SESSION 1

THE ELEVENTH BAWDEN LECTURE

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Genetic Engineering - Prospects for Use in Crop Management

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ABSTRACT

The Agrobacterium tumor-inducing (Ti) plasmid inserts a segment of its DNA, called T-DNA, into host plant cells, transforming them into tumor cells that grow rapidly. Although the mechanism of this gene-transfer process is not understood, it can nevertheless be exploited by plant genetic engineers. The T-DNA on the Ti plasmid can be replaced with genes of interest for crop improvement. If such genes come from very unrelated organisms (bacteria or yeast for example), they must be modified to make them function in the crop plant. Model experiments in such gene modification have been successful, and plants have been engineered with functional bacterial genes. This genetic engineering strategy has two limitations. Only one class of crop plants is susceptible to Agrobacterium infection, i.e. the dicots (soybean, potato, tomato, tobacco, and many vegetable crops). Monocots (corn, wheat, rice) seem immune. Secondly, the crop plant must be regenerable from tissue culture cells, a serious problem at present for soybean.

Supposing that means are developed for direct gene insertion into valuable crop plants, the next challenge will be choosing and isolating single genes that will improve the crop. Today it is feasible to produce plants resistant to agricultural chemicals. Improvement of nutritional quality of seeds can readily be accomplished by directed changes in seed storage protein genes. The prospects are more long range for protecting plants against pathogens, improving yield, affecting plant size and shpae or protecting the crop against environmental stress. Problems of patent protection and governmental regulation add an element of risk to all genetic engineering projects.

INTRODUCTION

A central figure in the new technology of plant genetic engineering is the plant pathogen Agrobacterium tumefaciens, agent of crown gall disease. The bacterium carries a large virulence plasmid, the Ti (tumor-inducing) plasmid, that possesses the unique ability to insert a part of its DNA into the chromosome of the host plant cell. The transferred DNA, T-DNA, is a specific part of the Ti plasmid and contains genes that function only after transfer to the plant cell. In response to these new functions, the plant cell is stimulated to divide rapidly and to synthesize novel metabolites, opines, that are specific nutritional substrates for the pathogenic bacterium. The gall is thus a factory for production of nutrient for Agrobacterium, and the pathogen is a microscopic genetic engineer. The details of the discovery of T-DNA transfer and opine biosynthesis have been summarized in several recent reviews (Nester and Kosuge 1981, Van Montagu and Schell 1982, Bevan and Chilton 1982, Hooykaas and Schilperoort 1984).

T-DNA is a specific small part of the large Ti plasmid, and luckily what marks it for transport to the plant cell is not the genes in T-DNA. There are signals at the left and right borders of T-DNA (Yadav et al. 1981, Zambryski et al. 1982), and all of the genes in T-DNA are dispensible (Garfinkel et al. 1981, Leemans et al. 1982.) Genes elsewhere on the Ti plasmid are responsible for sending T-DNA along to the plant cell. Addition of extra DNA to the middle of T-DNA did not interfere with the T-DNA transfer process, and indeed this passenger DNA was carried along to the plant cell together with the natural T-DNA (Hernalsteens et al. 1980). T-DNA could therefore be exploited as a carrier (vector) for introducing desirable genes.

INSERTION OF FOREIGN DNA INTO T-DNA

Insertion of DNA into small plasmids can be achieved by a few simple enzymatic steps (Figure 1). The small plasmid is cut with a restriction endonuclease that cleaves in one site. Novel DNA fragments that have been cut with the same enzyme are added to the plasmid. The mixture is reassembled by use of the "stitching" enzyme ligase, forming recombinant plasmids containing novel DNA inserts.

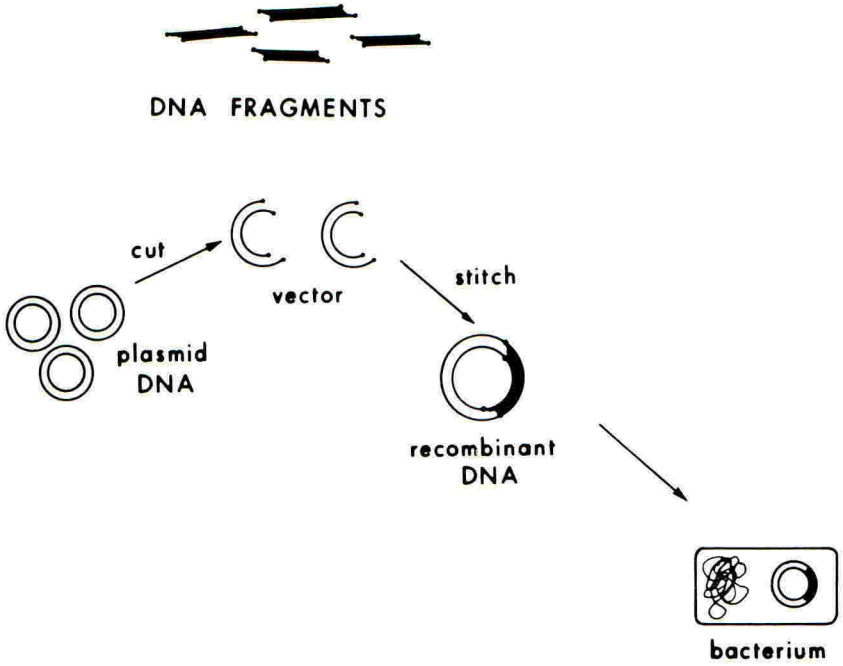

Fig. 1. Insertion of DNA fragments into a small plasmid. Small circular plasmid DNA (white) is cut once with a restriction endonuclease. DNA fragments (black), cut from plant or other DNA of interest with the same restriction endonuclease, are added. The fragments are stitched together by adding DNA ligase, to yield a mixture of recombinant DNA plasmids, each containing a different black fragment. The recombinant plasmids are introduced into a population of bacteria (one per bacterium). A pure culture derived from each bacterium contains one type of recombinant plasmid. Many such bacteria constitute a "library" of DNA fragments, among which the desired "book" (plasmid can be found by several techniques.

Novel DNA cannot be directly inserted into T-DNA of the Ti plasmid by this approach because all restriction endonucleases cut the Ti plasmid into 10-50 pieces (Sciaky et al. 1978). To circumvent this problem we use a combination of recombinant DNA manipulation and bacterial genetics to get new genes into T-DNA at any desired location (Matzke and Chilton 1981, Leemans et al. 1981). Details of one type of procedure are shown in Figure 2. Slight modification of the strategy allows us to delete small or large protions of the natural T-DNA during the insertion process. This powerful but laborious procedure makes it possible to rebuild T-DNA in any way we wish.

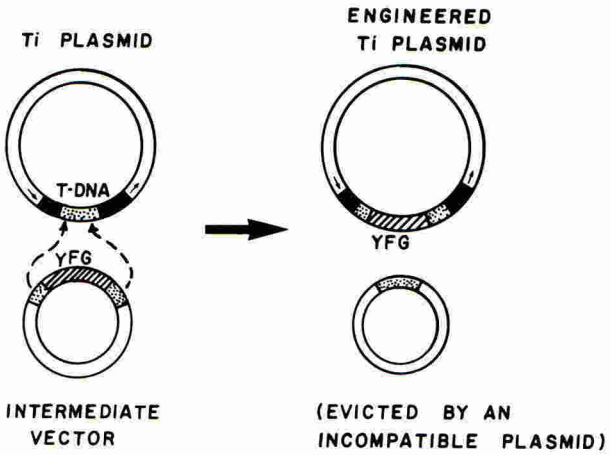

Fig. 2. Strategy for insertion of foreign DNA into T-DNA on the Ti plasmid. A subfragment (stippled region) of T-DNA (black region) is cloned into a wide host range intermediate vector. Foreign DNA, symbolized by YFG (your favorite gene) together with a selectable genetic marker (antibiotic resistance), is cloned into the center of the stippled region. The engineered intermediate vector is introduced into Agrobacterium containing a Ti plasmid. Two recombination events (dotted arrows) bring about rare exchange of the engineered trait onto the Ti plasmid. The small arrows flanking T-DNA represent the border repeats that define the region of the Ti plasmid transferred to the plant cell.

Simplification of the procedure has provided more convenient methods for producing genetically engineered Ti plasmids (Comai et al. 1983, Van Haute et al. 1983, Zambryski et al. 1983). However the ultimate simplification was the discovery that T-DNA need not be on the Ti plasmid: it can be on a separate MINI-Ti plasmid in Agrobacterium, together with a "helper" Ti plasmid lacking T-DNA (Figure 3). The helper plasmid provides all the functions needed to send T-DNA on its way into the plant genome (De Framond et al. 1983, Hoekema et al. 1983). This MINI-Ti strategy offers great promise for design of versatile, convenient vector systems into which desirable genes can be inserted directly. A MINI-Ti vector consists of a wide host range plasmid containing left and right T-DNA border signals and between the borders, one or more unique cut sites for restriction endonucleases.

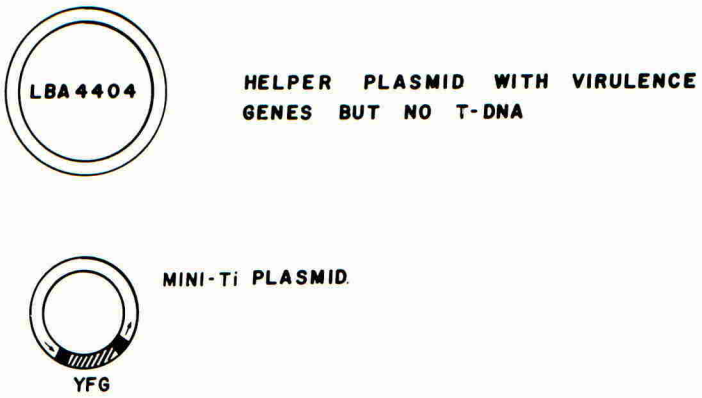

Fig. 3. MINI-Ti Vector. A MINI-Ti plasmid vector contains left and right borders on a wide host range plasmid. YFG is cloned between the borders, and the vector is introduced into Agrobacterium containing a helper plasmid. No recombination onto the helper plasmid is required: T-DNA transfer is mediated by the helper plasmid in trans.

SELECTABLE MARKERS

Tumorous plant cells do not regenerate into complete healthy plants as do their normal counterparts. Elimination of one (Barton et al. 1983) or more (Zambryski et al. 1983) genes in T-DNA solves this problem. However it creates another problem: it is difficult to find the transformed cells among large populations of untransformed cells. (Tumor cells are easy to find: they grow on hormone-free agar, while the normal cells die.) To allow easy detection or selection of transformed cells, "chimeric" genetic markers have been constructed. Bacterial genes, yeast genes and other very foreign types of genes do not function in plants because the start and stop signals in plant genes are different. Attaching plant start and stop signals to a bacterial gene produces a chimeric gene structure that does function in the plant. In most of the experiments reported thus far, the "plant" signals were in fact cannibalized from a T-DNA gene, the nopaline synthase gene. Chimeric bacterial drug resistance genes (Herrera-Estrella et al. 1983, Bevan et al. 1983, Fraley et al. 1983) and β-galactosidase (Helmer et al. 1984) have been shown to function in plant cells after insertion by Ti plasmid T-DNA.

TRANSFORMATION OF PROTOPLASTS BY A NON-T-DNA VECTOR

Recently Paszkowsky et al. (1984) have shown that plant protoplasts can be transformed by naked plasmid DNA containing a selectable marker but no T-DNA border sequences. A chimeric kanamycin resistance gene with signals from a plant viral gene (cauliflower mosaic virus gene VI) was introduced into tobacco protoplasts. After selection of the transformed cells on kanamycin-containing medium, plants were regenerated and shown to transmit kanamycin resistance to their progeny as a dominant Mendelian trait. This finding points the way to a transformation method for plants outside the host range of Agrobacterium, which is restricted to dicots.

REGULATION OF FOREIGN GENES INTRODUCED INTO PLANTS

Chimeric genes formed from the nopaline synthase signals express in all types of plant cells: they seem not to be developmentally regulated. If the signals are taken from a light-regulated plant gene, the resulting chimeric gene is also light-regulated (Herrera-Estrella et al. 1984). It is plausible to suppose that signals from a plant gene that expresses only in roots would provide chimeric genes that are root-specific, etc. This will be important for some kinds of genetic engineering projects: engineering a nematode resistance gene to express in leaves would be uselss when the roots are the point of attack. Herbicide resistance, on the other hand, might be needed only in leaves.

TECHNICAL PROBLEMS REMAINING

The major problems in vector design are solved for plants within the host range of the Agrobacterium Ti plasmid. So far as we now know, this is restricted to dicotyledonous plants. More detailed knowledge of why Agrobacterium fails to produce tumors on monocots may reveal a means of adapting the Ti plasmid to this group of plants. Alternatively, it may be necessary to develop completely new strategies. Transformation of plant protoplasts by naked DNA (Paszkowski et al. 1984) is an attractive approach; however important cereal crops fail to regenerate from protoplasts to complete plants. Transformation of pollen with DNA would provide an ideal solution, yielding genetically engineered plants with minimal in vitro manipulation.

Soybean, an important dicot crop that is susceptible to the Ti vector strategies outlined above, is not readily regenerable from tissue culture. Thus genetically engineered soybean plants have not yet been produced. Several groups are currently reporting hopeful results in soybean regeneration, and it appears likely that this challenge will be met within a year.

A general problem for the genetic engineer wishing to produce plants from engineered plant cells is the occurrence of high genetic variability in regenerated plants of clonal origin. This "somaclonal" variation, while it may prove useful in its own right as a source of new kinds of genetic variation for plant breeders, is unwanted in engineering new genes into existing desirable genotypes. An understanding of the molecular basis of this variation might aid in eliminating it during genetic engineering projects.

The most challenging technical problem is the choice of single-gene-encoded traits that can be used to improve the quality of a crop plant. The most obvious choices are genes that confer resistance to herbicides or other useful agricultural chemicals. Nicotiana plumbaginifolia and N. tabacum plants resistant to the antibiotic kanamycin have been engineered by introduction of chimeric genes that detoxify kanamycin (Horsch et al. 1984, Paszkowski et al. 1984). Neither of these plants is a major food crop, nor is kanamycin an important agricultural chemical, but the success of these model experiments augurs well for projects of this type. It is less clear how to find or construct single genes that will solve other problems for the farmer: resistance to fungal or bacterial pathogens, tolerance to environmental stress, susceptibility to insects or nematodes, or improvement of yield. Improvement of the amino acid balance of seed storage protein can be attempted by manipulation of single genes that are readily isolable from plants. This objective however, is not high on the farmer's wish list. Many approaches are clear for combatting viral diseases, but further basic research is needed to determine the best method.

Foreign proteins introduced by genetic engineers may find themselves in a hostile environment for which they have not been prepared by natural selection. Plant proteases may cleave them, or low pH environment in the plant cell may make them enzymatically inactive. We have had too little experience to predict how frequently we may encounter problems of this kind. It may prove important to direct the engineered protein to a particular compartment of the plant cell in order to allow it to function.

For some kinds of genetic engineering objectives, it will be important to direct the expression of the foreign gene precisely. Although results available thus far are encouraging (Broglie et al. 1984, Herrera-Estrella et al. 1984), the chimeric gene approach may not solve all problems in this area. We may find that the position at which the foreign gene is inserted in the host plant genome affects the outcome. There are already isolated reports of changes in gene expression after the new gene is transmitted by seed.

This li t of challenges clearly shows that the genetic engineer still has important work ahead. There are few agriculturally significant objectives that can be approached with complete confidence today.

STRATEGIC PROBLEMS

In addition to the scientific problems outlined above, companies working in genetic engineering face strategic problems in evaluating project alternatives. It is not clear how to protect a product that is a genetically engineered plant (Williams 1984). It is not clear whether genetically engineered plants will, like novel chemicals, come under governmental regulation. The criteria for acceptance, if regulation comes into being, are completely unknown. These two important problems introduce an element of risk into all genetic engineering projects.

An additional strategic problem in evaluation of many genetic engineering projects is the estimation of their marketability. Genetic engineers could, in principle, produce plant genotypes so novel that

their marketability is completely unkown. For example, who will buy high-protein potato tubers? Will they be susceptible to attack by new kinds of pests? Will they require storage at temperatures inconsistent with maintenance of the starch content? Will they have acceptable taste and texture? Will the yield suffer?

CONCLUSIONS

Impressive progress in plant genetic engineering over the last five years seems to predict a bright outcome to the significant scientific challenges remaining. The problems of protectability and regulation add an element of risk to all genetic engineering projects. The most novel products to emerge from this new technology will carry the added business risk of unpredictable marketability. It is clear that the technology of plant genetic engineering is well-suited to certain kinds of crop improvements. For other problems, it may never be useful. Genetic engineering will provide plant breeders with a unique new source of genetic traits that will make significant contributions to traditional breeding programs by the turn of the century.

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SESSION 2

CEREALS—PEST AND DISEASE CONTROL

CHAIRMAN	MR J. W. BARBOUR
SESSION ORGANISERS	Mr M. G. ALLEN DR. M. E. FINNEY

POSTER PAPERS	2A-1 to 2A-23
LECTURES	2B-1 to 2B-4

FREQUENCY OF SPRING BARLEY DAMAGE BY LEATHERJACKETS IN NORTHERN IRELAND

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ABSTRACT

Northern Ireland grass supports large numbers of leatherjackets but reports of leatherjacket damage to spring barley are infrequent. It was postulated that this was because cultivation reduced numbers and populations above a pre-cultivation threshold were not common. This hypothesis was tested by comparing the results of surveys of leatherjacket numbers in brairding spring barley in 1983 and 1984 with the predicted frequency of populations above an estimated pre-cultivation threshold of 1.9 m ha^{-1}, derived from 19 years data on populations in grass. No significant difference was found between actual and predicted frequencies of economically damaging populations.

INTRODUCTION

Leatherjackets (Tipula spp.) have long been considered as one of the few serious pests of spring barley in Northern Ireland. Consequently an annual leatherjacket survey has been undertaken since the winter of 1965/66. This survey samples leatherjacket populations in established grass and is used to forecast the likelihood of leatherjacket damage to spring-sown cereals. However, even in years such as 1984 when leatherjackets have been particularly numerous and caused extensive damage to grass swards reports of damage to spring barley are relatively few.

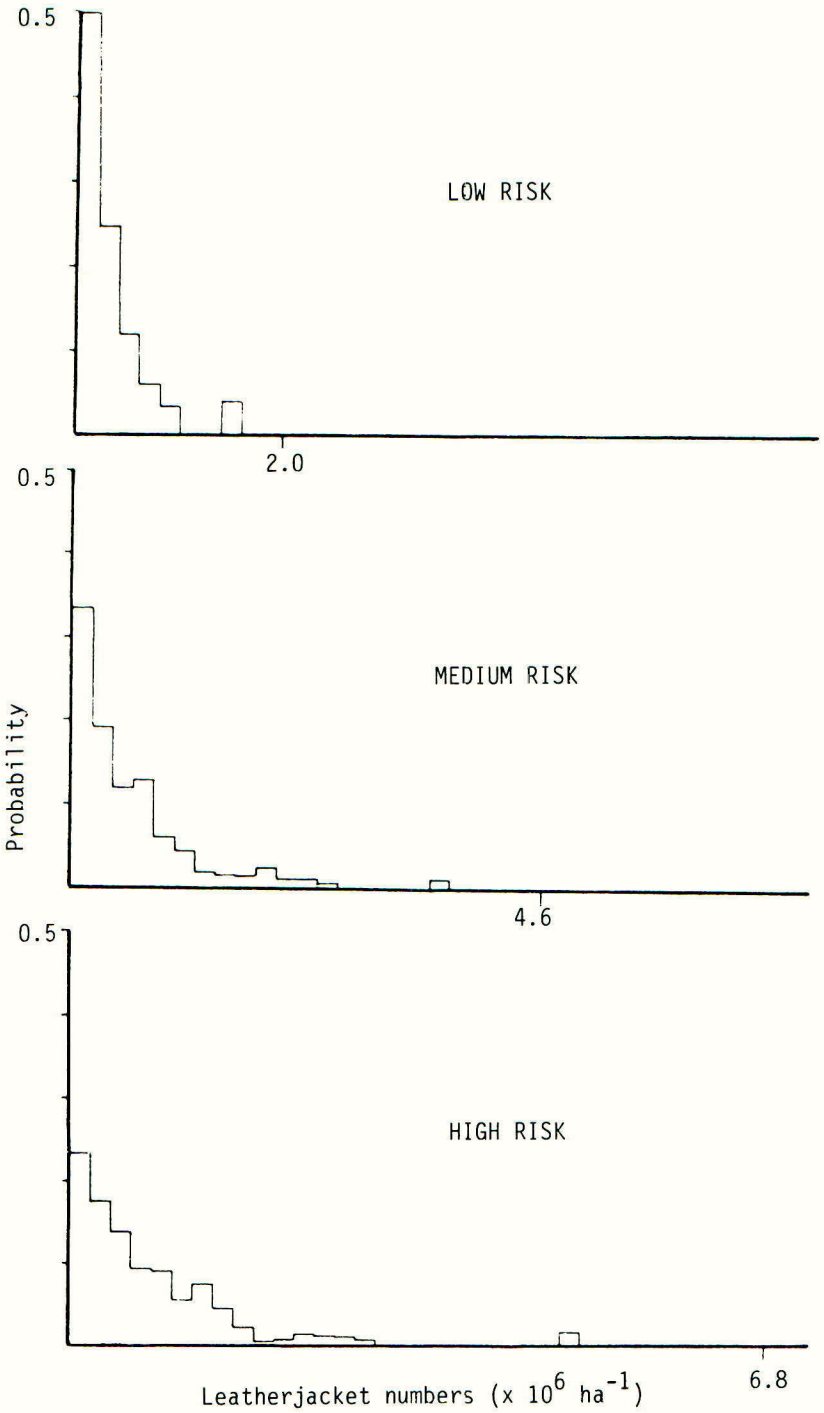
A feature of leatherjacket populations in Northern Ireland grass is that although high average populations are maintained the range of population sizes is less than in other areas of the UK (Blackshaw, 1983). Since mortality due to cultivation has been reported as 75% in Northern Ireland (Anon, 1976) it is possible that few fields have pre-cultivation populations of sufficient magnitude to leave numbers above the spray threshold in the crop. A study was therefore made of the frequency of damaging populations in spring barley in 1983 and 1984 and this was compared to the expected probability of a damaging population occurring.

METHODS

In 1983 and 1984 a number of brairding spring-barley crops were examined for the presence of leatherjackets by searching twenty 30 cm lengths of drill per field. The number of leatherjackets found and other information, most notably the number of cultivations the field had undergone since last in grass, were recorded. Populations were converted to thousands ha^{-1}.

Separate years of the annual leatherjacket survey results were allocated to leatherjacket risk categories on the basis of the mean annual population. Three risk classes were used; low (< 400,000 ha^{-1}), medium (400,000-675,000 ha^{-1}) and high (> 675,000 ha^{-1}). Probabilities for the occurrence of field populations were calculated for each risk category.

Fig. 1 Probabilities of leatherjacket population sizes with changing risk categories



RESULTS

The mean leatherjacket populations found in the spring barley survey are shown in Table 1. The spray threshold, as recommended by ADAS, is 15 leatherjackets per ten 30 cm drill lengths examined at 18 cm drill spacings (c 280,000 ha^{-1}). Only three fields in 1983 and two in 1984 had populations above this threshold and these were in fields out of grass. The populations found for fields in their first year of cultivation were compared (t-test) with the pooled data for fields that had undergone more than one cultivation. The fields out of grass had significantly more leatherjackets in both 1983 ($P<0.001$) and 1984 ($P<0.05$).

Table 1 Mean leatherjacket numbers (ha^{-1}) in brairding spring barley categorised by the number of cultivations undergone by a field

		Number of cultivations					
		1	2	3	4	5	6
1983	x	122,413	5,346	21,382	10,691	-	-
	SEM	105,735	10,691	-	15,074	-	-
	n	31	4	1	2	-	-
1984	x	110,547	41,681	29,155	-	37,383	9,346
	SEM	171,984	54,239	41,231	-	-	13,217
	n	24	8	2	-	1	2

The probability distribution of the three risk categories for leatherjacket attack in any year are shown in Fig. 1. An approximation to the reduction in leatherjacket numbers occurring between the time of the survey (January/February) and brairding (late April/early June) was made by comparing the mean annual leatherjacket population in grass for 1983 (757,000 ha^{-1}) and 1984 (854,000 ha^{-1}) with the respective mean numbers in fields in their first year of cultivation (Table 1). The mean reduction was 85.4%. Given a threshold of 280,000 ha^{-1}, only fields that have populations in excess of 1,918,000 ha^{-1} in January/February will result in economically damaging numbers after cultivation.

Both 1983 and 1984 were high risk years for leatherjacket damage. In a high risk year the sum of the probabilities of a field population > 1,918,000 ha^{-1} indicates an expected rate of economically damaging populations of 6.7%. Pooling the data for 1983 and 1984 shows that there were five fields with damaging populations out of 55 sampled. The expected number of grass fields with populations > 1,918,000 ha^{-1} was 3.69. There was no evidence for a significant difference between observed and expected values (X^2, = 0.356) using Yates' correction for continuity (Snedecor and Cochrane, 1973).

DISCUSSION

Only those spring barley fields in their first year of cultivation after grass were at risk of economic damage by leatherjackets. The predicted levels of damaging leatherjacket populations in spring barley in high risk years did not differ significantly from those observed in the

field. If the probability levels do provide a reasonable means of estimating the likelihood of damaging numbers occurring then, in low risk years we would expect 0.4% of fields to have damaging populations and in medium risk years 5.2%.

The frequency of damaging populations in spring barley largely depends upon two interacting factors; population distribution and the effects of cultivation on leatherjacket numbers. Cultivation effects are drastic enough to ensure that a high pre-cultivation population is necessary to result in numbers in excess of the economic threshold in the crop and the distribution of field populations in Northern Ireland means that these populations do not frequently occur.

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WEED GRASSES AS HOSTS OF CEREAL APHIDS AND EFFECTS OF HERBICIDES ON APHID SURVIVAL

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ABSTRACT

The susceptibility to cereal aphids of a selection of grass weeds commonly found in cereal crops was studied by measuring some aspects of the settling and reproductive behaviour of Rhopalosiphum padi and Sitobion avenae. Both aphids reproduced significantly better on some weed grasses than on others. Prediction of the risk of aphid infestation on cereal crops may need to include reference to plant species in assessments of distribution and abundance of weeds.

Herbicides commonly used to control grass were sprayed onto a weedy stubble and changes in aphid populations measured. Aphids survived longer following glyphosate than paraquat/diquat treatment. Herbicide choice may affect risk to cereals.

INTRODUCTION

The bird-cherry aphid, Rhopalosiphum padi, and the grain aphid, Sitobion avenae, are important vectors of barley yellow dwarf virus between cereals and grasses (Plumb, 1977). Cereals may be infested with aphids coming from grasses in a variety of situations: grass leys, permanent pasture, hedgerows and field margins, grass weeds within crops, and grass weeds between crops (the 'green bridge').

In a recent survey by the Weed Research Organisation (Chancellor and Froud-Williams, 1984) the most common grass weeds of cereals in central Southern England were found to be Agropyron repens (couch grass), Avena fatua (wild oat), Alopecurus myosuroides (black grass) and Poa trivialis (rough meadow grass). Other common grass weeds are Bromus sterilis (barren brome), Poa annua (annual meadow grass), Agrostis gigantea (black bent), Phleum pratense (large leaved timothy grass), Arrhenatherum elatius (onion couch or false oat grass) and Phalaris paradoxa (canary grass).

Some of these grasses were included in a group of 20 tested for susceptiblity to aphid infestation (Wright, Smith and Kendall, 1984); large differences in susceptibility were found between the grass species, up to three-fold with R. padi.

We report here results of similar tests with other important grass weeds of cereals and for comparison some of the most susceptible and most resistant species identified in earlier work have been included.

Herbicides are used to kill grass and other weeds before new crops are established. The effects of two commonly used herbicides on aphid populations in a stubble containing large populations of grass weeds are described.

MATERIALS AND METHODS

The suitability of grasses for aphid settling was assessed on leaves of two ages cut from potted plants of 9 grass species. The leaves were either fully grown (mature)or half grown (young). Cut ends were put in water through a slit in a parafilm membrane. Single apterous 4th instar aphids were placed at the base of each leaf and their behaviour noted in a 3 min period; 10 different aphids were used on each grass species. Aphids for all tests were taken from a clonal culture on oats cv. Blenda. The position on the leaf where aphids eventually settled was also noted (base, mid part or tip).

Aphid reproduction was measured on single plants grown in pots and kept in a growth room with a 16 h day, day temp 18°C and night temp 15°C. Ten apterous 4th instar R. padi or S. avenae were placed on each plant when it had a total leaf area of 4-500 cm^2. The number of offspring produced in 10 days from the onset of reproduction was noted in each of 10 replicates.

Reproduction was also measured in the same way on plants of Poa annua either when flower-heads were present or on plants from which flower-heads were removed.

The influence of herbicides on aphid populations was assessed on 4 x 4 m plots in an unreplicated field experiment at Long Ashton. Either paraquat + diquat (Cleansweep, 4 litres/ha) or glyphosate (Roundup, 4 litres /ha) was sprayed onto a barley stubble on 8 August 1983, which by then was densely covered with a mixture of grass weeds. Aphid population samples were taken every few days from different places in treated areas and from neighbouring untreated plots using a 'D-vac' suction sampling machine.

RESULTS

Aphid behaviour and reproduction on grasses

Table 1 shows that significantly more R. padi settled at the base of the leaf than at the tip in contrast to S. avenae which preferred the leaf tips. This is consistent with their known field behaviour.

Table 2 shows that taking all grasses together significantly more R. padi than S. avenae settled on young leaves in less than 2 mins but there was no difference between species on mature leaves. Analysis of settling on individual grasses however showed that whilst R. padi settled more readily on some grass species the reverse was true for other grasses.

TABLE 1

Number of aphids, out of a sample of 10, settling on different parts of leaves. Average of all grasses

		Base		Mid		Tip
Leaves						
Mature	R. padi	5.8	**	3.7	**	0.5
		**		ns		**
	S. avenae	1.0	**	4.0	ns	5.0
Young	R. padi	5.4	ns	4.0	**	0.6
		**		ns		**
	S. avenae	1.7	**	4.4	ns	3.9
Overall	R. padi	5.6	**	3.85	**	0.55
		**		ns		**
	S. avenae	1.35	**	4.20	ns	4.45
SED (mature and young leaves)		0.601		0.670		0.759
SED (overall means)		0.425		0.474		0.536

Significant differences P = 0.01 indicated by ** and P = 0.05 by *

TABLE 2

Number of aphids, out of a sample of 10, settling within different periods. Average of all grasses

		0-1 min		1-2 min		2-3 min	< 2 min
Leaves							
Mature	R. padi	1.9	**	5.2	**	2.8	7.1
		ns		ns		ns	
	S. avenae	1.5	**	5.4	**	2.3	6.9
Young	R. padi	2.1	**	6.0	**	1.9	8.1
		ns		ns		*	**
	S. avenae	1.2	**	5.4	**	3.2	6.6
				ns			
Overall	R. padi	2.00	**	5.60	**	2.35	7.60
		ns		ns		ns	*
	S. avenae	1.35	**	5.40	**	2.75	6.75
				**			
SED (mature and young leaves)		0.508		0.594		0.503	0.460
SED (overall means)		0.359		0.420		0.356	0.325

Table 3 shows that aphids reproduced significantly better on some grasses than on others. Bromus erectus was least suitable for reproduction and the order of preference was very similar for both aphids, the only differences being that there were more R. padi on Bromus sterilis than on Poa annua, whilst the reverse applied to S. avenae.

TABLE 3

$\sqrt{\text{Number}}$ of 4th and 5th instar aphids produced by 10 aphids in 10 days from the onset of reproduction

		R. padi	S. avenae
(a)	Bromus erectus (upright-brome)	4.55	3.02
(b)	Agropyron repens (couch)	5.40	4.27
(c)	Agrostis gigantea (black bent)	6.53	4.95
(d)	Lolium perenne (perennial rye grass)	9.16	6.24
(e)	Phalaris paradoxa (canary grass)	10.81	6.42
(f)	Alopecurus myosuroides (black grass)	11.07	6.76
(g)	Poa annua (annual meadow grass)	11.30	7.15
(h)	Hordeum murinum (wall barley)	11.41	8.20
(i)	Bromus sterilis (barren brome)	11.47	6.76

SED = 0.371

a < b < c < d < efghi
* ** ** **

a < bc < defgi < h
** ** **

Table 4 shows that the aphid species differed in their reproductive capacity when they fed on Poa annua plants with flowerheads and plants of the same age from which flowerheads had been removed. S. avenea reproduced significantly better on plants with flowerheads unlike R. padi, but the latter was again somewhat more successful than S. avenea on this grass. Whilst such differences were not large they could have considerable influence on the size of field populations after several generations.

TABLE 4

$\sqrt{\text{Number}}$ of 4th and 5th instar aphids produced by 10 aphids in 10 days from the onset of reproduction on Poa annua

	R. padi		S. avenae
+ flowerheads	12.35	**	9.66
	ns		**
- flowerheads	11.80	**	7.97

Effects of herbicides on aphid survival

Fig. 1 shows that aphids survived longer on glyphosate treated than on paraquat/diquat treated plants. Whilst aphid populations had fallen 5 days after paraquat/diquat treatment a similar population decline was not reached on glyphosate treated grass for at least a further week. It was observed that plants died more quickly when treated with paraquat/diquat.

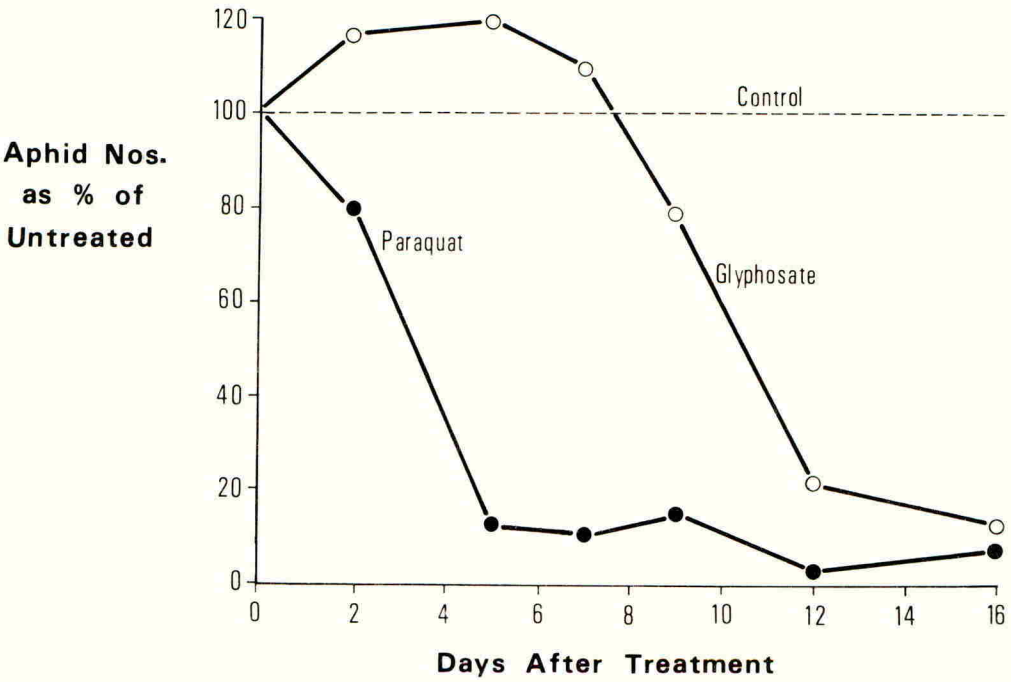

Fig. 1. Effect of paraquat/diquat or glyphosate sprays on aphid survival in grass.

DISCUSSION

Whilst all the grass weeds in these experiments could act as alternate hosts for the two main cereal aphid species, and most aphids settled to feed on them within 2 minutes, R. padi was generally more successful than S. avenae. R. padi is usually associated with transmission of the most damaging strains of Barley Yellow Dwarf Virus from grass to cereals. It has been shown (Wright, Smith and Kendall, 1984) that grasses, including some cereal weeds, can vary in their suitability as aphid hosts and in these experiments other cereal weed grasses ranged between similar extremes. Comparison of results reported here with those previously obtained shows that among the least susceptible cereal weed grasses are Agropyron repens, Arrhenatherum elatius, Phleum pratense and Agrostis gigantea whilst among the best aphid hosts are Bromus sterilis, Avena fatua, Poa annua and Alopecurus myosuroides. Settling and reproduction appear to be related and the correlation is most marked, with both aphid species, for aphids settling on mature leaves in less than 2 mins. Reproduction, and possibly virus spread, can be influenced by species but also by the age and nature of plant

tissue, as shown by the experiments with Poa annua, and in assessments of the importance of different sources of aphids and virus it may be necessary to combine information on distribution and density of host plant species with growth stage.

Differences in aphid survival after glyphosate compared with paraquat/diquat treatment could affect the risk of Barley Yellow Dwarf Virus infection spreading to following cereal crops, particularly if time is short between herbicide treatment and emergence.

We are currently investigating relationships between aphid suitability and virus infection in the main cereal weeds, and in collaboration with ADAS, the influence of herbicide treatments at different times on the carryover of aphids and virus from grass weeds in stubbles, and from grass leys, to cereal crops.

ACKNOWLEDGEMENTS

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FACTORS AFFECTING CEREAL APHIDS IN FIELDS MONITORED BY RISCAMS IN 1983

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ABSTRACT

In a survey of wheat fields in the vicinity of three RIS suction traps in Eastern England in 1983 the greatest numbers of aphids, especially Sitobion avenae, were recorded in the Broom's Barn area, and the least near Rothamsted in Hertfordshire. Within each area insecticides had the greatest effect on aphid numbers, but on unsprayed fields, early sown crops supported more aphids than late sown. In the Writtle area, less S. avenae were found on Rapier wheat than on other varieties. Few fields had damaging levels of aphids due largely to the depredations of natural enemies.

INTRODUCTION

In 1982, the Rothamsted Insect Survey Cereal Aphid Monitoring Scheme (RISCAMS) surveyed 100 wheat fields in the vicinity of suction traps at Rothamsted in Hertfordshire, Writtle in Essex and Broom's Barn in Suffolk, to identify factors contributing to the variance in aphid numbers between fields within and between different regions (Dewar, 1983). However aphid numbers were generally low in all three areas in that year resulting in little measurable variation, which was further reduced by differential predation which masked the effects of agricultural practices on aphid density. The survey was continued in 1983 in the same three areas in the hope that, with greater aphid numbers, the effect of these agricultural practices could be better quantified. The 1983 results are presented in this paper.

MATERIALS AND METHODS

In 1983, ninety-seven wheat fields, all within 35 km of one of the three RIS suction traps at Rothamsted, Broom's Barn and Writtle (Fig. 1), were monitored for four weeks in June and early July by three non-entomologists trained in aphid identification, sampling procedures and data recording. The numbers of Sitobion avenae, Metopolophium dirhodum and Rhopalosiphum padi present were estimated by counting the proportion of tillers infected with each species and converting this figure to actual density using published regression equations (Rabbinge et al., 1980). In practice R. padi was rare and data on this species is not presented here. For each field records were obtained of the cultural and chemical treatments applied, the general topography, growth stage of the crop, and presence of the more easily recognisable natural enemies, such as coccinellids, syrphids, lacewings, parasite mummies and aphids infected with Entomophthora.

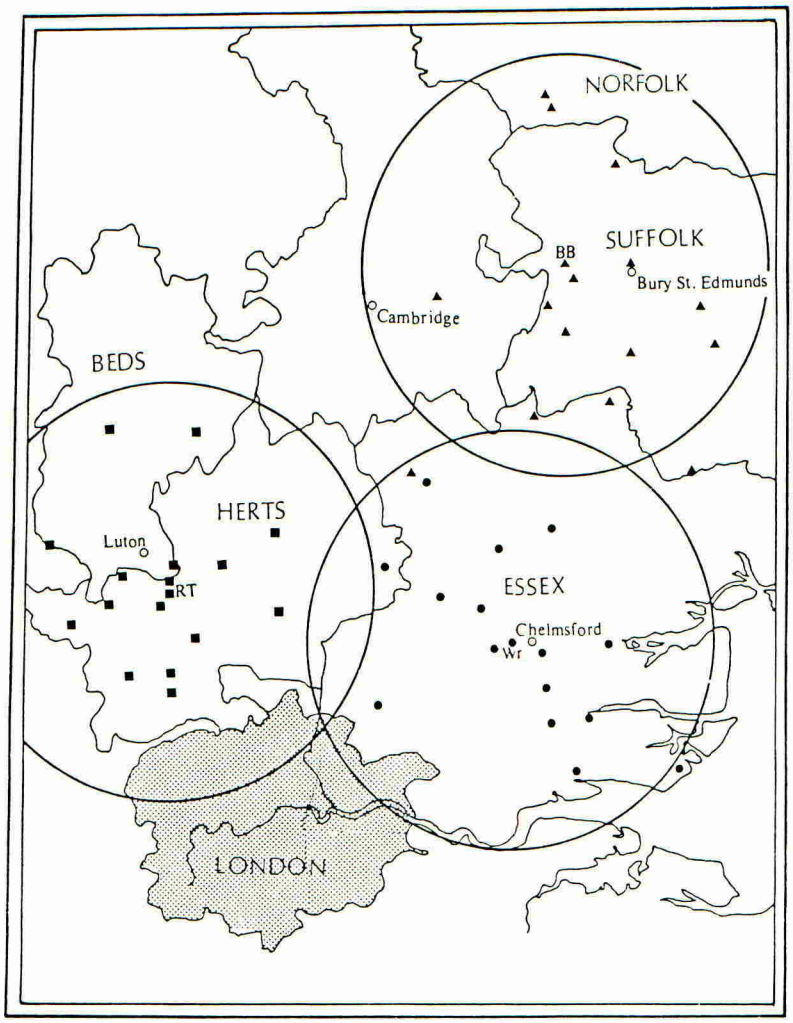

Fig 1. RISCAMS sample sites in 1983. Circles denote 35 km radius from suction traps at Rothamsted (RT), Broom's Barn (BB) and Writtle (WT).

RESULTS

Regional differences

Aphids in 1983 were much more abundant than in the previous year and there was much greater variation between fields within and especially between regions. S. avenae was the predominant species in all fields with M. dirhodum present only in very low numbers. The highest individual peak density (>25 S. avenae per tiller) was recorded in a field near the Essex coast, but the highest average densities were found in the Broom's Barn zone, while numbers in the Rothamsted zone were generally lower than the

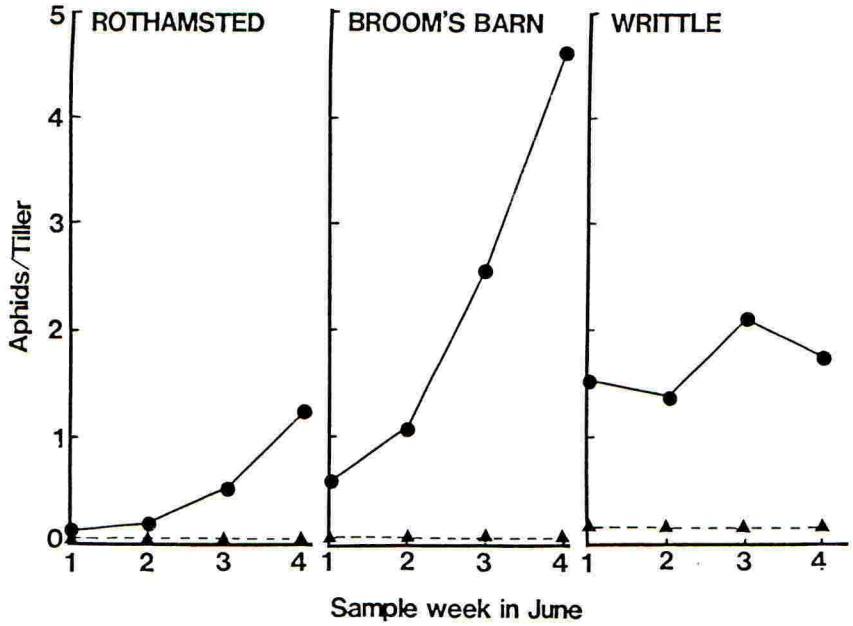

Fig 2. The number of S. avenae (—●—) and M. dirhodum (—▲—) per tiller in wheat fields near Rothamsted, Broom's Barn and Writtle in 1983.

The effect of insecticides

Insecticides, not surprisingly, had the greatest effect on aphid numbers and their effect is considered separately from the other factors.

The use of insecticides in the summer varied considerably between regions, but reflected the comparative abundance of aphids in unsprayed fields in those regions. Over 77% of fields in the Broom's Barn zone were sprayed at least once, while 56% of those in the Writtle zone and only 29% of those in the Rothamsted zone received an aphicide. Sprayed fields were treated with either pirimicarb (56% of sprayed fields) demeton-S-methyl (22%) or dimethoate (22%), but the effectiveness of each product could not be evaluated in this survey as the fields were sampled at different times after treatment. Most sprayed fields (87%) received only one spray but several (11%) were sprayed twice and one received three sprays.

The only sample fields to receive autumn-applied insecticides were in the Broom's Barn zone where they were used primarily to control Barley Yellow Dwarf Virus (BYDV) in early sown crops. Of the thirteen sprayed fields, ten were treated with cypermethrin, two with deltamethrin and one with dimethoate. There were fewer aphids in these autumn-sprayed fields than in untreated fields at the beginning of June, but, since most of them (11) were sprayed with another aphicide during the sampling period, it was not possible to determine whether this difference would have persisted, except in the two fields which were not sprayed. In these latter fields, numbers never rose above 2 per tiller.

The effect of other factors

Analyses of the effect of agricultural practices, other than insecticide use, on aphid abundance could only be done on fields not

receiving an insecticide. Thus, all the fields receiving an autumn insecticide and a few that had been sprayed before the survey commenced were excluded from the subsequent analyses. To maximise the number of remaining fields, especially in the Broom's Barn zone, data from those that were eventually sprayed were included in the analyses up until the date of spraying. Although this procedure led to different numbers of fields being included in the analyses from week to week, it resulted in more replicates of each factor being examined, at least in the first week or two of the survey. Only those factors which showed significant differences are discussed here.

(a) Sowing date. More aphids (mainly S. avenae) were found in crops sown before 14 October than crops sown later throughout the sampling period in the Rothamsted and Writtle zones and for the first three weeks in the Broom's Barn zone (Table 1). Late sown crops at Broom's Barn eventually supported higher populations than early sowings.

TABLE 1

Mean aphid numbers (per tiller) in unsprayed wheat crops sown before and after 14 October the previous year.

Sample week in June	AREA					
	Rothamsted		Broom's Barn		Writtle	
	sown early	sown late	sown early	sown late	sown early	sown late
1	0.21(11)	0.11(23)	1.19(8)	0.13(9)	1.12(9)	1.67(23)
2	0.23(11)	0.15(21)	1.85(8)	0.41(9)	3.31(9)	0.58(20)
3	0.61(11)	0.46(17)	2.44(6)	2.09(9)	4.13(8)	1.31(20)
4	1.70(9)	0.95(15)	3.39(4)	5.23(9)	3.28(3)	1.38(13)

( ) refer to the number of fields in each category.

The larger number of aphids in the early sown crops was attributed to their colonisation by alate aphids after emergence in the autumn. Late sown crops avoided this immigration as they did not emerge until after the autumn migration had ceased in early November (Taylor et al., 1983). S. avenae increased gradually throughout the mild winter of 1982/83 on early-sown crops (Dewar and Carter, 1984) giving rise to the higher observed densities, which persisted until early July at Rothamsted and Writtle, and late June at Broom's Barn.

(b) Varieties. Seventeen varieties or mixtures of varieties were sown in the sample fields in 1983. Avalon and Norman were the most common

varieties at Rothamsted and Broom's Barn but Rapier was most popular at Writtle. Meaningful comparisons between these three varieties could only be made in the Writtle zone where a number of fields were sown to each variety.

Fewer S. avenae were recorded on Rapier than on Avalon and Norman (Table 2). These results confirmed other unpublished observations in variety trials at Rothamsted when Rapier supported the lowest number of aphids. Rapier was also found to be relatively resistant in breeding trials at Cambridge (Lowe, 1982, 1984; and unpublished data).

TABLE 2

Mean number of S. avenae per tiller found on three varieties of wheat in the Writtle area in 1983.

Sample week in June	VARIETY		
	Avalon	Norman	Rapier
1	1.21 (7)	1.00 (5)	0.29 (8)
2	1.08 (6)	1.24 (5)	0.27 (7)
3	2.28 (6)	2.63 (5)	0.58 (7)
4	2.76 (4)	2.40 (2)	0.73 (5)

( ) refer to the number of fields in each category.

Of the other varieties which were unsprayed, there were no obvious and consistent differences in aphid numbers. The highest density (>25 per tiller) was recorded in a field of Highbury - normally a spring variety, but in this case sown in early October - but this result could be attributed to the location of the field on the Essex coast, where aphid overwintering is traditionally more successful than elsewhere.

(c) Natural enemies. The method of recording the abundance of natural enemies was not rigorous enough to allow statistical comparisons between fields or regions, but the observations made suggested that they were an important contributing factor limiting aphid numbers in many of the fields. Detailed observations in trials at Rothamsted confirmed that coccinellid, syrphid and lacewing larvae were the most important natural enemy groups present in 1983 (Powell, unpublished data).

CONCLUSIONS

The RISCAMS survey in 1983 identified insecticide use, sowing date and choice of variety as factors influencing the abundance of aphids within a region, but the greatest variation occurred between regions. Surveys of

this kind can help to pinpoint areas of the country which are most at risk from aphids and can identify agricultural practices which exacerbate aphid attack especially when insecticides are not applied. However the greatest difference observed in the survey was between 1983 and 1982, thus illustrating the need to continue RISCAMS in future years in order to understand better the complex interactions between aphids and their host crops.

ACKNOWLEDGEMENTS

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THE CONTRIBUTION OF RESISTANCE TO CEREAL APHID CONTROL

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ABSTRACT

Evidence for both antixenotic and antibiotic resistance to the grain aphid, Sitobion avenae, in wheat is presented. The combined impact of these resistances on field populations of S.avenae was studied in 2 years of field trials and more extensively by means of a simulation model. Both of these assessments indicated that by sowing resistant cultivars aphid infestations can be reduced on average by 75%. Greater reductions may be achieved by utilizing awned and early maturing cultivars, although the latter character is constrained by yield requirements. Nevertheless regular reductions of aphid numbers by 85% are feasible. This would decrease the frequency of aphid outbreaks and lessen the need for routine applications of insecticide during the summer.

INTRODUCTION

The prediction of pest outbreaks and the formulation of more biologically based methods of pest control are the two major approaches to reducing the high usage of insecticides on crops. This paper considers the latter, with respect to host-plant resistance, which is widely acknowledged as an important component of pest management schemes. As yet, however, few crop cultivars resistant to insects have been developed in the UK.

The grain aphid, Sitobion avenae, remains a prominent pest of cereals in the UK and Carter, McLean, Watt & Dixon (1980) stated that resistance was the most viable alternative to insecticidal control. Partial resistance in wheat to this aphid is well documented (Lowe,1980; 1981; 1984; Kay, Wratten & Stokes, 1981; Sotherton & van Emden, 1982; Lee, 1984). In the light of this, a series of laboratory, field and simulation model studies were carried out in order to determine the level of control of the grain aphid that could be achieved on wheat through utilizing resistance.

MATERIALS AND METHODS

Laboratory tests

A number of experiments were conducted at 20 C and a 16 hour photoperiod to assess antibiosis in 4 spring wheat cultivars and potential cultivars, 708/41, 320/30, Sandown and QY1/59, known to represent the extremes of resistance to S.avenae (Lowe, 1984).

Adult apterous S.avenae taken from culture were clip-caged on the flag leaf of wheat plants at developmental stage (d.s) 38 and allowed to reproduce one nymph before being removed. The nymphal developmental time, nymphal mortality and 15 day reproduction, up to d.s 61, of these individually caged aphids were measured on each of tne four wheat stocks.

From these data and those of a similar experiment, estimates of two widely recognized indices; mean relative growth rate (RGR) (van Emden, 1969), and the intrinsic rate of natural increase (r_m) (Wyatt & White, 1977), were calculated for aphids feeding on each cultivar, thus enabling the results to be compared with those of other workers.

Similar data on aphid performance were collected for aphids feeding on tne ears of each cultivar from d.s 59-73.

Field trials

In 1983, 6 spring wheats, 708/41, 320/30, Sandown, QY1/59, 1199/298 and 896/12, were sown at two sites 1km apart at the Plant Breeding Institute, Cambridge. They were sown in randomized blocks, with one plot per cultivar per block. Each plot measured 7.6 x 5.2m. Natural infestations of each cultivar were monitored from tillering onwards, until the peak populations were reached. 50 tillers per plot were sampled each week and the aphids were recorded by morph and instar. Similarly in 1984, plots of 708/41, 320/30, Sandown, QY1/59, 1169 and Newmarket were sown on a single site at Cambridge, using a similar experimental layout. The aphid populations on these plots were monitored as above. The peak aphid populations on each cultivar in each year were compared.

A measure of antixenosis was obtained by summing the number of alates counted on each cultivar in 1983. This gives a good estimate of alate colonization as alates produced on the crop remain tnere for only a short period (Rabbinge, Ankersmit & Pak, 1979).

Simulations

To give a more extensive appraisal of the impact of resistance in the field, the resistance was studied by means of a simulation model that describes the population development of S.avenae on wheat. A full description of the model is given in Carter, Dixon & Rabbinge (1982).

Antibiosis was simulated by incorporating the aphid reproductive and developmental rates on each cultivar, measured in the laboratory tests, in to the model. Antixenosis was simulated by varying tne number of alates colonizing each cultivar and this was estimated from the counts of alates made in the field. The model was run with tnis aphid data along with the metereological, suction trap and natural enemy data for Norfolk 1976-81. Then the predicted levels of reduction due to the resistance in each year were applied to the peak numbers of aphids observed in fields of cv. M.Huntsman, a highly susceptible cultivar (Lowe, 1980;1981), in Norfolk from 1976-81. This gave an estimate of the

peak numbers of aphids in those years, had resistant cultivars been grown.

The predicted range of infestation on the most resistant and most susceptible cultivars were compared with the actual range of infestation observed in the field in 1983 and 1984.

The value of the observed and predicted levels of resistance was considered in terms of reducing outbreaks of S.avenae and hence reducing the incidence of prophylactic spraying of insecticides against this aphid.

RESULTS

The expression of antibiosis as estimated by RGR and r_m was not very dramatic (Table 1). For example, the difference in r_m between cultivars is less than that between apterous and alate morphs of S.avenae (Watt, 1979).

TABLE 1

The range of antibiosis expressed by 4 spring wheat cultivars, summarized as RGR and r_m.

	Cultivar			
	708/41	320/30	Sandown	QY1/59
r_m	0.290	0.299	0.322	0.291
RGR	0.331	0.360	0.414	0.366

However, there is a four fold difference in alate colonization due to antixenosis (Table 2), and because this antixenosis is associated with moderate levels of antibiosis the combined effect of the resistances is very significant.

The resistance was expressed consistently in the field in 1983 and 1984. There were up to 90% fewer aphids on 320/30, the most resistant cultivar, compared with the most susceptible cultivar, Sandown (Table 3).

TABLE 2

The number of alate S.avenae counted on 6 spring wheat cultivars on two sites in 1983.

	Cultivar							
	708/41	320/30	Sandown	QY1/59	1199/298	896/12	χ^2	sig.
Site 1	67	37	144	126	119	128	84.5	***
Site 2	58	27	134	104	132	95	97.0	***

(*** denotes significance at $p<0.001$)

Table 3

The peak numbers of S.avenae/tiller on naturally infested field plots in 1983 (2 sites) and 1984.

	Cultivar									
Year	708/41	320/30	S/down	QY1/59	896/12	1199/298	1169	N/mkt	$H^{\dagger}$	sig.
1983	2.86	1.12	4.18	4.84	3.06	3.88	-	-	47.6	***
	1.48	0.78	3.60	2.52	1.98	3.82	-	-	51.5	***
1984	7.53	3.53	37.58	15.47	-	-	13.17	16.90	104.0	***

(† Kruskal-Wallis one way analysis of variance. *** denotes significance at $p<0.001$)

The simulation studies revealed a similar level of resistance. Had cultivars with resistance equal to that of 320/30 been grown during the period 1976-80 in Norfolk it is predicted that the numbers of aphids infesting wheat would have been up to 75% fewer than those actually observed on fields of cv.M.Huntsman. In 1981, when aphids overwintered on the crop, the resistance was expressed less strongly (Table 4).

TABLE 4

The peak number of S.avenae/tiller observed on fields of cv. M.Huntsman in Norfolk from 1976-81 and the predicted peak populations had a resistant cultivar been grown.

Year	Observed peak (susceptible cv.)	Predicted peak (resistant cv.)
1976	47.7	7.2
1977	88.7	18.6
1978	5.0	0.9
1979	5.5	0.8
1980	39.1	5.1
1981	1.8	1.0

DISCUSSION

The implication of these studies is that resistant cultivars would regularly support 75% fewer S.avenae than susceptible wheat cultivars. When aphids overwinter on the crop the resistance is less marked, due to the reduced effect of antixenosis. However, overwintering is not common as autumn populations of S.avenae are often sprayed to protect crops from the spread of Barley Yellow Dwarf Virus of which S.avenae is a vector (Plumb, 1974).

The definition of an aphid outbreak causing economic damage varies between authors (Vickerman & Wratten, 1979) but can be estimated as 20-30 aphids/tiller at peak. By this definition there were 3 outbreaks in Norfolk between 1976 and 1981, and it is suggested that if resistant cultivars had been grown these would not have occurred. Also, in the field in 1984, damage of economic importance would have been caused by the aphid infestations on the susceptible but not the resistant cultivars. This reduction in outbreak frequency would make prophylactic spraying of insecticide very uneconomic. Watt (1983) suggested that with an outbreak probability of 0.2 or less prophylaxis should not be considered.

Early maturing cultivars support fewer aphids than late maturing cultivars (Acreman & Dixon, in prep) and awned cultivars support up to 40% fewer aphids than comparable awnless ones (Acreman, unpublished). Hence cultivars could be found which would regularly reduce aphid infestations of wheat by 85%. Even so, in years when S.avenae is particularly abundant (e.g Kolbe, 1969, recorded 200 aphids/tiller), the resistance would need to be supplemented with insecticides to prevent economic damage.

In the long term it may be possible to transfer the strong resistance to S.avenae observed in ancient wheats (Sotherton & van Emden, 1982; Lee, 1983) to modern wheat cultivars. Already the

resistance known to exist in modern cultivars could largely replace the routine insecticidal applications now used to control S.avenae.

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PREVENTION OF BARLEY YELLOW DWARF VIRUS (BYDV) AND CONTROL OF YELLOW CEREAL FLY (OPOMYZA FLORUM) IN WINTER CEREALS WITH DELTAMETHRIN

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ABSTRACT

Trials carried out in the U.K. between 1980 and 1984 have demonstrated that deltamethrin, a synthetic pyrethroid, applied at 5.0-7.5 g a.i./ha is a very effective treatment for controlling aphid vectors and thus reducing the incidence of BYDV in winter cereals. In addition, autumn/winter applications aimed at BYDV prevention have also given a useful control of Opomyza florum. Sprays applied at egg-hatch of this pest in late winter/early spring have similarly shown a good reduction of 'dead-heart' symptoms. This paper reports and discusses the results of these trials and compares with several years' experience of similar usage of deltamethrin in France.

INTRODUCTION

With the continuing intensification of winter cereals, especially winter barley, the incidence and importance of BYDV (barley yellow dwarf virus) has become a major consideration among arable farmers over the last few seasons. The virus is transmitted by aphids, particularly Rhopalosiphum padi (bird cherry aphid), which migrate into newly-emerged cereal crops in the autumn. Recent evidence also implicates Sitobium avenae (grain aphid) as a further carrier. Winged aphid migration continues until late October/early November, so crops emerging before this time are at risk from BYDV. As drilling dates for winter cereals are tending to be earlier, this represents the majority of crops grown.

Most infection is spread by wingless progeny of the invading aphids, and symptoms, in the form of patches of stunted and discoloured plants, do not normally show up until early spring. By this time, it is generally too late to treat as the only effective control measure is to prevent viral transmission in the autumn. All types of winter cereal may be affected, although traditionally winter barley is most seriously hit.

In addition to BYDV, attacks from Opomyza florum (yellow cereal fly) have become a further threat to winter wheat growers. This pest causes 'dead-heart' symptoms, similar to those of Delia coarctata (wheat bulb fly). Severe attacks may lead to uneven ripening and a reduction in grain quality.

Initial trials in 1980-1982, despite very low viral symptoms, suggested that an autumn application of deltamethrin could greatly reduce the incidence of BYDV infection. Independent studies also indicated that synthetic pyrethroid materials were effective (Kendall and Smith, 1982). Furthermore, work at the Norfolk Agricultural Station had shown that an autumn application of a pyrethroid material could also reduce attack by O. florum (NAS 1983).

This paper reports and discusses the results of detailed trials carried out by Hoechst U.K. Ltd. since 1982 investigating the prevention of BYDV and the control of O. florum with deltamethrin.

MATERIALS AND METHODS

Trials were carried out on commercial cereal crops in East Anglia, the Midlands and Southern England.

BYDV Trials

All BYDV trials were carried out on winter barley. Because of the invariably patchy occurrence of viral symptoms, it was necessary to use large plot sizes ranging from 50-400 m^2, either with two replicates or unreplicated. Applications were made using Van der Weij 'AZO' small-plot precision sprayers at a pressure of 250 kPa delivering 300 l/ha through eight Tee Jet 80015 spray nozzles, spaced 25 cm apart, on 2 m spray booms. Crop vigour assessments were made at regular intervals after application using the EWRS scale (Bolle 1964). Visual assessments of BYDV were made in the spring as crops progressed through the jointing stage, when symptoms were most visible. The percentage of crop on the untreated plot showing viral infection was recorded, and each treatment expressed as a percentage control figure relative to the untreated plot. Size of foci and description of symptoms were also recorded. Aphid counts were not carried out, as infectivity could not be determined. Yields were taken using a Hege small-plot combine harvester.

Series 1

1982/83 - 9 trials. A single application was made to each plot in late October/early November. Deltamethrin, as [R]Decis (25 g/litre e.c.) at 5.0-7.5 g a.i./ha was compared with a standard organo-phosphorous treatment of demeton-S-methyl (580 g/litre e.c.) at 244 g a.i./ha.

Series 2

1983/84 - 4 trials. Deltamethrin at 6.25 g a.i./ha was applied at three timings from crop emergence to early November. A two-spray programme was also included.

O. florum Trials

These trials were carried out in winter wheat fields with a history of O. florum. Trial designs were randomised blocks incorporating four replicates. Plot size was 15 m^2. Applications were made as in the BYDV trials, except Tee Jet 8001 spray nozzles were used delivering 200 l/ha. Crop vigour was monitored as before. Control of O. florum was assessed by counting 'dead-hearts' on 5 x 0.5 m row lengths of crop per plot and expressing the data as percentage control relative to the untreated value. Yields were taken using a Hege small-plot combine harvester.

Series 3

1982/83 - 5 trials. Treatments of deltamethrin at 5.0-7.5 g a.i./ha sprayed at the BYDV timing, were compared with a standard organo-phosphorous treatment of triazophos (420 g/litre e.c.) at 630 g a.i./ha applied at egg-hatch in late January/early February. In addition, a two-spray programme of deltamethrin (autumn) and triazophos (egg-hatch) was included, as was deltamethrin at 6.25 g a.i./ha at egg-hatch.

RESULTS

Data from each trial series are presented separately in Tables 1-3. No adverse effects on crop vigour were noted from any treatment at any site.

DISCUSSION

BYDV Prevention

In Series 1, where sprays were applied at the traditional timing of late October/early November, control from all treatments was excellent, averaging 94-96% overall (Table 1). However, at two sites (1 and 6) it was clear that some level of infection had occurred prior to treatment, as small localised foci were present on all treated plots in the spring. As aphids were already common at the time of spraying, an earlier spray timing may well have resulted in even higher control levels.

[R] Decis is a registered trademark of Roussel Uclaf

TABLE 1

Series 1 - BYDV Trials 1982/83

Site Details

	Site Number								
	1	2	3	4	5	6	7	8	9
Location:	Blythburgh, Suffolk	Leiston, Suffolk	Weeting, Norfolk	Ickburgh, Norfolk	Rhoose, S. Glam.	Anmer, Norfolk	Anmer, Norfolk	Ford, Sussex	Lavant, Sussex
Variety:	Igri	Igri	Igri	Igri	Fenella	Maris Otter	Igri	Sonja	Igri
Drilling Date:	11/09/82	20/09/82	28/09/82	15/09/82	12/09/82	09/09/82	13/09/82	28/09/82	16/09/82
Applic. Date:	29/10/82	01/11/82	05/11/82	02/11/82	11/11/82	07/11/82	07/11/82	04/11/82	05/11/82
Aphid Status at Application:	Common	Occasional	None found	None found	Common	Common	Occasional	Occasional	None found

Trials Results

Treatment	Rate g a.i./ha	**% Control of BYDV** Relative Yield (Untreated = 100)									Mean all Sites	Mean excluding Site 1
		1	2	3	4	5	6	7	8	9		
DELTAMETHRIN	5.0	**90**	**98**	**98**	**100**	**95**	**80**	**92**	**95**	**95**	**94**	–
		718	129		118	111	112	134			220	121
DELTAMETHRIN	6.25	**90**	**100**	**100**	**100**	**95**	**83**	**92**	**100**	**100**	**96**	–
		760	119		113	107	124	140			227	121
DELTAMETHRIN	7.5	**90**	**100**	**100**	**100**	**95**	**80**	**93**	**100**	**100**	**95**	–
		621	120		114	107	118	139			203	120
Demeton-S-Methyl	244.0	**90**	**95**	**100**	**100**	**95**	**82**	**95**	**100**	**100**	**95**	–
		782	116		111	107	125	132			229	118
Untreated (**% of crop affected by BYDV**/Yield in t/ha)		**90**	**25**	**35**	**20**	**30**	**65**	**50**	**5**	**5**	**36**	–
		0.81	7.64		6.30	6.10	5.42	5.70			5.33	6.23
Yield - SE											90.06	4.52
Yield - LSD (p = 0.05)											262.37	13.36

TABLE 2

Series 2 - BYDV Trials 1983/84

Site Details

	Site Number 1	2	3	4
Location:	Blythburgh, Suffolk	Ickburgh, Norfolk	Weeting, Norfolk	Southminster, Essex
Variety:	Igri	Igri	Igri	Halcyon
Drilling Date:	19/09/83	14/09/83	27/09/83	19/09/83
Applic. Date (Timing 1):	04/10/83	28/09/83	11/10/83	06/10/83
Aphid Status (Timing 1):	Occasional	None found	Occasional	Occasional
Applic. Date (Timing 2):	11/10/83	20/10/83	21/10/83	20/10/83
Aphid Status (Timing 2):	Occasional	Common	Occasional	Occasional
Applic. Date (Timing 3):	02/11/83	02/11/83	02/11/83	03/11/83
Aphid Status (Timing 3):	Occasional	Abundant	Common	Occasional

Trial Results

% Control of BYDV
Relative Yield (Untreated = 100)

Treatment	Rate g a.i./ha	Timing	Site Number 1	2	3	4	Mean all Sites	Mean excluding Site 2
DELTAMETHRIN	6.25	1	**89**	**100**	**95**	**100**	**96**	–
			119	360		157	212	138
DELTAMETHRIN	6.25	2	**97**	**100**	**100**	**100**	**99**	–
			129	298		160	196	145
DELTAMETHRIN	6.25	3	**98**	**100**	**95**	**100**	**98**	–
			125	278		157	187	141
DELTAMETHRIN + DELTAMETHRIN	6.25 + 6.25	1 + 3	**98**	**100**	**100**	**100**	**99**	–
			128	246		147	174	138
Untreated (**% of crop affected by BYDV**/Yield in t/ha)			**30**	**100**	**20**	**80**	**58**	–
			5.48	0.87		4.91	3.75	5.20
Yield - SE							48.59	13.77
Yield - LSD (p = 0.05)							153.23	50.03

This point was investigated in Series 2, where deltamethrin at 6.25 g a.i./ha was applied at a range of timings from crop emergence to early November (Table 2). At Site 1, Timing 1 showed limited foci suggesting that persistence of the early treatment was insufficient to control late aphid invasion. However, at Site 2, Timing 1 gave total control of a very high attack, despite aphids entering in large numbers after application. In general, control was most reliable from Timing 2 (mid October) which gave equivalent control levels to the two-spray programme.

It is clear that a flexible approach must be taken with respect to application timing. In very early-drilled crops treatments should be applied as soon as aphids are found in the crop, with a follow-up spray if necessary.

TABLE 3

Series 3 - O. florum Trials 1982/83

Site Details

	Site Number 1	2	3	4	5
Location:	Snettisham, Norfolk	Snettisham, Norfolk	Kineton, Warwicks.	Kineton, Warwicks.	East Raynham, Norfolk
Variety:	Rapier	Fenman	Avalon	Avalon	Rapier
Drilling Date:	20/09/82	20/09/82	15/09/82	05/10/82	18/09/82
Applic. Date: (Timing 1)	02/11/82	02/11/82	01/12/82	29/11/82	02/11/82
Applic. Date: (Timing 2)	28/01/83	28/01/83	02/02/83	02/02/83	26/01/83

Trials Results

Treatment	Rate g a.i./ha	Timing	% Control of O. florum Relative Yield (Untreated = 100) Site Number 1	2	3	4	5	Mean all Sites
DELTAMETHRIN	5.0	1	**65**	**58** 103	**55**	**55**	**56** 99	**58** 101
DELTAMETHRIN	6.25	1	**68**	**70** 99	**58**	**63**	**57** 102	**63** 101
DELTAMETHRIN	7.5	1	**84**	**74** 99	**71**	**75**	**71** 100	**75** 100
DELTAMETHRIN	6.25	2	**64**	**68** 102	**41**	**31**	**79** 99	**57** 101
Triazophos	630.0	2	**68**	**43** 105	**30**	**31**	**64** 100	**47** 103
DELTAMETHRIN + Triazophos	6.25 + 630.0	1 + 2	**90**	**83** 99	**90**	**70**	**82** 100	**83** 100
Untreated (**No. of 'dead-hearts'/m row of crop**/Yield in t/ha)			12	25 10.12	10	10	30 9.51	17 9.82
Yield - SE								1.48
Yield - LSD (p = 0.05)								4.93

Similar conclusions have come from independent trials (Port, 1983), and A.D.A.S. have recently amended their recommendations for 1984/85 accordingly (A.D.A.S. personal communication, 1984).

Yield data from the two series confirm the high level of yield reduction which can be caused by BYDV. At all sites, treatments gave an increase in yield ranging from 7-682% over the untreated value. As replication in these trials was low, differences within sites should be treated with caution. In particular, Site 2 in Series 2 was influenced by severe drought conditions, causing differential yield values across the trial area.

Overall findings confirm that deltamethrin applied at 5.0-7.5 g a.i./ha is a very effective treatment for controlling aphid vectors and reducing the incidence of BYDV in winter barley. This is supported by similar findings from French trials (Table 4) over a number of years where applications were made on aphid occurrence.

TABLE 4

France BYDV Trials 1979-1982 (Roussel Uclaf)

Treatment	Rate g a.i./ha	% Control of Aphid Vectors			Relative Yield (Untreated = 100)	
		Harvest Year			Harvest Year	
		1980	1981	1982	1980	1982
DELTAMETHRIN	5.0	100	100	-	110	-
DELTAMETHRIN	6.25	-	-	98	-	154
DELTAMETHRIN	7.5	100	100	100	111	155
Untreated (% Plants with aphids/Yield in t/ha)		38	22	41	4.30	3.79
Number of Trials		6	5	5	1	3

O. florum Control

The useful control of O. florum obtained by an autumn application of deltamethrin is clearly demonstrated in Series 3 (Table 3). It is felt that control is achieved either by killing the adult flies or that persistence of the chemical under cold, winter conditions, is sufficient to reduce larval numbers as they emerge. Control of the pest was also seen with deltamethrin applied at egg-hatch. Overall control in the trials was best from autumn deltamethrin followed by egg-hatch triazophos.

No consistent yield increases were seen from controlling this pest. However, observations on grain quality suggest that a more uniform maturity is obtained, whereas secondary tillering on untreated plots can lead to a proportion of immature grains in the sample.

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TRIADIMENOL SEED TREATMENT: IMPLICATIONS FOR TAKE-ALL

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ABSTRACT

Take-all was assessed in winter wheat and in winter barley in field plots which had been sown with seed treated with triadimenol (0.5 g/kg) and in plots sown with untreated seed. In the wheat experiment two sowing dates (7 September and 7 October) were compared at one seed rate (500 seeds/m^2), and in the barley experiment two seed rates (300 and 450 seeds/m^2) were compared for one sowing date (19 September). Infection developed rapidly in the wheat in autumn and became severe by summer. Infection was slight in the barley. Seed treatment did not significantly suppress take-all in either cereal.

INTRODUCTION

Triadimenol seed treatment of winter wheat suppressed infection by take-all (Gaeumannomyces graminis var. tritici) for about six weeks in Kansas, U.S.A. (Bockus 1983). In those conditions early autumn infection by take-all was related to yield loss and the reduction in take-all with seed treatment resulted in a yield increase. Seed treatment with other systemic fungicides failed to control take-all in British conditions (Jenkyn & Prew 1973; Prew & McIntosh 1975), but this was before the recent trend towards earlier sowing of winter wheat and concern over more severe root infection in autumn. Such early infection may be restricted by suitable seed treatment fungicides, but they are unlikely to control disease development in spring and summer. Although differences in amounts of infection in early and late sown wheat can persist throughout the growing season (Prew 1984) there is no evidence for autumn infection alone influencing yield. The effects of triadimenol, particularly in early sown cereals, are therefore being investigated.

MATERIALS AND METHODS

Seed of winter wheat cv Aquila (supplied untreated) was treated with triadimenol ('Baytan' at 2 g/kg) and methyl cellulose sticker in a mini-Rotostat. Plots (12 x 3 m) were drilled at 500 seeds/m^2 with either treated or untreated seed in four randomised blocks. Half the plots were drilled on 7 September and half on 7 October. In a similar experiment barley was drilled on 19 September 1983, and two seed rates (300 and 450 seeds/m^2) were compared.

Five 20 cm lengths of row were dug out from random positions in each plot at each of several samplings between October and May to assess take-all and other diseases. Ten lengths of row were taken for the late June or early July sample. After washing the root systems infected roots were counted and a take-all rating was calculated as % slight infection + (2 x % moderate) + (3 x % severe) (Prew & Dyke 1979).

RESULTS

In the wheat experiment take-all developed quickly and ten weeks after

each sowing date all plants were infected. By November the earlier sown wheat had 30% more roots infected than the later sown (Table 1). This difference persisted through to May, but by June had decreased to 15%. Take-all was severe in the summer, especially in the early sown plots. Seed treatment was often associated with a slight reduction in take-all (Table 1) but there was no statistically significant decrease in percentage of roots infected, or in take-all rating. There was less infection in the barley experiment (Table 2), and although there were no significant effects of treatment, there was a slight reduction in take-all with triadimenol at the larger seed rate, but only in March for the smaller seed rate. Results for samples after March are not yet available.

TABLE 1

The effect of triadimenol seed treatment on take-all in wheat crops sown on different dates

		% roots infected				Take-all rating
Sample time (Growth stage)		19 Oct (22)	21 Nov (20-23)	16 May (33)	21 June (77)	21 June (77)
Sowing date	Seed treatment					
7 Sept	Nil	68	76	61	85	268
7 Sept	Triadimenol	63	69	52	73	248
7 Oct	Nil	-	48	37	68	218
7 Oct	Triadimenol	-	43	37	63	213

TABLE 2

The effect of triadimenol seed treatment on take-all in barley crops sown on 19 September at different seed rates

		% plants infected		
Sample time (Growth stage)		25 Oct (20-22)	14 Dec (24-25)	19 Mar (30)
Seed rate (seeds/m^2)	Seed treatment			
300	Nil	6	30	43
300	Triadimenol	15	42	38
450	Nil	27	45	55
450	Triadimenol	9	40	46

DISCUSSION

Triadimenol seed treatment did not markedly affect autumn take-all in either the exceptionally early sown wheat or the later sown wheat or barley, nor did it influence later disease development. Although triadimenol has the potential to control take-all (Bockus 1983), the range of conditions in which the seed treatment can be effective may be very limited.

In early summer wheat plants were taller and greener in some plots where the seed had been treated with triadimenol and so there may have been beneficial effects of seed treatment unrelated to take-all. Such effects may be reflected in yields, which have still to be measured.

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FF4050 SEED TREATMENT - A NEW APPROACH TO CONTROL BARLEY DISEASES

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ABSTRACT

FF4050 is a new systemic fungicidal seed treatment containing flutriafol, ethirimol and thiabendazole. Applied at the rate of 500 ml/100 kg seed it provides dual mode of action against barley powdery mildew (Erysiphe graminis). Trials have demonstrated good crop safety. Mildew control and yield increases have been superior to current commercial treatments.

INTRODUCTION

UK winter and spring barley crops continue to be subject to heavy disease pressures, particularly as farmers strive for maximum yields through high fertiliser use, and early sowing of winter barley. In the absence of varieties with stable resistance, fungicide use is necessary to control diseases and optimise yield.

The most important disease of barley in the UK and N.W. Europe is powdery mildew caused by Erysiphe graminis. Ethirimol was introduced in 1969, the first seed treatment for systemic control of cereal powdery mildew. After its introduction, powdery mildew populations were examined over a period of six years and showed reduced sensitivity to the fungicide in those crops where it had been used. Nevertheless mildew control and yield benefits justified its use throughout this period. Its use on winter barley was withdrawn for a period of four years in order to avoid additional selection pressure during the autumn and winter (Shephard, Bent, Woolner and Cole, 1975). Use of ethirimol declined following the introduction of triadimenol/ fuberidazole as a seed treatment in 1978. This triazole fungicide offered good control of seed- and soil-borne diseases in addition to systemic control of powdery mildew and other air-borne diseases. Following extensive use of triazole foliar sprays and triadimenol-based seed treatments since 1978, reductions in the sensitivity of powdery mildews to these fungicides have also been noted (Fletcher & Wolfe 1982).

The reduction in powdery mildew sensitivity to triazoles has been concomitant with an increase in sensitivity of the same populations to ethirimol (Heaney et al, 1984). However, triazole fungicides have maintained reasonable efficiency against cereal powdery mildews, and as seed treatments their broad spectrum of action against seed- and soil-borne disease remains a major justification for their use. Work in Scotland showed that ethirimol efficiency had improved there in recent seasons (Stoddart & Northwood, 1984).

Generally it is accepted that disease control is less likely to be reduced through resistance when use is made of mixtures of compounds with differing modes of action. FF4050 is such a mixture being a liquid formulation containing 30g flutriafol, 400g ethirimol and 10g thiabendazole per litre. The recommended application rate is 500ml per 100kg of seed.

Skidmore et al 1983, described the control with flutriafol of all the important seed, soil and air-borne diseases of barley - loose smut (Ustilago nuda), covered smut (Ustilago hordei), seedling blight and foot rot (Fusarium spp.), leaf stripe (Pyrenophora graminea), seed-borne net blotch (Pyrenophora teres), powdery mildew (Erysiphe graminis hordei), leaf blotch (Rhynchosporium secalis), yellow rust (Puccinia striiformis) and brown rust (Puccinia hordei). This report describes laboratory and field studies which evaluated powdery mildew control and crop safety using FF4050 compared with ethirimol (+ mercury) and a standard triadimenol + fuberidazole mixture.

MATERIALS AND METHODS

FF4050 was tested from 1982 onwards on winter and spring barley. All trials were fully replicated using randomised block designs and were conducted throughout the main cereal growing areas of the UK. Plot sizes were 72 to 120 square metres. Crop safety was assessed in the field and laboratory. Crop emergence and establishment were evaluated by randomly selecting five 1 metre row lengths per plot and counting the number of normal plants. The standard MAFF germination test was also used, where four replicates each of 100 seeds were sown in Levington Universal compost at a depth of 15mm in seed trays, watered, covered, and kept at a constant 20°C for 6 days. Tests were assessed by a qualified seed analyst for the percentage of normal seedlings.

Disease assessments were made according to recognised guidelines on 10 to 25 leaves per plot and the percentage area of leaf covered by disease recorded. Trials were harvested using a small plot combine harvester and yields recorded. Where results from a single trial are reported, Duncan's multiple range test (Duncan, 1955) was used to compare statistically each treatment mean; values followed by a common letter are not significantly different at $P = 0.05$.

Seed was treated by either a Rotostat or Centaur applicator. FF4050 (3% flutriafol/40% ethirimol/1% thiabendazole as wv) was applied at 500ml/100kg of seed. Ethirimol was applied as 'Milstem' (58% wv ethirimol) at 670ml/100kg of seed. Triadimenol + fuberidazole was applied as 'Baytan' F (25% triadimenol/3% fuberidazole as ww) at 150g/100kg of seed. Mercury was applied as 'Ceresol' (2% wv phenyl mercury acetate) at 110ml/100kg of seed.

Details of the locations of field trials, barley varieties and drilling dates are shown below:

Trial No	Location	Variety	Drilling Date
EA 1/82	Walsham-le-Willows Suffolk	Georgie	27/3/82
EA 2/82	Rede, Suffolk	Georgie	26/3/82
NE 2/82	Dorrington, Lincs	Koru	28/3/82
EA 3/82	Balsham, Cambs	Maris Otter	27/9/83
EM 3/84	Horningsea, Cambs	Igri	26/9/83
SW 4/84	Bridgwater, Somerset	Sonja	23/9/83
NE 6/84	Sleaford, Lincs	Maris Otter	05/10/83
NA 21/84	Balsham, Cambs	Koru	07/3/84
EA 12/84	Norton, Suffolk	Georgie	16/3/84
SW 22/84	Tetbury, Glos	Georgie	07/3/84

RESULTS

Seed germination figures are presented in Table 1 for a range of important winter and spring barley varieties. FF4050 was safe with all varieties giving greater than the minimum 85% normal germination required by the Cereal Seed Regulations, 1980.

TABLE 1

% Germination of treated winter and spring barley varieties

Winter Barleys	Gerbel	Igri	Pirate	Tipper	Maris Otter
Untreated	98	98	98	97	98
FF4050	99	93	97	97	96
Triadimenol/fuberidazole	98	92	98	95	97

Spring Barleys	Kym	Atem	Patty	Triumph	Golden Promise
Untreated	94	98	93	98	98
FF4050	94	93	90	96	96
Triadimenol/fuberidazole	96	94	89	99	98

Table 2 presents the mean crop emergence and establishment figures from trials in 1982, 1983 and 1984 on winter and spring barley. FF4050 and the triadimenol/fuberidazole mixture caused a slight reduction in speed of emergence but eventual crop establishment was good.

TABLE 2

Crop emergence and establishment as % of mercury standard, 1982-84

Crop	Winter Barley				Spring Barley			
Year	1982	1983	1982	1983	1983	1984	1983	1984
Assessment	emergence		establishment		emergence		establishment	
No. of Trials	6	9	6	9	9	10	9	10
Mercury (Hg)	100	100	100	100	100	100	100	100
FF4050	84	88	91	95	89	87	97	99
Triad/fub'zole	86	89	90	96	90	93	95	99

Powdery mildew control after eight to thirteen weeks in 1982 from three trials on spring barley is presented in Table 3. Overall FF4050 was superior to the other treatments, and differences were statistically significant in trials EA1 and EA2 when assessed eight weeks after drilling.

TABLE 3

% Mildew control, spring barley, 1982

Trial No	EA1		EA2		NE2	
Wks after drilling	8	13	8	13	8	13
Untreated (Actual)	(12.9)a	(32.4)a	(18.4)a	(17.2)a	(33.0)a	(40.0)a
FF4050	99c	94b	96c	87c	99c	96c
Triad/fub'zole	95b	92b	89b	78b	98c	88c
Ethirimol (+Hg)	89b	96b	82b	52b	70b	37b
Leaf Assessed	L3	L1	L3	L2	L3	L2

Mildew levels in 1983 spring barley trials were generally low and data are not presented. However FF4050 gave superior mildew control to the other treatments. In 1984 FF4050 and ethirimol gave high levels of control on spring barley and were superior to triadimenol/fuberidazole at eight and thirteen weeks after drilling (Table 4). This difference was evident in eight trials out of ten in this series.

TABLE 4

% Mildew Control, spring barley, 1984

Trial No.	NA 21		EA 12		SW 22	
Wks after drilling	8	13	8	13	8	13
Untreated (Actual)	(3.4)a	(10.4)a	(7.7)a	(16.7)a	(15.7)a	(46.8)a
FF4050	99c	99c	90c	93c	99c	97c
Triad/fub'zole	80b	78b	72b	58b	90b	69b
Ethirimol (+Hg)	98c	97c	88c	85c	99c	97c
Leaf Assessed	L4	L4	L2	L3	L3	L2

Grain yields demonstrated the superiority of FF4050 compared to triadimenol/fuberidazole and ethirimol alone (Table 5).

TABLE 5

Yield as % untreated, 1982 and 1984

Trial No.	EA1/82	EA2/82	NE2/82	NA21/84	EA12/84	SW22/84
Untreated (t/ha)	(5.13)a	(4.92)a	(4.35)a	(5.44)a	(4.95)a	(5.53)a
FF4050	128c	116c	118b	115b	126c	109b
Triad/fub'zole	120b	110b	113b	110b	110b	107b
Ethirimol (+Hg)	121b	99a	104a	114b	122c	112b

TABLE 6

% Mildew control, winter barley, Autumn 1983

Trial No	EA3		EM3		SW 4	NE6
Wks after drilling	8	11	7	11	8	12
Untreated (Actual)	(10.8)a	(20.8)a	(25.3)a	(10.6)a	(24.5)a	(4.1)a
FF4050	92c	90c	92c	80c	95b	85c
Triad/fub'zole	74b	74b	72b	56b	91b	77bc
Ethirimol (+Hg)	90b	87c	90c	65b	87b	75b
Leaf Assessed	L3	L3	L3	L3	L3	L3

Autumn mildew control on winter barley was also superior with FF4050 compared to triadimenol/fuberidazole and ethirimol in four trials (Table 6).

DISCUSSION

A major consideration in the development of a new seed treatment is crop safety. FF4050 was safe to all winter and spring varieties evaluated in laboratory germination and field tests over three years.

Field trials in 1982 demonstrated improved mildew control with the two triazole-based treatments compared to ethirimol. However, in 1984, control after thirteen weeks with ethirimol was particularly good in two trials (LN20 and SW22) with high disease pressure. Also better mildew control with FF4050 compared to the triadimenol/fuberidazole mixture was observed in 1984. These effects may be attributable to the greater sensitivity of mildew populations to ethirimol in 1984 than in 1982. Yield increases obtained from fungicide treatment correspond well with the levels of mildew control achieved.

Overall the results confirm that flutriafol with ethirimol forms the basis of an excellent fungicide mixture. It gave a more stable and better performance through time than either ethirimol or triadimenol/fuberidazole alone. This greater predictability of performance against mildew, the major disease of barley, in a situation of changing pathogen sensivitity, is of great value to the grower.

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EVALUATION OF TRIADIMENOL AND OTHER CHEMICAL SEED TREATMENTS FOR THE CONTROL OF ERGOT (*CLAVICEPS PURPUREA*) IN CONTAMINATED SEED

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ABSTRACT

Seed treatment formulations containing triadimenol, bitertanol and phenylmercury acetate were applied to sclerotia of *Claviceps purpurea*. Results of field trials are reported in which the treated sclerotia were established together with blackgrass (*Alopecurus myosuroides*) within plots of winter wheat. Treatments containing triadimenol and bitertanol significantly reduced the % germination of sclerotia, the number of ascocarps formed and the number of ascocarps emerged above the soil surface at wheat anthesis. Although weather conditions were unsuitable for infection of wheat, ascospore infection of blackgrass did occur. There was a positive correlation between the number of emerged ascocarps and subsequent infection of blackgrass.

INTRODUCTION

The use of spray applications of protectant and systemic fungicides to prevent ascocarp formation on sclerotia of *Claviceps purpurea* from cultivated grasses has been investigated in the USA (Hardison 1977).

In the UK, seed dressing formulations of phenylmercury acetate, triadimenol and triadimenol plus fuberidazole were evaluated for suppression of germination of cereal ergot sclerotia following a period of burial in field soil (Shaw 1984). These preliminary investigations demonstrated that seed treatments containing triadimenol reduced both the % germination of sclerotia and the number of ascocarps formed. Inclusion of fuberidazole in a formulation with triadimenol did not appear to have had any additional effect on germination of the sclerotia. The degree of suppression of germination of sclerotia was found to vary when cereal ergots from different sources were used. It was suggested that retention of chemicals on the sclerotia may have been affected by many factors including surface texture, degree of absorption and the amount of rainfall during the period of burial of sclerotia in soil.

The present investigation seeks to further evaluate the potential use of seed treatments containing triazole fungicides for control of ergot sclerotia in cereal seed.

MATERIALS AND METHODS

Fungicide treatment of sclerotia

Samples of sclerotia requiring chemical treatment were first mixed with 5kg wheat grain to provide sufficient bulk for application of chemicals in a mini-Rotostat at the manufacturer's recommended rates. The following dry seed treatment formulations (DS) were used: 25% triadimenol plus 3% fuberidazole w/w (375 mg a.i. triadimenol plus 45mg a.i. fuberidazole/kg sclerotia, 'Baytan', Bayer); 37.5% bitertanol plus 2.3% fuberidazole w/w (563mg a.i. bitertanol plus 35mg a.i. fuberidazole/kg sclerotia, UK121, Bayer); phenylmercury acetate (PMA)(44mg a.i. (mercury)/kg sclerotia, 'Agrosan D', Plant Protection). In addition, a flowable seed treatment formulation (FS) containing 187.5g triadimenol/litre plus 22.5g fuberidazole

/litre (375mg a.i. triadimenol plus 45mg a.i. fuberidazole/kg sclerotia, UKO82f, Bayer) was used. Treated sclerotia were subsequently separated from the wheat grain/sclerotia mixture.

Sclerotia

Three of the samples (A, B and C) of sclerotia used in the present study (Table 1) were taken from collections that have also been used in previously reported investigations (Shaw, 1984).

TABLE 1

Sources of sclerotia of *Claviceps purpurea*

Ergot collection	Original Source		Multiplication of sclerotia		Date sclerotia harvested
	Host	Locality	Host	Locality	
A	Wheat	Essex	-	-	1981
B	Wheat	Essex	-	-	1982
C	Triticale	Cambridge	Triticale	Ewell, Surrey	1983
E	(as C above)		Wheat	Kent	1983

Experimental design and assessment

The basic unit in each trial consisted of a small plot (7.5m x 1.5m) of winter wheat cv. Rapier. Within each plot, plants along a 1.5m length of a central drill row were removed and replaced by eight, 10cm square plastic pots sunk into the ground so that the rim of each pot was level with the soil surface. In each pot, one sample of 20 treated or untreated sclerotia was buried at approximately 2cm depth. Within each plot, two samples each of ergot collections A,B,C and E (see Table 1) were thus positioned in a single row of plastic pots. All samples of sclerotia in a plot received the same treatment. Five treatments were established: one untreated control and four chemical treatments described above. Four replicates of the treatments (plots) were arranged in a randomised block design. Plots containing sclerotia were alternated with discard plots of wheat.

In addition, two plastic pots containing seedlings of blackgrass (*Alopecurus myosuroides*) were interspersed along each row of pots containing sclerotia. Ergot sclerotia and blackgrass were established at each trial site on dates shown in Table 2. At GS 60 (early anthesis), all pots were examined *in situ* to determine the number of ascocarps visible above the soil surface. At this time, four pots of sclerotia (one sample each of collections A,B,C and E) were removed from each plot, leaving behind a duplicate set of material to be examined at a later date. Sclerotia were washed and sieved from the soil and examined under a stereomicroscope. Germination of sclerotia (here defined as the presence of at least one ascocarp forming on a sclerotium), numbers and stage of development of ascocarps and frequency of secondary colonisation of sclerotia were recorded. Pots containing blackgrass were also removed from the trial at GS 60 and incubated in a humid greenhouse for 21-24 days. All inflorescences were then removed, soaked and shaken in 200ml water for 30 min to obtain a suspension of conidia produced by ergot infection. Using a counting chamber, the total number of conidia in washings from blackgrass in each plot was estimated.

Trial sites

Sites (Table 2) were selected to provide contrasting climatic conditions and different soil types. At Aberystwyth the trial was situated on an exposed hillside, elevation 200m. Here, the stony soil was a silty

clay loam above solid rock. Although total rainfall was greater than at Great Dunmow, rainfall during May and June was low. Consequently the well drained soil became relatively dry during the period when sclerotia were germinating. At Great Dunmow the trial was on a chalky boulder clay soil. Here, no rain was recorded between 12 April and 14 May but thereafter until 20 June a few heavy showers did occur, causing soil moisture and humidity within the crop canopy to be generally high. Hot, dry weather conditions prevailed throughout the flowering period of the winter wheat cv. Rapier.

TABLE 2

Trial sites and rainfall recordings

Location of trial	Ergot sclerotia: Dates buried (1983)	Ergot sclerotia: Dates recovered (1984) Batch 1	Ergot sclerotia: Dates recovered (1984) Batch 2	Rainfall: May (mm)	Rainfall: 1 June to 21/22 June (mm)	Rainfall: During period of burial of sclerotia (mm)
Throws Farm, Great Dunmow, Essex	27 Oct	21 June	3 July	77	33	356
Welsh Plant Breeding Station, Aberystwyth	4 Nov	22 June	-	47	34	480

RESULTS

Results of germination of sclerotia are shown in Table 3, whilst Table 4 shows the relationship between emergence of ascocarps above the soil surface and subsequent infection of blackgrass plants. No infection of wheat was found at either of the two trial sites.

Many sclerotia were found to be colonised by fungal saprophytes. This was particularly evident at Aberystwyth where 90-100% of untreated sclerotia and sclerotia treated with bitertanol or triadimenol had fungal growth over part of their surfaces. Only 10-30% of sclerotia treated with PMA were similarly affected. In view of the decay of sclerotia and continued dry weather at this site, examination of the later harvested samples of sclerotia was not completed.

DISCUSSION

Germination of sclerotia was assessed for a total of 36 combinations of four different collections of ergot sclerotia treated with three formulations containing triazole chemicals at two trial sites. In 34 of these combinations there was a significant reduction of % germination compared with untreated sclerotia. Least well controlled were sclerotia from collections A (39-83% reduced germination) and B (64-97% reduced germination), whilst 84-100% reduction of germination of sclerotia from collections C and E was achieved. The reason for varying levels of suppression of germination of sclerotia from different sources remains unclear and is a subject for further investigation.

In cases where substantial numbers of sclerotia treated with bitertanol and triadimenol did germinate, the proportion of immature to mature asco-

TABLE 3

Effects of bitertanol plus fuberidazole (bitertanol F.), triadimenol plus fuberidazole (triadimenol F.) and phenylmercury acetate (PMA) on ascocarp formation by ergot sclerotia.

Ergot (see Table 1)	Date Sclerotia removed from plots	Fungicide treatment of sclerotia	Germination of sclerotia Mean % (AT+)	Mean number of ascocarps ++ Immature with <2mm stipe	Developing or mature with >2mm stipe	Emerged above soil surface on 21June	Emerged above soil surface on 3July
Throws Farm, Great Dunmow, Essex							
A	21 June	Untreated control	26.2 (30.6)	3.0	5.3	3.0	
		Triadimenol F.(DS)	16.0 (20.4)	2.5	2.0	0	
		Bitertanol F.	8.4 (14.1)	2.8	1.0	0	
		Triadimenol (FS)	4.5 (8.7)	0	2.3	1.0	
		PMA	27.6 (31.5)	2.8	4.8	3.0	
		LSD (p=0.05)	(15.2)	NS	NS	NS	
	3 July	Untreated control	19.0 (22.6)	3.8	1.8	1.8	1.0
		Triadimenol F.(DS)	3.4 (7.5)	1.0	0	0	0
		Bitertanol F.	6.3 (12.5)	1.0	0.5	0	0
		Triadimenol F.(FS)	4.7 (6.4)	0.5	0.5	0	0
		PMA	23.9 (29.2)	3.8	2.5	1.5	1.0
		LSD (p=0.05)	(14.7)	2.2	NS	1.1	NS
B	21 June	Untreated control	34.2 (35.7)	2.5	7.8	2.0	
		Triadimenol F.(DS)	7.2 (13.1)	0.5	0.8	0	
		Bitertanol F.	12.2 (17.7)	0.8	1.5	0	
		Triadimenol F.(FS)	5.8 (12.0)	0.8	0.3	0	
		PMA	31.1 (33.9)	1.0	15.3	4.3	
		LSD (p=0.05)	(12.4)	NS	2.9	2.5	
	3 July	Untreated control	33.3 (35.2)	5.5	5.3	3.3	2.5
		Triadimenol F.(DS)	8.8 (14.4)	2.5	0.5	0	0
		Bitertanol F.	10.2 (18.6)	1.3	0.5	0	0
		Triadimenol F.(FS)	6.2 (10.3)	2.5	0	0	0
		PMA	33.8 (35.5)	5.8	6.0	3.5	3.0
		LSD (p=0.05)	(11.7)	NS	2.2	2.0	1.5
C	21 June	Untreated control	91.0 (75.2)	31.8	46.5	5.8	
		Triadimenol F.(DS)	3.8 (9.7)	0.8	0	0.3	
		Bitertanol F.	9.3 (15.1)	2.0	0	0	
		Triadimenol F.(FS)	8.3 (14.5)	1.8	0.3	0	
		PMA	75.1 (61.1)	9.0	38.3	1.3	
		LSD (p=0.05)	(15.2)	8.4	9.0	NS	
	3 July	Untreated control	70.0 (56.9)	11.8	12.3	4.0	4.0
		Triadimenol F.(DS)	0 (0)	0	0	0	0
		Bitertanol F.	0 (0)	0	0	0	0
		Triadimenol F.(FS)	0 (0)	0	0	0	0
		PMA	56.6 (48.7)	11.0	11.3	0.5	1.5
		LSD (p=0.05)	(4.5)	5.3	4.5	1.6	2.2

+ Angular transformed data.
++ Mean number of ascocarps per sample of 20 sclerotia sown.

cont'd....

TABLE 3 (continued)

Ergot (see Table 1)	Date Sclerotia removed from plots	Fungicide treatment of sclerotia	Germination of sclerotia Mean % (AT+)	Mean number of ascocarps ++ Immature with <2mm stipe	Developing or mature with >2mm stipe	Emerged above soil surface on 21June	3July
Throws Farm, Great Dunmow, Essex							
E	21 June	Untreated control	87.4 (70.4)	52.0	43.8	1.0	
		Triadimenol F.(DS)	2.6 (4.7)	1.0	3.8	0	
		Bitertanol F.	0 (0)	0	0	0	
		Triadimenol (FS)	1.3 (3.3)	0.3	0	0	
		PMA	50.8 (45.5)	17.5	17.5	4.0	
		LSD (p=0.05)	(13.0)	11.8	17.1	NS	
	3 July	Untreated control	59.8 (50.9)	26.8	13.5	0.5	0.8
		Triadimenol F.(DS)	0 (0)	0	0	0	0
		Bitertanol F.	0 (0)	0	0	0	0
		Triadimenol F.(FS)	0 (0)	0	0	0	0
		PMA	22.4 (28.3)	3.8	5.3	0	0
		LSD (p=0.05)	(6.7)	7.6	5.6	NS	NS
Welsh Plant Breeding Station, Aberystwyth, Dyfed						22 June	
A	22 June	Untreated control	22.0 (27.8)	0.8	5.3	2.0	
		Triadimenol F.(DS)	6.4 (10.4)	0.3	0.8	0	
		Bitertanol F.	8.0 (16.2)	0.8	1.3	0	
		Triadimenol F.(FS)	5.8 (7.2)	0.5	0.3	0	
		PMA	35.4 (36.5)	3.0	11.0	3.3	
		LSD (p=0.05)	(13.3)	NS	4.5	1.9	
B	22 June	Untreated control	42.2 (40.5)	4.3	5.8	1.0	
		Triadimenol F.(DS)	1.4 (3.4)	0.3	0	0	
		Bitertanol F.	7.5 (15.9)	1.3	0	0	
		Triadimenol F.(FS)	2.1 (4.2)	0.3	0	0	
		PMA	45.9 (42.6)	5.3	10.8	3.5	
		LSD (p=0.05)	(7.9)	2.1	5.7	2.3	
C	22 June	Untreated control	58.9 (50.2)	9.5	9.0	1.3	
		Triadimenol F.(DS)	9.6 (17.9)	2.3	0	0	
		Bitertanol F.	5.0 (9.2)	1.5	0	0	
		Triadimenol F.(FS)	3.0 (7.1)	0.8	0.8	0	
		PMA	85.2 (67.6)	16.8	21.5	3.0	
		LSD (p=0.05)	(10.2)	4.9	9.0	NS	
E	22 June	Untreated control	45.7 (42.5)	9.5	6.8	1.0	
		Triadimenol F.(DS)	2.5 (6.5)	0.5	0	0	
		Bitertanol F.	1.3 (3.2)	0	0.3	0	
		Triadimenol F.(FS)	0 (0)	0	0	0	
		PMA	44.4 (41.7)	10.8	6.5	0.8	
		LSD (p=0.05)	(8.0)	3.5	3.4	NS	

+ Angular transformed data.
++ Mean number of ascocarps per sample of 20 sclerotia sown.

TABLE 4

Numbers of conidia in washings from inflorescences of A. myosuroides in relation to the number of ascocarps emerging above the soil surface from treated and untreated sclerotia

Fungicide treatment of sclerotia	Great Dunmow		Aberystwyth	
	Mean number of ascocarps	Mean number of conidia($x10^7$)	Mean number of ascocarps	Mean number of conidia($x10^7$)
Untreated control	21.3	12.7	8.0	67.9
Triadimenol F.+(DS)	0.3	1.6	0	1.3
Bitertanol F.	0	0	0.3	6.1
Triadimenol F.(FS)	1.0	0.4	0	13.0
PMA	18.0	20.8	14.5	134.0
LSD	8.9	11.1	4.6	70.4
r Ascocarps vs conidia	0.761(19df)		0.592(19df)	

+ Plus fuberidazole

carps formed was generally greater than with untreated and PMA treated samples. This indicates delayed development of ascocarps on germinating sclerotia treated with triazole chemicals. The combined effects of reduced % germination and delayed ascocarp development are demonstrated in results showing the number of ascocarps emerged above the soil surface at anthesis of wheat. This is a critical factor determining the potential for ascospore infection of wheat which is only susceptible for a short time during flowering. In the trials reported here, weather conditions were not conducive to infection of wheat, but blackgrass, whose protogynous flowering mechanism and exposed stigmas increase susceptibility to ergot, did become infected and subsequently produce ergot honeydew bearing a large number of conidia. Significantly greater numbers of conidia were produced on blackgrass from plots containing untreated and PMA treated sclerotia than on blackgrass from plots containing sclerotia treated with seed treatment formulations containing triadimenol and bitertanol.

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FIELD STUDIES ON THE EFFECTS OF A TRIADIMENOL BASED SEED TREATMENT ON WINTER WHEAT 1978-1984.

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ABSTRACT

Trials and observations between 1978 and 1984 show that a triadimenol/fuberidazole seed treatment on winter wheat will control a range of foliar diseases over the winter period and reduce disease levels in the spring and summer. Additionally it can have a useful but variable effect on stem base diseases which may persist throughout the season. Although some inhibition of early plant growth can result from treatment, a positive effect follows during the tillering phase whereby tiller size and strength are improved. Beneficial effects on yield and lodging are shown but these cannot always be associated with disease control.

INTRODUCTION

Wainwright *et al* (1979) reported that a formulation of triadimenol/fuberidazole was an effective treatment for the major seed borne pathogens on autumn drilled wheat, at the same time providing control of mildew *(Erysiphe graminis)*, at least over the winter period.

Since 1978 trials and observation plots have been laid down across the main cereal growing areas of the UK to further examine the effect of this formulation on winter wheat under practical farming conditions.

MATERIALS AND METHODS

In all trials a dry seed treatment containing 25% triadimenol and 3% fuberidazole, known as 'Baytan' and referred to in this paper as Triadimenol ST, used at the rate of 150gm/100kg seed, was compared with seed treated with the recommended rate of a phenyl mercury acetate formulation (Standard ST).

Trial Details

Series	Year	Number	Type	Plot size	Sowing Date	Cultivars
A	1978/79	10	Replicated split plots	22.5 sq m	Oct/Nov	Hobbit Sportsman
B	1981/82	13	Single large split plots	0.5-1ha	Oct/Nov	Brigand
C	1983/84	9	Unreplicated large plots	0.2-0.5ha	Sept/Oct	Avalon, Rapier, Stetson, Moulin, Galahad, Longbow

Series A was drilled with an Oyjord, and farm drills were used in Series B and C. Target depth was 2 - 4 cm, with the drills calibrated in an attempt to achieve identical sowing rates with each treatment. Series B additionally compared both treatments ± a full spring/summer spray programme. In Series C both treatments were subjected to the farm spray programme. Where the use of sprays is referred to this usually consisted of triadimefon + carbendazim at GS 30/32, followed by triadimefon + captafol at GS 39/55. Many opportunities were also taken to assess additional sites, usually where farmers and seed producers were making their own comparisons.

Assessments were made of plant establishment, crop growth including tillering, plant weight and height, ear numbers and yield. Diseases assessed included mildew, leaf spot *(Septoria tritici and S.nodorum)*, brown rust *(Puccinia recondita)*, eyespot *(Pseudocercosporella herpotrichoides)*, sharp eyespot *(Rhizoctonia cerealis)*, and *Fusarium spp*.

RESULTS

Foliar Airborne Disease Control

A total of 166 assessments of foliar disease levels have been made between December and July. Results are presented in TABLE 1 from assessments carried out in the winter/spring period. These show a high level of mildew and *Septoria tritici* control which can still exceed 80% up to April, this effect being comparable to a spray of triadimefon in Jan/Feb.

TABLE 1 DISEASE CONTROL (SERIES C + OTHER LARGE PLOT COMPARISONS 1983/84)

			Mean % Control			
Disease	Season	Comparisons	January	February	March	April
Mildew	82/83	(19)	87	64	72	84
	83/84	(52)	95	92	90	59
Septoria tritici	82/83	(11)	-	86	85	93
	83/84	(48)	100	87	75	74

Other data came from two sites in 1981/82 involving 7 cultivars in large plot trials where Triadimenol ST gave a high level of mildew control (94%) in March/April, but which had declined by the end of May.

In the Oct/Nov drilled trial series (TABLES 2 and 3), Triadimenol ST was affecting levels of mildew, septoria and brown rust in the summer, on the flag leaf and the ear. The use of Triadimenol ST in combination with a fungicide spray programme increased the control of all four diseases.

TABLE 2 MEAN % MILDEW CONTROL WITH TRIADIMENOL ST (6 sites in Series A)

Treatment	Winter	May-June	July	Ear
Standard ST + Spray*	-	70	57	35
Triadimenol ST	100	70	64	41

* Triadimefon applied at GS 12/24.

TABLE 3 SUMMER DISEASE CONTROL WITH TRIADIMENOL ST + SPRAYS (Series B)

	Mean % Control			
	S.tritici	*S.nodorum*	Brown rust	
Treatment	May-June (1 site)	July (8 sites)	Flag leaf (7 sites)	Top 3 lvs (5 sites)
Standard ST (% infection)	(7)	(33)	(7)	(12)
Triadimenol ST	62	9	44	60
Standard ST + Sprays	81	49	73	92
Triadimenol ST + Sprays	93	59	82	94

Stem Base Diseases

Initial data on these diseases came from Series A where Triadimenol ST, in two out of the five trials, gave a 30-40% reduction in tillers infected with eyespot and a 70% reduction in severe infection. However there was no effect in the other three trials. Two of the trials in Series B also produced an effect where Triadimenol ST affected the severity of both diseases (TABLE 4) but did not reduce total levels.

By GS 25/32 at many sites a reduction in stem base browning was noted (TABLE 5). Eyespot was accurately assessed on 30 occasions, sharp eyespot on 6, and fusarium on 17. Levels of these diseases were also assessed after the plots had received a full foliar fungicide spray programme (TABLE 6).

TABLE 4 CONTROL OF SEVERE 'EYESPOTS' (more than 75% stem girdled) (Series B)

% Reduction in tillers severely infected at GS 75

	SHARP EYESPOT		EYESPOT	
	-Sprays	+Sprays	-Sprays	+Sprays
Standard ST	0	22	0	75
Triadimenol ST	11	56	75	100
Level of disease on Standard ST - Sprays	36%		12%	

TABLE 5 EARLY STEM BASE DISEASE CONTROL WITH TRIADIMENOL ST (Series C)

% Reduction in tillers affected at GS30-32

	AVALON	RAPIER	STETSON	LONGBOW	GALAHAD	MEAN	(Infection) (Range)
BASAL BROWNING	58	25	+20	50	37	41	(4-63%)
EYESPOT	58	5	60	73	53	53	(6-11%)
SHARP EYESPOT	50	28	100	33	100	71	(14-36%)

+ signifies an increase in infection.

At this early stage an increase in *Fusarium culmorum* levels with Triadimenol ST was recorded in 65% of cases.

TABLE 6 LATE 'EYESPOT' CONTROL WITH TRIADIMENOL ST (3 sites Series C)

% Reduction in tillers infected at GS68-85

	AVALON	RAPIER	STETSON	LONGBOW	GALAHAD	MEAN	(Infection) (Range)
EYESPOT							
Total infection	14	40	+53	0	38	12	(13-68%)
Moderate + Severe	54	78	+92	17	76	28	(12-41%)
SHARP EYESPOT							
Total infection	82	+48	40	+4	60	36	(19-39%)
Moderate + Severe	81	100	72	73	85	78	(7-24%)

+ signifies an increase in infection.

Effects on Growth and Yields

TABLE 7 MEAN % FIELD ESTABLISHMENT* OF TRIADIMENOL TREATED SEED.

	Series B	Series C
Triadimenol ST	81.0	74.9
Standard ST	80.3	73.7

* Based on the number of seeds sown and number of plants emerged.

Early Growth

In some trials triadimenol led to a delay of 2-5 days in emergence and visual grading of the crop mass indicated that this delay could result in a reduction of aerial crop biomass up to 100 days after drilling, although in Series A this averaged only 5% at this time. This was greatest where drilling was late or deeper than 4 cm, and confirms the findings of Wainwright *et al* (1979). Specific inhibition was noted in coleoptile internode length and coleoptile tiller production (TABLE 8).

The earliest, more critical assessment of crop mass in Series C was made in January and revealed no difference in plant dry weight. Thereafter assessments on all but tiller production showed positive effects from the Triadimenol ST (TABLE 9).

TABLE 8 EFFECT ON COLEOPTILE INTERNODE AND TILLERS (2 sites Series C)

	Standard ST	Triadimenol ST
Coleoptile internode length (cm) (Mean of 6 varieties)	1.56	0.22
% Plants with Coleoptile Tiller (Mean of 3 varieties)	35	13

The result of the coleoptile internode reduction was to place the crown roots deeper than with the Standard ST.

TABLE 9 EFFECTS OF TRIADIMENOL ST ON GROWTH OF WINTER WHEAT (Series C)

Data are expressed as percentages relative to Standard ST.

Cultivar	AVALON	RAPIER	STETSON	LONGBOW	GALAHAD	MEAN
Plant Height ≠	106	106	117	107	111	109
Plant Weight ≠	106	109	112	116	106	110
Tillers/Plant* ≠	85	84	91	82	79	84
Tiller Weight ≠	119	115	132	130	126	124
Tiller Survival	128	108	112	119	130	119
Ears/Plant	109	90	103	98	103	100

≠ Assessed at GS 30/32.
* Includes the main shoot.

At one site growth assessments, made on 4 occasions between GS 11-22 and GS 32, showed that the peak tiller number with Triadimenol ST was reduced by 20%, but that the final number was down by only 5%.

The effect on shoot weight suggests that the strength of individual tillers is increased, and some confirmation for this was to be found in assessments of crop lodging at GS 75/85 (TABLE 10).

TABLE 10 % AREA OF PLOTS LODGED (1 site Series B)

Cultivar	AVALON	RAPIER	STETSON	LONGBOW	GALAHAD	MOULIN
Standard ST	45	90	50	27	80	75
Triadimenol ST	11	80	25	15	15	25

This 50% reduction in lodging with Triadimenol ST cannot be fully explained by the effect on stem base diseases.

Yields and Grain Quality

Series A, sown in Oct/Nov, produced no yield differences due to Triadimenol ST or to an autumn spray of triadimefon, despite some positive effects on disease levels from both treatments. However in 1981/82 using the variety Brigand, susceptible to most of the important foliar diseases, yield increases were recorded (TABLE 11).

TABLE 11 MEAN YIELD INCREASES FROM TRIADIMENOL ST (t/ha) (Series B)

		October sown		October sown
No of trials	All trials (14)	(12)	(10)+	After cereals (8)
In absence of spray programme	·215	·257	·347	·412
Where spray programme used	.336	.462	.697	.645

+ Omitting the results from trials where seed was sown 5 - 8 cm deep and yield reductions occurred.

Except at two sites in Series A and B, Triadimenol ST gave no positive effect on grain quality, as measured by grain size and hectolitre weight. In one case this was attributable to the effect of Triadimenol ST on eyespot, and in the other on *Septoria nodorum*.

In 1982/83 no formal trials were laid down but 34 large plot comparisons, covering eight varieties were carried out by farmers and seed producers. The majority of these were sown in Oct/Nov (TABLE 12).

TABLE 12 YIELDS FROM 34 LARGE PLOT COMPARISONS 1982/83

	Mean Yield t/ha
Standard ST	7.452
Triadimenol ST	7.904

It is anticipated that the yield results from the 1983/84 studies will be presented at the conference.

DISCUSSION

These studies show that triadimenol/fuberidazole seed treatment is able to provide consistent control of mildew and *Septoria tritici* over the winter in a range of autumn sown wheat varieties grown throughout the UK, under the differing conditions of 3 seasons. This effect continued until April/May and resulted in improved control being obtained with the spring/summer fungicide programmes, an effect also shown with brown rust, which does not usually manifest itself until GS39.

The prolonged period of control experienced in many trials is probably solely due to disease control during the pre-winter period, and suggests that Triadimenol ST will be of greatest benefit on early drilled crops and those following wheat crops, where the inoculum is high in the autumn/winter.

Early reduction of basal diseases was consistent, but the effects on specific stem base diseases were less so, though in the majority of cases the use of Triadimenol ST resulted in lower disease levels of both 'eyespots' at the end of tillering and after ear emergence. Eyespot and sharp eyespot were reduced in 50-60% of cases, although this was improved to 70-80% when only the more severe infections were considered. However in some situations levels were not affected or, less often, increased. These variations occurred across sites and varieties and provide an area for investigation. It is possible that the effect on stem base diseases is a combination of the control of early infections plus stronger, more resistant plant stems. Differences in tiller density could also alter disease patterns.

Triadimenol ST appears to reduce or inhibit early growth, but this effect is reversed during the tillering phase, with increases in plant weight and height. Tillering is delayed and/or reduced, but tiller survival is improved so that ear numbers/unit area are not affected. This improvement in growth during the late winter-early spring could be associated with a deeper root system, produced as a result of coleoptile growth inhibition. Heavier tillers and improved tiller survival both suggest an increase in tiller strength, a factor which seems to be confirmed by the reduction in lodging.

Yield data over 3 years indicate no adverse effects with this early delay, indeed in 2 seasons, on disease susceptible varieties, mean yield increases of from 3-9% were obtained, with the highest responses from crops sown in Sept/Oct, or where they followed straw crops. The greatest benefit was obtained where Triadimenol ST was followed by a full foliar fungicide programme, though this could not always be associated with disease control.

ACKNOWLEDGEMENTS

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FF4021 AND FF4022, TWO NEW NON-MERCURIAL SEED TREATMENTS BASED ON CARBOXIN

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ABSTRACT

FF4021 and FF4022 are two new liquid cereal seed treatments based on the active ingredients carboxin, thiabendazole and imazalil.

In trials carried out between 1981 and 1984, FF4021 gave excellent control of the major seed borne pathogens of wheat and rye, such as Fusarium spp., Septoria nodorum, Ustilago nuda, Tilletia caries and Urocystis occulta. FF4022 gave excellent control of the major seed borne pathogens of barley and oats such as Fusarium spp., Ustilago spp. and Pyrenophora graminea, and useful control of P. teres and P. avenae.

Both products had a wide margin of crop safety and were safely applied to seed in mixture with several co-pesticides. These products offer a viable alternative to the currently used organomercury-based products with an important advantage over organomercury in their control of loose smut diseases.

INTRODUCTION

Cereal seed can be infected by a variety of seed and soil-borne diseases which affect crop establishment, grain quality and yield.

Mercury based seed treatments have been extensively used over the last 50 years in the United Kingdom to provide effective control of the major cereal seed and soil-borne diseases. The continuing need for treatment is demonstrated wherever seed treatment is omitted (Hewett, 1974).

This paper describes trials carried out in the UK between 1981 and 1984 with two new seed treatment products, 'Cerevax' (FF4021) based on carboxin and thiabendazole (TBZ) and 'Cerevax' Extra (FF4022) based on carboxin, TBZ and imazalil. FF4021 was used on wheat and rye and FF4022 was used on barley and oats. The disease control spectrum, crop safety and compatibility of both products was demonstrated.

FF4021 and FF4022 are shown to be viable alternatives to organomercury based products.

MATERIAL AND METHODS

Infected seed was obtained from the Official Seed Testing Station (OSTS) at Cambridge with the following exceptions:

Bunt (Tilletia caries)

Bunt spores collected in the previous season were applied at a rate of 2g (ICI trials) or 5g (Uniroyal trials) per kg of wheat seed.

Fusarium culmorum

Wheat seed was inoculated using a spore soak of a suspension of $1x10^6$ spores/ml of an isolate of F. culmorum known to be pathogenic on cereals. Seed was air-dried and stored at 10^oC before chemical treatment.

The contents and normal rates of use of FF4021 and FF4022 are given in Table 1. Both products are aqueous-based flowable concentrate (FS) formulations. Storage tests have shown that these formulations remain stable, even at elevated temperatures.

TABLE 1

Rates of a.i., product application rates and theoretical seed loadings of FF4021 and FF4022.

Product	Crop Use	Rate (ml/ 100 kg Seed)	Carboxin		TBZ		Imazalil	
			A	L	A	L	A	L
FF4021	Wheat, Rye	250	36%	900	2.5%	50	-	-
FF4022	Barley, Oats	200	30%	600	2.5%	50	2%	40
	Barley Basic Seed	300	30%	900	2.5%	75	2%	60

A = % a.i. in product L = loading, ppm a.i. on seed

In Uniroyal trials 200g quantities of seed were treated in a 1.5 litre, wide neck bottle by micropipetting an appropriate quantity of the treatment into the bottles and spreading it evenly around the base and lower sides of the bottle. The seed was poured in, the top replaced and the bottle quickly and vigorously shaken to ensure an even coating of the seed. In ICI trials seed was treated in 400g quantities using a bench mounted mini-'Rotostat'.

Sowing rates equivalent to 150-190 kg seed/ha were used. Field plots were sown by hand or using a motorised small plot drill. The plot size varied from 1m x 3m to 2.1m x 25m depending on the aims of the trial. In yield trials the plots were 2.1m x 25 m in size and were harvested using a Claas Compact Combine Harvester. In all trials treatments were replicated four times in a randomised block design.

Trials were assessed for crop safety and/or disease control effects. Details are given on the individual tables of results.

In crop safety trials, seed of the major varieties of wheat and barley were treated by 'Rotostat' with the appropriate product at normal and twice normal loadings, with and without Liquid Gamma HCH, ('Gammasan' 30), Liquid chlorfenvinphos ('Birlane') or ethirimol seed dressing ('Milstem') as applicable.

RESULTS

Smut Diseases (Ustilago spp.)

Results (Table 2) obtained on winter and spring barley show the consistent high levels of control of Ustilago nuda obtained with carboxin.

Canadian workers have shown that carboxin also provides good control of U. hordei (Smith, 1983 a,b) and U. avenae (Smith, 1983 c, Piening et al, 1983).

TABLE 2

Per Cent control of Loose Smut (Ustilago nuda) on Winter and Spring Barley

Treatment	Rate (ml or g/100 kg seed)	Trial Year Source	Winter Barley 1 '81 Uni.	2 '82 ICI	3 '84 ICI	Spring Barley 1 '82 Uniroyal	2 '82 Uniroyal	3 '83 Uniroyal	4 '83 Uniroyal	5 '83 Uniroyal
FF4022	200		100	93	95	97	100	100	98	98
FF4022	300		100	-	-	100	93	-	-	-
Carboxin + Organomercury	225		100	-	-	100	100	99	99	99
Triadimenol + fuberidazole Organomercury	150		96	96	100	100	90	100	100	99
	110		30	-	-	0	0	21	0	12
Untreated	-		0	0	0	0	0	0	0	0
Infection level in untreated			1.7% smut	34 infected ears/m^2	28	2.2 infected ears/m^2	4.8	19.3	10.3 infected ears /m of row	9.5

Bunt (Tilletia caries)

Carboxin is very active against common bunt of wheat. In most trials it performed better than the organomercury standard (Table 3).

TABLE 3

Per Cent Control of Bunt (Tilletia caries) on Winter Wheat

Treatment	Rate (ml or g/100 kg seed)	Trial Year Source	1 '81 Uniroyal	2 '81 Uniroyal	3 '81 Uniroyal	4 '81 Uniroyal	5 '81 ICI	6 '82 Uniroyal	7 '82 Uniroyal	8 '82 Uniroyal	9 '83 ICI
FF4022	250		85	98	93	95	99	89	97	100	100
Carboxin + Organomercury	225		93	98	92	99	-	89	100	93	-
Triadimenol + fuberidazole	75		99	100	100	100	-	95	89	100	-
"	150		-	-	-	-	-	-	-	-	100
Organomercury	110		79	64	90	93	96	83	100	83	100
Untreated	-		0	0	0	0	0	0	0	0	0
Infection level in untreated (%)			41	25	56	38	68	52	18	15	30

Seedling blights (Fusarium spp. and Septoria nodorum)

Although carboxin itself has useful activity against seedling blights caused by Fusarium spp. and Septoria nodorum, thiabendazole was added to both products and provided a consistently high level of control(Tables 4,5).

Leaf Stripe (Pyrenophora graminea)

Imazalil was included in FF4022 to control leaf stripe. Consistent, high levels of control were shown on both winter and spring barley (Table 6).

TABLE 4

Control of *Fusarium* spp. on Winter Wheat in a growth room test, (ICI, 1983)

Treatment	Rate (ml or g/100 kg seed)	% Emergence	% Diseased Seedlings
FF4021	250	78.1	3.9B
Triadimenol + fuberidazole	150	75.7	4.5B
Organomercury	110	76.3	3.0B
Untreated	-	79.7	15.7A

TABLE 5

Control of *Fusarium* spp. in Spring Barley and *S. nodorum* in Winter Wheat with a Carboxin/TBZ mixture (ADAS, 1981/82)

Treatment	Rate (ml or g/100 kg Seed)	Spring Barley *Fusarium* spp.		Winter Wheat *S. nodorum*	
		% plants infected	Emergence (plants/m)	% plants infected	Emergence (plants/m)
Carboxin/TBZ*	250	6.8C	45.6	0.9B	38.1
Organomercury	110	25.5B	46.8	1.2B	38.8
Untreated Control	-	58.7A	45.0	11.0A	37.2
No. of sites		7	7	7	6

* at a loading of 750 ppm carboxin, 34 ppm TBZ

TABLE 6

Control of leaf stripe (*Pyrenophora graminea*) in Winter and Spring Barley

Treatment	Rate (ml or g/100 kg seed)	% Control											
		Winter Barley					Spring Barley						
	Trial	1	2	3	4	5	1	2	3	4	5	6	7
	Year	--'81-		---'82----			'81	'82	-------'83---------				
	Source	ICI	---Uniroyal---				ICI	--------Uniroyal---------					
FF4022	200	92	100	96	96	94	99	99	99	100	100	99	96
Carboxin + Organomercury	225	-	99	94	100	100	-	95	99	99	100	99	95
Triadimenol + fuberidazole	75	-	42	0	0	0	-	96	92	98	100	99	86
"	150	37	-	-	-	-	-	-	-	-	-	-	-
Organomercury	110	100	99	95	97	91	100	99	97	99	100	93	96
Untreated	-	0	0	0	0	0	0	0	0	0	0	0	0
		44	10.4*	2	2.2	1	256	4.2	7.4	10	4.4	5.8	2.9
* % infection		----------Infected tillers per m^2----------											

Note: Treatment values followed by different letters are significantly different at P = 0.05 in Tables 4 and 5

The imazalil component in FF4022 also provides useful activity against the related diseases, leaf spot of oats (Pyrenophora avenae), seedling net blotch of barley (Pyrenophora teres) and seed-borne inoculum of Cochliobolus sativus, causing seedling death of barley (Uniroyal, unpublished data).

Crop Safety

Both products were tested for their safety to a range of varieties of barley, wheat, oats and rye (Tables 7,8,9) in both the laboratory and field.

In none of the tests was any significant deleterious effect noted with FF4021 or FF4022 alone or in mixtures with Gamma HCH, or chlorfenvinfos at normal (N)and twice normal (2N) rates.

TABLE 7

Per cent germination of Winter Barley varieties at 3 months after treatment with FF4022 in a laboratory test (ICI, 1983)

Rate	Igri	Tipper	Sonja	M. Otter	Medallion	Athene	Gerbel	Pirate
N	95	95	93	96	100	100	100	99
2N	94	96	94	91	100	100	99	98
Untreated	94	96	97	97	97	100	98	98

TABLE 8

Field establishment and yield of FF4021 and FF4022 treatments (as per cent untreated)

Treatment	Rate	Winter Wheat Establishment	Winter Wheat Yield	Winter Barley Establishment	Winter Barley Yield
FF4021/2*	N	98	98	104	96
FF4021/2	2N	96	100	98	97
FF4021/2 + Gamma HCH	N	101	100	98	101
FF4021/2 + Gamma HCH	2N	99	98	98	98
Organomercury	N	100	97	106	97
Organomercury	2N	97	101	98	97
Organomercury + Gamma HCH	N	100	97	102	97
Organomercury + Gamma HCH	2N	53	99	98	96
FF4021/2 + chlorfenvinphos	N	92	94	-	-
FF4021/2 + chlorfenvinphos	2N	98	100	-	-
FF4021/2 + Gamma HCH + ethirimol SD	N	-	-	96	101
Organomercury + Gamma HCH + ethirimol SD	N	-	-	104	97
Untreated	-	100 (45 plants/ sq. m)	100 (9.92 t/ha)	100 (32 plants/ sq. m)	100 (8.07 t/ha)
*FF4021 used on wheat FF4022 used on barley	Variety:	Mean of 4 trials Avalon		Mean of 4 trials Igri	

TABLE 9

Effects of FF4021 and FF4022 on the per cent germination of Rye and Oats (Official Seed Testing Station, 1983)

Treatment	Rate	cv:	Rye Animo	Spring Oats Trafalgar	Winter Oats M. Osprey
FF4021	N		88	88	70
FF4021	2N		86	90	82
FF4022	N		87	87	76
FF4022	2N		75	82	67
Untreated	-		87	84	60

DISCUSSION

Organomercurial seed treatments have provided effective control of cereal seed and soil-borne diseases for many years. FF4021 and FF4022, as has been shown above, are effective replacements for organomercury, which can control the major seed and soil-borne diseases of wheat, barley, oats and rye. They have an advantage over organomercury in that they will also control loose smut diseases of cereals. Loose smut of barley, in particular, has been an increasing problem in the UK over the last few years (Hewett, 1983, 1984). Both products have a wide margin of crop safety, alone and in mixture with the other seed treatment products mentioned in this paper.

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NOTE: 'Cerevax', 'Gammasan', 'Milstem' and 'Rotostat' are Trade Marks of Imperial Chemical Industries PLC. 'Birlane' is a trade mark of Shell Chemicals (UK) Ltd. Carboxin is a product of Uniroyal Inc; thiabendazole is a product of Merck, Sharp and Dohm Ltd and imazalil a product of Janssen Pharmaceuticals.

CONTROL OF TYPHULA SNOW ROT IN WINTER BARLEY

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ABSTRACT

Advisory investigations into outbreaks of snow rot in winter barley caused by Typhula incarnata indicated the importance of snow cover to the severity of the disease. Additionally, the health status of plants in the autumn appeared to be related to the incidence of the disease. In one year of fungicide trials significant reductions in disease were achieved with a triadimenol/fuberidazole seed dressing. Fungicide sprays, particularly benodanil and triadimefon, applied in November were also effective but the control achieved was more variable. However, yields did not correlate to the control achieved. Guidelines to winter barley growers for control of snow rot are outlined.

INTRODUCTION

Snow rot caused by Typhula incarnata was first observed in Scotland in the spring of 1963 on a range of grasses and occasional crops of winter wheat (Gray, 1963). There was a steady but unspectacular increase in the incidence of snow rot in winter barley crops in the north of Scotland from the 1980 sowing until the 1982 sowing as the acreage of winter barley in the area increased. In the spring of 1984, following a period of snow cover in January and February lasting between 3 and 10 weeks snow rot was found in most fields of winter barley in the area. This prompted a large number of advisory enquiries which were investigated. In addition, trials had been set down in the 1983 sown crops to compare a range of fungicide treatments for control of the disease. This report details both observations from advisory experience and the results of trials on fungicidal control.

MATERIALS AND METHODS

A total of 38 advisory cases involving snow rot were investigated at the North of Scotland College of Agriculture. These included samples examined in the laboratory and/or field visits. Details relating to each case were assembled to provide information on the underlying trends associated with the incidence of disease.

To evaluate autumn fungicide treatments for the control of snow rot in winter barley cv Igri three trials were laid down in Grampian Region. At two sites (Laurencekirk and Stonehaven) a strip of seed dressed with triadimenol/fuberidazole was drilled in amongst an otherwise untreated (single purpose, mercury-dressed seed) crop. At the third site (Whiterashes) a strip of mercury dressed seed was sown amongst a triadimenol/fuberidazole dressed crop.

Replicated strips across both triadimenol/fuberidazole dressed and untreated areas were sprayed with a range of foliar fungicides during November (Table 1). For two trials (Laurencekirk and Stonehaven) a tractor mounted sprayer was used to apply the fungicides whilst at the third trial an Allman Rapid MkV trolley sprayer (E. Allman & Co. Ltd., Chichester, Sussex) was used. All fungicides were applied in 300 litres water/ha. Plot sizes were 24 m x 3.7m for the first two trials and 24 m x 8 m for the third. Unsprayed plots were left as controls.

Throughout the year the trial areas received the same husbandry treatments as the surrounding crops. For two crops this included an autumn fungicide treatment for control of foliar diseases particularly Pyrenophora teres (net blotch) and Erysiphe graminis (mildew).

TABLE 1
Fungicide treatments tested for the control of Typhula incarnata

	Treatments (active ingredients)	Concentration of active ingredients	Rate of application
A	Untreated control	-	-
B	Benodanil	50% wt/wt	1.0 kg/ha
C	Carbendazim	50% wt/vol	0.5 kg/ha
D	Carbendazim/Maneb/Tridemorph	3.8%/40%/9.4% wt/wt	4.0 kg/ha
	+ Chlorothalonil	+50% wt/vol	+1.0 l/ha
E	Chlorothalonil	50% wt/vol	2.0 l/ha
F	Iprodione	25% wt/vol	2.0 l/ha
G	Tolclofos-methyl (e.c. formulation)	25% wt/vol	2.0 l/ha
H	Triadimefon	25% wt/wt	0.5 kg/ha
I	Vinclozolin	50% wt/wt	1.0 kg/ha
	Triadimenol/fuberidazole (seed dressing)	25%/3% wt/wt	150g/100 kg seed

Disease assessment

In the advisory investigations particular note was made of the percentage of plants killed by T. incarnata and that this fungus was the primary pathogen.

The trials were assessed during late February and March for infection. Firstly, two 2 m runs of drill within each plot were removed, washed and each plant scored on a 0-3 scale for the degree of infection and plant death.

0 indicated no infection
1 indicated one third of plant tissue infected
2 indicated two thirds of plant tissue infected
3 complete plant death

Interpolation between these scores was made as necessary. A mean score for each plot was obtained by averaging the scores for each plant. Secondly, at two sites the percentage area killed out by T. incarnata (flattened areas of crop showing no signs of spring regrowth) was assessed.

Plot yields were measured at only one site (Whiterashes) and adjusted to 15% moisture content.

RESULTS

Advisory investigations

An observation common to nearly all the reports of snow rot was that the severity was greatest in areas where the snow cover persisted longest such as the margins of fields, hollows and other snow traps. Fields at higher altitudes (150 m) where the snow cover had persisted for up to 10 weeks showed some of the more severe examples of the disease.

In general winter barley crops treated with an autumn fungicide for foliar disease control were less affected by snow rot than crops that had not received any autumn fungicides. However, where crops had been stressed by post-emergence herbicide scorch, shallow sowing or tractor wheelings the incidence of snow rot was especially prevalent even if efficient foliar disease control with fungicides had been practiced. Furthermore, the earlier the sowing date the greater was the incidence of snow rot. Field observations showing that Igri, the most popular variety in the north of Scotland, was susceptible whereas Gerbel, the other main variety, was resistant, was in keeping with their reported responses (Anon., 1984). In several crops totalling approximately 75 ha, all in north facing fields, nearly all plants had been killed and these crops were ploughed in. More commonly, 'footprint' sized patches of dead plants were scattered through infected crops and there were signs of reduced plant vigour in the early spring in sub-lethally infected plants.

Fungicide trials

In the two trials where the effect of a triadimenol/fuberidazole seed dressing was assessed, this treatment resulted in large and significant reductions in plant infection compared to the untreated control. Foliar sprays superimposed on the seed treatment failed to give further significant reductions in infection.

Spray treatments were compared in the absence of the triadimenol/fuberidazole seed dressing at all three sites (Tables 2 & 3). At Stonehaven, all spray treatments tested significantly reduced infection and at Whiterashes all treatments except carbendazim, iprodione and vinclozolin significantly reduced infection. However, at

Laurencekirk only the carbendazim/maneb/tridemorph with chlorothalonil, chlorothalonil and triadimefon treatments significantly reduced infection. Generally, benodanil and triadimefon were the most consistently effective spray treatments.

At the two sites where the percentage area of plots killed out by T. incarnata was estimated, all treatments except carbendazim, iprodione and vinclozolin at the Whiterashes site significantly reduced kill. Where a treatment was superimposed on the triadimenol/fuberidazole seed dressing the percentage area killed out was consistently less than where this seed dressing was not used.

There was no correlation at the Whiterashes site between the yield of grain and either the infection score or percentage area killed out. The carbendazim treatment, whether superimposed over the seed dressing or not, gave the lowest yield and was significantly less than the respective unsprayed controls.

TABLE 2
Effect of fungicide treatments on the infection of winter barley by T. incarnata

Treatment	Stonehaven (sprayed 14/11/83) Seed Dressing				Laurencekirk (sprayed 11/11/83)
	Nil	T/f*	Nil	T/f	Nil
	Infection Score		% area killed		Infection Score
A	1.014	0.147	11.7	0.0	0.902
B	0.041	0.014	0.7	0.0	0.435
C	-	-	-	-	1.073
D	0.557	0.097	7.7	3.3	0.314
E	0.516	0.078	6.0	0.0	0.199
F	0.180	0.105	5.0	0.3	0.790
G	0.418	0.045	3.3	0.3	0.702
H	0.422	0.070	0.7	0.3	0.156
I	0.846	0.034	6.7	0.7	1.105
SED Between seed treats	0.0669		0.88		-
SED Between spray treats	0.1339		1.77		0.2319
SED Seed x spray interaction	0.1893		2.50		-
df	30		30		24
Assessment date	13/3/84		13/3/84		5/3/84

*T/f = triadimenol/fuberidazole seed dressing

TABLE 3

Effect of fungicide treatments on the infection by T. incarnata and yield of winter barley

Treatment	Whiterashes (sprayed 8/11/83)					
	Seed Dressing					
	Nil	T/f*	Nil	T/f	Nil	T/f
	Infection Score		% area killed		Yield of Grain (t/ha)	
A	0.306	0.050	27.0	1.0	11.28	10.62
B	0.000	0.026	4.8	0.4	10.56	10.31
C	0.450	0.070	36.5	2.6	9.65	8.56
D	0.204	0.088	10.5	1.3	10.06	10.42
E	0.248	0.048	20.0	1.8	9.81	10.52
F	0.438	0.263	23.0	2.9	10.27	11.13
G	0.256	0.234	17.0	1.3	10.99	11.30
H	0.024	0.005	8.5	0.4	10.53	10.99
I	0.319	0.164	23.0	2.4	9.51	10.73
SED Between seed treats	0.0432		1.18		0.178	
SED Between spray treats	0.0917		2.49		0.378	
SED Seed x spray interaction	0.1297		3.53		0.534	
df	51		17		17	
Assessment date	28/2/84		14/3/84		17/8/84	

*T/f = triadimenol/fuberidazole seed dressing

DISCUSSION

The longevity of snow cover is an important factor affecting the severity of snow rot. Thus the significance of the disease as a factor in winter barley growing will vary from year to year according to the snow cover and prediction of disease severity is unlikely to be possible. There were indications from advisory investigations and one fungicide trial that crops can tolerate relatively severe attacks without loss in yield. At the Whiterashes site areas killed out as a result of Typhula infection were mostly small 'foot-print' sized patches. Given a spring and summer entirely favourable for the growth of winter barley, it would seem that small patches although covering 27% of the area in the untreated control were compensated for by surviving plants and there was little effect on yield. What the effect of a less favourable season for growth on a similar kill would be only future investigations will reveal. It is clear that the disease/yield loss relationship cannot be established and the pattern of plant kill is probably important. Farmer's experiencing over 80% death of plants reported yields of only 2.5 t/ha.

One year of trials has indicated that fungicides can be effective in controlling snow rot. The triadimenol/fuberidazole seed dressing was particularly effective. Fungicide sprays, particularly benodanil and triadimefon, were also effective but the control achieved was

variable. It is possible that the timing of the fungicide sprays could, in part, explain the variability and the time of application requires investigation, particularly in relation to the biology of the fungus. Ground conditions during November and December are generally not suitable for heavy spraying machinery and this factor alone might prohibit late autumn spray treatments.

The control of snow rot as assessed by plant infection or percentage area killed out may not simply reflect how effective the fungicide treatments were against T. incarnata. The advisory observations suggest that the health and vigour of a crop entering the winter can influence its susceptibility to infection. In general it would appear that the more dead and senescing tissue present, the more the opportunity for the fungus to infect. One cause of premature leaf senescence, particularly in early sown crops, is that of foliar diseases such as mildew and net blotch and this could explain the apparent reduction in snow rot in crops receiving an autumn fungicide.

In the fungicide trials it is possible that since some of the fungicide treatments are effective against foliar diseases and mildew and net blotch continued to develop through the autumn the control of snow rot achieved was mediated through the improved health status of the plants. This might also explain the variability in the effectiveness of spray treatments. For example, the infection score for iprodione (which has some control of net blotch) at Stonehaven was lower than all other treatments except benodanil. Iprodione at Whiterashes was much less effective but the level of net blotch at this site was a less important factor because an autumn spray to control net blotch had been applied over the whole field.

Crops thought most likely to be at risk from an attack of T. incarnata are those in fields where infection has been readily found in the previous year and the following guidelines for control were developed for this situation. Because of the lack of predictability advice offered to growers was aimed at minimising infection.

1. Avoid north facing fields.
2. Plough (as well as possible) to bury sclerotia.
3. Where possible select a resistant variety.
4. Avoid early sowing - in late August and early September.
5. Maintain the health status of the crop by good husbandry and judicious control of foliar diseases.
6. In high risk situations where infection in the previous year was severe or where the other guidelines cannot be followed consider a specific fungicide treatment for Typhula.

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INTERACTIONS BETWEEN STEM BASE PATHOGENS OF WHEAT AND THEIR CONTROL BY SEED TREATMENT AND FUNGICIDE SPRAYS

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ABSTRACT

In dual infections of stem base pathogens in wheat plants, Gaeumannomyces graminis dominated all other pathogens and Rhizoctonia cerealis dominated Fusarium culmorum. Inoculated alone, G. graminis decreased crop height by c. 45% but in combination with either Pseudocercosporella herpotrichoides, R. cerealis or F. culmorum, height decreased by c. 65, 59 or 63% respectively. In field experiments in 1983 best overall control of stem base diseases by GS 31 sprays (all the above 4 pathogens were present), was given by prochloraz + carbendazim, carbendazim and chlorothalonil + carbendazim. Triadimenol seed treatment in autumn 1983 had little effect on take-all during the winter but by March the infections had decreased by c. 50%. Eyespot infections had decreased by 30 April but not by July. The yield from triadimenol-treated seed plots was greater (9%) than from mercury-treated seed plots. The best overall stem base disease control and yield figures were given by triadimenol seed treatment plus sprays of carbendazim or carbendazim mixtures.

INTRODUCTION

The stem base diseases of cereals, eyespot (P. herpotrichoides), sharp eyespot (R. cerealis), foot rot (Fusarium spp.) and take-all (G. graminis) occur commonly in winter wheat and winter barley. Individually they can decrease yield by interrupting the transport of nutrients to the grain or by weakening the stems and making them liable to lodge. Their interactions have seldom been studied. The carbendazim-generating fungicides and more recently prochloraz have been widely used commercially for control of eyespot, but are reported to be ineffective against sharp eyespot (van der Hoeven & Bollen 1980, Davies & Price 1983). Bockus (1983) reported decreases in take-all following triadimenol seed treatment; there is little other evidence of fungicidal control.

This paper examines the effects and interactions of stem base diseases of winter wheat, and evaluates their field control by seed treatment and foliar fungicide sprays.

MATERIALS AND METHODS

Pathogenicity and Interactions: Glasshouse tests

The following isolates had been obtained from diseased plant material: P. herpotrichoides (E2-MD10) 'wheat-type' carbendazim-sensitive, R. cerealis (C36-101), F. culmorum (IMI-271936), G. graminis (Gg.B-FH1). Mycelial discs, 5 mm in diameter, taken from the edge of 2-week-old cultures grown on potato dextrose agar at 19°C were applied to winter wheat seedlings, cv. Kador, grown as 5 plants per pot in a cool glasshouse. Each seedling was inoculated at GS 13 by positioning a mycelial disc beside the stem base (just below for G. graminis), and covering with soil. For dual inoculations mycelial discs were placed on opposite sides of the stem. Eleven different inoculum combinations were replicated as 4 pots of 5

plants, randomized within the area of the experiment. Disease symptoms were identified and assessed at GS 34 and 83 and stem height was measured.

Field Experiment I (1982/3)

This was done on winter wheat cv. Avalon sown in October 1982 on a site at Long Ashton Research Station with a 5-year history of cereals and bi-annual MBC use. Much eyespot, sharp eyespot, foot rot and take-all had been recorded during this time and in the previous year 10% of eyespot isolates had been found to be MBC-resistant.

At GS 31, (14 April) anilazine, benodanil, carbendazim, chlorothalonil, chlorothalonil + carbendazim, prochloraz and prochloraz + carbendazim in the respective commercial formulations Dyrene, Calirus, Bavistin Flowable, Bravo, Bravocarb, Sportak and Sportak Alpha, were applied at manufacturers' recommended concentrations at 250 l/ha. Each stem base disease was assessed by measuring lesion length and stem girdling on 100 stems per plot. A "disease score" for eyespot and sharp eyespot was calculated as: % tillers with full girdling + 0.75 (% tillers with 3/4 girdling)+ 0.5 (% tillers with ½ girdling)+ 0.25 (% tillers with 1/4 girdling).

Field Experiment II (1983/4)

On the same site, 48 plots of winter wheat cv. Norman, seed-treated with triadimenol or mercury at the recommended rates of the respective formulations Baytan or Ceresol, were sown on 24 September 1983. Superimposed on these seed treatments, prochloraz, prochloraz + carbendazim, prochloraz + carbendazim + benodanil, prochloraz + benodanil, carbendazim, carbendazim + benodanil, and benodanil, were sprayed at GS 31 as described previously. There were three replicates of each treatment.

Take-all was assessed in autumn and spring by removing a 50 cm row of plants per plot, washing off the soil and counting the numbers of roots showing blackening, especially of vascular tissue. Take-all was confirmed by isolation of G.graminis on potato dextrose agar.Stem base diseases were assessed on 50 stems per plot at GS 34 and 75. In late July, ears from two, 1m rows per plot were removed and the number of poorly filled ears ("whiteheads") recorded. Ears were then threshed and grain weights calculated after correction to 85% dry matter.

RESULTS

Pathogenicity and Interactions

Symptoms developed on almost all stems inoculated with the single pathogens (Table 1). Symptom expression from dual inoculations showed that G. graminis dominated all other pathogens, R.cerealis dominated F.culmorum, and P. herpotrichoides co-dominated with R. cerealis or F. culmorum.

When inoculated alone, P. herpotrichoides, R. cerealis and F.culmorum had little effect on crop growth and vigour, whereas G. graminis decreased crop height by c. 45%. However, when G. graminis had been inoculated with either P. herpotrichoides, R. cerealis or F. culmorum, height was decreased by 65, 59 and 63% respectively. In terms of lesion area, R. cerealis appeared to develop less when in combination with any other pathogen than when inoculated alone, but the differences were not significant. Bruck and Schlosser (1982) and Kapoor (1984) reported similar antagonism of Rhizoctonia spp., especially by P. herpotrichoides.

TABLE 1

Effect of interactions of stem-borne wheat pathogens on crop height, symptom development and disease severity

Inoculated pathogen(s)	Stem height (cm)	Symptom expression #	Lesion area (back-transformed means) (mm²) /
Uninoculated	101.2	-	-
Pseudocercosporella herpotrichoides(PH)	104.0	80E	28.6
Gaeumannomyces graminis(GG)	55.8	100G	169.4
Rhizoctonia cerealis(RC)	95.4	95S	239.8
Fusarium culmorum(FC)	85.4	100F	114.8
PH + FC	95.3	60EF,30F,SE	101.9
PH + RC	98.0	40SE,35E,20S	148.9
RC + FC	96.9	60S,20SF,10F	104.0
PH + GG	41.9	95G,5GE	229.4
RC + GG	36.2	65GS,20G	247.1
FC + GG	41.6	65G,20GF	218.0
LSD (5%) cf.inoculations	11.29	LSD(% larger mean)	61.3

Figures are % of inoculated plants showing symptoms; E,T,S,F denote symptoms typical of eyespot, take-all, sharp eyespot and fusarium foot rot respectively. Where both symptoms of inoculated pathogens are expressed, the dominant one is recorded first.

/ Lesion area calculated by: lesion length x fraction of girdling (¼,½,¾,full) x stem diameter (taken as 10 mm²).

Field Experiment I (1982/3)

On 22 June 1983 prochloraz, prochloraz + carbendazim, carbendazim alone and chlorothalonil + carbendazim all decreased the eyespot score, reflecting mainly a lower number of tillers with ¾ girdling (Table 2). By 22 July, prochloraz + carbendazim, carbendazim alone and chlorothalonil + carbendazim still gave significant control of eyespot but prochloraz alone was less effective. In June, prochloraz, prochloraz+carbendazim, carbendazim alone and chlorothalonil + carbendazim also gave a higher proportion of tillers with sharp eyespot up to ¼ girdling, leading to a significant increase in sharp eyespot score in the two former treatments. The same trend was present in July. At both assessments benodanil gave a lower sharp eyespot score than unsprayed and in the first assessment a lower score than all other treatments. However, it also caused a significant increase in eyespot score. No significant effects of chemicals versus Fusarium spp. were found in June but in July Fusarium foot rot was shown to be significantly less frequent with prochloraz than unsprayed.

Prochloraz + carbendazim, carbendazim alone and chlorothalonil + carbendazim all increased the number of healthy tillers in June, though by July, prochloraz + carbendazim was the only treatment to increase the proportion of healthy tillers.

Field Experiment II (1983/4)

Triadimenol seed treatment had little effect on take-all during autumn and winter but by 7 March root infection was significantly decreased (Table 3). A triadimenol-induced decrease in eyespot was detected in April, but not in July (Table 4).

TABLE 2

Field Experiments I: Effects of fungicide sprays on stem base diseases

Treatment 14 May GS 31	g ai ha⁻¹	[x] Disease score 22 June Eyespot	22 June Sharp Eyespot	22 July Eyespot	22 July Sharp Eyespot	% tillers affected (22 July) [+] E	SE	F	H
Unsprayed	-	46.6	6.7	56.0	15.3	71.3	21.6	6.8	0.5
Prochloraz	400	21.9**	18.5*	49.2	15.2	74.8	24.8	0.5	0
Carbendazim	250	16.4**	10.0	31.5**	13.3	63.6	26.4	9.3	1.0
Benodanil	1000	65.1*	1.1**	71.4	2.4*	92.1	2.5	5.5	0
Chlorothalonil	880	45.2	8.9	61.0	8.6	83.3	12.8	3.5	0.5
Anilazine	1875	34.1	5.5	58.6	6.4	82.6	10.3	7.3	0
Prochloraz + carbendazim	400 +225	9.6**	17.7*	22.1**	20.3	41.3	38.3	11.5	9.0
Chlorothalonil + carbendazim	1125 +250	17.9**	13.1	29.6**	22.0	52.0	34.8	12.3	1.0

Very small amounts of Fusarium foot rot were recorded in June.
+ Letters indicate diseases as in Table 1; H indicates 'healthy'.
* and ** differ significantly at p = 0.05 and p = 0.01 from unsprayed.

TABLE 3

Field Experiment II: Effects of seed treatments on take-all

Assessment date	Triadimenol % diseased plants	Triadimenol % diseased roots	Mercury % diseased plants	Mercury % diseased roots
11 Oct.1983	1.0	0	0	0
27 Oct.1983	12.7	2.7	12.8	2.4
22 Nov.1983	29.9	9.1	27.7	8.6
15 Dec.1983	59.4	13.6	68.4	16.6
7 Mar.1984	48.9	9.8	91.4	38.2

Best eyespot control was provided by treatments that contained carbendazim. Prochloraz + carbendazim was more effective than prochloraz alone. Benodanil gave no control of eyespot though it was again the most effective treatment versus sharp eyespot (Table 4).

Lodging was not significantly affected by seed treatment but was decreased by all four carbendazim-containing foliar sprays (Table 4); this reflected best eyespot control. However, "whiteheads" were significantly fewer in triadimenol seed-treated plots than in mercury seed-treatments, which correlated with control of take-all.

TABLE 4

Field Experiment II: Effects of fungicide seed treatments and foliar sprays on stem base diseases[x], yield, lodging and "whiteheads"

		Disease scores (back-transformed)							
		[+]Take-all	Eyespot		[+]Sharp Eyespot	Weight/ 100 ears	Yield	Lodging	"Whiteheads" (back-transformed)
		7/7	30/4	7/7	7/7	(g)	(t/ha)	(%)	(%)
Seed treatment:	g/kg								
Mercury	22	5.3	4.5	49.3	1.2	204.0	9.18	38	25
Triadimenol	375	2.1	2.2	49.3	0.7	229.1	9.99	27	14
LSD (5%) for comparison with mercury		+4.15 -2.49	+4.24 -2.36	+7.53 -7.50	+1.37 -0.77	±13.34	±0.264	±11.5	+5.6 -5.3
GS 31 sprays:	g.a.i./ha								
None	-	3.1	4.1	72.8	0.5	192.3	8.50	58	28
Prochloraz	400	3.2	2.6	65.6	1.5	213.8	9.36	47	21
Carbendazim	250	2.6	1.4	26.4	4.0	225.0	10.53	11	14
Benodanil	1000	2.1	3.9	75.5	0	196.2	8.58	69	31
Prochloraz + carbendazim	400+ 225	2.4	3.3	26.3	1.8	217.3	10.28	1	16
Prochloraz + benodanil	400+ 1000	8.8	6.2	55.9	0.4	228.1	9.02	66	25
Prochloraz + carbendazim + benodanil	400+ 250+ 1000	4.2	4.8	28.7	0.4	234.5	10.11	1	13
Carbendazim + benodanil	250+ 1000	3.5	1.5	44.1	2.1	225.5	10.29	10	10
LSD (5%) for comparison with no spray		+11.83 -2.86	+17.76 -3.80	+13.23 -18.82	+3.84 -0.80	±36.23	±0.716	±31.1	+16.5 -13.8

x Fusarium foot rot was not present at significant levels at either assessment date.
+ Insignificant levels of take-all and sharp eyespot on 30/4.

With the exception of benodanil alone, all fungicide treatments applied at GS 31 increased yield. Irrespective of the sprays at GS 31, more yield was obtained from triadimenol seed-treated plots than from mercury-treated plots, a difference of 9%. Best yield was obtained from triadimenol-treated seed in plots sprayed with prochloraz + carbendazim at GS 31, 40% more than from mercury-treated seed in unsprayed plots.

DISCUSSION

Damage caused to cereal stem bases sometimes may be mistakenly attributed to only one of a complex of pathogens. This study has indicated that more than one pathogen can co-exist in a stem, causing more damage than the individual pathogens alone. Symptom expression is not always a true reflection of the pathogens present, since dual inoculations involving G. graminis showed principally take-all symptoms yet the effect on plant growth was greater than that caused by G. graminis alone.

Best field control of eyespot, given by carbendazim and carbendazim mixtures, especially prochloraz + carbendazim, was reflected in increased yield and less lodging. The use of fungicide mixtures to control eyespot is now generally recommended since the occurrence of carbendazim resistance in P.herpotrichoides became widespread 2 years ago (Griffin & Yarham 1983).

Contrary to the findings of Bockus (1983), triadimenol seed treatment did not protect wheat plants from take-all during autumn. However, in our experience it inhibited G. graminis root-colonizing activity in the spring (as well as decreasing eyespot at this time), decreased numbers of white-heads and increased yield. Further work is necessary to establish the reliability of this effect.

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OBSERVATIONS ON THE CURRENT INTEREST IN CHLORIDE AND TAKE-ALL

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ABSTRACT

In a field trial comparing nitrogen top dressings, ammonium chloride was no more effective than ammonium sulphate, urea, or ammonium nitrate in decreasing take-all in winter wheat.

INTRODUCTION

Take-all is usually a problem only when two or more wheat or barley crops are grown consecutively. It is well known that crops given no nitrogen suffer more from take-all than crops receiving nitrogen. In Britain in the 1940s ammonium sulphate fertiliser was recommended for crops at risk from take-all. Subsequently experiments in the U.S.A. showed that ammonium sulphate decreased disease more than ammonium nitrate. (Huber et al. 1968).

Recently it has been claimed that spring application of chloride fertiliser decreased take-all (Christensen et al. 1982). Autumn application of potassium chloride at Rothamsted had no effect on take-all except where phosphate was deficient; spring application was not tested (Mattingly et al. 1980). Powelson et al. (1983) in the U.S.A. reported that adding chloride enhanced the controlling effect of ammonium nitrogen (Smiley & Cook, 1973), but an effect of ammonium nitrogen has not been demonstrated unequivocally in the U.K. (Hornby & Brown, 1977).

Over 50% of winter wheat in Britain is grown after a previous wheat or barley crop and is at risk from take-all. In the absence of economic chemical controls and resistant varieties any treatment which is claimed to decrease take-all commands attention. We report results of some field tests on one such treatment, chloride.

MATERIALS AND METHODS

Ammonium chloride, ammonium sulphate, urea and ammonium nitrate (as nitrochalk) were applied to winter wheat cv. Longbow in a randomised block design of four replicates. The site had grown oats in 1981 and winter wheat in 1982 and 1983 and was expected to have severe take-all in 1984. Assessment in March, prior to the application of nitrogen fertiliser, showed an average of 2 roots with take-all per plant. Normally this proves sufficient to cause a severe attack of take-all if conditions remain favourable. Nitrogen was applied in early March (40kg N/ha) and mid April (160kg N/ha). Take-all was assessed five weeks after each application and at the beginning of July (G.S. 69-71).

RESULTS

Take-all did not differ significantly among treatments but ammonium sulphate plots had least disease, agreeing with general experience that this fertiliser often decreases take-all. Plots looked alike and take-all patches were common throughout the experiment.

TABLE 1

Effects of fertilisers on take-all incidence and severity in winter wheat (fertilisers applied: 40kg N/ha on 9 March and 160kg N/ha on 16 April)

Treatment	Sample date 16 April (G.S. 2.1-2.4) % plants with take-all	25 May (G.S. 37) Take-all rating (0-300)	2 July (G.S. 69-71) Take-all rating (0-300)
Ammonium chloride	73.6	104	211
Ammonium sulphate	71.2	98	197
Urea	70.7	122	219
Ammonium nitrate (nitrochalk)	72.9	100	220

DISCUSSION

This experiment was designed to test the claims that ammonium chloride decreases take-all of winter wheat by comparing it with other forms of nitrogen top dressing. The results revealed no significant differences between treatments, and the disease ratings for ammonium chloride were not the lowest. Agronomic and climatic conditions in the U.S.A. frequently differ from those in Britain and it should not be expected that responses of take-all to ammonium and chloride fertilisers will be the same in both countries.

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