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AN APPROACH TO THE INTEGRATED CONTROL OF CEREAL LEAF DISEASES

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Summary The effectiveness of some recently introduced fungicides for cereal leaf diseases may encourage growers to neglect other disease control measures. Experience with wheat yellow rust and barley mildew in south-east Scotland led to the formulation of an advisory policy which attempts to integrate the available control measures in an overall strategy. Farmers are advised to avoid these disease problems by not growing highly susceptible varieties and by minimising winter carry-over. The risk of disease attack, and of consequent loss, may be lessened by the growing of a diversity of varieties. The use of fungicides should be considered in the light of the resultant disease situation.

INTRODUCTION

In recent years new fungicides have been introduced to control several cereal leaf diseases. Some of these products have proved very effective and there is emerging a tendency among growers to consider disease control primarily in terms of which fungicide to apply and the potential profitable responses to such an application. Indeed, techniques are available to assess the expected profitability in a given disease situation and to help a grower to decide his course of action in the light of his attitude to 'risk' (Gilmour and Fawcett 1973).

There may, however, be dangers in this investment appraisal approach to the use of fungicides, because it focuses attention on one aspect of disease control strategy to the exclusion of others, and does not take into account the wider consequences of an individual grower's actions. Recent advisory experience in south-east Scotland suggests that a more integrated approach to disease control is likely to be of greater benefit to the agricultural community as a whole.

YELLOW RUST ON WINTER WHEAT

Epidemics of yellow rust (*Puccinia striiformis*) have been a recurrent feature of wheat growing in south-east Scotland (Trotter 1811; Dennis 1944; Batts 1957; Foister 1961; Zadoks 1961; Boyd 1962; Gilmour 1968). These epidemics caused serious losses, especially when the florets were infected. When, in 1954, Cappelle-Desprez was severely infected with race 40 E72 (formerly race 2B. Johnson *et al* 1972) for the first time in south-east Scotland, Dr. Batts wrote of a variety trial which he visited in the Carse of Gowrie: "It was an amazing sight; worse infection could not be imagined".

The epidemic of race 37 E132 (formerly race 60) on Rothwell Perdix in 1966 (Macer and Doling 1966; Gilmour 1968) was of particular significance because it brought to an end a period of relative complacency about the importance of new physiologic races and as a result the Physiologic Race Survey of Cereal Leaf Pathogens was set up, replacing the somewhat informal previous arrangements

(Chamberlain et al 1972). Subsequent investigation revealed that race 37 E132 could have been present in south-east Scotland at least two years earlier (Gilmour 1968) and this stimulated an increased local contribution to the Physiologic Race Survey.

In 1967 yellow rust was again widespread and was severe on varieties susceptible to race 37 E132 which predominated in south-east Scotland (Chamberlain 1968; Stubbs et al 1968). In contrast levels of yellow rust were very much lower in 1968 and race 37 E132 was found there only once (Chamberlain 1969). The decision of the plant breeders and their agents to withdraw Rothwell Perdix and related varieties, undoubtedly played a large part in bringing about this change.

In 1971 and 1972 yellow rust became epidemic on Joss Cambier and Cama which were then the two highest yielding varieties on the Scottish Recommended List. The losses on some farms were great, especially where the entire wheat acreage had been sown with these two varieties. A similar epidemic occurred in the south of England (Walker and Roberts 1974), but with the important difference that the race involved in England was almost exclusively 104 E137 (formerly 3/55D), while that in Scotland was 41 E136 (formerly 58C) (Chamberlain 1972). This caused great concern because Joss Cambier had previously shown good adult plant resistance to these races of yellow rust although it was susceptible to them in seedling tests. Johnson and Taylor (1973) later demonstrated that in both cases the yellow rust fungus had become adapted to Joss Cambier in a way that could not be detected in the seedling tests used in the Physiologic Race Survey.

In 1972 the use of fungicides, especially tridemorph/dithiocarbamate and chloraniformethan/propineb mixtures, was a new feature in the attack on yellow rust. Where these were applied at a sufficiently early stage they gave obvious disease control on the leaves and a reduction in the proportion of florets subsequently infected. A number of farmers reported profitable yield increases from these treatments.

These outbreaks of yellow rust led to the formulation of a policy of diversification in the choice of variety coupled with good husbandry practices to minimise disease carry-over (Gilmour 1971a), similar to that suggested following the 1961 epidemic on Cappelle-Desprez (Boyd 1962). In 1972 wheat growers were strongly recommended to abandon the growing of high susceptible varieties (Gilmour 1972). This policy of abandoning highly susceptible varieties, and of not introducing new ones which might present similar risks, would appear to have been successful because yellow rust has not been a significant problem during the past three seasons.

In contrast, yellow rust has been of some concern each year since 1972 in England where some highly susceptible varieties have been grown. For example, about 4000 acres of Maris Templar were grown in southern and eastern England in 1973, when an inspection of 90 seed multiplication crops revealed some yellow rust infection in 75% of them (Johnson and Taylor 1974). The apparent restriction of race 41 E136, to which Maris Templar is susceptible, to south-east Scotland and Northumberland was undoubtedly a major factor in the decision to introduce this variety in southern England. However, by the time that decision was taken race 41 E136 had spread to eight widely scattered centres in England (Chamberlain 1972) and was found at 34 sites from Yorkshire southwards in 1972 (Chamberlain 1973). There were severe outbreaks of yellow rust on Maris Templar in 1974 and 1975, and large acreages of it have been sprayed with fungicides (ADAS 1975).

Susceptible varieties, such as Maris Templar, raise the general level of an epidemic, thereby reducing the value of the resistance of other varieties. This was well illustrated during the epidemics on Joss Cambier and Cama, when more severe infection was recorded on many varieties, including Cappelle-Desprez, Maris Huntsman and Maris Nimrod, when they were growing near these susceptible varieties than when they were growing well away from such sources of inoculum. This risk may be present even when fungicides are used to control yellow rust, because applications which give large and profitable yield responses do not necessarily reduce the level of leaf disease sufficiently to eliminate this source of inoculum (Frost et al 1973; Frost 1975).

In 1974 several crops of Maris Huntsman in Yorkshire and Durham had higher levels of yellow rust (50% leaf area infected) than expected from previous experience (10%). These outbreaks were probably due to variants of race 41 E136 which had become adapted to Maris Huntsman (Johnson et al 1975; Priestly et al 1975). If tests made on adult plants during 1975 confirm the existence of these variants, they will provide evidence of another risk which should be considered before highly susceptible varieties are grown, viz that when the general level of an epidemic is raised there is an increase in the probability that a potentially damaging mutant of the pathogen will become established. The loss of Maris Huntsman would be a high price to pay for the introduction of Maris Templar.

MILDEW ON SPRING BARLEY

The barley mildew (Erysiphe graminis) situation in south-east Scotland is quite different from that for yellow rust on winter wheat. Foister (1961), reviewing the period from 1924 to 1957 wrote: "Mildew is widely distributed but is normally negligible". It remained so until 1968 when Golden Promise first occupied a significant part of the barley acreage in south-east Scotland. Weather favourable to mildew development occurred during May and June, and a mildew epidemic ensued. A similar epidemic has developed each year from 1970 to 1974. Despite its extreme susceptibility to mildew Golden Promise has gained in popularity, so that by 1973 it accounted for 75% of the barley acreage in Angus, Perthshire, Kinross and Fife and 50% of the acreage in the Lothians and the eastern Borders (Richardson 1974). In the 10 years following the introduction of Golden Promise barley growing has been greatly intensified in Scotland, the acreage increasing by almost one-half. During this period the acreage of rotational crops in south-east Scotland declined slightly, so that one acre in every 2.8 is now under barley (DAFS 1974). In the most intensively arable area, East Lothian, this ratio is one in 2.3. The risks associated with this intensity of production must be clearly recognised, especially when such large acreages are sown with such a susceptible variety. Inevitably the potential value of the more mildew resistant varieties was reduced as Golden Promise raised the general level of inoculum. Farmers seemed prepared to accept this situation, at least at first, because Golden Promise offered a combination of malting quality and a number of desirable agronomic characters, in particular, earliness of ripening, stiffness of straw, resistance to grain splitting and resistance to wind loss. To some extent this was also a reflection of the lesser potential of this disease to reduce yield compared, for example, with yellow rust on winter wheat.

It was, however, the introduction of fungicides which ensured the continued popularity of Golden Promise, because both seed treatments and spray applications gave good disease control and highly profitable yield responses (Gilmour 1971b; Gilmour 1973a; Gilmour and Fawcett 1973). Some of these products have given such a good return that there was very little Golden Promise grown in south-east Scotland without routine chemical control of mildew in 1974 and 1975. It seems likely that this blanket use of fungicides delayed the onset of the general mildew epidemic by two to three weeks in 1974, despite the occurrence of weather favourable for mildew. In 1975 cold weather in the late spring helped to keep inoculum levels low and so increased the effectiveness of the fungicides that most crops had only negligible levels of mildew until the end of the season.

Our main concern now is that most of the farmers are using just one fungicide for mildew control. It is estimated that more than 90% of the Golden Promise in south-east Scotland is grown from ethirimol treated seed and this fungicide is also used on a proportion of the other varieties. Increased insensitivity to ethirimol has been demonstrated where this fungicide has been used (Wolfe and Wright 1975) and it has been suggested that the pathogen population may respond to this selection pressure in the same way that it has done to genetically controlled resistance in its host (Wolfe and Dinoor 1973). While there has so far been no obvious reduction in the effectiveness of this fungicide due to the increased insensitivity which the Physiologic Race Survey has shown to be present in south-east Scotland, this risk would clearly be lessened if a diversity of chemicals was available for use as seed treatments to control barley mildew.

Attempts to persuade farmers to lessen the risks of mildew by diversifying their barley varieties have so far been generally unsuccessful in south-east Scotland. While the higher price paid for malting samples has undoubtedly been a factor in maintaining the large acreage of Golden Promise, its combination of desirable agronomic characters is probably more important because only 27% of the total barley production in Scotland is taken for malting and distilling (DAFS 1975). There is thus little prospect for a policy of diversification until plant breeders can at least match the specification of Golden Promise with a more disease resistant variety.

There has, however, been greater success in persuading farmers in south-east Scotland not to grow winter barley which is suspected of being an important source of over-wintering inoculum. When this campaign was started it was estimated that there were fewer than 300 acres of winter barley in south-east Scotland, but these crops had been seen to create quite serious local problems over a number of years in adjacent crops of Golden Promise spring barley (Gilmour 1973b). These observations were reinforced in 1973 when the typical pattern of spread from the winter barley was seen in spring barley crops grown from ethirimol treated seed. In the worst cases it was necessary to spray the spring barley adjacent to the winter barley to achieve adequate disease control (Gilmour 1974). It is likely to become increasingly difficult to maintain the present position as winter barley varieties with higher potential yields are introduced. It would of course be appropriate to review this policy if these winter barley varieties have adequate levels of disease resistance.

CONCLUSION

Experience in south-east Scotland with these important cereal leaf diseases indicates that an effective disease control strategy must take into account as many as possible of the factors which influence the course of disease epidemics. Thus we have advised our cereal growers:

a) to abandon established varieties which have become highly susceptible;

b) not to introduce new varieties which are known to be highly susceptible;

c) to grow several different varieties on any substantial acreage and whenever possible to choose varieties which will lessen the risks from the races known to be important in the local pathogen population;

d) not to grow winter barley to reduce the carry-over of mildew and yellow rust;

e) to adopt husbandry practices which will minimise disease carry-over: specifically, to avoid early sowing and to clean up stubbles before the new brairds emerge;

f) to consider the use of fungicides in relation to the total disease situation and not as a control measure to be used in isolation.

There would appear to be very real prospects for extending this approach. For example, it may be possible to integrate chemical control of a disease with genetically controlled host resistance in a way which lessens the selection pressure on the pathogen from both of them and may thus provide a disease control measure which is more durable. This approach is being explored in a barley project sponsored by EUCARPIA and the International Organisation for Biological Control, in which the control of mildew by ethirimol applied as a seed treatment at the standard rate and at one third of that rate is compared on varieties with differing levels of genetically controlled resistance to the disease. In the one local trial there are indications that some varieties with partial resistance respond at least as well to the reduced dose of fungicide as to the full dose, but a full evaluation must await the completion of the five year project.

While it may be possible to recommend an overall strategy which integrates these various control measures, the decisions of individual growers about their adoption may differ depending on their attitudes to risk. There may, in some circumstances, be a conflict between the immediate decision of an individual farmer and the longer term interests of the wider community of growers. Where cereal leaf diseases are concerned, the interests of the wider agricultural community should be paramount in the formulation of advisory policy.

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CONTROL OF SEED-BORNE DISEASES OF WINTER WHEAT WITH BENOMYL - AND CARBENDAZIM - DITHIOCARBAMATE MIXTURES

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Summary Field trials with a benomyl plus thiram seed treatment have demonstrated high levels of control of loose smut (*Ustilago nuda*) in winter wheat. Bunt (*Tilletia caries*) and seedling diseases caused by Septoria (*Leptosphaeria nodorum*) and Fusarium (*Calonectria nivalis*) were controlled to similar extents by this dressing and by organomercury compounds. Initial results with low rates of a carbendazim plus maneb seed treatment have given excellent control of bunt, Septoria and Fusarium.

Resume En essais de plein champs, le mélange bénomyl plus thiram s'est montré très efficace dans la lutte contre le charbon nu du blé d'hiver (*Ustilago nuda*). La carie (*Tilletia caries*), les maladies de semis telles que la Septoriose (*Leptosphaeria nodorum*), la Fusariose (*Calonectria nivalis*) ont été controlées avec autant d'efficacité par ce traitement ainsi que par les produits organo mercuriques. Les premiers resultats obtenus à doses faibles de carbendazim plus manèbe ont mis en evidence un excellent contrôle de la carie, de la Septoriose ainsi que de la Fusariose du blé.

INTRODUCTION

The broad spectrum activity of benomyl created interest in its possible use as a seed treatment in wheat. It was thought that the systemic activity could lead to improved levels of control of deep-seated infections. Recently there has been general concern in the seed trade about increasing levels of loose smut, and the previous standard treatment with hot water was far from satisfactory. In addition, control of bunt, Septoria and Fusarium was necessary, and could be expected following treatment with benomyl. In the initial development work thiram was added to broaden the spectrum further and protect the developing seedling from damping-off diseases. The benomyl + thiram mixture, which contains 30% benomyl and 30% thiram, already is being marketed as a seed treatment for use in winter wheat, peas, beans and onions. The rate of application on winter wheat for loose smut is 227.2 g/100 kg seed. A later formulation, containing 15% carbendazim and 60% maneb, has been developed for seed treatment and is currently under intensive development. The carbendazim + maneb formulation is being investigated due to the broader spectrum of maneb with particular regard to bunt and Septoria.

We hoped in this way to develop a safe alternative to organomercury seed treatments and to achieve high levels of control of all the major diseases in wheat.

RESULTS

The following three sections each deal with major diseases and the results of trials carried out since 1973.

1. Loose Smut

Seed samples of Maris Ranger and Cappelle were obtained from N.I.A.B. and commercial sources with known high levels of seed-borne disease. All treatments were applied as a dry dressing by mixing the seed and powder together in a churn and turning to ensure thorough and uniform coverage. The seed for large scale trials was treated by standard commercial seed treaters. The plots were 1 acre blocks in grower trials and 1.22 m x 15.85 m in replicated trials, which were randomised with 4 replicates of each treatment. Drilling was carried out with either a hand-controlled single-row precision drill in replicated trials, or with a standard farm drill, in soil types which covered a wide range from organic fen soil to coarse sand. Assessments were made when all the smutted ears were clearly visible, and results are expressed as number of smutted ears per 5000 ears.

Treatments were untreated control, benomyl + thiram at 56.8, 113.6 and 227.2 g product per 100 kg seed and various organomercury standards both with and without carboxin at the recommended commercial rates.

Table 1

Loose Smut - Results of replicated trials carried out in 1973 and 1974

Treatment	Rate g product/100 kg seed	Individual Trial Results no. smutted ears/5000 ears				
Sites		1	2	3	4	5
Untreated	-	36.8	16.5	23.5	20.4	7.9
Benomyl + Thiram	56.8	-	-	0	0	0
" "	113.6	-	-	0	0.3	0.3
" "	227.2	0	0	0	0	0
Organomercury + Carboxin	-	4.6	1.0	-	-	-

Loose Smut - Results of grower trials carried out in 1973 and 1974

Treatment	Rate g product/100 kg seed	Individual Trial Results no. smutted ears/5000 ears								
Sites		1	2	3	4	5	6	7	8	9
Untreated	-	-	-	-	-	2.7	3.9	1.1	11	19
Benomyl + Thiram	227.2	0	0	3	2	0.1	0.1	0	0	0
Organomercury + Carboxin	-	0	6	23	16	-	-	-	-	-
Organomercury	-	6	4	21	31	2.3	7.1	1.6	14	13

The initial level of infection varied from 36.8 to 7.9 smutted ears/5000 ears but control was virtually 100% at all three rates of benomyl + thiram regardless of disease level. The average level of disease was 31.0 smutted ears in the untreated plots of the 9 grower trials but only 0.6 where seed had been treated with benomyl + thiram 227.2 g/100 kg.

2. Bunt

Replicated trials were carried out in 1973, 1974 and 1975. Commercial seed stocks of Cappelle and Maris Ranger were artificially infected with bunt balls prior to seed treatment, and the seed was hand drilled in small plots. Untreated plots were drilled last. Plots were hand harvested and the percentage of bunted ears recorded per plot. A wide range of soil types was covered including black fen (40% organic matter), loamy very fine sand, silty clay loam, coarse sandy loam and clay.

Treatments were untreated control, benomyl + thiram at 56.8, 113.6 and 227.2 g product and carbendazim + maneb at similar rates of formulated product per 100 kg seed, compared with standard organomercury materials at the recommended commercial rates.

Table 2

Bunt - Results of replicated trials carried out in 1973, 1974 and 1975

Treatment	Rate g product/100 kg seed	% Ears infected with bunt Mean (5 sites)	Mean (2 sites)	Mean (4 sites)
Untreated	-	47.5	35.8	29.5
Benomyl + Thiram	56.8	7.5	-	-
" "	113.6	2.0	-	-
" "	227.2	1.1	-	0.05
Carbendazim + Maneb	56.8	-	6.9	-
" "	113.6	-	1.7	-
" "	227.2	2.0	1.5	-
Organomercury	-	38.7	27.2	0.5

Table 2 gives the results from the trials carried out in 1973, 1974 and 1975. Benomyl + thiram and carbendazim + maneb at 56.8, 113.6 and 227.2 g/100 kg seed have given a very high level of bunt control, better than the organomercury standard. Infection levels varied from 5.2% to 83.5% but control was not affected by initial infection levels.

3. Septoria and Fusarium

Trials were carried out in 1973, 1974 and 1975. Specially selected seed stocks were obtained from N.I.A.B. or commercial sources with known high levels of disease. Drilling was carried out with precision drill or standard farm equipment. Seed treatment and plot sizes were similar to those already described in the section on loose smut.

Assessments were made at the 1-3 leaf stage by examining the coleoptiles for lesions. Septoria was positively identified only by the presence of Kietreiber knobs. Fusarium was identified by the presence of diffuse brown staining on the coleoptiles. The results are expressed as percentage of seedlings infected. It is reasonable to consider the two diseases together because they have similar effects on the crop, both giving rise to "seedling blight".

Table 3

Septoria - Results of replicated trials carried out in 1973, 1974 & 1975

Treatment	Rate g product/100 kg seed	% Seedlings infected Mean
Untreated	-	24.4 (10 sites)
Benomyl + Thiram	56.8	1.0 (2 sites)
" "	113.6	0.4 (3 sites)
" "	227.2	0.2 (7 sites)
Carbendazim + Maneb	56.8	1.6 (3 sites)
" "	113.6	0.1 (4 sites)
" "	227.2	0.3 (6 sites)
Organomercury	-	0.4 (10 sites)

Septoria - Results of grower trials carried out in 1974

Treatment	Rate g product/100 kg seed	Mean of 3 sites
Untreated	-	13.2
Benomyl + Thiram	227.2	0.3
Organomercury	-	1.4

Table 4

Fusarium - Results of replicated and grower trials carried out in 1974 & 1975

Treatment	Rate g product/100 kg seed	Replicated (19 sites) Mean % seedlings infected	Grower (13 sites) Mean % seedlings infected
Untreated	-		21.5
Benomyl + Thiram	56.8	17.5	-
" "	113.6	1.0	-
" "	227.2	0.8	0.6
Carbendazim + Maneb	56.8	1.4	-
" "	113.6	0.6	-
" "	227.2	0.5	-
Organomercury	-	1.5	2.2

The results set out in Tables 3 and 4 show that all rates of benomyl + thiram or carbendazim + maneb reduced Septoria and Fusarium infection to levels equivalent to or lower than that following application of the organomercury standard treatment.

DISCUSSION

The trials comparing benomyl + thiram and organomercury + carboxin on loose smut demonstrated the high levels of control achieved. It is known that organomercury compounds have little or no effect on this disease and results showed benomyl + thiram to be superior to organomercury + carboxin.

Control of bunt was achieved with all rates of benomyl + thiram and carbendazim + maneb. Even at high infection levels low rates gave better control than that given by the organomercury standard. The results of these trials gave ample evidence of the poor control achieved by mercury.

Similar results were obtained with Septoria and Fusarium, where benomyl + thiram and carbendazim + maneb at all rates provided control at least comparable to that given by the organomercury standard. In the case of Fusarium both mixtures gave slightly better control than did the standard organomercury treatment, thereby substantiating to some extent the original contention that a fully systemic chemical could give improved control of deep-seated infections.

Although emergence and yield trials were conducted only in the presence of disease, no adverse effect on emergence or yield could be detected (Tables 5 & 6). Experience on a very wide range of soil types indicated that the activity of neither benomyl + thiram nor carbendazim + maneb was affected by soil type.

The results have shown that benomyl + thiram at the recommended rate of 227.2 g/100 kg will give excellent control of loose smut and the other major seed-borne diseases of winter wheat. Preliminary data indicate that carbendazim +

maneb, even at the low rates of 56.8 and 113.6 g/100 kg will give control of the "seedling blight" diseases and bunt comparable to the organomercury standards. There exists in these two mixtures truly safe alternatives to organomercury compounds giving control of all the major seed-borne diseases of wheat.

Table 5

Emergence - Results of emergence counts in 1974 & 1975

Treatment	Rate g product/100 kg seed	Number of plants emerged per metre Variety W.Desprez Mean(3 sites)	Champlein Mean(4 sites)	Chalk Mean(3 sites)	M. Ranger Mean(12 sites)
Untreated	-	29.6	36.0	31.6	33.2
Benomyl + Thiram	56.8	-	-	-	(25.5)*
" "	113.6	-	-	-	(25.2)*
" "	227.2	40.7	56.7	-	36.7
Carbendazim + Maneb	56.8	-	-	36.9	(25.5)*
" "	113.6	-	-	37.1	(23.5)*
" "	227.2	-	-	37.5	(25.1)*
Organomercury	-	47.7	58.5	34.6	38.1

* = 3 sites only

Table 6

Yields - Results of yield trials in 1974

1. Replicated trials - Results derived from Fusarium and Septoria trials

Treatment	Rate g product/100 kg seed	Individual Sites kg/plot at 15% M/C					
Sites		1	2	3	4	5	Mean
Untreated	-	9.6	19.0	7.0	8.8	13.8	11.6
Benomyl + Thiram	227.2	9.9	18.6	6.6	9.0	14.0	11.6
Organomercury	-	9.9	19.2	6.9	9.0	14.2	11.8
L.S.D. 5%							N.S.

2. Grower trials - Results derived from Loose Smut and Fusarium trials

Treatment	Rate g product/100 kg seed	Individual Sites tonnes/ha at 15% M/C				
Sites	-	1	2	3	4	Mean
Untreated	-	3.4	4.9	4.7	4.8	4.5
Benomyl + Thiram	227.2	4.5	4.6	4.5	4.5	4.5
Organomercury	-	5.0	4.7	4.4	4.8	4.7
L.S.D. 5%						N.S.

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THE EFFECTIVENESS OF GUAZATINE AND IMAZALIL AS SEED TREATMENT FUNGICIDES IN BARLEY

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Summary Guazatine at 0.6g/kg seed has been shown to have high activity against a wide spectrum of cereal seed-borne diseases including Leptosphaeria nodorum, Calonectria nivalis, Pyrenophora avenae, Tilletia caries and Ustilago avenae. Control of Ustilago nuda on wheat and barley has been achieved by the addition of carboxin at 0.75 g/kg seed. This combination has however given only 90% control of high infections of Pyrenophora graminea on barley. Control of P. graminea, equal to that given by organomercury, has been achieved by the addition of imazalil at 0.04g to guazatine at 0.6 g/kg seed, applied as liquid seed treatments.

Résumé On a démontré que guazatine à 0,6 g/kg de graine à une haute activité contre une grande gamme de malaises transmises par les graines de céréales y compris Leptosphaeria nodorum, Calonectria nivalis, Pyrenophora avenae, Tilletia caries et Ustilago avenae. Le contrôle d'Ustilago nuda sur le blé et l'orge a été obtenu par l'addition de carboxin à 0,75 g/kg de graine. Pourtant, cette combination a donne seulement un contrôle de 90% sur les infections graves de Pyrenophora graminea sur l'orge. Le contrôle de P. graminea, égal à celui donné par l'organomercure a été obtenu par l'addition d'imazalil a 0,04g à guazatine à 0,6 g/kg de graine, appliqués comme des traitements liquides de la graine.

INTRODUCTION

The performance of bis (8-guanidino-octyl)amine (guazatine) alone and in combination with other fungicide seed treatments has been described by Jackson et al. (1973). Up to 1973 guazatine was investigated as the water-soluble acetate or insoluble sesquisulphate salt. A powder combination of guazatine sesquisulphate with maneb and a slurry combination of guazatine acetate with carboxin were tested in an attempt to improve the control of P. graminea by guazatine. The guazatine/carboxin slurry gave 90% control of a 7% infection of P. graminea on spring barley, while the guazatine/maneb powder gave 93.8% control and organomercury liquid gave 97.9% control. Chemical instability made it impossible to prepare a slurry formulation of guazatine and maneb.

Work in 1974 and 1975 has been directed toward finding a fungicide which, when combined with guazatine, would give control of P. graminea equal to that given by organomercury, with an added requirement that the material must be capable of being formulated as a liquid or slurry for application through the Mist-O-Matic seed dresser. Imazalil was found to conform to these specifications and the results of field trials with guazatine/imazalil and guazatine/imazalil/carboxin mixtures compared with guazatine alone are reported here.

Imazalil or R23979[+] is 1-(β-(allyloxy)-2,4-dichlorophenethyl)imidazole. Imazalil is a light brown oily liquid which is slightly soluble in water (0.14g/100 ml water) but very soluble in most organic solvents. Toxicological data are shown in Table 1.

Table 1

Toxicology of imazalil

Route	Animal	LD_{50} mg/kg
Acute oral	Rat (M)	320
Acute oral	Dog	>640
Acute oral	Japanese quail	510
Acute dermal	Rat (M)	4,200
	Rat (F)	4,880

METHODS AND MATERIALS

Formulations

Guazatine as the water soluble acetate (30% a.i. w/v), and imazalil as the acetate salt, were combined in various ratios as shown in Table 2.

Table 2

Details of formulations

Treatment	Formulation	% a.i.	Rate ml/kg seed	g a.i./kg seed guazatine	imazalil	carboxin
guazatine	liquid	30	2	0.6		
guazatine/imazalil	liquid	30/10	2	0.6	0.2	
guazatine/imazalil	liquid	30/8	2	0.6	0.16	
guazatine/imazalil	liquid	30/7.5	2	0.6	0.15	
guazatine/imazalil	liquid	30/5	2	0.6	0.10	
guazatine/imazalil	liquid	30/4	2	0.6	0.08	
guazatine/imazalil	liquid	30/2	2	0.6	0.04	
guazatine/imazalil	liquid	30/1	2	0.6	0.02	
guazatine/imazalil/ carboxin	slurry	20/2.7/25	3	0.6	0.08	0.75

These formulations were compared with commercially available formulations of organomercury (phenyl mercury acetate) and organomercury/carboxin seed dressings.

+ a product of Janssen Pharmaceutica, Beerse, Belgium.

Seed treatments A compressed gas atomiser was used to spray the liquid formulations on to a thin layer of seed, which was shaken immediately in a polythene bag to obtain a good distribution.

The slurry formulation was applied by shaking the chemical and seed together in a large glass jar.

Trial Layout Small plots (1 x 10m) were employed in randomised block arrangements with four replicates. The plots were drilled with a tractor-mounted Øyjord drill at a sowing rate of 160 kg/ha.

Assessments Emergence was determined by counting the number of plants in a 5 x 1m row length at random in each plot at growth stage 1-2 (Feekes scale). The extent of infection by P. graminea was assessed by counting the number of infected plants per plot when the crop was coming into ear. Infection by Cochliobolus sativus was assessed at growth stage 3 by digging 150 plants, at random, from each plot and examining them in the laboratory. The severity of Ustilago nuda infection was assessed by counting the total smutted ears per plot. Pyrenophora avenae infection was assessed at growth stage 2 by counting the number of diseased and healthy plants in five random 1m row lengths per plot.

RESULTS

(a) Barley leaf stripe (Pyrenophora graminea)

The results obtained from the 1974 trials at three sites are shown in Table 3. All three guazatine/imazalil treatments gave control of P. graminea superior to that obtained with organomercury.

Table 3

% control of P. graminea on spring barley cv. Edda II at three sites in 1974

Treatment	g a.i./kg seed	% control of P.graminea: Site A	Site B	Site C	Mean
guazatine/imazalil	0.6/0.10	97.7	98.6	100	98.8
guazatine/imazalil	0.6/0.15	98.1	98.2	98.6	98.3
guazatine/imazalil	0.6/0.20	98.4	99.5	98.6	98.8
organomercury	0.02	93.7	96.6	95.7	95.3
untreated % infection		4.1	3.9	6.6	4.9
S.E.		±3.8	±3.6	±1.2	

In 1975 guazatine, at constant rate, was evaluated in combination with imazalil at a range of rates lower than those used in 1974. The results of three trials (Table 4) show that none of the treatments appeared adversely to affect the barley emergence.

The control of P. graminea in 1975, by the organomercury, was better than in 1974 in the barley cv. Tern (Table 5) and as good as in 1974 in the barley cv. Clermont (Table 6). Guazatine alone gave a mean control of 49% in Tern and 59% in Clermont, whilst the addition of imazalil at rates of 0.04 g/kg seed, or above, gave control equal to organomercury.

Table 4

Emergence of spring barley cv. Tern with a 50% infection of P. graminea at three sites in 1975

Treatment	g a.i./kg seed	Emerged plants/m of row Site A	Site B	Site C	Mean
guazatine	0.6	30.4	24.6	30.1	28.4
guazatine/imazalil	0.6/0.02	34.9	25.2	29.3	29.8
guazatine/imazalil	0.6/0.04	29.7	25.1	26.8	27.2
guazatine/imazalil	0.6/0.08	30.0	24.9	29.2	28.0
guazatine/imazalil	0.6/0.16	30.8	22.2	32.1	28.4
organomercury	0.02	31.7	22.8	31.7	28.7
untreated		32.1	28.2	24.6	28.3
S.E.		N.S.	N.S.	N.S.	

Table 5

% control of P. graminea on spring barley cv. Tern at three sites in 1975

Treatment	g a.i./kg seed	% control of *Pyrenophora graminea* Site A	Site B	Site C	Mean
guazatine	0.6	57.0	41.2	48.8	49.0
guazatine/imazalil	0.6/0.02	99.6	96.0	90.0	95.2
guazatine/imazalil	0.6/0.04	99.8	98.7	98.1	98.9
guazatine/imazalil	0.6/0.08	100	99.8	99.7	99.8
guazatine/imazalil	0.6/0.16	100	100	100	100
organomercury	0.02	100	98.5	99.4	99.3
untreated % infection		5.4	5.3	4.5	5.1
S.E.		±2.0	±3.6	±11.0	

(b) Foot rot (*Cochliobolus sativus*)

This disease is not, at present, common in the U.K., but it may become as important in the future as it is now in N. America. The fungus produces dark brown lesions on the roots which can, under the right conditions, kill the seedlings. The plants generally grow to maturity, but the heads are poorly filled and become covered with secondary black moulds (Moore and Moore, 1961). In this trial there appeared to be little or no seedling death, as can be seen from the emergence counts in Table 6.

C. sativus is not well controlled by organomercury, which, in this trial achieved only 29% control (Table 6). The combination of organomercury/carboxin gave 70% control which was similar to the 69% control given by guazatine alone. The addition of 0.08g imazalil to guazatine gave 78% control which was increased to 87% by the addition of carboxin.

Table 6

Emergence of spring barley cv. Clermont and % control of Cochliobolus sativus and P. graminea at Site C in 1975

Treatment	g a.i./kg seed	Emerged plants per metre	% control C.sativus	% control P.graminea
guazatine	0.6	29.4	69.0	58.9
guazatine/imazalil	0.6/0.02	29.1	77.5	87.0
guazatine/imazalil	0.6/0.04	29.2	70.3	94.1
guazatine/imazalil	0.6/0.08	29.3	77.8	99.2
guazatine/imazalil	0.6/0.16	25.6	87.5	97.7
guazatine/imazalil/ carboxin	0.6/0.08/0.75	27.3	89.4	96.6
organomercury/ carboxin	0.02/0.75	29.9	69.9	97.2
organomercury	0.02	28.7	28.9	95.8
untreated (% infection)		27.3	(33.5)	(4.1)
S.E.		N.S.	± 9.0	±9.1

(c) Loose smut (Ustilago nuda)

The results of the 1975 trials at three sites are shown in Table 7. The control of U. nuda achieved by the combination of guazatine/imazalil/carboxin was equal to that given by the standard organomercury/carboxin treatment.

Table 7

% control of U. nuda on spring barley cv. Sultan at three sites in 1975

Treatment	g a.i./kg seed	% control of U. nuda Site A	Site B	Site C	Mean
guazatine/imazalil/ carboxin	0.6/0.08/0.75	92.9	97.0	96.6	95.5
organomercury/ carboxin	0.02/0.75	92.7	98.9	94.9	95.5
organomercury	0.02	6.8	0.0	5.4	4.1
untreated % infection		2.3	1.1	1.2	1.5
S.E.		±10.0	±16.2	±9.7	

(d) Oat leaf spot (Pyrenophora avenae)

The results obtained from the 1975 trials at Sites A and C are shown in Table 8. Organomercury gave very poor control of P. avenae, and uncombined guazatine was markedly superior. At Site A, combinations of guazatine/imazalil gave increasing control with increasing rate of imazalil: the highest rate, 0.6/0.16, gave 84% control. The results at Site C were not dose-responsive.

Table 8

% control of P. avenae on oats cv. Astor at two sites in 1975

Treatment	g a.i./kg seed	Site A	% control P. avenae Site C	Mean
guazatine	0.6	39.4	71.4	55.4
guazatine/imazalil	0.6/0.02	44.5	68.1	56.3
guazatine/imazalil	0.6/0.04	63.5	53.7	58.6
guazatine/imazalil	0.6/0.08	73.9	66.5	70.2
guazatine/imazalil	0.6/0.16	83.7	59.5	71.6
organomercury	0.02	0.0	40.0	20.0
untreated % infection		6.2	13.8	10.0
S.E.		±31.3	±19.3	

DISCUSSION

The results of these trials show that imazalil at 0.04g a.i./kg seed added to guazatine at 0.6g a.i./kg seed, can control P. graminea as well as can organomercury. The addition of imazalil also improved the control of C. sativus by guazatine, which itself was markedly superior to organomercury.

This improved control of C. sativus is thought to be due to the guazatine/imazalil combination penetrating the seed and killing the fungal mycelium. Organomercury is thought to kill only the spores adhering to the outside of the seed.

Relatively poor control of U. nuda, given both by the organomercury/carboxin standard and by the guazatine/imazalil/carboxin treatments, may be attributable to the relative inaccuracy of the hand-spraying application technique used, which may not achieve the 99% control encountered in commercial practice.

While not strictly within the scope of this paper, the results of two trials carried out on oats have been included because of the interest in the organomercury resistant P. avenae. The 55% control given by guazatine alone in 1975 was less than the 80% control achieved previously (Jackson et al.1973); however there did appear to be some additive effect from the addition of the imazalil. Further trials are needed to confirm the level of control which consistently can be achieved.

The crop safety of guazatine has been reported previously (Jackson et al. 1973). The safety of guazatine/imazalil has been demonstrated by the high emergence rates observed in our trials. Yield data has not been included in this report as these small-plot trials were primarily intended for disease assessment and were not suitable for valid yield assessment.

Results of these trials with guazatine/imazalil and of previous trials with guazatine alone (Jackson et al.1973) indicate that a combined liquid formulation of guazatine/imazalil at 0.6/0.04g a.i./kg barley seed could be used as an effective alternative to organomercury.

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EXPERIMENTAL INSECTICIDES AS SEED TREATMENTS FOR THE CONTROL OF WHEAT BULB FLY IN CEREALS

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Summary Of several insecticides tested as seed treatments against wheat bulb fly in 1973-4 and 1974-5 the organophosphorus compounds triazophos and isofenphos and the pyrethroid permethrin were most effective. Mixtures of carbophenothion and chlorfenvinphos also gave good results. Deep sowing of untreated seed and seed treated with dieldrin or chlorfenvinphos considerably increased the severity of attack.

Resumé D'aprés les essais faits en 1973-4 and 1974-5 le triazophos et l'isofenphos, des dérivés de l'acide phosphorique, et une pyrethroide la perméthrine ont données les meilleurs résultats pour le traitement de la graine contre la mouche grise du blé. Des mélanges d'essais de carbophenothion et chlorfenvinphos ont aussi donné des resultats satisfaisants.

L'enfouissement profond de la graine non traitée ou traitée à la dieldrine ou au chlorfenvinphos accroit le pourcentage de plants endomages.

INTRODUCTION

An ideal seed treatment against wheat bulb fly should be consistently effective under the varied conditions encountered in practice, but safe to operators during handling and sowing; it should also be harmless to wildlife, and there should be a wide safety margin between the dose that is toxic to insects and the dose that harms the plant. Judged by these criteria none of the present materials is entirely satisfactory and the purpose of the tests described in this paper was to examine untried insecticides and methods of application that might have advantages over those now in use.

METHOD AND MATERIALS

1973-4 trials

All insecticide treatments (Table 2) were applied to winter wheat cv. Bouquet, previously treated with a liquid organomercury fungicide. Two insecticides, CGA 12223 (O,O-diethyl-O-(1-isopropyl-5-chloro-1,2,4-triazolyl-(3))-thiophosphate and isofenphos were obtained as formulated dusts from the manufacturers, but the others were made into 20% dusts by mixing technical material with talc (B.D.H. Ltd). All dusts were applied to seeds by mixing together in a beaker using 6 ml of 3% methyl cellulose/100g seed as a sticker, a method that ensures that 90% or more insecticide is retained on the seed (Bardner, 1960). Liquid insecticides were applied to 500g batches of seed using the rotating drum apparatus described by Jeffs (1973). Preliminary germination tests in the laboratory had determined the dosage levels to be tested in the field. Treatments with γ-BHC, done with the help of the staff at ICI Plant Protection Division, Fernhurst, comprised 40% γ-BHC powder applied by a small Rotostat or small Plantector machine, with or without a sticker, in this case 12 ml of 6% aqueous emulsion of soya bean oil/kg seed. The amounts of γ-BHC on treated seeds were determined by the method of Lord et al (1967).

1974-5 trials

Promising materials from the 1973-4 trials were compared as liquid and powder formulations, the latter with or without a 6% aqueous emulsion of soya bean oil as a sticker. In addition, isofenphos powder, rolled with seed in a glass container for 30 min until the powder became firmly compacted on the seed, provided another experimental treatment. One new material SD 8832 (2-chlorovinyl ethyl diethylphosphoramidate, mixture of E and Z isomers) was included and, in addition to the chlorfenvinphos standard treatment, chlorfenvinphos mixed 1:4 with the synergist piperonyl butoxide was also tested. As in 1973-4 all insecticides were applied to seed previously treated with a liquid organomercury fungicide, but two varieties of seed were used in 1974-5, Maris Templar on the clay loam, and Bouquet on the peaty loam (Table 1).

In both years 10g lots of seed were sown by hand at a depth of 2-3 cm in 3.05 m furrows in fields severely infested with wheat bulb fly eggs. To minimise effects of neighbouring treatments, seeds were sown in 'plots' consisting of 3 adjacent rows, but only the middle row was sampled and examined. The 'plots' were arranged as 4 randomised blocks at each site. Deep sowings in 1973-4 were achieved by placing seeds in slits, 10 cm deep, made with a spade.

When the seedlings had emerged but before wheat bulb fly eggs had hatched, each plot was scored visually on a scale 0-10 to determine if any treatments had affected early growth in field conditions. In late February or in March, plants from 1.22 m centre row were removed from each plot and dissected in the laboratory to assess the effectiveness of the treatments in preventing insect attack or in killing insect larvae within the plants. At Whittlesey in 1973-4 combine drilling of the surrounding area of the field extended by mistake into parts of the experimental area, so only certain plots could be sampled.

Table 1 gives details of the trial sites, with dates of sowings and examinations.

Table 1

Short Row trials - Site Details

	1973-4				1974-5	
	Abbotsley	Caythorpe	Rothamsted	Whittlesey	Abbotsley	Pondersbridge
Soil type	Clay loam	Fine loamy drift on Lincs limestone	Flinty clay loam over clay-with-flints	Peaty loam	Clay loam	Peaty loam
Egg count millions/ha	9.0	9.9	5.9	6.2	8.8	6.3
Sowing date	23.10.73	30.10.73	1.11.73	26.11.73	21.10.74	3.12.74
Seed variety	Bouquet	Bouquet	Bouquet	Bouquet	Maris Templar	Bouquet
Plot size	3 rows x 3.05m	3 rows x 3.05m	3 rows x 3.05m	3 rows x 3.05m	3 rows x 3.05m	3 rows x 3.05m
Date of visual score at emergence	23.11.73	7.1.74	14.12.73	15.1.74	6.12.74	15.1.75
Sample date	25.2.74	19.3.74	7.3.74	25.3.74	17.3.75	5.3.75

Table 2

Experimental treatments and visual scores at emergence 1973-4

Treatment	Material (P) powder (L) liquid	% a.i. to weight of seed	Visual score at emergence (Max 40) A+	W+	C+	R+	Treatment code
Experimental insecticides stuck to seeds with methyl cellulose	Permethrin 20%P	0.5	28	24	30	20	E.I. 1
		0.1	23	28	28	17	2
	CGA 12223 20%P	0.2	13	7	10	0	3
	Isofenphos 20%P	0.3	28	20	34	23	4
	Cyanofenphos 20%P	0.5	31	21	34	33	5
		0.1	25	20	33	23	6
	Triazophos 10%P	0.2	23	5	24	5	7
		0.1	24	9	28	12	8
	Aldicarb 20%P	0.5	17	21	31	21	9
		0.1	24	17	32	24	10
	Terbufos 20%P	0.5	30	19	30	24	11
		0.1	27	17	32	20	12
Standards	Chlorfenvinphos 32.2%L	0.1	25	19	33	26	S 1
	Carbophenothion 60%L	0.12	29	16	31	28	2
	Dieldrin 60%P	0.12	20	19	30	18	3
	Control		24	23	31	18	C
Deep sown treatments	Chlorfenvinphos 32.2%L	0.1	16	7	31	12	D.S. 1
	Dieldrin 60%P	0.12	15	8	28	4	2
	Control		14	16	28	15	3
Mixtures	Chlorfenvinphos/ carbophenothion	0.1/ 0.12	23	11	30	20	M 1
	Chlorfenvinphos/ carbophenothion	0.05/ 0.06	29	11	31	26	2
Rotostat treatments	γ-BHC 40%P	420*	24	14	30	22	R 1
	SBO (soya bean oil)		38	21	35	31	2
	SBO + γ-BHC 40%P	794*	21	12	29	21	3
Plantector treatments	γ-BHC 40%P	425*	13	13	24	11	P 1
	SBO + γ-BHC 40%P	838*	23	20	24	20	2

* analysed dosages (ppm)

A+ = Abbotsley, W+ = Whittlesey, C+ = Caythorpe, R+ = Rothamsted

RESULTS

1973-4 trials (Tables 2 and 3)

Aldicarb and terbufos are very toxic to mammals but were included to see if they would give insect control superior to that of the more moderately toxic insecticides currently in use. Plant emergence was satisfactory (Table 2) but only terbufos at 0.5% a.i. to weight of seed had much activity against wheat bulb fly (Table 3). Cyanofenphos was relatively ineffective except at Abbotsley, where, at 0.5% a.i. to weight of seed, it decreased the percentage of damaged shoots and at both dosages decreased the percentage of plants with live larvae. CGA 12223 was more phytotoxic than preliminary laboratory tests had suggested: therefore, although it decreased live larvae, it did not improve plant stands, as indicated by the numbers of healthy shoots.

Triazophos considerably decreased the percentages of damaged shoots and live larvae (Table 3) but did not improve plant stands at Whittlesey or Rothamsted because of phytotoxic effects noted at germination (Table 2).

Permethrin greatly decreased the percentage of damaged shoots so that few plants contained larvae; however, larvae that succeeded in entering the plants survived. The excellent germination of seeds treated with permethrin and the effect of this material in preventing larval entry resulted in large numbers of healthy shoots. Isofenphos was the most active insecticide; in addition to decreasing the percentage shoots damaged by wheat bulb fly, it also killed many larvae inside the plants. Therefore the percentage of plants with live larvae was much less than occurred after treatment with the standard materials chlorfenvinphos, carbophenothion and dieldrin, all of which were reasonably effective compared with the controls.

Deep sowing delayed germination and resulted in decreased scores at emergence (Table 2). The percentages of damaged shoots and of plants containing live larvae were greater than in corresponding treatments (dieldrin, chlorfenvinphos and control) in which the seeds were sown more shallowly. Final plant stands, judged by the number of healthy shoots per m row, were less in deep sown treatments than in their shallow-sown counterparts.

Seeds treated with mixtures of carbophenothion and chlorfenvinphos at both dosage levels germinated well except at Whittlesey (Table 2) and were amongst the most effective treatments with respect to all variates measured in the plant samples (Table 3).

Of the treatments applied by commercial machinery, soya bean oil (without insecticide) gave unexplained large scores at emergence but most of the γ-BHC treatments gave smaller visual scores at emergence than the controls (Table 2). Despite considerably increased loadings of γ-BHC achieved by the use of soya bean oil as a sticker, insect control was not measurably improved.

1974-5 trials (Table 4)

The only new compound tested, SD 8832, was ineffective and gave results similar to that of the untreated control. At Abbotsley the standard insecticide chlorfenvinphos also gave results similar to the control, whereas at Pondersbridge, although it decreased plant scores at emergence, it also decreased the percentage of damaged shoots and the percentage of plants with live larvae. Chlorfenvinphos with piperonyl butoxide gave very similar results to those achieved with chlorfenvinphos alone.

Table 3

Seed treatment trials 1973-4

Treatment code (see Table 2)	% damaged shoots				% plants with live larvae				Healthy shoots per m row			
	A^{+}	W	C	R	A^{+}	W	C	R	A^{+}	W	C	R
E.I. 1	9	12	9	6	12	21	17	12	167	150	119	162
2	9	16	16	11	4	26	33	18	121	153	111	129
3	38		39	19	18		38	28	51		48	83
4	3	4	4	4	0	1	0.5	0.5	154	103	225	182
5	25		35	21	24		60	35	131		81	113
6	37		39	16	24		65	31	90		93	131
7	10	9	8	13	2	0	4	7	119	16	110	75
8	13	24	16	6	6	6	15	4	152	51	121	155
9	42		39	22	34		65	46	74		104	109
10	41		41	17	16		71	34	84		78	143
11	23		23	10	13		25	16	135		154	157
12	35		59	16	24		72	29	94		38	152
S 1	16	17	18	10	14	14	25	13	144	60	159	169
2	25	23	30	8	23	16	54	13	108	94	118	203
3	32	35	28	16	16	3	17	11	82	56	98	135
C	42	46	35	20	39	57	61	35	76	57	82	119
DS 1	40		37	21	39		48	30	99		67	70
2	46		39	28	41		44	36	61		69	49
3	57		62	34	50		80	45	26		28	42
M 1	12	6	9	3	12	0.2	9	4	148	75	148	164
2	10	13	20	8	13	8	39	11	167	96	166	136
R 1	28		30	19	11		47	31	97		131	97
2	29	44	43	13	21	61	58	30	149	37	90	172
3	26		29	16	14		51	26	71		88	97
P 1	23		36	17	8		50	30	44		62	60
2	22		39	11	10		68	20	87		44	102
S.E. difference	5.4		8.3	3.6	6.8		9.8	6.2	23		31	20

$^{+}$Spray drift at Abbotsley from nearby aerial application of omethoate on 14 Feb 1974 probably affected results from all plots to some extent

Table 4

Seed treatment trials 1974-5

Treatment	Material (P) powder (L) liquid	% a.i. to weight of seed	Visual score at germination (max 40) A^+	Visual score at germination (max 40) P^+	% damaged shoots A^+	% damaged shoots P^+	% plants with live larvae A^+	% plants with live larvae P^+	Healthy shoots per m row A^+	Healthy shoots per m row P^+
Stuck to seed with soya bean oil	Permethrin 20%P	0.2	29	31	16	18	28	44	134	103
	Isofenphos 40%P	0.2	30	28	14	15	18	19	162	88
		0.4	33	24	10	8	17	5	187	101
Compacted on seed	Isofenphos 40%P	0.2	28	31	8	15	22	11	183	89
With no sticker	Permethrin 20%P	0.2	31	30	12	13	29	31	135	122
	Isofenphos 40%P	0.2	29	32	11	20	26	16	129	98
	SD 8832 20%P	0.2	30	30	17	37	34	71	152	61
Liquid formulations	Permethrin 50%L	0.2	30	34	11	17	25	46	167	107
	Isofenphos 50%L	0.2	29	34	12	10	25	6	176	106
	Chlorfenvinphos 32.2%L	0.1	26	21	20	20	44	33	119	80
Synergised insecticide	Chlorfenvinphos 32.2%L + piperonyl butoxide	0.1	25	21	17	20	34	30	130	66
Sticker alone	Soya bean oil		29	29	19	26	41	55	134	76
Control			27	35	21	33	36	72	142	87
S.E. difference					3.5	3.4	7.7	7.1	22	16

A^+ = Abbotsley, P^+ = Pondersbridge

In the second year in which they were tested, isofenphos and permethrin again showed activity against wheat bulb fly larvae. The best treatment was isofenphos at 0.4% a.i. stuck to seed with soya bean oil. Both isofenphos and permethrin decreased larval attack and increased the number of healthy shoots when applied to seed at 0.2% a.i. in either liquid or powder formulations, thus indicating the possibility of practical control with these materials.

DISCUSSION

Seed treatments for use against wheat bulb fly must be effective in a wide range of soil conditions and the tests reported here were done on several soil types. Deep sowing of some treatments was tested because this practice may become more common with increasing use of modern pre-emergence herbicides. Most published evidence (Way, 1959; Lord et al, 1967; Maskell, 1970) suggests that insecticides whose main mode of action is to prevent entry of larvae into plants are affected more severely by deep drilling than those insecticides that mainly kill larvae within the plant. Dieldrin and, to a lesser extent, chlorfenvinphos belong to the latter class of insecticide but the results of the 1973-4 trials showed that even these insecticides are less effective when sowing is as deep as 10 cm, and that plant stands resulting from such sowings on soils infested with wheat bulb fly are inferior to those from similar seed sown at 2-3 cm.

Synergism of chlorfenvinphos was investigated because of a report that vinyl phosphates are synergised by sesamex (Sun & Johnson, 1972). No improvement was noted in our tests, possibly because a slightly different synergist, piperonyl butoxide, was used, or not enough synergist was employed, or it did not persist long enough in the soil.

Mixtures of insecticides would present difficulties in practice but were tested for two reasons. First, organophosphorus insecticides tend to vary in relative effectiveness in different soil conditions: this may be attributable in part to varying degrees of adsorption and movement in soils of different characteristics and moisture contents, so that conditions that favour one insecticide may decrease the effectiveness of another. A mixture, therefore, might give greater reliability if the two insecticides have complementary properties. Secondly, there is the possibility of synergism, leading to increased insecticidal activity. The mixtures did control insects well at all sites and at both dosage levels but the standard insecticides worked well singly in 1973-4 so that improvement in activity was hard to demonstrate.

Of the experimental compounds, isofenphos, permethrin and triazophos had the greatest effect on insect larvae. The usefulness of triazophos is limited by adverse effects on plant emergence but a slow release formulation, e.g. a micro-encapsulated seed dressing, might decrease phytotoxic hazards whilst retaining insecticidal activity.

Isofenphos was exceptionally active against wheat bulb fly, decreasing the percentage of shoots attacked and also killing larvae inside the plant; the samples taken from the four trial sites in 1973-4 had a total of 313 live larvae in the controls but only 3 live larvae in plants grown from seed treated with isofenphos at 0.3% a.i. This level of control has not been achieved before with a seed treatment. In neighbouring ADAS trials at Abbotsley and Whittlesey in 1973-4, isofenphos at 0.05% a.i. to weight of seed was no better than chlorfenvinphos at similar dosages, suggesting that the main advantage of isofenphos is its greater safety to the plants, allowing it to be applied at greater dosages. Unfortunately, practical difficulties of obtaining large loadings with present formulations make it unlikely that isofenphos will be developed commercially as a seed dressing for wheat bulb fly control.

The characteristics of the stable pyrethroid permethrin were described by Elliott et al (1973). The results with permethrin in these trials were encouraging, as they represent the first occasion that any insecticide other than an organochlorine or organophosphate has been effective as a seed treatment against wheat bulb fly larvae. Its activity in these short row trials was about equivalent to that of the standard insecticides now in use. Permethrin, however, acts almost entirely by preventing larvae from entering the plant, and has little or no systemic action, so its activity would probably be greatly decreased by deep sowing. Despite this possible disadvantage, related pyrethroids would be worth testing, and analysed loadings of permethrin on the seed should be examined further in large plot trials that will give reliable yields; this work is now being done.

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THE CONTROL OF WHEAT BULB FLY WITH FONOFOS GRANULES

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Summary Wheat bulb fly damage in winter wheat was reduced using fonofos granules at 0.84 to 3.36 kg/ha a.i. (0.75 to 3.0 lb/ac a.i.) (optimum rate between 1.1 and 1.7 kg/ha a.i.) in field trials in 1974-1975. This confirms earlier work carried out since 1965. Fonofos was applied as an overall application at drilling. Larval entry into the shoot was reduced and larval mortality within the shoot was increased. No adverse effects on seedling emergence, tillering and yield on crops with and without wheat bulb fly infestation were observed over the entire range of fonofos concentrations tested. Yields were increased by fonofos in comparison to untreated controls and standard seed treatments. A glass-house trial showed no deleterious effect of applying fonofos to seed already treated with wheat bulb fly seed treatments.

Résumé Les détériorations par la mouche grise du blé ont été réduites dans le blé d'hiver par l'utilisation de granules de fonofos à 0,84 à 3,36 kg/ha a.i. (0,75 à 3,0 lbac a.i.) (taux optimum entre 1,1 et 1,7 kg/ha a.i.) lords d'essais en plein champ en 1974-1975. Ceci confirme les travaux effectués précédemment depuis 1965. Le fonofos a été employé comme application générale lors de semis en lignes. La pénétration de larves dans la pousse a été reduite et la mortalité des larves dans la pousse a été accrue. Aucun effet adverse sur l'émersion de plantules, la pollinisation et la rendement des cultures avec ou sans attaque de mouche grise du blé n'a été obervé sur toute la gamme des concentrations de fonofos essayées. Le fonofos a accru les rendements en comparaison avec des contrôles non traités et des traitements standard de semence. Un essai sous serre a montré qu'aucun effet nuisible n'intervient lors de l'application de fonofos à des semences dejà traitées avec des applications pour semence contre la mouche grise du blé.

INTRODUCTION

Wheat bulb fly (Leptohylemyia coarctata) is a major insect pest of winter wheat in eastern England. Control measures before 1975 were mainly limited to seed treatments, often supplemented by foliar sprays of insecticides in the spring. This report illustrates a new technique of control involving an overall application of fonofos granules at drilling to give protection from wheat bulb fly throughout the growing season.

The effect of fonofos granules on wheat bulb fly has been demonstrated in ADAS (NAAS) trials in 1965 and 1973 to 1975. Mathias and Roberts (1967) and Catling (1967) showed in a series of five trials comparing a number of new products against standard seed treatments and untreated controls that:-

(i) Fonofos at 1.0 and 1.1 Kg/ha a.i. (two trials) gave 22% and 29% damaged shoots, compared to 42% and 49% with untreated. Yield with fonofos increased by 0.3 and 0.9 t/ha over untreated, and with dieldrin by 0.3 and 0.5 t/ha over untreated. These rates appear to be sub-optimum.

(ii) Fonofos at 1.7 kg/ha a.i. (one trial) gave 19% damaged shoots compared to 74% with untreated. Yield with fonofos increased by 4.9 t/ha over untreated, and with dieldrin by 3.9 t/ha over untreated. This rate appears to be close to the optimum.

(iii) Fonofos at 2.2 kg/ha a.i. (two trials) gave 15% and 3% damaged shoots, compared to 74% and 46% with untreated. Yield with fonofos increased by 3.3% t/ha over untreated, and with dieldrin by 3.9 t/ha over untreated. Yields were not taken on the second trial at this rate. This rate appears higher than optimum.

In 1973-74 and 1974-75, further ADAS trials (ADAS Eastern Region and East Midland Region - unpublished) gave results as shown in Table 1:-

Table 1 Preliminary ADAS Trial Results

Year	Treatment	Healthy shoots per m	% attacked shoots	% Plants with live larvae	Yield t/ha
1973/74	Untreated control	-	30 (34)	47 (43)	6.1
	Fonofos 5%	-	4 (10)	6 (12)	6.7
	1.7 kg/ha a.i.		± (1.7)	± (2.3)	± 0.15
1974/75	Untreated control	88	38	62	5.4
	Fonofos 10%	133	23	42	7.0
	1.7 kg/ha a.i.			No. of live larvae/m	
1974/75	Untreated control	46	69	9	4.3
	Fonofos 10%	148	11	1.5	6.4
	1.7 kg/ha a.i.				

Figures in brackets are angular transformations

EXPERIMENTAL

One trial was laid down on sandy clay infested with wheat bulb fly (egg population of 1.25 million/ac). Seed of Atou winter wheat, which had not been dressed with insecticides, was drilled in mid-October. In another trial, also on infested land but with an unknown egg population, non-dressed seed of Maris Huntsman was sown on sandy clay loam in mid-December. The five treatments were: untreated control, 0.8, 1.7 and 3.4 kg/ha a.i. of fonofos 10% granules (Dyfonate* 10G) and BHC seed treatment (Mergamma W), each replicated four times on 36 m x 3.3 m plots. Application was made with a Horstine Farmery motorised knapsack applicator, incorporated with a single pass of a fixed harrow immediately prior to drilling.

*Dyfonate is a Registered Trade Mark of Stauffer Chemical Company

A third trial on non-infested land was late drilled with non-insecticidal-treated Maris Templar wheat on clay soil. Treatments were untreated control, 1.7 and 3.4 kg/ha a.i. of fonofos granules, and an experimental seed treatment, each replicated four times on 8 m x 2 m plots. Application of granules was made with a pepper pot applicator and incorporated by raking.

Emergence counts were made at the 2 leaf stage by counting all wheat plants in 10 samples per plot, each of 2 x 0.3 m. Counts of healthy shoots per row length were made at tillering from 3 samples per plot, each of 2 x 0.3m. The results given in Table 2 show that there was no significant reduction in seedling emergence, tiller numbers, or plant vigour with increasing dosage rates of fonofos. Samples for larval counts were taken in March by lifting all the plants in 3 samples per plot, each of 2 x 0.3 m, followed by laboratory dissection into the number of healthy shoots per metre row length, percentage affected plants, and percentage of plants with live and dead larvae. These results, and yields determined by combine harvesting the plots, are given in Table 3. They show that the percentage of attacked shoots was reduced with treatment, significantly more so at 1.7 and 3.4 kg/ha a.i. than at 0.8 kg/ha a.i. and with the seed treatment. The percentage of plants with live larvae was similarly reduced and the number of dead larvae was higher with treatment than without. This combination of factors gave an increase in the number of healthy shoots per metre with treatment.

Yields have shown that fonofos gave a significant increase over untreated in trials 1 and 2 (infested), and over the seed treatment in trial 1. Yields in the non-infested trial were not significantly altered.

The combined effect of seed treatments and fonofos was tested in seed trays under glass by applying 0, 1.7 and 3.4 kg/ha a.i. fonofos granules to both treated and non-treated seed as follows:-

Cultivar Maris Templar treated with chlorfenvinphos

Cultivar Chalk treated with carbophenothion

Cultivar Maris Huntsman treated with gamma BHC

Counts of emerged seedlings from 100 seeds drilled were made at 7 and 12 days post drilling and all seedlings were cut for weight of tops at 18 days. Table 4 shows that seed treatments reduce emergence, but that fonofos applied in addition does not lead to significant further reductions.

Table 2 Plant counts and vigour assessments at the 2 leaf stage (for phytotoxicity) and tillering (for combined phytotoxicity and wheat bulb fly effect).

TREATMENT	NUMBER OF PLANTS OR SHOOTS PER m.						PLANT VIGOUR 0-10 where 0 = bare ground 10 = maximum height & density					
	2 leaf stage (plants)			Tillering stage (shoots)			2 leaf stage			Tillering stage		
Trial No.	1 Infested	2 Infested	3 Non Infested	1 Infested	2 Infested	3 Non Infested	1 Infested	2 Infested	3 Non Infested	1 Infested	2 Infested	3 Non Infested
Untreated control	45.0	24.3	38.4	86.4	15.3	-	9.0	7.5	8.7	7.0	1.0	8.7
Standard Seed treatment	46.2	21.6	35.1	105.6	65.7	-	9.2	9.7*	8.5	8.5	8.2	-
Fonofos 0.8 kg/ha a.i.	45.9	25.5	-	93.0	67.8	-	9.2	8.5	-	8.5	7.0	7.7
Fonofos 1.7 kg/ha a.i.	46.5	26.1	34.2	108.0	86.7	-	9.2	8.5	8.5	9.0	9.0	8.5
Fonofos 3.4 kg/ha a.i.	44.7	26.4	37.2	94.5	80.1	-	9.0	8.5	8.7	9.0	9.2	9.0
*Drilled 1 week earlier	N.S	N.S	N.S	N.S								
				LSD 5% =	39.6							
				LSD 1% =	55.5							

Table 3 Results of plant dissection in March and yield at harvest

	Healthy shoots per m		Percentage Attacked shoots		Percentage of plants with larvae: Live		Percentage of plants with larvae: Dead		Yield (at 15% moisture)					
Trial	1	2	1	2	1	2	1	2	1 t/ha	1 (cwt/ac)	2 t/ha	2 (cwt/ac)	3 t/ha	3 (cwt/ac)
Untreated control	107.1	36.9	32.1	50.7	26.3	40.0	0	0	6.85	54.4	2.91	23.1	3.33	26.4
Standard seed treatment	165.0	84.0	19.5	15.6	9.8	10.6	0.7	2.5	6.41	50.9	5.16	41.0	3.63	28.8
Fonofos 0.8 kg/ha a.i.	140.4	93.9	21.7	20.0	6.4	9.4	4.5	4.3	7.16	56.9	5.37	42.6	-	-
Fonofos 1.7 kg/ha a.i.	162.6	121.5	12.2	3.2	0.8	0.8	5.1	0.4	7.30	57.9	5.65	44.9	3.33	26.4
Fonofos 3.4 kg/ha a.i.	153.9	126.9	4.3	5.9	0.9	3.0	0.9	0.7	7.46	59.2	5.76	45.8	3.63	28.8
LSD 5%									0.50		0.70		N.S.	
1%									0.70		0.98			

Table 4 Seedling emergence following combined seed treatment/granule treatment

Variety/Treatment	No. of seedlings emerged from 100 seeds drilled								
	7 days post drilling			12 days post drilling (full emergence)			Weight of tops g		
kg/ha a.i. fonofos	0	1.7	3.4	0	1.7	3.4	0	1.7	3.4
Maris Templar									
treated with chlorfenvinphos	30	30	30	34	57	56	9.9	10.7	11.2
Non-treated	40	40	40	34	64	73	12.8	12.6	19.4
Chalk									
treated with carbophenothion	5	5	5	34	47	35	5.3	8.6	7.5
Non-treated	5	5	5	34	40	62	3.3	8.7	10.3
Maris Huntsman									
treated with gamma BHC	30	20	20	54	52	61	10.1	7.6	12.0
Non-treated	50	50	50	88	78	85	20.8	19.7	15.5
						Mean	10.3	11.3	12.6

DISCUSSION

The current practice of wheat bulb fly control, that of treating the seed prior to drilling in the autumn with suitable concentrations of insecticides, applied either as a liquid or a powder, acts mainly in preventing larval entry into the young plants following egg hatch from mid January onwards. Little or no action occurs against larvae in the soil, but some dressings can achieve limited control within the plant. Work with seed treatments (Dixon 1967) has shown that control is far from complete and, in farming practice, a second control measure is often adopted, namely that of applying a foliar spray in the spring to control larvae already in the shoots, thus reducing further damage to the plant.

The nature and timing of application of fonofos granules has given results which demonstrate a dual action against the pest. Overall application to the seed bed in the autumn followed by light incorporation and further dispersal by rainfall, gives protection throughout the zone of hatching eggs and, being larvicidal and adequately persistant (Stauffer Chemicals Dyfonate Bulletin - unpublished data), a high proportion of larvae fail even to reach the young plant. The chemical also comes into contact with the germinating seed, giving some seed treatment action. Larval entry into the plant due to these factors is therefore reduced, as shown in Tables 1 and 3, where the number of attacked shoots has been reduced from high infestation levels of 30 to 69% to more acceptable levels of 4 to 23% in ADAS trials, and from the 32 to 51% levels of infestation to below 12% at 1.7 and 3.4 kg/ha a.i. in the trials described in this report.

The second action of fonofos is to give a limited systemic action which kills some larvae within the plant. J.B. McBain and J.J. Menn (unpublished data, Stauffer Chemical Co.) have shown that fonofos can be detected in the young shoot and leaves of corn. It is not yet known whether this level is, in itself, larvicidal, or whether the chemical ingested from the soil is a necessary factor. Nevertheless, Table 3 shows that, whereas the number of dead larvae within the plant treated with a seed treatment is low (0.7 and 2.5%), with fonofos it is sufficiently high to suggest that larvae are killed within the young plant. Residue studies (ADAS unpublished data) at harvest showed no detectable fonofos in grain and straw, but it had persisted in the soil to give 0.74 ppm.

The effect of fonofos on the crop prior to wheat bulb fly attack is shown by emergence counts and visual observations to show no statistically significant or consistent reductions in plant numbers or vigour with increasing dosage rates. It is therefore considered that, both in the presence and absence of the pest, fonofos is not phytotoxic at the concentrations tested even where seed treatments have also been applied. In the presence of high levels of wheat bulb fly eggs and subsequent severe plant attack where yield on untreated areas is reduced below economic levels, fonofos has given yield increases consistently greater than standard seed treatments, with a positive correlation between yield and dosage rate. Yield from the present trials show the same trend of increasing yield with increasing rates of fonofos, and significantly higher yields from fonofos treatment than from seed treatment or no treatment. Considering all the yield data available, the optimum dosage rate combining effectiveness with economics falls between 1.1 and 1.7 kg/ha a.i.

Acknowledgements

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Proceedings of the 8th British Insecticide and Fungicide Conference (1975)

CHEMICAL CONTROL OF LEATHERJACKETS (TIPULA spp) IN CEREALS

A Contribution from the Closed Conference of Advisory Entomologists
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Summary Trials carried out with chemicals for the control of leatherjackets in cereals at 17 sites in Great Britain over a period of 3 years, have shown good control with chlorpyrifos emulsifiable concentrate and wettable powder sprays, and 5% granules, applied at a rate equivalent to 0.75 kg ai/ha. Carbofuran 5% granules at 1.0 kg ai/ha gave moderate control and should give good control if applied at 1.25 kg ai/ha. Eleven-milligram bait pellets containing 1.8% BHC gave good control when applied at the rate of 15 kg pellets/ha, but larger 41 mg pellets were not satisfactory. Triazophos spray at 0.8 kg ai/ha, and isazofos spray and granules used at 1.0 kg ai/ha also merit further investigation, but other materials included in the trials either gave inadequate or variable results, or their commercial future did not justify further work.

The trials were carried out in a range of weather conditions that indicated that consistent results from chemical control can be expected only if the mean air temperature over the period following treatment exceeds 6°C.

Resume Les essais effectués sur 17 sites en Grande Bretagne au cours de 3 années utilisant des produits chimiques dans la lutte contre les larves des Tipules, a démontré que les traitements par liquide pulvérisé, ou par granules à 5%, de chlorpyrifos appliqué à raison de 0.75 kg ma/ha, sont efficaces. Les granules de carbofuran à 5%, appliqués à raison de 1.0 kg ma/ha ont donné des résultats médiocres, mais si appliqués à 1.25 kg ma/ha donneraient des résultats **satisfaisants**. Les appâts en granules de 11 mg, et contenant de 1.8% HCH, ont donné des résultats satisfaisants, appliqués à raison de 15 kg/ha de granules, mais les granules de plus gros taille (41 mg) n'étaient pas tres efficaces. Triazophos sous forme liquide à raison de 0.8 kg ma/ha, et isozofos sous forme liquide et granulaire à raison de 1.0 kg ma/ha réclament la poursuite d'essais complémentaires, mais les autres matériaux utilisés dans les essais ont donné des résultats médiocres ou variables, ou leur perspective commerciale ne justifait pas des recherches plus approfondies.

Les essais ont été effectives dans différentes conditions météorologiques qui ont montré qu'on ne peut atteindre des résultats constants par un contrôle chimique que si la température moyenne de l'air pendant la période qui suit le traitement excède 6°C.

INTRODUCTION

A series of trials with alternatives to persistent organochlorine insecticides for the control of leatherjackets in spring cereals was described at the 5th British Insecticide and Fungicide Conference (Rayner, 1969). In those trials, **bran baits** containing gamma BHC or fenitrothion proved to be consistently effective; parathion 10% granules were effective in some trials, while methiocarb spray, and methiocarb or bromophos with bran bait, were effective in single trials. Farm-prepared baits are inoonvenient, the ready-made bran crumb bait used in the earlier trials is no longer available, and the parathion granules have been withdrawn from the British market. Trials were therefore continued in 1973 to 1975 in which organo-phosphorus and carbamate insecticides and new formulations of ready-made gamma BHC baits have been tested.

These trials include several on winter cereals. At the time of the first series of trials, experience with winter cereals had been mainly of damage occurring in late autumn. Some trials on winter cereals had been done at low temperature, and materials which had been effective when used in the spring, had proved to be unsatisfactory under such conditions, DDT spray and parathion granules giving the only reasonably consistent results. In recent years damage to winter cereals has occurred from January to March, often at comparatively high temperatures, when the conditions and time of application have been comparable with those for spring cereals. In this report, therefore, there is no distinction made between trials on winter and on spring cereals.

METHOD AND MATERIALS

Most of the trials were on crops that had already suffered damage, when they were treated at growth stage 1 to 5, but at Rothesay and Badminton in 1975 (see Table 1), treatments were applied before crop emergence.

Each trial area was sampled with a 6 or 10 cm diameter sampling tool, to a depth of 5 to 15 cm, before treatment; from 40 to 600 samples were taken per site. Treatment effects were assessed by sampling with similar tools, to a depth of 5 to 10 cm taking from 10 to 40 samples per plot. Leatherjackets were extracted either by washing, using the Bristol method, (Mayor and Browne 1964), or a modification of the Salt and Hollick method (Cockbill et al, 1945), or by hand sorting, samples at most sites being checked by a second observer. A heat extraction method was used, for some sites, and where this or hand sorting by one observer was the method employed, leatherjacket populations may have been underestimated by as much as 30%

At only one site (Monknash, 1974) was the heat extraction method used for assessing treatment effects. Leatherjackets showing any signs of life were recorded for assessment of treatment effects where the other methods were used, and thus some moribund larvae were classified as alive. The heat extraction method relying on leatherjackets' own mobility would probably not recover such leatherjackets, and treatment effects would be slightly overestimated.

Assessments were made 2 to 3 weeks after treatment except at Alnwick where the initial assessment was made after 17 days at low temperatures. Poor results were obtained, and the assessment was repeated 6 weeks later, after 25 days of milder weather.

The trials were laid out in 4 or 5 randomized blocks, (and one 4 x 4 Latin square), with plots 6, 9 or 10 metres square (mostly 10 m square). Further site details are listed in Table 1.

The treatments were applied either as emulsifiable concentrate, or wettable powder sprays, in 225 l to 600 l water per hectare, as pelleted baits, or as granules. Further details of treatments are included in Table 2.

Table 1.

Chemical control of leatherjackets in cereals
Details of Sites

Year	Site No	Location	Soil Type	Cereal	Sowing date	Treatment date	Pre Treatment leatherjacket population 000's/ha
1973	(1)	Drumclog, Lanarkshire	Peaty loam	Barley	Spring 1973	8 May 1973	1240
	(2)	Malvern, Herefs-Worcs	Silty clay loam	Barley	April 1973	7 May 1973	926
	(3)	Copplestone, Devon	Gravelly loam	Barley	Spring 1973	1 May 1973	1450
1974	(4)	Dinchope, Salop	Silt loam	Wheat	Nov 1973	20 Feb 1974	1450
	(5)	Monknash, Glamorgan	Silty clay	Wheat	Oct 1973	25 Feb 1974	2559
	(6)	Southerndown, Glamorgan	Silty clay	Barley	April 1974	23 April 1974	889
	(7)	Westbury, Wilts	Silty clay	Wheat	Autumn 1973	19 March 1974	400
	(8)	Wadebridge, Cornwall	Silt loam	Barley	Spring 1974	6 May 1974	462
1975	(9)	Rothesay, Bute	Silty clay	Barley	Mar 1975	3 April 1975	1235
	(10)	Newton Mearns, Renfrewshire	Clay loam	Barley	April 1975	18 April 1975	1112
	(11)	Alnwick, Northumberland	Clay loam	Barley	Nov 1974	7 March 1975	1235
	(12)	Aberdaron Gwynedd	Sandy clay loam	Barley	Mar 1975	28 April 1975	700
	(13)	Stackpole, Dyfed	Fine sandy loam	Oats/ Tares	Oct 1974	7 Jan 1975	7886
	(14)	Monknash, Glamorgan	Silty clay	Wheat	Autumn 1974	7 Jan 1975	1897
	(15)	Tenbury, Herefs-Worcs	Silty clay loam	Wheat	Dec 1974	29 Jan 1975	2130
	(16)	Badminton, Avon	Silty loam brash	Barley	May 1975	14 May 1975	1077
	(17)	Andover, Hants	Clay loam with flints	Barley	Feb 1975	24 Mar 1975	1326

RESULTS

The results are presented in Table 2 as the reduction in leatherjacket population resulting from treatment, expressed as a percentage of the control plot population at the time of assessment.

The figures for mean air temperature at each site are based on data from a nearby meteorological station, adjusted for differences in altitude between the site and the station.

Table 2.

Chemical control of Leatherjackets in Cereals. Results of Assessments of Post Treatment Leatherjacket Populations.

Quantities of insecticides as kg/ha of formulation (baits) or of ai (ec, wp, granules)

% Control (Difference between treatment and control plot populations as % of the latter)

Site No	Date of Assessment	Mean air temp °C	Control plot popn. 000/ha	Gamma BHC pellets 0.97% 41mg 20kg	1.8% 41mg 15kg	1.8% 11mg 15kg	Pirimiphos methyl 50% ec 0.75-1.0kg	Pirimiphos ethyl 50% ec 1.0kg	Chlorpyrifos 48%ec 25%wp 0.72-0.75kg	5%gran 0.55-0.75kg	Methiocarb 50%wp 1.0kg	Phorate 10%gran 1.5kg	Carbofuran 5%gran 0.75-1.0kg	Triazophos 40%ec 0.8-1.1kg	CGA 12223 (Isazofos) 50%ec 1.0kg	10%gran 1.0kg	Fenitrothion 50%ec 1.0kg
(1)	29 May	9.2	775	60			46		54				62				
(2)	21 May	11.2	504	18			33		92				74				
(3)	21 May	10.1	837*	85			85		100					100//			
(4)	14 Mar	3.1	976							48		16	27				
(5)	11 Mar	3.6	1438				51		88	59	64						68
(6)	16 May	9.0	686			80	43	67	73	70	80						80
(7)	4 Apr	6.7	875			80	64	66	75			62					
(8)	24 May	10.1	566			72	76	92	65	76	89	54			100//	100//	
(9)	24 Apr	8.0	371*		83				42	75	42		75	50			
(10)	5 May	7.9	1081		86						83			63	69	80	
(11)	24 Mar	2.4	479		0				38	23	6		45	36	64	29	
	5 May	8.3/	324*		62				91	85	43		66	81	81	85	
(12)	14 May	9.2	1328		42				13	64	13		67	96	81	64	
(13)	28 Jan	7.4	2194*		63				96	79	46		75	96			
(14)	29 Jan	7.1	1170		39				63		38		59	19	78		38
(15)	19 Feb	4.4	1640		21				58	33	4		0	26	9	48	
(16)	4 Jun	8.8	185*		50	50			83		50			11	0		
(17)	16 Apr	4.8	880		0				0	0	0		0	0	0	0	

* fewer than 30 Leatherjackets in control plot samples
/ mean temperature for 25 day period before second assessment
// Unreplicated plots

DISCUSSION

The spring of 1975 was characterised by marked reductions in leatherjacket populations, attributable to natural causes, and at 4 sites, indicated in Table 2, there was a total of fewer than 30 leatherjackets in the control plot samples, as also at one site in 1973. These small numbers are inadequate for reliable assessments of treatment effects, and figures indicating percentage control for individual treatments at these sites should therefore be treated with some reserve.

Sites with mean temperatures below 6°C during the period from treatment to assessment, with the exception of Monknash, 1974 (Table 2, site (5)), have given only poor to moderate results with all treatments. The percentage control figures at Monknash may be over estimates as suggested under Methods and Materials. At Alnwick, (11) assessments made after a 2½ week interval with a mean temperature of 2.4°C, gave poor results, but assessments repeated 6 weeks later, immediately following a 3½ week period at a mean of 8.3°C, gave good results. Consistently good results from insecticide applications can be therefore only expected if a period with a mean air temperature of 6°C or more follows treatment.

Observations at Tenbury (15) suggested that at the lower temperatures there is little crop damage by leatherjackets, so that in practice treatment can be delayed until there is a prospect of a rise in temperature. The Alnwick results suggest however, that even if treatments are applied at the lower temperature they can still be effective some weeks later, when the temperature rises.

The results obtained at low temperatures have been disregarded in the following assessment of individual insecticides.

In the earlier paper (Rayner, 1969) 70% control was regarded as satisfactory, and judging by this standard, neither of the 2 large formulations of gamma BHC pellets (41 mg) can be considered to be really satisfactory; however, the smaller pellets gave better results and justify further work.

Chlorpyrifos applied as a spray, at the higher temperatures, at 7 sites with significant leatherjacket populations, gave good, or very good control at 3 sites, and only once gave really poor control, at Aberdaron in 1975 (12). This poor result is surprising in view of the degree of control achieved by the granules at that site. The less than satisfactory result at Drumclog in 1973 (1) may be accounted for by the peat content of the soil; chlorpyrifos is known to be less effective in soils with a high organic content (Sparrow, 1973).

The 2 remaining moderate results from Wadebridge in 1974 and Monknash in 1975, (8) and (14), were close to the accepted standard of control. The 5 remaining trials, which had few leatherjackets in the untreated plots, showed very good control at 4 sites, but, although at the fifth site control was rather poor, these 5 results taken together suggest a satisfactory level of control. Considering the results overall, it seems that chlorpyrifos at 0.75 kg ai/ha as a spray can be regarded as a satisfactory material for leatherjacket control. Chlorpyrifos granules gave satisfactory results at 4 sites where used at 0.75 kg ai/ha, and at 2 out of the 4 sites in 1974 where they were used at 0.55 kg ai/ha, and can also be considered a satisfactory material at the higher rate. With both formulations the mean air temperature must be 6°C or higher if consistently good control is to be expected.

Methiocarb spray gave good control at only 3 sites out of 9 where it was tested. This includes 4 sites with low leatherjacket populations, but as all gave only moderate control, there is little ground for recommending this material.

Carbofuran where used at the 1.0 kg ai/ha rate (all sites except Dinchope (4)), gave either satisfactory or almost satisfactory results, suggesting that at a higher rate of application, consistently satisfactory results could be achieved.

Triazophos sprays have given variable results, but there are too few reliable results for assessing the value of this material, and further work is required. CGA 12223 (isazofos) has given only one poor result as a spray and the granules have given good control at the few sites where they were used. However, reliable results are too few for any final conclusions to be drawn, and further work with these materials is required also.

Pirimiphos-methyl has not given consistently good control, and although pirimiphos-ethyl gave satisfactory control at a few sites, the commercial prospects have not justified further work. Only moderate control was achieved with phorate granules at two sites.

The few rather variable results for fenitrothion include one with moderate control at a low temperature. The earlier series of trials included 14 where fenitrothion spray was used, and very good, moderate and very poor results were obtained. Further examination of those data shows that 5 satisfactory results, and one unsatisfactory, were obtained at sites where treatment assessments were made 3 weeks or more after treatment, whereas of 8 trials assessed 13 to 20 days after treatment, only 2 gave a satisfactory result. It was considered for the present series of trials that assessment at 2 weeks was desirable; if a material is not effective within this period, it is too slow-acting to be satisfactory. The few results in this trial do nothing to dispel the view that fenitrothion spray is too variable in its effect to be relied on.

In conclusion, chlorpyrifos as a spray or granule, at 0.75 kg ai/ha is the only insecticide which on the basis of these trials, can be confidently recommended for leatherjacket control in cereals, but the small gamma BHC pellets, triazophos spray, and isazofos spray and 10% granules, justify further investigation. There is a clear indication that carbofuran 5% granules at a higher rate of application such as 1.25 kg ai/ha would be effective and reliable.

In a series of trials with insecticides for control of leatherjackets in grassland, chlorpyrifos wp at 0.75 kg ai/ha mostly in 225 l water, has consistently given good control and was superior to any other suitable insecticide tested. At 0.5 kg ai/ha, less satisfactory control was achieved.

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