, although some of the treatments were partially supervised. To conform with recommended commercial practice it was decided that a majority of the stocks should be treated on the harvester using either the Mantis or the Delavan. All the TBZ treatments (as "Storite Flowable", Merck Sharpe & Dohme Ltd) were done well within the manufacturers recommended period of within two weeks after lifting. The dates of lifting and treatments are shown in Table 1.

The potatoes, regardless of treatment, were all stored in similar sized boxes kept together on the farm and no account was made of the position of the individual boxes. No replication of treatments was attempted on any farm and only one box per

Table 1

Potato stocks, date of lifting, fungicide treatments and residues

Stock	Cultivar	Date of Lifting	Fungicide & Treatment	Date	Residue of TBZ (mg/kg)	Residue of 2-AB (mg/kg)
DAFS Supervised						
1	Record	29/10	TBZ-Mantis/H*	29/10	3.8, 6.2, 1.5	
			2-AB	6/11	1.0, 0.7, 0.7	3, 18
			Untreated		0.3, 0.6	
2	Pentland Squire	27/10	TBZ-Mantis/H	27/10	2.4, 45.0, 7.5	
			2-AB	6/11	0.2, 0.2, 0.2	22, 12
			Untreated		0.2, 0.4	
3	Record	10/10	TBZ-Mantis/H	10/10	4.4, 2.8, 4.2, 2.7	
			2-AB	23/10	0	19, 22
			Untreated		0	
4	Desiree	10/10	TBZ-Delavan/H	10/10	14.4, 11.6, 11.0, 6.9	
			2-AB	23/10	1.2, 2.6	49, 33
			Untreated		1.3, 0.6	
5	Desiree	5/11	TBZ-Delavan/H	5/11	3.8, 5.0, 3.6	
			2-AB	6/11	0, 0	69, 77
			Untreated		0, 0	
6	Pentland Hawk	26/10	TBZ-Delavan/E*	26/10	0.8, 5.3, 1.9	
			2-AB	6/11	0.6, 1.0, 0.5	56, 73
			Untreated		3.8, 0.3, 0.2	
7	Pentland Dell	13/10	TBZ-Delavan/E	13/10	15.5, 9.5, 6.2, 5.8	
			2-AB	23/10	1.3, 0.3	30, 14
			Untreated		0.8, 0.6	
8	Desiree	5/11	TBZ-Mantis/D*	12/11	6.8, 6.0, 3.9	
			2-AB	12/11	1.6, 4.0, 1.5	58, 74
			Untreated		3.2, 3.5, 0.7	
9	Up to Date	31/10	TBZ-Mantis/D	7/11	3.1, 5.4, 1.4	
			2-AB	12/11	0.2, 0.3	74, 66
			Untreated		0.2, 0.2	
10	King Edward	1/11	TBZ-Mantis/D	10/11	0.2, 0, 0	
			2-AB	6/11	0	22, 24
			Untreated		0	
NOSCA Supervised						
11	Desiree	3/10	TBZ-Delavan/H	3/10	0.2, 0.1, 0.1, 0.1	
			2-AB	22/10	0.2, 0.3	40, 29
			Untreated		0.2, 0.2, 0.4, 0.2	
12	Desiree	31/10	TBZ-Mantis/H	31/10	0.9	
			2-AB	6/11	0, 0	17, 13
			Untreated		0.2, 0.4	
13	Desiree	29/10	TBZ-Mantis/H	29/10	3.1	
			2-AB	6/11	-	43, 39
			Untreated		-	
14	Desiree	28/10	TBZ-Mantis/E	28/10	4.7	26, 21
			2-AB	6/11	-	
			Untreated		-	

*H - Harvester, E - Elevator, D - Dresser.

treatment was used, from which tubers were removed for residue analysis and disease assessment. The efficiency of application of all the chemical treatments was established by chemical analysis. Measurement of the levels of fungicide was considered essential because TBZ treatments were done separately on eleven different farms.

The intended rate of treatment for both chemicals was at the recommended commercial rates, which were 40 mg/kg for TBZ and 200 mg/kg for 2-AB. No account was taken of the type of harvester or grading machinery used because all potatoes of any one stock received similar handling, except those which were transported in their boxes to and from the fumigation chamber where they were treated with 2-AB. No deliberate damage was inflicted on the potatoes nor was there any artificial inoculation so that the storage diseases which developed resulted from normal farming practices and natural sources of inoculum. Fourteen stocks of potatoes were used in this trial because naturally occurring infection can frequently be absent. The cultivar Desiree was preferred as it is widely grown in the area and is moderately susceptible to gangrene, but this cultivar was not always available and others were included.

Immediately after treatment, samples of tubers were taken from each box for analysis for 2-AB and TBZ residues by DAFS. The tubers were analysed as received, so that any soil adhering to the tubers was included in the analysis.

Disease assessment

On the DAFS supervised farms approximately 1,000 tubers were visually examined for rots during the first week of February 1981, while at the NOSCA farms 200 tubers were examined in late January 1981. All tubers showing lesions of a size which allowed identification were removed and the numbers recorded. A selection of these tubers were taken to the laboratory where the identity of the disease organism was confirmed. On the farm, the remaining tubers were passed over the commercial grading machinery and all the tubers returned to store. A final disease assessment was made in the last week of March (DAFS trial) or in the last week of April (NOSCA trial). One hundred tubers were taken from each stock to the laboratory where they were washed and assessed visually for the presence of surface skin spot infection.

RESULTS

Chemical Analysis

Samples of tubers from all treatments (including untreated controls) were analysed for the presence of the fungicides. The results are shown in Table 1. The results show that erratic treatment and cross-contamination occurred widely. The levels of TBZ were variable but many were within the limits expected of such treatments, with the possible exception of three stocks (Numbers 10, 11 and 12) where levels of TBZ were very low. The levels of 2-AB were also variable but were typical of many commercial treatments.

Disease levels

(i) Gangrene

The results are shown in Table 2. In four of the stocks no disease developed. Of the remaining ten, three had levels of 5% gangrene or less and the differences were probably of no practical importance. Seven stocks had more than 5% gangrene; the mean level of gangrene in all the untreated stocks was 10.1%. In the

TBZ-treated potatoes there was a mean of 6.3% while in those fumigated with 2-AB the level was 0.7%. Thus the level of gangrene was reduced by about 40% when TBZ was used and by more than 90% when 2-AB was used.

Table 2

Effect of fungicide treatment and method of application on the incidence of gangrene on tubers (% infected tubers)

Stock	Cultivar	TBZ Treatment		% tubers infected with gangrene		
		Sprayer	Location	TBZ	2-AB	Untreated
DAFS Supervised						
1	Record	Mantis	Harvester	2.2	0.9	4.0
2	Pentland Squire	Mantis	Harvester	0	0	0
3	Record	Mantis	Harvester	0.8	1.1	4.4
4	Desiree	Delavan	Harvester	5.3	3.9	15.0
5	Desiree	Delavan	Harvester	5.5	0.4	15.3
6	Pentland Hawk	Delavan	Elevator	0	0	0
7	Pentland Dell	Delavan	Elevator	0	0	0
8	Desiree	Mantis	Dresser	2.2	0.1	3.7
9	Up to Date	Mantis	Dresser	15.6	0.4	21.0
10	King Edward	Mantis	Dresser	7.9	0.5	17.6
NOSCA Supervised						
11	Desiree	Delavan	Harvester	3	1	7
12	Desiree	Mantis	Harvester	2	0	0
13	Desiree	Mantis	Harvester	12	2	26
14	Desiree	Mantis	Elevator	31	0	27
Mean incidence of gangrene				6.3	0.7	10.1

(ii) Skin spot

Only five stocks had infections of skin spot at a level where visual assessment could be made. No attempt was made to assess "eye" infection levels. The results are shown in Table 3. While the results are not extensive it is apparent that, while the control obtained using TBZ was limited, that obtained with 2-AB was very much better.

Table 3

Effect of fungicide treatment on the incidence of skin spot on tubers in five stocks with infection (% infected tubers)

Stock number	Treatment		
	None	TBZ	2-AB
1	80	65	0
5	42	16	2
10	77	89	13
12	91	77	9
13	45	17	0

(iii) Fusarium spp

No dry rot (Fusarium coeruleum) was found in any tubers. There were occasional tubers infected with other Fusarium spp. but no further attempt was made at identification. Single infected tubers were found in two stocks with no treatment, one stock treated with TBZ and three stocks treated with 2-AB. However in stocks (Numbers 8, 13 and 14) when treated with 2-AB, 1.8%, 4.0% and 2.0% tubers were infected with Fusarium spp. while in the untreated tubers there was no infection and 1% in those treated with TBZ.

DISCUSSION

The intention of these trials was to determine the level of control given by TBZ against the potato storage diseases gangrene and skin spot, which occur widely as the most prevalent disease problems on potatoes grown in the North of Scotland. These trials were done under a range of experimental and farming conditions to cover the normal farming practices where possible.

In contrast to the large number of workers (Hide et al 1969 and 1980; Logan et al 1975 and 1978; Henrikson, 1978) who have found TBZ to provide control of gangrene in their trials, the repeated experiments done by DAFS and NOSCA and the work reported here, showed that under the conditions of all their trials, this material is relatively less effective in its control.

There is no obvious single cause for the conflicting results. In 1980 the lack of control of gangrene by TBZ may have been partially due to the late lifting as a result of very adverse weather and soil conditions. Tubers were thus more mature than normal and more opportunity may have been given to the fungus to establish infection within the tuber. In countries such as the Netherlands, seed potatoes are lifted very early compared to Scotland, and good control of Fusarium with TBZ is regularly obtained. No treatments were done in any of the trials reported here on potatoes of maturity similar to that occurring in the Netherlands. The skins may have been more impervious to the TBZ which was thus unable to reach the fungus. This conclusion is supported by experiments to be reported elsewhere, which showed that in potatoes taken from this trial, after peeling, less than 1% of the TBZ measured on the whole tuber is found in the flesh; at the same time, light rinsing of the tubers with water removed 80% of the TBZ. It is also likely that, as a result of wet lifting conditions, much of the toxicant measured as residue was absorbed in the soil adhering to the tubers and not available for disease control. By comparison, analysis of 2-AB treated potatoes showed about one-third of the residue was in the flesh.

Frequently it has been observed that TBZ provides antifungal protection on open wounds. However gangrene has been observed to occur at sites where no obvious wounding has occurred. Much of the disease evaluation done by other workers, particularly those in the UK, has involved the deliberate wounding of tubers before or after treatment to induce rotting. This practice is not consistent with agricultural practice and was avoided in these trials where naturally occurring damage was accepted.

In spite of adverse field conditions in 1980 the 2-AB again gave a high level of control (90%) of these diseases. In most stocks, levels of infection were reduced to 1% or less even when the incidence of disease on untreated tubers was 20% or above. By comparison the mean control of gangrene when TBZ was used was about 40%. Although late lifting has been blamed for lack of control by TBZ this is not supported by the results obtained on stocks 4 and 5. The stocks were the same cultivar and treated similarly. Stock 4 had a higher deposit of TBZ than

Stock 5 and though it was lifted a month earlier, the reduction in gangrene was no better. Both stocks when untreated had about the same level of gangrene present. The location of either type of sprayer/applicator on the harvester for treatment of the tubers on lifting resulted in 60% mean control of gangrene. When potatoes were treated on dressers about one week after lifting only about 40% control of gangrene was observed. No conclusions could be drawn from these trials to establish which of the factors, lapse of time between harvest and treatment or the location of sprayer, contributed to the poorer control.

CONCLUSIONS

Although a range of combinations of sprayer/applicators, and lapse in time between harvest and treatment were represented by the fourteen stocks chosen, there was no combination which showed a significantly higher level of control of gangrene or skin spot by treatment with TBZ, compared to 2-AB. It is possible that delay of a week from harvesting to treatment may have been the reason for less good control than immediate treatment at harvest and also that late lifting and adverse tuber condition may have adversely affected the performance of TBZ more than 2-AB. While the control of gangrene obtained with TBZ may have been better in some cases than those observed earlier it was less good than when using 2-AB. Similarly, control of skin spot was very good with 2-AB but only moderate to poor with TBZ in the few infected stocks. In three stocks there was a slight but inexplicable increase of *Fusarium* spp. present when 2-AB was used, although the occurrence of *Fusarium* in recent years has been of little economic importance.

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