A TECHNIQUE TO STUDY UPTAKE OF TRIADIMENOL THROUGH WHEAT CARYOPSES

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ABSTRACT

[^{14}C] triadimenol uptake through the caryopsis was investigated in a special experimental design with single seed grains in plexiglass holders. In totally treated caryopses about 5%, and in partially treated caryopses (embryo untreated) 4.5% of the applied radioactivity reached the winter wheat shoots after 21 days up to GS 13. Uptake of labelled a.i. through the pathway pericarp - testa - endosperm - scutellum - seedling up to GS 13 was therefore confirmed. Furthermore, [^{14}C] triadimenol was also translocated through the caryopses into the roots and was released into the nutrient solution.

INTRODUCTION

With the development of triadimenol, the a.i. of (R) Baytan, a fungicide for cereal seed treatment has become commercially available which is both taken up by seed during germination and exerts direct eradicative and curative effects on seed-borne pathogens. Also, after being taken up through the roots from the treatment zone and systemically distributed within the plant, it affords control of soil-borne and wind-spread fungal pathogens (Frohberger, 1978).

The studies published to date provide no elucidation of whether the a.i. is supplied to the plant embryo via the caryopsis or via the roots. An experimental system was developed for this purpose which excluded the formation of a treatment zone around the roots. Furthermore, the experiment should provide additional information on the uptake of triadimenol after total and partial treatment of caryopses.

MATERIALS AND METHODS

Active ingredient, formulation and dry treatment

The study was performed using a dry seed treatment (DS) formulation of Baytan with 25% [benzene ring-UL-^{14}C] triadimenol.

Before treatment, the pericarp above the embryo and the micropyle of 60 wheat grains (cv. Jubilar) were masked with adhesive plaster. These partially masked wheat grains were then transferred, together with unmasked wheat grains (13.9 g in total), to a 100 ml pear-shaped flask and, after addition of 20.8 mg [^{14}C] Baytan (12.95 MBq], corresponding to a required

dose rate of 150 g Baytan/100 kg seed, were intensively mixed for 15 minutes on a laboratory vibrator.

Applied radioactivity

To determine the mean applied radioactivity on the grains, 50 totally treated and 40 partially treated wheat grains were taken and, after removal of the adhesive plaster, extracted with dichloromethane. The non-extractable radioactivity was determined by combustion in an oxidizer. The radioactivity was measured in a liquid scintillation counter. The mean applied radioactivity on the pericarp above the embryo was calculated from the difference between the two mean values. After allowing for the radioactivity incorporated in the sealing compound the reference radioactivity was determined.

Experimental design, nutrient solution, plants

The study was performed under long-day conditions in a climate chamber. The daytime temperature was 23°C with a relative humidity of 65 - 70%. the night-time temperature fell to 16°C with a relative humidity of 85 - 90%.

Two plexiglass chambers, each containing 20 separate nutrient solution cells, served as experimental vessels. The plexiglass holders were attached to a clamping strip above the aerated nutrient solution cells. The partially and totally treated wheat seed grains were placed in succession in the horizontal holes (diameter 5 mm, depth 12 mm) of the plexiglass holders and kept in place by means of a foam underlay. The embyros protruded from the end of the hole. The circular gap between the hole and the embryo was plugged with a physiologically neutral sealing compound. After embedding the partially treated caryopses, the adhesive plasters over the embryos were removed. To accelerate the swelling of the wheat grains, the plexiglass holders were filled with 200 µl distilled water through a vertical hole.

Sampling of plants, nutrient solution and processing

After 21 days (GS 12 - 13) the plants were separated into leaves, coleoptiles, caryopsis and roots. The fresh weight was determined and the samples were dried at 40°C. The radioactivity in the nutrient solution was measured at the end of the study.

RESULTS

Accountability of applied radioactivity and a.i.

For the totally treated wheat grains, a seed treatment application of 12.5 +/- 1.9 µg a.i./wheat grain was calculated by reference to the specific radioactivity, which is equivalent to 100 g Baytan 25 DS/100 kg seed. The corresponding values for the partially treated wheat grains were 11.6 +/-3.4 µg a.i. or 93 g Baytan 25 DS/100 kg seed. The means of the application variants show no significant differences.

The radioactivity difference between totally and partially treated caryopses showed that with totally treated wheat grains about 7% of the applied radioactivity or 0.9 µg a.i. adhered to the pericarp in the region of the embryo. After subtracting the moieties of seed treatment bound in the sealing compound, a corrected a.i. quantity/grain of 11.3 µg, equivalent to 90.4 g Baytan 25 DS/100 kg seed was found for totally treated seed and 10.5 µg a.i., equivalent to 84 g Baytan 25 DS/100 kg seed, for partially treated seed. The inadequate treatment was largely due to the unexpectedly high degree of binding to the adhesive plasters on the partially masked wheat grains (16 +/- 2.4 µg a.i. grain). Altogether, the adhesive plasters of 60 individual grains absorbed 18.5% of the applied quantity of a.i.

Radioactivity in wheat from partially and totally treated seed and in nutrient solution

The results presented in Table 1 show that radiolabelled a.i. and/or metabolites can be taken up into the shoot and roots up to GS 13, both through partially and totally treated caryopses. No significant differences in uptake were detected in the shoots of totally treated wheat caryopses with 5.0% and the shoots of partially treated caryopses with 4.5% of the applied reference radioactivity.

The highest uptake of radioactivity was found in the first leaf, both of totally treated wheat with 2.7% and of partially treated wheat with 2.3%. Uptake into the coleoptile was limited at 1 to 1.2%. A continuous decrease in radioactivity uptake was apparent in the second and third leaf. This decrease evidently resulted from the initial depletion of the endosperm reserves with the result that, with the decreasing supply of mobilized reserve materials through the scutellum, less ^{14}C-labelled a.i. and/or metabolites were also transported to the shoot and roots.

About 11% of the reference radioactivity was measured on and in the caryopses of the treated seeds at GS 13. About 72 - 91% remained in the plexiglass holders (sealing compound and foam underlays (Table 2)). Radiolabelled a.i. and/or metabolites were presumably transported through the symplast into the roots, together with the reserve materials translocated from the endosperm into the roots. These contained 1.2 and 0.9% respectively of the reference radioactivity (Table 1). Also striking was the relatively high incorporation of radioactivity into the nutrient solution, at 7.7% for the totally treated and 8.9% for the partially treated seeds (Table 2). Incomplete sealing of the plexiglass holders or uncontrolled introduction of radioactivity into the nutrient solution cells were excluded, and the higher mean radioactivity level of the nutrient solutions of totally treated winter wheat is attributable to external contamination of the primary roots after penetrating the micropyle. Further investigations will be needed to clarify whether the radioactivity entered the nutrient solution through root transpiration or with root exudates.

DISCUSSION

Triadimenol uptake through the caryopsis can be divided into three phases as follows:

Dormancy phase

In wheat grains with a moisture content of about 15%, no uptake of (^{14}C) triadimenol into the caryopsis was observed after dry seed treatment (Steffens et al. 1982).

Germination phase

Microautoradiographs by Steffens et al. (1982) have confirmed that, similarly to water uptake, radiolabelled triadimenol is absorbed primarily into the embryo three days after the start of swelling, but that only comparatively small quantities of radioactivity are detectable in the endosperm. However, the barrier function of the testa for the penetration of (^{14}C) triadimenol into spring wheat caryopses observed by Steffens et al. (1982) in short-term trials (up to six days) evidently persists for only a limited time, since microautoradiographs of winter wheat caryopses have demonstrated the penetration of ^{14}C-labelled compounds into the endosperm under climate chamber and field conditions (Thielert et al. 1987). Field lysimeter experiments by Thielert et al. (1986) have shown that up to 10.3% of the radioactivity applied to winter wheat was recovered after emergence (GS 10) in the caryopses. The level of a.i. uptake into the endosperm was decisively influenced by the rainfall distribution. (^{14}C) triadimenol as a DS formulation was rapidly transported from the pericarp into the surrounding soil under the influence of high rainfall immediately after sowing, with the result that the incorporation of a.i. into the caryopsis and thus the maximum possible utilization of uptake through the scutellum into the shoot and root primordia was reduced at an early stage.

Endosperm depletion phase

The further uptake of triadimenol into the seedling after emergence of the primary roots and bursting of the testa and pericarp by the coleoptile can follow three pathways:

1. primary roots
2. coleoptile
3. scutellum

Sealing of treated wheat caryopses in plexiglass holders has shown that when the quantity of a.i. at the immediate periphery of the caryopses is limited, uptake into the shoot and roots is also possible through the pathway pericarp - testa - endosperm - scutellum up to GS 13.

To develop its photosynthetic apparatus and primary roots, the germinating plant depends on a supply of mobilized organic reserve substances from the endosperm (Sauerbeck, 1967). Together with these mobilized reserves, part of the radioactivity absorbed by the endosperm is also translocated through the vascular bundle of the scutellum into the shoot and roots. ^{14}C-labelled a.i. and/or metabolites will thus probably have been translocated to the roots through the symplast, while uptake into the shoot probably occurred through the symplast and the apoplast. With the commencement of photosynthetic activity, autotrophic and heterotrophic nutrition processes run parallel, until the endosperm reserves are exhausted. The increase in radioactivity uptake up to the time of formation of the first leaf and the decrease in radioactivity from the first to third foliage leaf thus corresponds to the metabolism kinetics of the endosperm reserves.

Uptake of (^{14}C) triadimenol through the roots from the treatment zone as early as GS 11 has been demonstrated by Thielert et al. (1986). The relative proportion of the total radioactivity translocated into the shoot was 6.7%. At GS 12, this proportion rose to 7.9%. Uptake from the treatment zone only assumed greater importance at GS 13 stage. In late sown winter wheat, for instance, 23% of the total radioactivity translocated into the shoot up to this stage was supplied through the roots from the treatment zones of the neighbouring plants in the row. It is possible that the a.i. and/or metabolites are also taken up by the proximal roots and the base of the shoot growing through the treatment zone, as Shone & Wood (1973) have demonstrated for the systemic fungicide ethirimol. These authors, however, excluded cross-transport of the a.i. into the base of the shoot sheathed by a coleoptile.

Release of ^{14}C-labelled compound to the nutrient solution was unexpectedly high. Since the experimental design virtually excluded contamination of the nutrient solution it is assumed that ^{14}C-labelled a.i. and/or metabolites were also released with root exudates into the nutrient solution. The activity of triadimenol against Gaeumannomyces graminis var tritici observed by Bockus (1983) to last up to 6 weeks after liquid seed treatment of winter wheat with Baytan may possibly also be attributable to the uptake of triadimenol into the roots and additional release through root exudates into the rhizosphere outside the treatment zone.

In conclusion, it can be stated that uptake of triadimenol into the shoot was higher the longer the a.i. could be retained in concentrated form on and in the caryopsis, between germination and GS 13 (Thielert et al. 1986). This was evidently due to the increased supply of triadimenol through the pericarp - testa - endosperm and scutellum pathway into the shoot and roots. Suitable formulation techniques should therefore be applied to guarantee uptake of the maximum possible quantity of a.i. through the caryopsis.

TABLE 1

Uptake of radioactivity into wheat up to GS 12 - 13 through the caryopsis after total and partial treatment with (^{14}C) triadimenol as Baytan 25 DS formulation

		Coleoptile	1st leaf	2nd leaf	3rd leaf	grain	root	shoot
		% of reference radioactivity/grain						
Totally treated	$\bar{x}$	1.17	2.74	0.95	0.12	11.10	0.90	4.86
	s	0.42	1.12	0.52	0.12	3.19	0.73	1.93
Partially treated	$\bar{x}$	1.00	2.29	1.37	0.17	11.00	1.24	4.46
(pericarp above embryo untreated)	s	0.63	1.28	1.03	0.11	3.98	1.18	2.83

Reference radioactivity/totally treated grain = 100% = 11.3 µg a.i.
Reference radioactivity/partially treated grain = 100% = 10.5 µg a.i.
Means of 20 replicates

TABLE 2

Radioactivity in plants, nutrient solution, sealing compound, foam underlays and accountability

		Plants	Nutrient solution	Sealing compound	Foam underlay	Accountability
		% of reference radioactivity/grain				
Totally treated	$\bar{x}$	16.86	7.65	15.7	56.1	96.2
	s		3.81			
Partially treated	$\bar{x}$	16.70	8.90	23.7	67.3	116.2
(pericarp above embyro untreated)	s		1.99			

Reference radioactivity/totally treated grain = 100% = 11.3 µg a.i.
Reference radioactivity/partially treated grain = 100% = 10.5 µg a.i.
Means of 20 replicates

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EFFECTS OF FUNGICIDE TREATMENT OF RYEGRASS SEED FOR THE CONTROL OF SEEDLING DISEASES

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ABSTRACT

In a glasshouse experiment six fungicide treatments (drazoxolon and five combinations of an MBC compound and either captan, thiram or metalaxyl) were applied to ryegrass seed to determine the effects of controlling seedling diseases. Four treatments improved seedling emergence, by up to 33%. A post-emergence infection by powdery mildew (Erysiphe graminis) was well controlled by four fungicide treatments. Carbendazim + captan, which gave the highest seedling emergence and the best control of mildew, increased herbage yield by 49%. The same six treatments were used in a small-plot experiment and although none had a significant effect on seedling emergence, when combined with post-emergence insecticide sprays both the control of frit fly and herbage yield were better than that for insecticide alone. In another small-plot experiment, at a July sowing, fungicide seed treatment alone increased emergence by 25% and the herbage yield by 18%.

INTRODUCTION

In a glasshouse experiment to investigate factors that may influence the susceptibility of perennial ryegrass seedlings to soil-borne fungal pathogens, pre-emergence death of seedlings was greatest in warm, dry soil (Lewis & Lam,1983). Adding an inoculum of Fusarium culmorum further increased seedling death and this fungus was the one most frequently isolated from ungerminated seeds and dead seedlings growing in unamended soil. Seed treatment with benomyl + captan has given excellent protection against high seedling losses in soil artificially infected with F. culmorum (Holmes,1983). The present paper gives results of sowing perennial ryegrass seed treated with benomyl + captan, and other fungicides, in an unamended soil in a glasshouse and in the field.

METHODS

In all experiments seed of perennial ryegrass cv. Parcour was sown in a field at Hurley, or in soil collected from that field. The soil is a sandy loam.

Fungicides formulated as a powder were applied to the seed using a laboratory seed dresser with a drum rotational speed of 120 rev/min for 5 min. Liquid formulations were applied using a mini 'Rotostat'. Seed was sown within a few weeks of applying the treatments. Post-emergence insecticide sprays were applied in 440 litres water/ha using a hand-propelled wheeled plot sprayer constructed at IGAP. A forward speed of 0.45 m/s, a pressure of 140 KPa and Spraying Systems Co. Tee-jets with 80015LP tips were used.

Glasshouse experiment

Seed treated with each of six fungicide combinations (Table 1), or untreated, was sown in soil in pots. One hundred seeds were sown in each of five replicate pots for each treatment, and in ten pots for untreated seed. The pots were arranged in a completely randomised design in a glasshouse maintained at about 15°C. Water was applied sparingly after sowing, to slow down the pre-emergence growth of seedlings with the intention of increasing the risk of infection by F. culmorum. The number of emerged seedlings in each pot was counted 68 days after sowing.

A post-emergence infection of seedlings by powdery mildew (Erysiphe graminis) occurred and the level of infection was assessed 98 days after sowing, using a subjective rating of nil, slight, moderate or severe. The dry weight of seedlings per pot was obtained by cutting them at soil level and drying them at 100°C overnight.

Field experiment A

An experiment using the same treatments as for the glasshouse work was done in the field. Plots (size 1.5 x 6m) were sown on 27 August 1985 with an Oyjord precision drill fitted with 14 coulters spaced 10 cm apart. The seed rate used was 17 kg/ha, equivalent to 1000 seeds/m^2 or a 1 cm spacing between seeds in a drill row. The six fungicide treatments (Table 1) were allocated at random to two plots in each of five replicate blocks, and four plots sown with untreated seed were included in the randomisation for each block. When the seedlings emerged, one of the two plots for each fungicide treatment and two of the plots sown with untreated seed in each block were sprayed twice with insecticide to control stem-boring larvae. Chlorpyrifos was applied at early emergence and omethoate at full emergence; dose rates are given in Table 2.

Seedling emergence was assessed by counting the number of seedlings in a 30 cm length of 12 of the 14 drill rows on each plot; the two outermost rows were not assessed. The proportion of tillers damaged by stem-boring larvae was assessed by taking one 5 cm diameter core at random from one drill row in each plot and dissecting each tiller to locate any larvae present.

Herbage yield was assessed by cutting and weighing the herbage from each plot using a Haldrup plot harvester. A sub-sample of 500 g fresh weight was taken from each plot and dried overnight at 100°C to determine the dry matter content.

Field experiment B

Plots (size 1.5 x 6 m) were sown at Hurley on five occasions in 1985 (Table 2), using the same method as for Field experiment A. Two fungicide seed treatments were used, benomyl + captan and carbendazim + captan, and each was allocated at random to one plot in each of five replicate blocks. Two plots sown with untreated seed were also included in the randomisation for each block. After the seedlings had emerged, the plots sown with seed treated with benomyl + captan were sprayed with chlorpyrifos and omethoate, as for Field experiment A. The assessments made were the same as for Field experiment A. Stem-boring larvae were assessed for the August sowings only.

RESULTS

Glasshouse experiment

Seed treatment with carbendazim + captan and the three compounds containing thiabendazole significantly increased emergence, but benomyl + captan and drazoxolon had no significant effect (Table 1). Infection of seedling leaves by mildew was totally prevented by carbendazim + captan and good control was provided by benomyl + captan, thiabendazole + captan and thiabendazole + metalaxyl. Thiabendazole + thiram had no significant effect and drazoxolon increased the severity of infection. Only carbendazim + captan increased significantly the dry weight of herbage (Table 1).

Field experiment A

The six fungicides, with or without the insecticide sprays, did not differ significantly in their effect on seedling emergence, herbage yield or stem-borer attack. Therefore results are given as the overall means of the six fungicide treatments (Table 2). Fungicide seed treatment had no significant effect on seedling emergence, but when combined with post-emergence insecticide sprays it significantly increased herbage yield and reduced damage by stem-boring larvae. Insecticide treatment alone also reduced stem-borer damage significantly but did not increase yield significantly.

Field experiment B

At the July sowing, seed treatment with benomyl + captan significantly increased seedling emergence; the insecticides were applied after the seedling count (Table 3). The combination of benomyl + captan and insecticides significantly increased herbage yield 6 weeks after sowing. Carbendazim + captan, without insecticides, also increased herbage yield but the increase was significantly lower than that for benomyl + captan with insecticides. At the other sowings the only significant effects of treatment were obtained with the combination of benomyl + captan and insecticides. In all three August sowings the combined treatment significantly reduced damage by stem-borers, but this increased herbage yield only at the sowing on 27 August.

DISCUSSION

In the glasshouse experiment fungicide seed treatment substantially increased the emergence of ryegrass seedlings grown under a low moisture regime. Therefore, fungal infection appears to be one cause of poor emergence in dry soil conditions. Although no attempt was made to isolate fungi from dead seedlings, F. culmorum is strongly implicated - it is known to cause the greatest reduction in emergence of wheat seedlings in warm, dry soil (Colhoun & Park, 1964).

In the field sowings, an increased emergence from fungicide seed treatment occurred only in the July sowing. During July, temperatures were higher and rainfall was lower than during the other two months in which sowings were made. Fungicide seed treatment did not increase emergence in the August sowings, but when used in combination with insecticide sprays, control of stem-borers and herbage yield were improved over that for insecticide alone. F. culmorum reduces

seedling vigour (Holmes,1979), and possibly the control of sub-lethal infection by fungicide seed treatment improved vigour which in turn reduced the damage caused by stem-borers (Bentley, 1984). The impact of pest and disease control on newly-sown ryegrass can be judged from the results of another experiment sown in August 1985 in the same field used for the present work. Here seed treatment with benomyl + captan, followed by sprays of chlorpyrifos and omethoate, all at the same rate used in the present work, gave a yield response greater than that obtained by a four-fold increase in either seed-rate or fertiliser use (Clements et al. 1986).

Although benomyl + captan improved emergence in Field experiment A, it was less successful in the glasshouse experiment than some of the other, similar treatments tested. However, more work is required on formulation and dose rates before comparisons between treatment can be made.

The finding that fungicide seed treatment controlled post-emergence mildew infection may not be as important to grass crops as it was to cereal crops, where the technique has become common practice. This is because mildew infection in newly-sown grass crops is both less common and less damaging than in cereal crops. However, an increase of nearly 50% in herbage dry weight was obtained in the present work by treatment with carbendazim + captan, which gave the best control of mildew and the highest value for emergence.

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TABLE 1

Effect of six fungicide seed treatments on emergence, post-emergence infection with powdery mildew and dry weight of perennial ryegrass cv. Parcour seedlings grown in soil in pots.

Fungicide treatment and dose rate (g a.i./kg seed)	Emerged seedlings (%)	Seedlings with mildew infection (%)				
		Nil	slight	moderate	severe	dry wt (g)/pot
benomyl + captan (3+3)[a]	71.0	96.7**	3.3**	0.0*	0.0	1.07
carbendazim + captan (3+3)[b]	83.4**	100.0**	0.0**	0.0*	0.0	1.21*
thiabendazole + captan (3+3)[a]	79.2**	77.5**	19.9**	2.6	0.0	0.89
thiabendazole + metalaxyl (3+5.6)[a]	79.0**	66.7**	32.4**	0.8*	0.0	0.94
thiabendazole + thiram (3+3)[b]	78.6**	31.6	62.6	5.8	0.0	0.98
drazoxolon (3)[b]	67.0	5.0	28.6**	55.9**	10.5*	0.88
Nil	62.7	13.7	67.8	17.8	0.6	0.81
SED (DF 33)	3.54	9.50	10.49	6.49	2.23	0.111

[a] powder formulation

[b] liquid formulation

* significantly different from nil treatment ($P<0.05$)

** significantly different from mil treatment ($P<0.01$)

TABLE 2

Effect of six fungicide seed treatments and post-emergence insecticide sprays in a field sowing of perennial ryegrass cv. Parcour sown on 27 August 1985.

	No. seedlings/30 cm drill row 30 Sept 85		Herbage DM yield t/ha 4 Nov 85		% tillers with stem-boring larvae 22 Nov 85	
	No insecticide	With insecticide[b]	No insecticide	With insecticide[c]	No insecticide	With insecticide[c]
No fungicide	12.0	11.3	0.16	0.21	3.2	0.5**
With fungicide[a]	11.0	12.0	0.15	0.27**	2.8	0.1***
SED (DF 76)	0.91		0.034		0.94	

** significantly different from no fungicide, no insecticide treatment, P<0.01
*** " " " " " " " P<0.001

[a] mean of six fungicide treatments: see Table 1 for details

[b] chlorpyrifos (0.72 kg a.i./ha)

[c] " " + omethoate (0.65 kg a.i./ha)

TABLE 3

Effect of fungicide seed treatment and post-emergence insecticide sprays on perennial ryegrass cv. Parcour sown on five occasions in 1985.

	Date of sowing					Date of sowing					Date of sowing		
	1 May	3 Jul	12 Aug	19 Aug	27 Aug	1 May	3 Jul	12 Aug	19 Aug	27 Aug	12 Aug	19 Aug	27 Aug
	No. seedlings/30 cm drill row					Herbage DM yield t/ha					% tillers with stem-boring larvae		
Treatment	30 May	22 Jul	28 Aug	9 Sep	20 Sep	30 Aug	6 Sep	30 Oct	4 Nov	4 Nov	25 Nov	26 Nov	27 Nov
carbendazim + captan (3g + 3g a.i./ kg seed)	25.2	28.6	21.0	17.9	15.4	3.76	2.90*	1.73	1.02	0.29	NA	NA	NA
benomyl[b] + captan (3g + 3g a.i./ kg seed) + chlorpyrifos + omethoate (0.72 kg + 0.65 kg a.i./ ha)	25.4	32.3*	23.3	16.3	15.8	3.47	3.12**	1.87	1.11	0.53**	1.7**	1.3*	0*
Nil	26.5	26.1	19.4	17.2	18.0	3.72	2.45	1.68	0.96	0.32	6.6	4.7	3.2
SED (DF 21)	1.58	2.54	2.62	1.74	1.67	0.206	0.176	0.092	0.086	0.060	1.40	1.21	1.14

[a] liquid formulation

[b] powder formulation

* significantly different from nil treatment, P<0.05

** significantly different from nil treatment, P<0.01

MORPHOLOGICAL INFLUENCES OF SEED-APPLIED TRIADIMENOL, FLUTRIAFOL AND OTHER COMPOUNDS ON SPRING BARLEY

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ABSTRACT

Seed-applied triadimenol plus fuberidazole; flutriafol plus ethirimol plus thiabendazole; ethirimol plus phenyl mercury acetate, and phenyl mercury acetate alone at commercial rates were compared for their influences on the growth of spring barley (cv. Triumph). In glasshouse experiments the triadimenol treatment consistently reduced subcrown internode extension compared with phenyl mercury acetate and gave plants with deeper crown nodes. Effects of the other treatments were not consistent. In the field both the triadimenol and flutriafol treatments reduced subcrown internode extension and increased crown node depth. These influences on growth were not related in the glasshouse or field to effects on foliar disease development.

INTRODUCTION

Seed treatment with systemic fungicides has proved an effective method of controlling a number of cereal diseases which may develop during growth (Anon. 1986). Foliar infection of barley by powdery mildew was the first disease to be controlled by application of the systemic hydroxypyrimidine fungicide ethirimol to seed (Hall,1971), and the reported benefits of treatment included improved root development, the production of more ears and better grain growth which formed the basis of yield responses (Brooks,1972). Broader spectrum disease control became possible with the development of seed-applied triazole chemicals (Wainwright et al. 1979). In addition to fungicidal properties some triazoles have also been reported to exhibit growth regulating activity (Anderson et al. 1985), although in the field it is difficult to distinguish between this activity and indirect influences on growth through disease control. A better understanding of these effects however, might support their further exploitation for modifying growth.

Few comparisons have been reported of the influences of different products, commercially available as seed treatments, on the growth and development of spring barley beyond their effects on disease. In the present study the effects of seed-applied products containing the systemic chemicals triadimenol (Martin et al. 1981) and flutriafol (Northwood et al. 1984) are compared with ethirimol (Brooks,1972) and a standard non-systemic phenyl mercury acetate material on infection and growth. Following interest in early-sown spring barley (McDonald,1985), and improved winter hardiness of oats following seed treatment with a triazole chemical (Anderson et al. 1985), the treatments were studied in the field in autumn-sown plots in addition to experiments in the glasshouse.

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MATERIALS AND METHODS

Plant material

Seed batches of spring barley cv. Triumph from a single source were treated using a mini-Rotostat at commercial rates, either with 25% w/v a.i. triadimenol plus 3% w/w a.i. fuberidazole (Baytan, Bayer) at 150 g product/100 kg of seed; 58% w/v a.i. ethirimol (Milstem, I.C.I. Plant Protection) at 670 ml product/100 kg seed plus 2% w/v a.i. phenyl mercury acetate (Ceresol, I.C.I. Plant Protection Division) at 110 ml product/100 kg seed; 3% w/v a.i. flutriafol plus 40% w/v a.i. ethirimol plus 1% w/v a.i. thiabendazole (Ferrax, I.C.I. Plant Protection Division) at 500 ml product/100 kg seed, or 2% w/v a.i. phenyl mercury acetate (Ceresol) at 110 ml product/100 kg seed. Following treatment in September the seed was kept in paper sacks at approximately 10°C in a seed store.

Glasshouse experiments

Seeds were sown at equal spacing, 5 to a 15 cm diameter pot, using a calibrated dibber, at a depth of approximately 20 mm in John Innes No. 3 compost. Ten replicate pots were arranged in a randomised block design. The first experiment was established 5 February 1986 with a minimum daytime temperature of 15°C, minimum night temperature of 7°C and 16 hour day length including supplementary illumination provided with high pressure sodium lamps. The second experiment was established under similar conditions on 7 May.

Field experiment

Seed was drilled into a sandy loam on 20 October 1985 with a Hege plot drill at 400 seeds/m^2. Four replicate plots of 1.65 m x 5 m were arranged in a randomised block design.

Assessments

Powdery mildew (*Erysiphe graminis* f.sp. *hordei*) development in the glasshouse was assessed on the top three leaves of the main stem on each plant, and in the field each leaf on 20 plants per plot was examined for disease using standard keys (Anon. 1976). Measurements of development of all plants in the first glasshouse experiment were made on 19 March at G.S. 32 (Anon. 1976), in the second glasshouse experiment on 26 June at G.S. 39, and on 10 plants per plot in the field on 6 March at G.S. 22. Following plant removal the seed depth was measured as the length of white tissue of the shoot to the top of the seed. Subcrown internode length was measured from the crown node to the top of the seed. The depth of the crown was obtained by subtraction.

RESULTS

Subcrown internode extension was significantly inhibited in plants treated with triadimenol plus fuberidazole (Tables 1, 2 and Figure 1) and the first study plants grown from flutriafol treated seed also had a shorter subcrown internode than the phenyl mercury acetate treated plants (Table 1).

Crown nodes of the triadimenol plus fuberidazole treated plants were significantly deeper than those of plants from the ethirimol plus phenyl mercury acetate and phenyl mercury acetate treated seed (Tables 1 and 2). Flutriafol treated plants had significantly deeper crowns than plants treated with phenyl mercury acetate in the first experiment (Table 1), and plants from ethirimol plus phenyl mercury acetate treated seed had deeper crowns than the phenyl mercury acetate treated plants and shallower crowns

Table 1 Effects of seed-applied fungicides on the development of spring barley cv. Triumph grown in the glasshouse (first experiment)

Treatment	Subcrown internode (mm) length	Crown node depth (mm)	Seed depth (mm)	Tiller number
triadimenol + fuberidazole	1.42	13.04	14.46	4.88
flutriafol + ethirimol + thiabendazole	3.24	13.24	16.48	4.90
ethirimol + phenyl mercury acetate	7.26	9.50	16.76	5.34
phenyl mercury acetate	11.24	7.70	18.94	5.54
S.E.M. (27 DF)	0.745[a]	0.542	0.813	0.172

a Not applicable to ethirimol + phenyl mercury acetate owing to variance heterogeneity (18 DF)

Table 2 Effects of seed-applied fungicides on the development of spring barley cv. Triumph grown in the glasshouse (second experiment)

Treatment	Subcrown internode (mm) length	Crown node depth (mm)	Seed depth (mm)	Tiller number
triadimenol + fuberidazole	3.90	13.04	16.94	4.82
flutriafol + ethirimol + thiabendazole	6.98	11.16	18.14	5.22
ethirimol + phenyl mercury acetate	6.62	10.54	18.26	5.36
phenyl mercury acetate	7.76	8.90	16.40	5.58
S.E.M. (27 DF)	0.858	0.837	0.485	0.363

Table 3 Development of powdery mildew infection in the glasshouse on plants of spring barley cv. Triumph treated with seed-applied fungicides (first experiment)

Treatment	Days after sowing	% Powdery mildew[a] 19	23	28	34
triadimenol + fuberidazole		1.82	4.92	24.02	43.72
flutriafol + ethirimol + thiabendazole		0.27	1.66	13.81	13.94
ethirimol + phenyl mercury acetate		0.28	1.31	12.12	13.88
phenyl mercury acetate		2.14	9.34	37.02	44.20
S.E.M. (27 DF)		-	-	3.317	4.522

a Data from the first two assessments were not analysed statistically owing to variance heterogeneity.

Table 4 Effects of seed-applied fungicides on the development of spring barley cv. Triumph grown in the field

Treatment	Subcrown internode length (mm)	Crown node depth (mm)	Seed depth (mm)
triadimenol + fuberidazole	0.35	39.73	40.30
flutriafol + ethirimol + thiabendazole	0.46	37.31	37.78
ethirimol + phenyl mercury acetate	11.53	22.98	34.50
phenyl mercury acetate	11.80	23.60	35.60
S.E.M. (9 DF)	1.459[a]	1.105	0.594

a Not applicable to triadimenol and fuberidazole owing to variance heterogeneity (6 DF)

than those grown from flutriafol treated seed (Table 1).

Plants grown from seed treated with triadimenol plus fuberidazole had a significantly shallower seed depth than plants treated with phenyl mercury acetate in the first glasshouse experiment (Table 1). Both triadimenol and flutriafol treated plants had fewer tillers than phenyl mercury acetate treated plants in the first experiment (Table 1) but, although tiller number was less on the triadimenol treated plants, in the second study (Table 2) there was no significant difference between treatments.

The relative efficacy of the systemic fungicides against powdery mildew was similar in both glasshouse experiments. Control of powdery mildew infection was greatest with ethirimol and flutriafol treatments (Table 3). Up to 28 days after sowing the development of powdery mildew was suppressed on the triadimenol treated plants but the inhibition was not maintained subsequently (Table 3).

In the field triadimenol and flutriafol appeared to delay emergence and retard plant growth. No disease developed on the plants up to March. Seed and crown node depth of the triadimenol and flutriafol treated plants were deeper in the field and the subcrown internodes were substantially shorter than those of plants from the other treatments (Table 4).

DISCUSSION

Where subcrown internode extension had been inhibited it generally resulted in deeper crown nodes, except where the treatments altered seed depth. The triazole components of the seed treatments appeared to have the greatest influence on subcrown internode extension. Although subcrown internode growth appeared to be inhibited by ethirimol plus phenyl mercury acetate in one glasshouse experiment, resulting in significantly deeper crown nodes, the effect was slight and inconsistent relative to Ferrax treatment containing both ethirimol and flutriafol.

Subcrown internodes were shorter on plants treated with the triadimenol and flutriafol products in the field, and the reduction in length was of a greater magnitude than the reported influences of the seed-applied triazole chemical tetcyclasis on winter oats, which improved winter hardiness by providing greater thermal insulation of the crowns (Anderson *et al.* 1985). In other work, deeper crown nodes in wheat varieties have been correlated with improved winter-hardiness (Webb & Stephens,1936). Increased crown node depth from some seed treatments was insufficient in the present field study to prevent plant death in the severe winter weather conditions of 1986.

Greater crown node depth in oats has been found to reduce lodging (Hamilton,1951). Improved lodging control from triadimenol seed treatment has been reported in wheat, together with delayed and reduced tillering (Clark *et al.* 1984). Martin *et al.* (1981) reported no effect of triadimenol plus fuberidazole treatment on tillering in spring barley crops, but in the present study both triadimenol and flutriafol reduced tiller number in the first glasshouse experiment. Further study is required therefore of the impact of these treatments on tillering and their possible implication for lodging.

The possible influences of triadimenol and flutriafol treatments in delaying emergence and retarding the early growth of plants also require

further study in early-sown spring barley relative to any possible benefit of improved hardiness from deeper crown nodes. In the field the depth of the crown can be influenced by a number of factors, including sowing depth, soil temperature and moisture (Troughton,1962), which may interact with seed treatment. Different varietal reactions to seed treatment could also be of consequence. The observed influences of some seed treatments on growth could not be related to effects on disease in the present studies. The present studies emphasise that effects of seed treatments, particularly of triazole products in spring barley, directly on growth need to be included in any future considerations of influences on yield in addition to their fungicidal influences.

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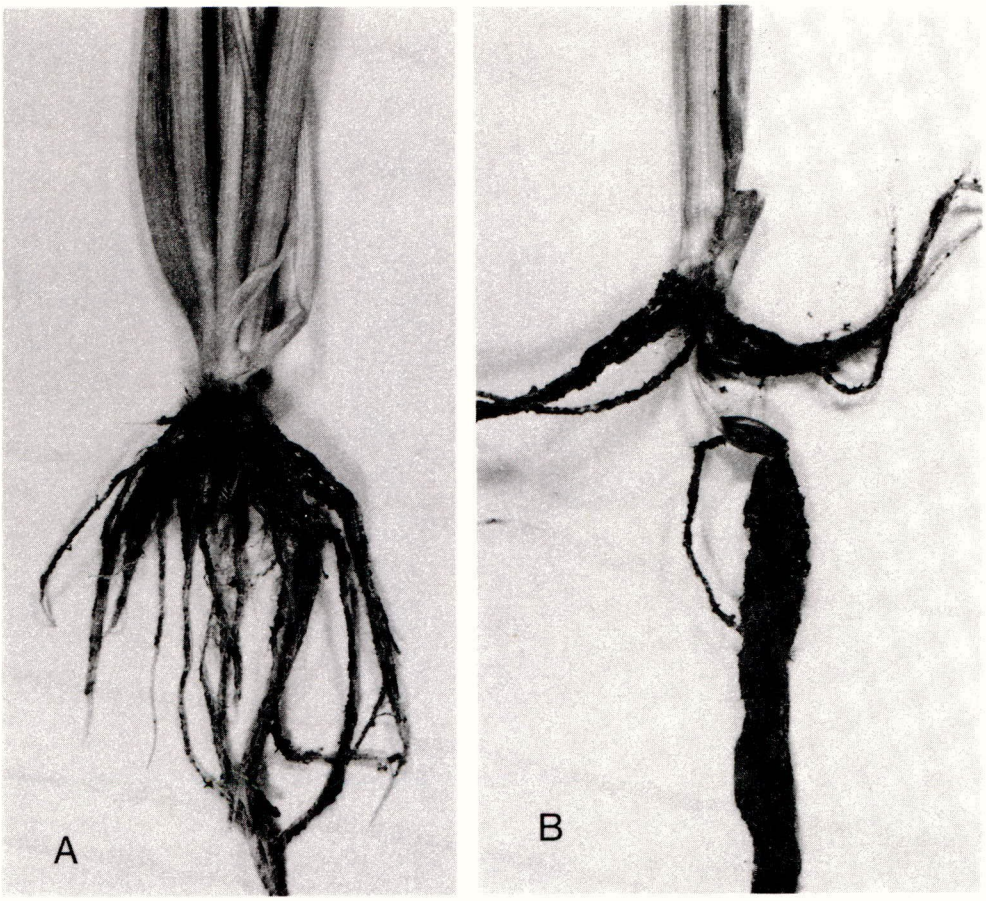

Fig. 1. Spring barley plants grown from seed treated with (A) triadimenol plus fuberidazole, (B) phenyl mercury acetate.

PEA SEED TREATMENTS: NEW OXADIXYL BASED MIXTURES FOR BROAD SPECTRUM DISEASE CONTROL

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ABSTRACT

Two oxadixyl based products are now registered in France as seed treatments for the control of diseases in peas. "Pulsan" combines oxadixyl, cymoxanil and mancozeb and controls downy mildew (Peronospora pisi), foot rot and leaf spot (Mycosphaerella (Ascochyta) pinodes) and damping off (Botrytis cinerea). "Pulsan TS" is a product based on oxadixyl + cymoxanil and controls downy mildew but can be tank mixed with mancozeb or other fungicides to give broad spectrum disease control. Although both products give an excellent control of P. pisi the triple mixture is better suited to conditions where a more serious risk of downy mildew attack is probable. If Fusarium or Botrytis is more likely to occur then the oxadixyl + cymoxanil based product is preferable as it can be complemented by other fungicides.

INTRODUCTION

The increase in the area of commercial peas grown in France has been accompanied by a corresponding increase in the level of diseases. Among these downy mildew (Peronospora pisi), which effectively overwinters in the soil, has rapidly gained in importance, especially in those regions where peas are grown on short rotations.

The initial attempts to control downy mildew were made by treating the foliage with contact fungicides such as dithiocarbamates and phthalimides or with local-systemic products based on cymoxanil. Their effectiveness has proved to be insufficient where significant infection levels occur. The fact that downy mildew develops in peas by internal infection led to the investigation of the effectiveness of seed treatments with products containing phenylamide systemic fungicides.

The mixture of oxadixyl + cymoxanil + mancozeb, already introduced for the control of potato blight in France, has been evaluated since 1983 as a seed treatment in peas to control downy mildew. The inclusion of mancozeb broadened the spectrum of the product to include foot rot and leaf spot (Mycosphaerella (Ascochyta) pinodes) and damping-off (Botrytis cinerea).

These diseases may be treated with specific fungicides which have to be used in association with an anti-mildew treatment. The mixture of oxadixyl + cymoxanil is being developed to meet this requirement.

MATERIALS AND METHODS

TABLE I

Experimental compounds used in these experiments

Active ingredients	Content %	Formulation	Rates/100 kg seed	
			Products kg	Active ingredients
oxadixyl + cymoxanil + mancozeb	8 + 3.2 + 56	WP	0.625	50g + 20g + 350g
oxadixyl + cymoxanil	40 + 16	WP	0.125	50g + 20g
Systemic 1	35	WP	0.2	70g
Systemic 2 + folpet	6 + 45	SC	1.0 l	60g + 450g
benomyl	50	WP	0.2	100g
carbendazim + captan	25 + 20	SC	0.3 l	75g + 60g

Diseases

Downy Mildew (P. pisi)

Field scale trials were carried out. The seed was dressed using an experimental seed treater and sown through farm drills.

Observations on crop tolerance were made at crop emergence, and on disease control at 30 and 45 days after crop emergence. Crop yields were taken from the most representative of the trials.

Foot rot and leaf spot (M. pinodes); damping off (B. cinerea)

The studies were carried out in the laboratory (INRA - 78 La Miniere) in Petri dishes with seed lots previously examined and known to be infected. The observations measured the percentage of disease on seeds treated with the different products, in comparison with the reference standards and the untreated control.

RESULTS

Downy Mildew (P. pisi)

TABLE 2

Efficacy against downy mildew (P. pisi)

Treatments	Rate g/100kg seed	% efficacy/untreated					
		1984 (1 trial)	1985 (1 trial)		1986 (3 trials)		1987 (2 trials)
		E+30	E+30	E+45	E+30	E+45	E+45
oxadixyl + cymoxanil + mancozeb	50 + 20 + 350	79	94(a)*	55(a)	96	77	90
oxadixyl + cymoxanil	50 + 20	-	91(a)	25(b)	89	66	80
Systemic 1	70	64	68(c)	0(c)	-	-	-
Systemic 2 + folpet	60 + 450	-	-	-	73	56	65
Untreated (mean no. diseased leaves/plant):		(18.7)	(37)	(55)	(17.1)	(113)	(81)

E+30; E+45 = 30 and 45 days after emergence of peas
* : Duncan's multiple range test

In 1984, in 5 trials with a medium infection which decreased during flowering the oxadixyl + mancozeb mixture was more effective than the standards (Table 2).

In 1985, weather conditions enabled mildew to develop until the end of flowering. Thirty days after emergence, oxadixyl + cymoxanil + mancozeb and oxadixyl + cymoxanil gave excellent results, superior to the standard. The second observation made 15 days later demonstrated the long term effectiveness of the oxadixyl + cymoxanil mixture.

In 1986, the results of the 3 trials made during conditions favouring the development of downy mildew confirmed these earlier observations.

In 1987 the downy mildew infection occurred very late (post flowering). Despite conditions which were unfavourable to seed treatments, the products based on oxadixyl + cymoxanil gave excellent results, superior to the reference standard.

In 1985, 1986 and 1987 the inclusion of mancozeb in the mixture with oxadixyl + cymoxanil consistently improved on the level of disease control. This may be due to the downy mildew being present on the seed coat (tegument) in addition to the level of disease present in the soil.

Foot rot and leaf spot (M. pinodes)

TABLE 3

Efficacy against foot rot and leaf spot (M. pinodes)

Treatments	Rate g/100kg seed	% efficacy/untreated	
		1986 (3 trials)	1987 (2 trials)
oxadixyl + cymoxanil + mancozeb	50+20+350	76	78
Systemic 2 + folpet	60+450	-	59
benomyl	100	100	-
Untreated: mean % diseased seeds		(8.4)	(17.5)

(Laboratory trials - INRA - 78 La Miniere)

The trials conducted in the laboratories at INRA demonstrated the efficacy of the oxadixyl + cymoxanil + mancozeb mixture against foot rot and leaf spot. Control was inferior to that given by benomyl but it was better than Systemic 2 + folpet (Table 3).

Damping off (B. cinerea)

TABLE 4

Efficacy against damping off (B. cinerea)

Treatments	Rate g/100kg seed	% efficacy/untreated 1987 - (4 trials)
oxadixyl + cymoxanil + mancozeb	50 + 20 + 350	62
carbendazim + captan	75 + 60	61
Untreated: mean % diseased seeds		(6.6)

(Laboratory trials - INRA - 78 La Miniere)

The low level of damping off in peas during 1984, 1985 and 1986 limited the scope of the trials. Under these conditions the mixture of oxadixyl + cymoxanil + mancozeb equalled the control given by the standard, carbendazim + captan (Table 4).

Selectivity

TABLE 5

Selectivity of oxadixyl mixtures in comparison with standard treatments

Products	Rate g/100kg seed	No. plants at emergence (% untreated) 1985	1986	Yield (% untreated) 1985	1986
oxadixyl + cymoxanil + mancozeb	50 + 20 + 350	110	99	105	101
oxadixyl + cymoxanil	50 + 20	101	103	107	104
Systemic 1	70	103	-	103	-
Systemic 2 + folpet	60 + 450	-	93	-	99

The selectivity of the two seed treatments was evaluated in three disease free trials. The two mixtures containing oxadixyl + cymoxanil did not cause any phytotoxicity at seedling emergence and did not affect the yields. Their selectivity was at least equal to those of the standards used (Table 5).

CONCLUSIONS

Mixtures based on oxadixyl + cymoxanil can provide effective fungicide protection to pea seeds.

The oxadixyl + cymoxanil + mancozeb mixture gave a very high level of control of downy mildew (*P. pisi*) with a long lasting effect, and satisfactory results under normal conditions against foot rot and leaf spot (*M. pinodes*) and damping off (*B. cinerea*). The oxadixyl + cymoxanil mixture which was very effective against downy mildew can be complemented by other fungicides to control heavy infections of foot rot and leaf spot, and damping off diseases.

FURTHER EVALUATION OF TRIADIMENOL SEED TREATMENTS FOR THE CONTROL OF ERGOT IN CEREAL SEED

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ABSTRACT

Seed treatments containing triadimenol plus fuberidazole were applied to samples of sclerotia from ten collections of ergot (Claviceps purpurea) prior to Autumn sowing in 1984 in field trials. During the following Spring treated sclerotia showed significantly reduced germination (%) and emergence of ascocarps above the soil surface. There was no overall difference in the control achieved by flowable and dry formulations of the seed treatments. Comparison of results from trial sites at Aberystwyth in West Wales and Great Dunmow in Eastern England showed 5-12% less efficient control at Aberystwyth where high rainfall may have leached chemicals from the treated sclerotia. Untreated sclerotia decayed during the Summer 1985, whereas many of the ungerminated, chemically treated sclerotia were preserved and germinated in the following year, though still with reduced ascocarp production.

INTRODUCTION

Potential for chemical prevention of ascocarp formation by sclerotia of ergot (Claviceps purpurea) has been investigated in ryegrass (Hardison, 1977), paspalum (Hampton, 1984) and in wheat (Shaw, 1984a; 1984b; 1986). In the studies on ryegrass and paspalum, chemicals were applied to the surface of soil contaminated with sclerotia. Chemical application was timed to be a few weeks before sclerotium germination commenced. Under laboratory and glasshouse conditions triadimenol treatments prevented ascocarp formation, but spray applications to ergot-infested field plots of the cultivated grasses gave incomplete control. Hardison (1977) suggested that, in the ryegrass plots, there may have been poor contact of chemicals with sclerotia germinating under the leaf canopy.

In studies of the potential for triadimenol treatments to control ergot contaminants in wheat seed (Shaw, 1984b) contact between chemical treatments and the sclerotia was assured by application of seed dressing formulations containing triadimenol to sclerotia before sowing in field plots in November, 1983. During the following Spring, results from two trial sites showed that treatments containing triadimenol caused significant reductions of the germination (%) of sclerotia, the number of ascocarps formed and the number of ascocarps emerging above the soil surface by the time of wheat anthesis. The trial sites, at Aberystwyth, Dyfed and Great Dunmow, Essex, had been chosen to provide contrasting field conditions, particularly with respect to drainage and rainfall. Unfortunately there was abnormally low rainfall at the Aberystwyth site so questions regarding the effect of high rainfall on retention of chemicals by the treated sclerotia, raised during preliminary investigation (Shaw, 1984a), remained unresolved.

MATERIALS AND METHODS

Fungicide treatments

Samples of sclerotia requiring chemical treatment were first mixed

with 5 kg of wheat grain to provide sufficient bulk for application of seed dressing formulations of chemicals in a mini-'Rotostat' at the manufacturer's recommended rate. Treated sclerotia were subsequently separated from the grain/sclerotia mixtures before planting in field trials.

The following treatments were used: dry seed treatment (DS) containing 25% triadimenol plus 3% fuberidazole wt/wt (375 mg a.i. triadimenol plus 45 mg a.i. fuberidazole/kg sclerotia, 'Baytan', Bayer); flowable seed treatment (FS) containing 187.5 g triadimenol/litre plus 22.5 g fuberidazole/ litre (75 mg a.i. triadimenol plus 45 mg a.i. fuberidazole/kg sclerotia, UK082f, Bayer).

Experimental design

At each of three trial sites the fungicide treatments were tested on ergot sclerotia from several different sources (Table 1). Geographic descriptions of the trial sites together with details of establishment and harvesting of samples of sclerotia at each site are shown in Table 2.

The basic element of the field experiment design was a 10 cm square plastic pot (with drainage holes) sunk into the ground and filled with soil so that the rim of the pot was level with the soil surface. In each pot a sample of treated or untreated sclerotia was buried at approximately 2 cm depth. Pots were arranged in a randomised block design. Each of five replicate blocks consisted of a small drilled plot of triticale within which a row of pots, one for each ergot collection/treatment combination, was centrally positioned. Three treatments were investigated; one untreated control and two chemical treatments described above.

At dates shown in Table 2, contents of pots were assessed *in situ* for the number of ascocarps (perithecial stromata) emerging above the soil surface. All pots were then removed from the trial sites at Aberystwyth and Great Dunmow. Samples of sclerotia were washed and sieved from the soil before microscopic examination and assessment of germination (defined as the presence of at least one ascocarp developing on a sclerotium) and ascocarp production. Pots containing ergot samples from the Warminster trial site were transported to Surrey where they were stored intact, at an exposed field site, for a further two years. Only visual assessment of ascocarps emerging above the soil surface was possible for these samples.

RESULTS

Results of assessments of germination of Autumn-sown sclerotia at Aberystwyth and Great Dunmow are shown in Table 3, whilst counts of emergence of ascocarps from Spring-sown sclerotia at Warminster are shown in Table 5. To facilitate comparison of data between different trial sites, between sources of sclerotia and between treatments, further analysis is shown in Table 4. Here, data is expressed as percent control:

$$\text{Control (\%)} = 100 - \left(\frac{\text{Untreated}}{\text{Treated}} \times 100\right)$$

TABLE 1

Sources of sclerotia of Claviceps purpurea

Ergot collection	Host	Locality	Year sclerotia harvested
F	Triticale	Great Dunmow, Essex	1984
G	Triticale	Cambridge	1984
H	Wheat	Essex	1984
K	Triticale	Cambridge	1983
L	Triticale	Icklingham, Suffolk	1984
M	Triticale	Cambridge	1984
N+	Wheat	Kent	1984
R	Wheat	Essex	1983
S	Triticale	Bardfield, Essex	1984

+Separated into sub-samples: NL (Sclerotia 1cm length)
NS (Sclerotia 1cm length)

TABLE 2

Trial sites

Location of trial	Trial site environment			Ergot sclerotia		
	Soil type	Elevation (m)	Rainfall during period of burial of sclerotia (mm)	Date sclerotia buried	Date Sclerotia recovered	Ergot collections used in trial (see Table 1)
Throws Farm, Great Dunmow, Essex	Chalky boulder clay	70	353	29 Nov 1984	1 July 1985	F,G,H,K, L,M,NL, NS,R,S
Welsh Plant Breeding Station, Aberystwyth, Dyfed	Stoney silty clay loam over solid rock	200	695	15 Nov 1984	21 June 1985	F,G,K,M, NL,NS,S
Warminster, Wilts	Icknield series (organic phase - 10% o.m.) over upper chalk	160	445	5 Feb 1985	15 Aug+ 1985	F,S

+Pots containing undisturbed soil and ergot sclerotia transferred to Coulsdon, Surrey where they were kept under field conditions until July 1987.

TABLE 3

Effects of dry (DS) and flowable (FS) seed treatments containing triadimenol plus fuberidazole (triadimenol F) on ergot germination and ascocarp formation

Ergot collection (see Table 1)	Fungicide treatment of sclerotia	Welsh Plant Breeding Station, Aberystwyth			Throws Farm, Great Dunmow, Essex		
		Germination of sclerotia	Mean number of ascocarps++		Germination of sclerotia	Mean number of ascocarps	
		Mean % (AT^+)	Mature ascocarps emerged above soil surface	Immature ascocarps failing to emerge above soil surface	Mean % (AT^+)	Mature ascocarps emerged above soil surface	Immature ascocarps failing to emerge above soil surface
F	Untreated control	97.9 (84.8)	159.0	11.6	94.2 (77.8)	124.4	23.2
	Triadimenol F(DS)	49.5 (44.7)*	30.6*	2.8	24.9 (29.7)*	5.2*	7.4*
	Triadimenol F(FS)	43.1 (41.0)*	26.6*	4.8	15.7 (22.7)*	2.0*	3.6*
G	Untreated control	96.3 (83.0)	135.8	3.4	84.9 (67.4)	66.4	7.6
	Triadimenol F(DS)	48.4 (44.1)*	11.8*	4.2	23.6 (28.2)*	2.4*	5.4
	Triadimenol F(FS)	41.2 (39.7)*	20.4*	1.6	33.0 (34.5)*	3.6*	6.6
H	Untreated control	-	-	-	45.8 (42.6)	10.0	3.8
	Triadimenol F(DS)	-	-	-	8.9 (15.5)*	0 *	1.2
	Triadimenol F(FS)	-	-	-	6.1 (8.9)*	0 *	1.0
K	Untreated control	56.5 (48.8)	14.4	1.8	37.5 (34.6)	11.6	1.6
	Triadimenol F(DS)	27.1 (30.5)*	2.2*	4.0	10.0 (16.1)	1.0*	1.6
	Triadimenol F(FS)	25.9 (30.4)*	3.0*	2.4	18.4 (21.5)	1.2*	9.0
L	Untreated control	-	-	-	84.6 (68.6)	86.2	12.0
	Triadimenol F(DS)	-	-	-	22.4 (27.5)*	9.0*	14.8
	Triadimenol F(FS)	-	-	-	16.5 (23.9)*	3.0*	10.6

M	Untreated control	98.8 (87.3)	138.8	3.8	89.5 (74.4)	64.8	7.0
	Triadimenol F(DS)	29.4 (32.2)*	11.6*	1.2	19.0 (25.9)*	1.2*	4.6
	Triadimenol F(FS)	33.5 (35.3)*	15.4*	1.2	15.2 (19.6)*	1.8*	6.0
NL	Untreated control	77.2 (61.8)	23.2	8.4	58.8 (50.4)	17.2	28.6
	Triadimenol F(DS)	0 (0)*	0*	0 *	3.0 (6.4)*	0*	0.2*
	Triadimenol F(FS)	0 (0)*	0*	0 *	0 (0)*	0*	0*
NS	Untreated control	75.0 (60.5)	3.6	17.8	20.5 (26.7)	2.2	2.4
	Triadimenol F(DS)	0 (0)*	0*	0 *	0 (0)*	0 *	0
	Triadimenol F(FS)	1.0 (2.6)*	0*	0.2*	3.1 (6.4)*	0 *	0.2
R	Untreated control	-	-	-	26.5 (29.9)	3.8	0.4
	Triadimenol F(DS)	-	-	-	12.4 (18.1)	0.8*	2.0
	Triadimenol F(FS)	-	-	-	8.5 (15.1)	0.8*	0.6
S	Untreated control	96.4 (81.6)	140.0	4.4	80.0 (66.8)	85.4	12.0
	Triadimenol F(DS)	23.4 (28.5)*	10.6*	2.4	10.7 (16.9)*	1.0*	4.0
	Triadimenol F(FS)	25.8 (30.2)*	8.8*	6.0	9.1 (15.5)*	1.0*	2.2

+ Angular transformed data ++ Mean number of ascocarps per sample of 20 sclerotia sown
* Significantly different from control (p = 0.05)

TABLE 4

Control (%)[+] of germination and ascocarp emergence by flowable (FS) and dry (DS) seed treatment formulations of triadimenol plus fuberidazole (Triadimenol F), (calculated from data presented in Figures 3 and 5).

Ergot collection (see Table 1)	Trial site (see Table 2)	Control (%)[+] of sclerotium germination		Control (%)[+] of ascocarp emergence	
		(DS)	(FS)	(DS)	(FS)
F	Aberystwyth	49.4	56.0	80.8	83.3
	Dunmow	73.6	83.3	95.8	98.4
	Warminster[++]	-	-	88.7	96.1
G	Aberystwyth	49.7	57.2	91.3	85.0
	Dunmow	72.2	61.1	96.4	94.6
H	Dunmow	80.6	86.7	100	100
K	Aberystwyth	52.0	54.2	84.5	78.9
	Dunmow	73.3	50.9	91.4	89.7
L	Dunmow	73.5	80.5	89.6	96.5
M	Aberystwyth	70.2	66.0	91.6	88.9
	Dunmow	78.8	83.0	98.1	97.2
NL	Aberystwyth	100	100	100	100
	Dunmow	94.9	100	100	100
NS	Aberystwyth	100	98.7	100	100
	Dunmow	100	84.9	100	100
R	Dunmow	53.2	67.9	78.9	78.9
S	Aberystwyth	75.7	73.2	92.4	93.7
	Dunmow	86.6	88.6	98.8	98.8
	Warminster[++]	-		99.9	100
Means:	Aberystwyth	71.0	72.2	91.5	90.0
	Dunmow[+++]	82.8	78.5	97.2	97.0
	All trial sites	75.5	76.0	93.6	93.7

[+] Control (%) = $100 - \left(\frac{\text{Treated}}{\text{Untreated}} \times 100\right)$

[++] Based on ascocarp emergence at 15 August 1985

[+++] Excluding ergot collections H, L and R.

TABLE 5

Effects of dry (DS) and flowable (FS) seed treatments containing triadimenol plus fuberidazole (Triadimenol F) on emergence of ascocarps at Warminster, February to August 1985 and subsequently during storage under field conditions at Coulsdon, Surrey until July 1987

Ergot collection (see Table 1)	Fungicide treatment of sclerotia	Mean number of ascocarps emerged above the soil surface per sample of 20 sclerotia sown				
		13 June 1985	20 June 1985	15 Aug 1985	10 June 1986	1 July 1987
F	Untreated control	6.2	18.6	40.6	0	0
	Triadimenol F.(DS)	0	0	4.6	7.2	0
	Triadimenol F.(FS)	0	0	1.6	7.4	0
S	Untreated control	2.2	8.0	15.4	0	0
	Triadimenol F.(DS)	0	0	0.2	2.0	0
	Triadimenol F.(FS)	0	0	0	2.8	0

DISCUSSION

Application of seed treatment formulations containing triadimenol plus fuberidazole to ergot sclerotia significantly reduced emergence of ascocarps above the soil surface in all combinations of chemical treatments with ten different ergot collections. The degree of control, summarised in Table 4, varied considerably between trial sites and between the collections of ergot tested, but there was no overall difference in the control achieved by flowable and dry formulations of the seed treatments. The chemical treatments appeared to be least effective (49-100%, mean 76% control) when the parameter used to estimate the degree of control was germination (%) of sclerotia. However, a more important factor, when considering the potential effect of chemical treatment on the spread of ergot in crops grown from ergot-contaminated seed, is the emergence of ascocarps above the soil surface, from where ascospores may be ejected into the air. In this respect a greater degree of control (79-100%, mean 94%) was generally achieved.

Much of the variation in results was associated with differences between ergot collections used to test the chemical treatments and also between trial sites. Results of tests on a total of 14 different collections of ergot have been described in the present and previous reports (Shaw, 1984a; 1984b). Sclerotia of varying size, age, surface texture, and from different hosts and localities have been used, but there do not appear to have been any consistent associations between the sclerotium characteristics and the effects of triadimenol treatments on sclerotium germination.

Most of the samples of sclerotia used in these studies were much larger than those which would normally remain in cereal seed after mechanical cleaning by seed merchants. Division of ergot collection N (Table 1) into large (>1 cm length) and small (<1 cm length) sub-samples was done to

determine whether the reduced loading of seed treatments on the smaller sclerotia affected the efficiency of chemical control. As shown in Tables 3 and 5, similar high levels of control of sclerotium germination were achieved with both sub-samples.

Comparison of results at Aberystwyth and Great Dunmow trial sites (Table 4) show consistently better chemical control of sclerotium germination and ascocarp production at Great Dunmow. Two factors - earlier germination and higher rainfall - at Aberystwyth may have influenced this result. Here, sclerotium germination commenced in early May and was almost complete by the time the final field assessment was made on 21 June. At Great Dunmow, later onset of germination at the end of May resulted in there being many immature ascocarps still remaining below the soil surface at the time of the final field assessment on 1 July. Rainfall recorded near to the trial sites at Aberystwyth (695 mm) and Great Dunmow (353 mm) together with differing soil types (Table 2) ensured contrasting soil conditions for overwintering and Spring germination of sclerotia. At Aberystwyth the combination of high rainfall and a well drained soil provided a severe test of the crucial requirement for retention of chemical seed treatments on or near the sclerotium surface.

Chemical treatments of Spring-sown sclerotia established at the Warminster trial site were also effective in suppressing ascocarp emergence (Table 4). However, after outdoor storage of pots containing treated and untreated sclerotia for a further year, it was found that whilst untreated sclerotia had decayed in the soil, chemical treatments had preserved some sclerotia which had then germinated, though still with reduced ascocarp production.

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