Proc. 6th Br. Insectic. Fungic. Conf. (1971)

CHANGES IN SUGAR BEET HUSBANDRY, AND SOME EFFECTS ON PESTS AND THEIR DAMAGE

R. A. Dunning,
Broom's Barn Experimental Station, Higham, Bury St. Edmunds, Suffolk

Summary The increased use of genetic monogerm seed and herbicides during the last decade, and the introduction of 'planting-to-a-stand', are recorded for England and for several other W. European Countries. In the U.K., methods of husbandry are changing faster with sugar beet than with any other field crop. Some of the changes, especially the steady decline in the number of seeds sown per acre, increase the risk of pest damage. However, in trials in 1965, and in field observations in 1964-1966, seedling losses due to pest damage did not increase with decline in numbers of seeds sown per acre. Some results of 1971 trials, testing the effects of different seed spacings, herbicide treatments and seedbed compactions on pest aggregation and damage, will be discussed at the Conference.

INTRODUCTION

A survey in 1970/71 on pest and disease incidence and insecticide usage (Dunning, 1972) also determined the changes occurring in sugar beet husbandry throughout Western Europe. Newly introduced methods of establishing the desired 30,000 plants/acre (74,600/ha), reviewed by Hull and Jaggard (1971), have increased the importance of seedling pests, or seem likely to, in many W. European countries. In 1965, and in 1970-71, field trials tested some effects of new methods of husbandry on pest incidence and damage, and on plant establishment.

CHANGES IN HUSBANDRY

Sugar beet costs about £80/acre (£198/ha) to grow (Sturrock, 1971), and changes in its husbandry save labour and make it cheaper to grow. In the early days of the industry 15-20 lb/acre (16.8-22.4 kg/ha) of natural multigerm seed was sown; seedlings grew thickly and irregularly and much hand labour was needed to single about 400,000 seedlings to the desired 30,000/acre (988,000 → 74,600/ha). Rubbing and grading of the multigerm seed was introduced in the early 1950s to give seed with more uniform shape and size, and with only one or two germs; up to 60% monogermity can be produced. Precision or space-drilling was then introduced; in 1955 5% of the crop was drilled in this way, in 1965 75%, and now almost 100%. Although row width has remained constant for many years at 20-22 in (51-56 cm), the number of seeds sown decreased from about 240,000/acre (593,000/ha) in 1965 (Dunning & Winder, 1966) to about 80,000/acre (198,000/ha) today. As in some other European countries, this decline has been accelerated by the rapidly increasing use of genetic monogerm seed since 1965 (Table 1), and of seed pelleting as an aid to precision drilling. In England nearly all genetic monogerm seed is pelleted, as is some of the best quality rubbed and graded multigerm seed. In 1971 89% of the U.K's 447,000 acres (181,000 ha) was sown with pelleted seed.

Table 1

Percentage of annual total sugar beet area sown with genetic monogerm seed

Country[1]	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971[2]
Denmark	-	-	-	-	-	-	<1	2	5	8
England	-	-	<1	3	6	14	26	44	63	75
Finland	-	-	-	<1	<1	1	3	21	60	73
France	-	-	-	-	1	6	10	12	15	20
Germany, W.	-	-	-	-	-	5	10	10	15	
Hungary	-	-	-	-	2	5	5	5	5	15
Ireland	-	-	-	-	-	-	<1	3	11	28
Italy	-	-	-	-	-	<1	1	3	5	7
Netherlands	-	-	-	-	-	<1	7	14	15	17
Poland	<1	1	3	6	13	22	27	26		
Sweden	-	-	-	-	6	51	97	99	100	100
Switzerland	-	-	-	-	-	-	4	16	23	40

(1) In Austria, Belgium, Czechoslovakia, Greece, Romania, Spain, Turkey and Yugoslavia little or no genetic monogerm seed is used; however, most of these countries today use technical monogerm seed (i.e. multigerm seed that has been mechanically processed to give a high proportion of monogerm fruits).

(2) Data collected winter 1970/71; 1971 figures estimated.

Herbicide usage has increased rapidly in the last decade, and is now extensive (Table 2). Using herbicides both before and after crop emergence can obviate the need to hoe. It thus becomes possible to establish the desired 30,000 plants/acre (74,000/ha) by 'planting-to-a-stand': monogerm seed sown at 5 in (12.7 cm) spacing in rows 20 in (51 cm) apart (63,000 seeds/acre : 156,000/ha) should give, on average an adequately correct and distributed plant population and, when herbicides are effective, hand labour will not be needed. Attempts to establish a plant population in this way are increasing (Table 3), but the method is hazardous. Herbicides are not always efficient and weed control by hoeing is then necessary, or they may be too efficient and kill all weeds and some sugar beet seedlings. On average about half the seeds sown should produce plants but, in practice, the range can be wide.

Other, perhaps less significant, changes occuring in husbandry are minimal cultivations to prepare seedbeds, and avoiding seed-bed compaction.

Table 2

Percentage of annual total sugar beet area treated with any herbicide

Country[1] (1000's ha beet grown)[2]		1962	1963	1964	1965	1966	1967	1968	1969	1970	1971[3]
Austria	(45)	-	-	-	2	10	19	30	60	73	
Belgium	(90)	5	18	48	83	90	95	99	100	100	100
Czechoslovakia	(182)	-	-	24	28	43	46	48	52	63	64
Denmark	(51)	2	12	29	34	53	62	78	82	88	90
England	(178)	12	15	24	40	54	70	78	83	89	93
Finland	(14)	-	-	-	-	-	-	-	67	70	80
France	(400)	-	-	2	15	75	80	85	90	95	95
Germany, W	(307)	20	30	40	70	85	90	95	97	98	
Greece	(21)	-	-	-	-	-	-	3	4	7	12
Hungary	(90)	-	-	-	-	-	-	-	-	5	10
Ireland	(25)	-	-	24	28	52	64	72	88	95	98
Italy	(292)	-	-	-	1	2	3	4	5	6	6
Netherlands	(104)	5	7	14	34	50	75	78	89	94	95
Poland	(401)	<1	<1	4	6	5	7	8	6		
Romania	(190)	-	-	-	-	-	-	<1	<1	<1	2
Spain	(155)	-	-	-	-	-	-	<1	<1	3	4
Sweden	(40)	-	-	-	10	45	60	83	82	83	
Switzerland	(9)	10	20	50	80	85	90	90	90	95	95

(1) Herbicides not used in Turkey (118) or Yugoslavia (80)
(2) Ha x 2.47 = acres.
(3) Data collected winter 1970/71; 1971 figure estimated.

Table 3

Percentage of total annual sugar beet area 'sown-to-stand'

(seed spacing 5 in (12.5 cm) or greater)

Country[1]	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971[2]
Austria	-	-	-	-	<1	2	7	21	24	31
Belgium	-	-	<1	3	13	20	20	29	34	38
Czechoslovakia	-	-	-	-	-	-	1	5	3	4
Denmark	-	-	-	-	-	-	<1	2	4	7
England	-	<1	<1	1	1	4	12	17	27	35
Finland	-	-	-	-	-	-	-	4	9	13
France	-	-	-	-	5	15	15	28	38	40
Germany, W	-	-	-	-	-	3	5	8	12	
Ireland	-	-	-	-	-	-	-	-	<1	2
Sweden	-	-	-	-	-	2	8	13	12	
Switzerland	-	-	-	-	-	-	<1	3	2	2

(1) Less than 1% 'sown-to-stand' in Greece, Hungary, Italy, Netherlands, Poland, Spain, Romania, Turkey, or Yugoslavia.

(2) Data collected winter 1970/71; 1971 figure estimated.

CHANGES IN INCIDENCE OF PEST DAMAGE

In each of the months April-July, the British Sugar Corporation fieldmen record the acreage of crop failure from damage by pests, the acreage damaged severely, moderately or slightly, and the acreage treated with pesticide. Seasonal fluctuations in the extent of damage by different pests are large, but no significant increase in damage by the common seedling pests has been recorded concurrent with the declining number of seeds sown per acre during the last few years. Damage by beet leaf miner (*Pegomya betae*) and by aphids transmitting virus yellows has been slight for several years, perhaps partly because systemic insecticides are frequently applied to control them. Damage by seedling pests such as beet flea beetle (*Chaetocnema concinna*) and pygmy beetle (*Atomaria linearis*) has fluctuated widely from year to year but the average amount over the years has not increased, perhaps because precautionary treatment with organo-chlorines is increasing (Dunning & Winder, 1971). (Slides will illustrate the incidence of damage by these and other pests).

METHODS, MATERIALS AND RESULTS

1965 Field Trials : Seedling populations

At Broom's Barn, pelleted 'Triplex M' multigerm seed, treated with 0.2% of dieldrin, was sown on 3rd April at four different spacings (1.5, 3, 6 and 10 in (3.8, 7.6, 15.2 and 25.4 cm)) in rows 20 in (51 cm) apart on plots 15 rows wide x 50 ft (15.2 m) long. Pyrazon herbicide was applied on the soil surface, at the manufacturer's recommended rate, over the rows at the time of sowing. The seedlings were counted on seven occasions between 20th April and 21st May on the same marked lengths of row. Damage by wireworms, symphylids and small birds late in April and early in May killed a few seedlings, but further pest damage could not be measured because the pyrazon killed 40% of the seedlings in the 2 rough-leaf stage during unusually hot weather at mid May (Table 4). Only 13,200 singled plants/acre (32,600/ha) were left after careful hand hoeing of the treatment with the fewest seedlings; greater plant populations were obtained on the other three seedling population treatments. The plants showing symptoms of virus yellows were counted on 15th September. Few plants were lost between singling and hand harvesting on 6th December, which determined the total number of roots, the percentage unharvestable, and the yield of harvestable roots (Table 4).

1971 Field Trials : Seedling populations/Herbicide treatments

Trials at three sites - Broom's Barn, Suffolk; Bottisham, Cambs; Welney, Norfolk - tested pelleted monogerm seed, without dieldrin seed dressing, at three spacings (1, 3 and 9 in (2.5, 7.6 and 22.0 cm)) in rows 20 in (51 cm) apart, both with and without the herbicide pyrazon overall at the standard commercial rate for the soil type. At Welney, pygmy beetle (*Atomaria linearis*), in the soil from the 1970 sugar beet crop, killed many seedlings before the cotyledons emerged above the soil. Whatever the seed spacing, only about 6% of the seeds sown produced a seedling and the trial had to be abandoned. Pygmy beetle and other pests fed on the seedlings at the other two sites, but were much less damaging. The numbers aggregating around the seedlings and the damage they caused will be related to seedling growth, and to yield obtained at harvest in October, when reporting the trial results at the Conference.

DISCUSSION

On average about 50% of seeds sown produce a plant, but the range is wide; it was 24-71% in a series of 16 field trials with pelleted monogerm seed in 1970 (Dunning, 1971). Some causes of seedling loss now differ from those reported by Jones and Humphries (1954), who suggested that of 100 viable seeds sown 5 failed to produce seedlings because of damage by insects, 10 by fungi and 55 by other, physical, causes. In a series of observations on seedling losses in 1964-66, effective fungicide and insecticide treatment, efficient precision drills and better husbandry all helped to decrease losses from pathogens and soil conditions.

In contrast, losses after seedling emergence were sometimes great, especially because of damage by herbicides, birds and mammals, and cultivations. At 9 sites in 1964, seedling emergence averaged 143,000 per acre (363,000/ha) and 8.6% were subsequently lost; losses at individual sites ranged from 1.5 to 26% (Dunning, 1965). At 9 sites in 1965, with a mean sowing date of 11th April and seed spacing of 1.75 in (4.45 cm), 143,200 seedlings emerged per acre (364,000/ha) and 7% were lost; in comparison, at 10 sites with a mean sown date of 8th April and seed spacing of 3.4 in (8.6 cm), 63,000 seedlings emerged per acre (156,000/ha) and only 5% were lost (Dunning, 1966). A greater range of seed spacings were compared in 1966 at 16 sites; at 1.8 in (4.6 cm) 127,300 seedlings emerged per acre (314,400/ha), of which 5.7%

Table 4

Seed spacing, seedling and plant populations at intervals during the season, virus yellows incidence, and yield at harvest on 6th December, Broom's Barn, 1965

Assessment	Date	Seed spacing			
		1.5 in	3 in	6 in	9 in
Number of seedlings/acre (2)	20 April	115,900	54,300	29,300	15,400
	23 April	161,800	79,500	39,300	22,700
	29 April	182,200	92,200	46,800	26,800
	6 May	186,300	94,400	46,300	27,100
	13 May	165,000	81,200	40,900	23,500
	19 May	121,500	64,300	28,100	16,600
	21 May	120,100	63,900	28,100	16,600
Number of plants/acre (2)	28 May	58,000	35,100	22,500	13,200
	4 June	57,600	34,800	22,100	12,900
	18 June	57,400	34,500	21,900	12,800
	30 June	57,300	34,400	21,700	12,800
	5 Aug.	57,300	34,300	21,700	12,800
% of plants with virus yellows (S.E. ± 3.4)	15 Sept.	0.4%	3.5%	6.6%	17.3%
Number of yellows infected plants/acre (2)	15 Sept.	229	1,200	1,432	2,214
Number of roots/acre (2) (S.E. ± 1,990)	6 Dec.	54,700	34,100	20,900	12,200
% of roots unharvestable (S.E. ± 1.7)	6 Dec.	21%	9%	4%	2%
Number of harvestable roots/acre (2) (S.E. ± 1,280)	6 Dec.	43,000	30,900	20,100	11,900
Sugar yield (cwt/acre) of harvestable roots (3) (S.E. ± 1.40)	6 Dec.	58.4	59.3	49.0	40.8

Conversion factors : (1) x 2.54 = cm

(2) x 2.47 = numbers/ha

(3) x 125.5 = kg/ha.

were lost, but at 4.8 in (12.2 cm) 55,600 emerged per acre (137,300/ha) and only 4.6% were lost (Dunning, 1967). Of these losses of emerged seedlings in 1966, 5% were caused by root disease, 11% by insect pests, 25% by birds and mammals, 29% by herbicide toxicity, 14% by wind, 12% by cultivations and 4% by unknown causes.

A greater concentration of pest damage on the wider spaced seedlings might have been expected but no significant differences were observed between causes of seedling death on the narrow and wide seed spacing. Similarly, in a trial at Ringshall, Suffolk (Dunning and Winder, 1966) wireworm did not kill a greater percentage of seedlings when the seeds were sown at 6 in (15.2 cm) spacing than at 1.5 in (3.8 cm). Such results seemingly contradict the suggestion of Jones and Dunning (1969) that, where seed spacing is greater than formerly, fewer pests per acre will be needed to cause significant damage.

However, there is evidence that some pests cause proportionately more damage when seedlings are widely spaced. Of many trials on the damage by beet leaf miner, significant yield loss occurred only when singling caused egg laying to be concentrated on the spaced seedlings (Dunning, 1961). Numbers of aphids per plant and of virus-infected plants per unit area usually increased when the plant population was decreased experimentally at the time of plant singling late in May (Heathcote, 1970). Such an effect occurred in the 1965 trial (Table 4), perhaps because more winged aphids aggregated on each seedling or plant, or because widely spaced plants were more attractive to aphids once big enough to contrast with the soil. Symphylids (Scutigerella immaculata) aggregated on and damaged the seedlings in a heavy silt soil at North Lynn, Norfolk in 1970; there was an average of 2.6/soil core centred on a seedling, but only 0.2/core in the row between the seedlings (Baker, 1971). Further studies are needed of the different pests of sugar-beet seedlings to determine which ones aggregate, and cause more damage, when seedlings are widely spaced.

Herbicides, by removing alternative plant food, may also increase the numbers of pests feeding on sugar-beet seedlings; in the Netherlands, herbicide usage has increased damage by springtails (Onychiurus armatus) (Heijbroek, personal comm.). Also, it seems probable that seedlings weakened by herbicide may suffer more than vigorous ones from pest damage; there is circumstantial evidence that this sometimes happens with the free-living nematodes that cause Docking disorder of sugar beet (Whitehead, Dunning and Cooke, 1971).

Trials in 1971 attempted to determine the effects of wide-seed spacings, herbicide, and seed-bed compaction on pest aggregation, and on seedling damage and vigour; the results will be discussed at the Conference.

Acknowledgements

I acknowledge the help given by Marie Winder and British Sugar Corporation fieldmen in recording the causes of seedling losses in 1964-1966, by A.N. Baker and G.H. Winder with the 1971 trials, and by numerous colleagues overseas who provided data for Tables 1-3.

References

BAKER, A.N. (1971) in Rep. Rothamsted exp. Stn for 1970, 250.

DUNNING, R.A. (1961) Mangold fly incidence economic importance and control. Pl. Path., 10, 1-9.

DUNNING, R.A. (1965) in Rep. Rothamsted exp. Stn for 1964, 258.

DUNNING, R.A. (1966) in Rep. Rothamsted exp. Stn for 1965, 264.

DUNNING, R.A. (1967) in Rep. Rothamsted exp. Stn for 1966, 279.

DUNNING, R.A. (1971) in Rep. Rothamsted exp. Stn for 1970, 250.

DUNNING, R.A. (1972) A survey of sugar beet pest and disease incidence and damage, and pesticide usage, in Europe, 1970. J. int. Inst. Sugar Beet Res. (In the press).

DUNNING, R.A. & WINDER, G.H. (1966) Sugar beet seedling populations and protection from wireworm injury. Proc. 3rd Br. Insectic. Fungic. Conf., 1965, 85-99.

DUNNING, R.A. & WINDER, G.H. (1971) Changes in organo-chlorine usage on sugar beet, and progress in the replacement of dieldrin seed treatment. Proc. 6th Br. Insectic. Fungic. Conf., 1971.

HEATHCOTE, G.D. (1970) Effect of plant spacing and time of sowing of sugar beet on aphid infestation and spread of virus yellows. Pl. Path. 19, 32-39.

HULL, R. & JAGGARD, K.W. (1971) Recent developments in the establishment of sugar-beet stands. Field Crop Abstracts, 24, 381-390.

JONES, F.G.W. & HUMPHRIES, K.P. (1954) The use of seed dressings containing γ-BHC in the establishment of sugar-beet seedlings. Ann. appl. Biol., 41, 562-577.

JONES, F.G.W. & DUNNING, R.A. (1969) Sugar Beet Pests, Bulletin 162, H.M.S.O. (new edition in the press).

STURROCK, F.G. (1971) Outlook for sugar beet. J. Roy. agric. Soc. Eng., 131, 18-29.

WHITEHEAD, A.G., DUNNING, R.A. & COOKE, D.A. (1971) Docking disorder and root ectoparasitic nematodes of sugar beet. Rep. Rothamsted exp. Stn for 1970, Part II, 219-236.

Proc. 6th Br. Insectic. Fungic. Conf. (1971)

LIMITATIONS OF SEED-TREATMENTS FOR PEST CONTROL

K. A. Lord, K. A. Jeffs
Rothamsted Experimental Station, Harpenden, Herts.
R. J. Tuppen
M.A.F.F. Plant Pathology Laboratory, Harpenden, Herts.

Summary Accurate loading of individual seeds with chemicals is difficult. Dry powders are usually more uniformly distributed than liquid formulations, but the seed is easily separated from the powder in subsequent operations. With combined liquid applications of insecticides and mercury fungicide the amounts of each on individual seeds varied greatly and apparently independently. Excessive doses on individual seeds are wasteful of pesticide, may harm the seed, but inadequate doses do not control pests and diseases.

INTRODUCTION

Treatment of seeds with "chemicals" to control pests and diseases has long been practised, with records from the 18th century of the use of urine, wine, brine and copper compounds. Reports of the use of organomercury compounds date from 1914 although the materials in use today were not introduced for another 10 to 20 years Hubert Martin, (1959).

Our interests are more recent and developed from the use of insecticides to control insect pests of wheat. In 1947 Potter et al. (1956) compared various ways of controlling the attack of wheat by wireworms (Agriotes spp.). They showed that treating seeds with BHC increased yields as much as did drilling the insecticide with the seed, which needed three times as much chemical. Broadcast treatments, using eight times the amount of BHC, were more effective. Treatments with even larger quantities of the fumigants DD and ethylene dibromide were little better than the seed treatments.

In addition to economy in the use of BHC, the seed treatments caused less taint in subsequent crops - an indication of smaller residues in soils, an important reason for the continuing use of seed treatments even though risk of taint has diminished with the use of purer forms of BHC and other pesticides. Later organochlorine seed dressings were used to control another soil insect pest - wheat bulb fly (Leptohylemyia coarctata) (1954). However seed dressing was not consistently effective, and our first tests were designed to seek explanations for the differing effectiveness of seed dressings in different soils, for patchy plant stands and occasional failure of control.

METHOD AND MATERIALS

Assays of pesticides in soils and on seeds using gas chromatography and X-ray spectrometry were described, Lord et al. (1967), Jeffs et al. (1968) and Lord et al. (1971). Seeds were treated with liquid formulations as described by Jeffs et al. (1968).

Methods used for testing seed treatments to control wheat bulb fly are based on those of Way (1959) using plants growing in boxes. Seeds were sown in John Innes No. 1 compost 1 in. deep, 3/4 in.apart in two rows 4 in. apart, 40 seeds per box. In spring, 20 live wheat bulb fly eggs were placed 1 in. deep in a furrow between the rows of seeds and covered. Three boxes were prepared for each treatment. Damage to tillers was assessed visually and the plants allowed to grow on.

RESULTS AND DISCUSSION

The first analyses were made on soils and plants taken from a field experiment to compare the efficiency of several insecticides applied as dry powder dressings to wheat seed grown at a peaty loam and a clay loam site. Seed dressings had little effect on yield at the peat site in contrast to the large increase on the clay site, where the untreated crops failed to yield. Although the effects on yield differed, about the same degree of control of the pests was obtained on both sites. Such differences of insect control as were noted, suggested that BHC and dieldrin were more available in the clay soil but the differences were not striking. Chemical analysis showed the pesticides were present in soils and plants in roughly equal amounts on both sites. It was not possible to be sure why the use of pesticides was associated with improved crop yield at the clay site, but not at the peat site, but differences in cultivations between the sites and the much more vigorous crop growth at the peat site were both sufficient to provide a tentative explanation of the effects on yield.

Some of the difficulty of drawing definite conclusions arose from the large variations in the amounts of insecticide found in samples taken from one plot at the same time. Part of the variation was caused by differences in the number of seeds found in 2 in. cores (all taken from rows of seeds) but these were too small to account for all the variation. We examined the amount of insecticide on individual seeds and found that it varied over a two-fold range, with the average amount only 3/4 or less of that expected. Because the seeds treated in the laboratory were deficient in pesticides, we decided to examine a few samples of commercially treated seeds and found that 3 of 10 were almost completely devoid of insecticide. These results indicated some disquieting possibilities, including deficiencies in applying seed-dressings. An investigation of seed treatment procedures seemed most urgent, because if they were unreliable this might account for reported erratic pest control; also our inability to apply known doses of pesticides to seeds would certainly handicap further investigations.

Two surveys of seeds commercially treated with BHC seed dressings made in collaboration with NACAM (now BASAM) and ABMAC (now BAA), showed that many samples of seeds treated with dry powder dressings were deficient in pesticides and in the Survey 1966-67, only 5 of 33 sets of samples carried more than 50% of the target dose of insecticide, Lord et al. (1971). The deficiencies seem to stem from failure of the pesticide to adhere on the seed - over 60% is removed by dropping the seed 45 cm through air. It is not appropriate to discuss the mechanics of loss in detail, but, after application, various proportions of pesticide are separated from the seed in the course of bulk moving and storage of the treated grain.

As a commercial alternative to treatment with a dry powder, seeds are also commercially treated with liquid formulations of pesticides, and we surveyed some samples of seeds commercially treated in this way, to discover that the amounts of insecticide on these seeds was nearer to the target; in only one of 17 sets of samples was it less than half the target dose, but the distribution of insecticide between individual seeds was variable. Doses on individual seeds frequently covered a thousand fold range, presenting a problem of distribution Jeffs et al. (1968), Lord et al. (1971), so that by comparison individual seeds treated with dry powders receive uniform doses.

Fig. 1 Effects of distribution between individual wheat seeds on the biological action of chlorfenvinphos

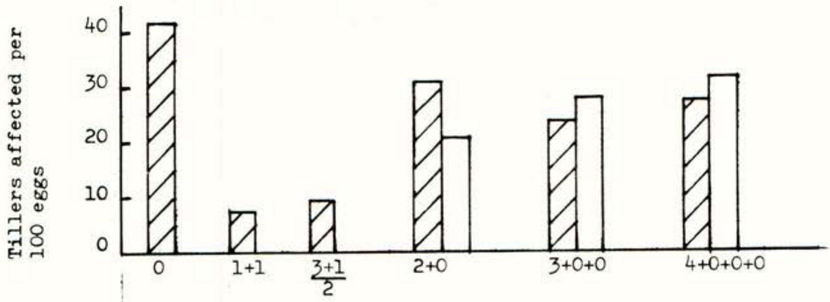


Fig. 1a Wheat bulb fly attack   damage to sowing pattern ▨
damage to untreated seeds ▭

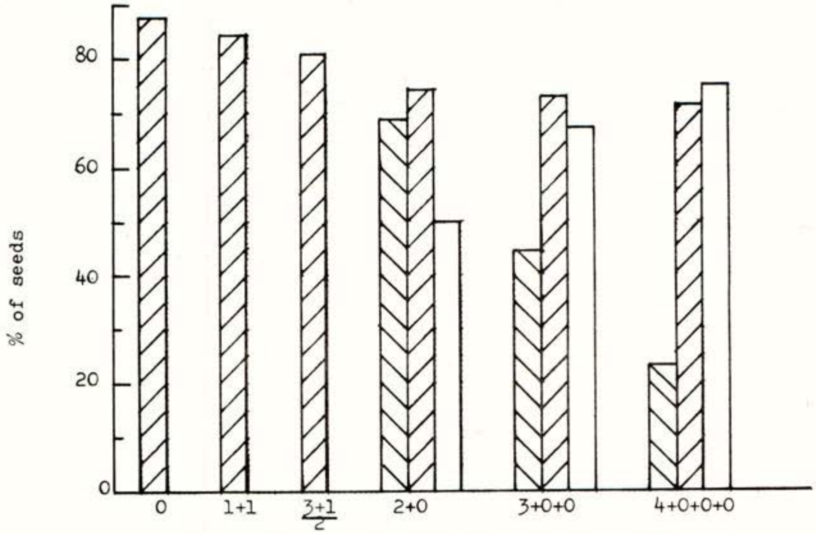


Fig. 1b Seed germination of sowing pattern ▨
of treated seeds ▧
% of seeds which were not treated ▭

Seeds treated with chlorfenvinphos were sown so that the average dose in any box was about 1000 ppm per seed

Key to sowing patterns and doses of chlorfenvinphos on individual seeds

0	Untreated seeds
1+1	Uniformly treated with 1312 ppm
$\frac{3+2}{2}$	Alternate seeds treated with 1875 or 500 ppm
2+0	Alternate seeds treated with 2819 ppm
3+0+0	Every third seed treated with 3500 ppm
4+0+0+0	Every fourth seed treated with 5944 ppm

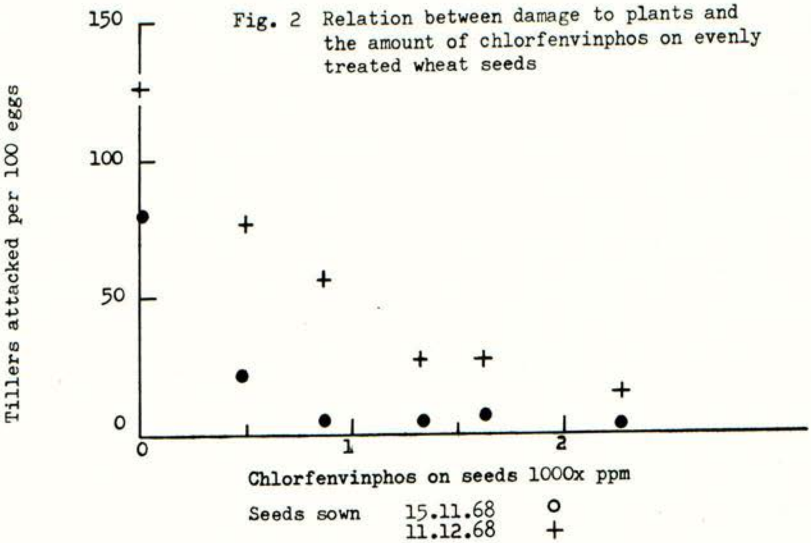


Fig. 2 Relation between damage to plants and the amount of chlorfenvinphos on evenly treated wheat seeds

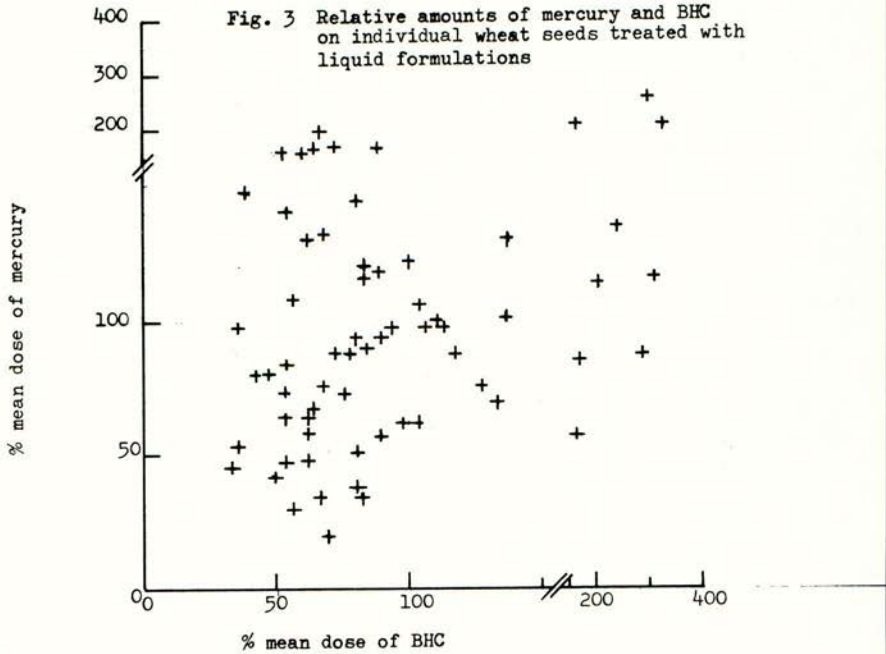


Fig. 3 Relative amounts of mercury and BHC on individual wheat seeds treated with liquid formulations

In practice 10% of seeds treated with liquid formulations carried more than 4 times the target dose - equivalent to about half the insecticide so that on most seeds the average dose was about half that expected. In these circumstances the pesticide on the heavily treated seeds would be wasted unless it migrated to protect other seeds.

Although we are not aware of any direct evidence, it seems improbable that the insecticides used to control wheat bulb fly will diffuse sufficiently in soil to protect seeds about half an inch (1.4 cm) away, the approximate average spacing for wheat sown at 150 lb/ac (168 kg/ha) with 7 in. (18 cm) between rows. Graham-Bryce (1969) estimates an upper diffusion rate in soil of 0.3 cm per month for disulfoton; chlorfenvinphos, BHC and aldrin are fat soluble, no more volatile than disulfoton and so probably diffuse no faster.

Box tests in which treated seeds were sown regularly interspersed between untreated seeds confirmed this conclusion, by demonstrating that there was no protective action when seeds were slightly more widely spaced 3/4 in. (1.9 cm). The efficiencies of treatments were assessed by observing damage to tillers of growing plants and calculating the number damaged per 100 eggs. A test with chlorfenvinphos is typical. In this test (Fig. 1a) about 40 tillers were attacked per 100 eggs when the seeds were untreated. With the standard dose (nominally 1000 ppm on the seed) evenly distributed between seeds, about 8 tillers were attacked. When untreated seeds were sown alternately with seeds treated with twice the standard dose, more than 20 tillers were attacked per hundred eggs, relatively more than would be expected if treated seeds were completely protected. When every 3rd or 4th seed was treated with 3 or 4 times the standard dose, the number of tillers attacked was almost the same as when only plants grown from untreated seeds were attacked.

This test also included the alternate sowing of seeds treated with half and one and a half times the standard dose. Control was about the same as when the seeds were uniformly treated.

In the same test, seed germination was observed (Fig. 1b). The average germination seemed to be little different whether the seeds were uniformly treated or a proportion of the seeds were heavily dosed. However calculation showed that the germination of the treated seeds diminished with increasing dose and when four times the standard dose was applied only one fifth of the seeds grew.

BHC had a similar adverse effect on germination, but large doses of aldrin did not seem to affect germination although later growth was distorted and diminished.

Damage to seeds and plants can be avoided by ensuring that too much is not applied to individual seeds. However with chlorfenvinphos in box tests, the standard dose (1000 ppm of seed) was barely sufficient to control wheat bulb fly damage, especially when the sowing was late (Fig. 2). Thus the safety margin between doses on individual seeds that protect and kill is small and uniform treatments of seeds is very desirable. The safety margins for BHC are also small.

In practice seeds may be treated with more than one chemical and our tests with wheat treated with liquid formulations of BHC and mercury fungicides (Fig. 3) showed that the amounts of each on individual seeds varied greatly, and apparently independently - thus a seed with a small dose of BHC might carry a large or small dose of mercury.

If the "therapeutic" index or safety margins are small and the doses of different pesticides vary independently, the proportions of seeds that survive the combined onslaughts of pests and chemical damage diminish rapidly.

CONCLUSIONS

The existing evidence indicates that seed dressings, when properly applied, can be an effective and economical method of pest control. Because application is restricted to the seed and the amount of poison used is small, seed dressings are likely to be selective and also to cause the minimum environmental contamination. However, it is technically difficult to treat bulk seeds on a commercial scale with a chemical so that each individual seed retains the correct dose. Despite the imperfections of the current methods for treating seeds, the benefits are such that many seeds are dressed with insecticides and fungicides.

Wheat seeds are usually treated with mercury fungicides and when there is a risk from wireworm or wheat bulb fly, the seeds are also treated with an insecticide. Seed treatment against wheat bulb fly is not always successful because there is little room for deviation and the standard procedures are difficult to control. Dry powder formulations become separated from the seed and lost. Liquid formulations are irregularly distributed between seeds. Heavily treated seeds are damaged by excess pesticide,- lightly treated seeds may not be protected and excess insecticide on individual seeds does not protect adjacent seeds. Novel formulations Griffiths *et al*. (1970) and methods of application (e.g. pelleting) have been shown to increase the margin between effective and damaging doses of pesticides. Better seed treatments may so improve the reliability of seed growth as to permit reduction of the amount of seed sown enough to cover increased costs of more complex methods of seed treatment.

References

GOUGH, H. C. & WOODS, A. (1945) Seed dressings for the control of wheat bulb fly. Nature (Lond.), 174, 1151-1153.

GRAHAM-BRYCE, I. J. (1969) Diffusion of organophosphorus insecticides in soil. J. Sci. Fd Agric., 20, 489-494.

GRIFFITHS, D. C., LORD, K. A. & SCOTT, G. C. (1970) Some experiments with different formulations of organophosphorus insecticides on seed dressing to control wheat bulb fly (*Leptohylemyia coarctata*). Pestic. Sci., 1, 3-4.

JEFFS, K. A., LORD, K. A. & TUPPEN, R. J. (1968) Insecticides on single seeds treated with liquid dressings. J. Sci. Fd Agric., 19, 195-198.

LORD, K. A., SCOTT, G. C., JEFFS, K. A., GRIFFITHS, D. C. & MASKELL, F. E. (1967) Persistence and distribution of insecticidal seed-dressings for control of the wheat bulb fly, *Leptohylemyia coarctata*. Ann. appl. Biol., 60, 173-180.

LORD, K. A., JEFFS, K. A. & TUPPEN, R. J. (1971) Retention and distribution of dry powder and liquid formulations of insecticides and fungicides on commercially dressed cereal seed. Pestic. Sci., 2, 49-55.

MARTIN, H. (1959) Scientific principles of crop protection. Edward Arnold, Lond.

POTTER, C., HEALY, M. J. R. & RAW, F. (1956) Studies on the chemical control of wireworms (*Agriotes* spp.) 1. The direct and residual effects of BHC, DDT, D-D and ethylene dibromide. Bull. ent. Res., 46, 913-923.

WAY, M. J. (1959) Experiments on the mode of action of insecticidal seed dressings especially against *Leptohylemyia coarctata* Fall. Muscidae, the wheat bulb fly. Ann. appl. Biol., 47, 783-801.

Proc. 6th Br. Insectic. Fungic. Conf. (1971)

THE EFFECT ON MILDEW DEVELOPMENT OF THE WIDESPREAD USE OF FUNGICIDE ON WINTER BARLEY

D. J. Yarham, E. T. G. Bacon and C. F. Hayward
Agricultural Development and Advisory Service, Eastern Region

Summary Large scale use of ethirimol seed dressing on winter barley in NW Norfolk reduced the amount of overwintering mildew and slightly delayed the development of the disease on spring barley in the area. Low levels of mildew were, however, present in the treated winter barleys and these were able to act as sources of inoculum for neighbouring spring sown crops. Disease levels within such spring crops rapidly attained to those present in comparable crops close to untreated winter barley in two control areas. Mildew development was much slower in spring crops distant from winter barley irrespective of whether those crops were in the treated area or the control areas. An attempt was made to assess the extent to which a slight delay in mildew development might affect the yield of spring barley. Three fields close to winter barley, in which mildew gradients had been detected in the spring, were sampled at harvest time. Yields were found to decrease with proximity to the autumn sown crop, but the possibility that the yield gradients were caused by factors other than mildew cannot be discounted.

INTRODUCTION

The importance of winter barley as a source of overwintering barley mildew (*Erysiphe graminis*) has long been recognised (Stephan, 1958). In an attempt to break the 'green bridge' carrying mildew and other leaf diseases through the winter the Danish Government has banned the growing of winter barley for an experimental period of 5 years (Stapel & Hermansen 1968). On a much smaller scale Evans (personal communication) and Yarham & Pye (1969) have studied the effects of eliminating winter barley from areas of a few square miles in Sussex and Cambridgeshire (1 sq mile = approx 2.6 sq km); this work gave inconclusive results, perhaps because the areas investigated were too small. In this country to eliminate winter barley from larger areas would be difficult since the crop plays an important part in the economy of many arable farms. It was thought, however, that the elimination of the winter crop might be unnecessary if the disease on it could be controlled by the use of fungicide. To investigate this possibility a collaborative exercise was undertaken in 1970-71 by Plant Protection Ltd, the Miln Marsters Group and the Advisory Service of the Ministry of Agriculture, Fisheries and Food.

MATERIALS AND METHODS

Some 60 tons (61 tonnes) of ethirimol treated winter barley seed was made available by Plant Protection Ltd, and the staff of the Miln Marsters Group arranged for this to be grown in a 25 sq ml (65 sq km) area of NW Norfolk - an area geographically isolated in that it is bounded by the sea to the north and west (the B1153 Docking - Brancaster road and the old Docking-Heacham railway line delineated the eastern and southern boundaries of the area). A few untreated winter barley crops were sown in the area, of these two were sprayed with ethirimol in December and two were sown so late that they developed little or no mildew in the autumn. Observations were concentrated on fields in the centre of the area to the north of the village of Ringstead. Two 'control' areas were chosen, one to the west of Burnham Market and one to the north east of Snettisham, to enable observations to be made in areas where untreated winter barley was being grown. In both these areas a proportion of the winter barley acreage was found to have been drilled with ethirimol treated seed.

Disease assessments in the areas investigated were carried out by staff of the Advisory Service of the Ministry of Agriculture, Fisheries and Food. Observations included detailed weekly assessments of mildew levels in 12 winter and 12 spring barley crops, carried out by assessing the amount of disease present on every leaf of each of 50 tillers selected at hap along one diagonal of each field. At intervals less detailed surveys were carried out on a larger number of fields.

Meteorological data was collected by a number of volunteers within and around the survey area. The co-operation of the Local Education Authority was obtained and meteorological records were kept at a number of schools in the area.

RESULTS

1. Winter Barley

The very mild autumn of 1970 led to the development of high mildew levels on the many volunteer plants in stubble fields in the area. Emerging winter barley crops were thus subjected to high inoculum pressure. By the end of October, crops drilled in mid September were in the tillering stage, and untreated crops already had up to 40% mildew on the lower leaves. Treated crops were far less severely infected but control was not complete, there being up to 3% mildew on the lower leaves of some crops.

Crops emerging after the end of October escaped severe autumn infection, but in the already infected, early sown crops disease development continued during the wet but unusually mild November. By the end of that month mildew levels on three of the very early sown treated crops were so high (up to 10% on the lower leaves) that it was decided to apply an ethirimol spray. This treatment was applied on 19 December.

The effect of severe autumn mildew infection on winter barley was clearly seen in a September sown field at Snettisham, part of which had been drilled with treated and part with untreated seed. Observations made during the winter showed the treated plants to have better root systems and significantly more tillers than the untreated ones. These observations are in accord with those of Finney & Hall (1971) made on a trial a few miles south of the NW Norfolk area.

Where, in the control areas, treated crops were drilled close to untreated winter barley it was noticeable that mildew levels on the treated plants were higher close to the untreated crops. The effectiveness of the fungicide in controlling the disease was inversely proportional to the inoculum pressure to which the treated plants were subjected.

The mild weather continued into mid January interrupted only by a cold spell around Christmas. During this period mildew continued to develop, though in many crops overall levels of the disease were reduced by the death of the worst infected lower leaves. Data from some of the fields examined in mid January are shown in Table 1.

Table 1

Mildew levels in mid January

Untreated crops				Treated crops			
Sowing date	Growth stage on 30 Oct	Mildew level on 14 Jan Top leaf	2nd leaf	Sowing date	Growth stage on 30 Oct	Mildew level on 14 Jan top leaf	2nd leaf
18 Sept	4	5%	10%	18 Sept	4	1-5%	5-10%
21 "	3	1-5%	10%	25 "	2/3	(1-5%)*	(5-10%)*
Early Oct	1(21f)	Up to 10%	Up to 25%	7 Oct	1(21f)	1% on lower leaves	
Mid Oct	1(11f)	1-5%	5-10%	11 "	1(11f)	1% on lower leaves	
29 "	Not emerged	1% on lower leaves		26 "	Not emerged	No mildew seen	

* levels found at north side of field near to the earlier drilled crop, elsewhere in the field levels were much lower.

The figures illustrate the way in which late drilling drastically reduced levels of over-wintering mildew even on the untreated crops, and the disappointing results obtained with the seed dressing on very early drilled crops. Fortunately very few of the treated crops had been sown in September and on the remainder mildew levels in January seldom exceeded 1% on the lower leaves.

A feature of the winter barley crops in mid January was the high level of brown rust (*Puccinia hordei*) found in many of them. This disease, associated in some cases with leaf blotch (*Rhynchosporium secalis*), aggravated the effects of frost (and, in untreated crops, of mildew) in killing off the lower leaves. Such loss of leaf during the subsequent two months resulted in the mildew levels in mid March being lower than at any time during the winter. By this time few of the fields in the treated area had more than occasional pustules in them, and in the great majority no mildew could be found at all. Mid March mildew levels in the untreated crops were very variable - in some only occasional pustules could be found, on others levels of up to 5% were recorded on the second leaf.

In late March and early April mildew levels increased slightly in sheltered fields. In more exposed situations further reduction appeared to occur - this was particularly noticeable in September drilled fields which had been very badly mildewed in the autumn and in which the plants were very poorly tillered.

For most of April temperatures never exceeded 10°C but a warm period occurred from 18 to 23 April when the mean maximum temperature over the whole area exceeded 15°C. This was followed by an increase in mildew levels in both treated and untreated crops, increases being most marked in sheltered positions and in fields in which the level of inoculum was high (Table 2).

Table 2

Mildew development in winter barley crops

Seed treatment	Situation	Sowing date	% mildew on top 3 lvs 28 Apr GS4	13 May GS7	4 June GS 10.4	Notes
-	Sheltered	26 Sept	46.0	0.9	3.0	Snettisham area
-	"	29 "	44.1	1.2	1.7	" "
-	"	26 Oct	2.2	0.3	0.9	Chloraniform spray - end April
-	Exposed	Early Oct	2.0	0.6	1.9	
-	Sheltered	"	0.5	0.1	1.2	Tridemorph spray - 18 April
-	Exposed	21 Sept	0.2	0.8	2.0	Mildew levels very low by mid April
+	Sheltered	7 Oct	2.4	0.3	1.1	
+	"	12 Oct	1.5	0.3	1.5	Volunteers within crop badly infected
+	"	7 Oct	0.9	0.2	0.4	
+		7 "	0.5	0.05	1.4	
+	Exposed	Mid Oct	0.05	<0.05	0.4)	Scarcely any mildew found
+	"	" "	<0.05	0.05	0.3)	during winter months

During the first two weeks of May crop growth greatly exceeded the rate of mildew development, and mildew levels on the top 3 leaves were, in consequence, drastically reduced. After GS 8 mildew on the top leaves increased again but, in general, levels remained low throughout the summer. The results of disease assessments carried out on 26 fields in early June (GS 10.5) are given in Table 3.

Table 3

Winter barley - % disease on leaf 2, 8-9 June (GS 10.5)

	No. of fields	Mildew	Brown Rust	Leaf Blotch
Seed treated	14	1.1	2.2	1.4
Seed untreated - unsprayed	10	1.8	7.3	0.4
" " - sprayed	2	1.4	4.2	0.3

Inexplicably brown rust appears to be far less severe on the fields treated with ethirimol.

2. Spring Barley

Mildew was first seen in spring barley on 19 April in crops close to untreated winter barley in the Burnham Market area. Disease gradients within the crops were taken as evidence that the winter barley was the source of the infection (Gregory 1961). The validity of the gradients was demonstrated by regression analysis. On 21-22 April mildew was looked for in 125 spring barley fields spread over the treated and 'control' areas. The results of this survey are presented in Table 4.

Table 4

Spring barley survey 21-22 April (GS 2-3)

	Number of fields	
	Mildew found	No mildew found
Control area	26	21
Treated area 1) < 1½ ml (2.4 km) from edge of area	20	22
2) > 1½ ml (2.4 km) " " "	0	34

On 29-30 April 21 crops in the treated area which had been free of mildew at the first visit were examined again. The following results were obtained:-

Fields < 1½ ml (2.4 km) from edge of area - mildew found in 5, no mildew found in 5
" > 1½ ml (2.4 km) " " " " - " " " 3, " " " " 8

The results of these surveys suggests that the development of mildew was delayed by the treatment of the winter barley, but it should be noted that within 10 days of the first appearance of the disease in the control area it could also be found in fields at the centre of the treated area.

That treated crops could act as sources of inoculum for surrounding spring barleys was demonstrated by the fact that in early May mildew gradients could be detected in spring barley fields adjacent to treated crops. Statistical analysis of data obtained from fields to the west and south of treated winter barley at Ringstead showed that the regression oflevel of mildew on distance from winter barley was significant at the 0.1% level (southern field $F_{(1,21)} = 23.74$, west field $F_{(1,36)} = 16.48$).

One treated winter barley crop at Holme was of particular interest in this context. It lay on a very exposed north facing slope and throughout most of the winter it had been impossible to find mildew in it. In late April mildew could be found but levels never exceeded 0.05% on the top three leaves until the second half of May. Figures obtained on 10 May from spring barley crops adjacent to this field are shown in Table 5.

Table 5

Av % mildew on lower leaves of spring barley at Holme

Direction relative to winter barley	Growth stage	Distance from edge of field nearest winter barley yd (m)	0 (0)	20 (18)	40 (37)	60 (55)	80 (73)	120 (110)	180 (165)	260 (238)
West	2		0.05*	1.4	0.6	0.2	0.1	-	0.1	-
East	4		1.9	1.8	1.8	2.1	1.3	0.4	-	-
North	3-4		0.01	0.03	0.2	0.1	0.1	-	-	0.03

* observations in thin crop on headland

The very low levels of mildew on the north (windward) side of this field and the suggestions of disease gradients in fields to the east and, more particularly, to the west suggest that the winter barley was acting as a spore source despite the low levels of mildew present in it.

The weather in early May was favourable to the build up of mildew. In the 7 day period from 6-12 May the mean maximum temperature at Ringstead exceeded the 20°C stated by Rosser (1969) to be particularly conducive to the development of the disease. Table 6 illustrates the changes in mildew levels occurring in the treated and untreated areas during this period.

Table 6

Disease development in spring barley crops

Field	Distance from nearest winter barley yd (m)	Position relative to nearest winter barley	Situation	Sowing date	Average % mildew on top 3 leaves 26 Apr	5 May	12 May	19 May	26 May	2 June
1. Crops in control areas										
S13	15(14)	E,S	Sheltered	26 Feb	4.6	3.7	20.4	30.3	28.0	27.0*
S124	1(0.9)	W,E	"	Late Feb	-	3.3	(27.6)*	27.4	35.1	20.2
S12	10(9)	NE	"	16 Feb	1.0	2.5	14.6	19.0	1.4**	0.2
S111	400(366) untreated crop	N	"	Early Mar	0.4	2.8	9.6	35.7	16.9	13.0
	100(91) treated crop	S,N								
S113***	10(9)	NE	Exposed	23 Mar	0.01	0.2	0.3	1.6	10.0	7.7
S8	800(732)	NW	"	23 Feb	0.01	0.08	0.1	1.5	11.4	4.6
S116	200(183)	NE	"	3 Mar	0.00	0.04	0.5	2.4	9.6	6.0
2. Crops in treated area										
S40	20(18)	NE		18 Mar	0.01	0.4	5.5	27.5	16.6	9.0
S50	20(18)	E, NE	Sheltered	31 Mar	0.00	0.1	4.5	3.6	19.3	25.7
S45	100(91)	E	"	1 Mar	0.06	1.0	5.8	3.1	3.5	5.5
S35	400(366)	NW	Exposed	8 Mar	0.01	0.02	0.7	2.0	5.7	10.3
S34	200(183)	NW	"	Early Mar	0.00	0.1	0.7	1.6	2.7	3.4

Mean maximum temperatures (°C) and wind direction in 7 days preceeding assessment

	26 Apr	5 May	12 May	19 May	26 May	2 June
Brancaster-N coast 10 ft (3m) ASL	14.1	12.8	18.2	15.9	14.9	16.6
Hunstanton-W coast 80 ft (24m) ASL	16.1	12.7	19.8	15.6	15.7	16.9
Ringstead - Inland 75 ft (23m) ASL	19.3	13.1	20.1	15.4	15.5	18.4
Docking - Inland 260 ft (79m) ASL	14.4	12.3	18.6	14.7	15.8	16.7
Wind direction (Holme)	E	N-E	E-S-W	W-N-E	E-SE	SE-N-SW

* Observations made 15 May

** Crop sprayed with tridemorph 19 May

*** Variety Vada (all remaining fields cv. Proctor)

In sheltered fields close to untreated winter barley rapid build-up of mildew in the spring crops occurred between 5 and 12 May. In crops more distant from the winter barley no substantial increase in disease levels occurred until after 19 May.

Mildew levels in spring barley at the end of April were very much lower in the treated area than they were in the control areas. Moreover the rate of mildew build up during the warm spell from 5 to 12 May was never so rapid in spring crops close to treated winter barley as it was in crops close to untreated winter barley. Nevertheless it was noticeable that on field S40 (close to treated winter barley) disease levels by 19 May were as high as those on S124 (close to untreated winter barley). On the later sown field S50, which was just as close as S40 to treated winter barley, there was, unaccountably, no substantial rise in mildew levels until after 19 May.

So far as fields distant from winter barley were concerned, by the first week in June there was little difference between mildew levels recorded in the treated area and those recorded in the 'control' areas. It is noticeable, however, that the mildew peak recorded in such fields in the untreated area on 26 May was not detected in similar fields in the treated area.

More marked than the differences between treated and control areas were the differences in mildew levels related to the proximity of spring crops to winter barley, these differences persisted until mid June as may be seen from the data from the Ringstead area presented in Table 7.

Table 7

Mildew levels in spring barley relative to distance from treated winter barley

Distance from winter barley	No of fields	% mildew on 15 June Lf1	Lf2	Lf3	Lf4	% senescence Lf4
Less than 50 yd (46 m)	23	Tr	1.1	7.0	34.4	30.4
50-200 yd (46m-183m)	14	0.0	1.2	5.8	28.6	21.4
More than 200 yd (183 m)	33	0.0	0.5	4.1	14.1	3.0

In mid June cool wet weather led to a decline in mildew levels in both the treated and the control areas. Later in the month however, a Rosser period was recorded all over the area except along the north coast and increases in mildew levels were recorded in many crops. By this time the differences in disease levels between crops close to and distant from winter barley had disappeared, nor could any difference be detected between mildew levels in the treated and the untreated areas. Table 8 presents data from a survey of 60 fields carried out on 29 June.

Table 8

Mildew on spring barley 29 June (GS 10.5)

	Area		Distance from winter barley		
	Treated	Control	< 50 yd (46 m)	50-200 yd (46-183m)	> 200 yd (183m)
% mildew on top 3 leaves	5.0	4.9	4.5	4.7	5.8

An attempt was made to assess the effect on final yield of slight delay in mildew development on a spring barley crop. It was known that in fields close to winter barley mildew gradients existed in late April and early May, and that in mid May these gradients generally levelled out. It was possible that these transient differences in mildew level early in the season would be reflected in yield differences across the field. If this could be demonstrated then it could be argued that yields would also be affected by the slight delay in spring mildew development achieved by the use of fungicide on the winter barley. At harvest time quadrat samples were taken by hand at regular intervals across three fields in which disease gradients had been detected in the spring. Data obtained from two of these fields are presented in Table 9. Field S was adjacent to an untreated, and field L to a treated, winter crop. To facilitate the presentation of results each figure given is the mean of 5 consecutive observations. Distances quoted refer to the distance from the winter barley of the central quadrat of the 5.

Table 9

Spring barley yield data

Field		Distance from edge of field nearest winter barley								
	yd (m)	15 (14)	40 (37)	65 (59)	90 (82)	130 (119)	180 (165)	230 (210)	280 (256)	330 (302)
S	Yield (g/quadrat)*	84.8	84.9	89.4	96.5	105.2	106.6	117.2	116.2	107.4
	Ears/quadrat	195	200	211	208	217	220	239	234	199
	Grains/ear	22.3	21.2	20.5	22.7	23.9	23.6	23.3	22.9	23.2
	1000 grain wt(g)	24.1	24.6	24.9	25.3	24.8	24.9	26.1	26.8	27.2
L	Yield (g/quadrat)	101.3	113.1	114.1	107.8	120.1	115.4	127.3	127.3	-
	1000 grain wt (g)	28.6	29.0	29.5	30.9	31.0	30.5	32.3	32.4	-

* size of quadrat 4 ft^2 (0.37 m^2)

On these fields yields declined as the winter barley was approached. Unless the yield gradients occurred purely fortuitously as a result of, say, fertility gradients across the fields, the depressions of yield close to the winter barley are likely to have resulted from diseases spreading out from the winter crops. The only diseases to reach significant proportions on the spring barleys were mildew and brown rust. For both of these the winter barley would have acted as a major source of inoculum. 1000 grain weight could have been affected by either mildew or rust, but variation in numbers of ears per unit area and numbers of grains per ear is more likely to have been caused by early differences in mildew levels than by any gradient in brown rust levels. The rust did not build up until late in the season and would therefore have little effect on tiller numbers or numbers of grains per ear. Unfortunately, no data on number of ears per unit area or numbers of grains per ear is available for field L.

The third field from which yield samples were taken (field S124 in table 6) had winter barley crops to the east and west of it. In April a mildew gradient confirmed that the eastern winter crop was acting as a source of inoculum, but the potency of this source was later reduced by its being sprayed with tridemorph. Assessments carried out on 15 May suggested that by this time the western winter barley was the main source of inoculum for the spring sown crop (though the mildew gradient was lost within a few days of these assessments being made). Pre-harvest sampling revealed an increase in yield from west to east across the spring barley field. While this yield gradient could have been due to differences in mildew levels in early May, the influence of soil factors cannot be ruled out as it was found that the depth of top soil varied across the field.

DISCUSSION

Since long distance spread of mildew conidia is known to occur (Hermansen 1968) the 25 sq ml (65 sq km) area in which the treated winter barley crops were grown was obviously far too small to obviate the possibility of mildew spreading in from untreated crops to the south, and more particularly (since this was the direction of the prevailing wind in the spring), to the east. The importance of spore sources close to the spring barley crop is, however, well known (Hermansen 1968, Yarham and Pye 1969), and the treatment of the winter barley might, therefore, be expected to influence at least the early stages of the mildew epidemic in the area.

The results of the late April surveys, and the data obtained in May from spring crops close to winter barley, suggest that disease development in the early stages of the epidemic was rather slower in the treated area than in the control areas. It could be argued that these differences in disease development resulted from differences in climate in the two areas rather than from differences in the use of fungicide. May temperatures at Ringstead were, however, generally higher than those at Burnham Market - so it might have been expected that disease development at Ringstead would have been more rapid, rather than slower, than that at Burnham. Temperatures at Dersingham (just south of the Snettisham control area) were generally higher than those at either Burnham or Ringstead, yet the patterns of mildew development in fields S6 and S12 in the Snettisham area did not differ substantially from those in the remaining 'control area' fields all of which were at Burnham.

Overwintering inoculum was not eliminated in the treated area since the fungicide did not control the disease completely. Moreover, it is likely that in the unusually mild winter there was some carry over on volunteer plants. Estimates of inoculum level based on an assessment of the disease pustules seen on the treated crops in early spring may be misleading as it is known (Brookes, personal communication) that sub lethal doses of ethirimol will inhibit the sporulation of *Erysiphe*. It is possible therefore that the pustules seen were producing only small numbers of spores. Nevertheless the disease gradients found on spring barleys in the area provided evidence that the treated crops were able to act as sources of infection. Despite this, however, there did appear to be some slight delay in the development of the mildew epidemic in the treated area as compared with that in the control areas. This was, presumably, a reflection of the lower inoculum potential within the treated area.

Van der Plank (1960) has demonstrated that the expected delay (Δt) in the development of a disease epidemic resulting from the reduction of the initial inoculum potential from I_o to I'_o, may be calculated from the equation:-

$$\Delta t = \frac{230}{r} \log \frac{I_o}{I'_o}$$

when 'r' is the rate of increase of the pathogen during the delay period. In 1971 temperatures in NW Norfolk were unusually high in early May and mildew therefore developed quite rapidly during the early stages of the epidemic. The value for 'r' in the above equation would therefore be high, and in order to have achieved any substantial delay in the development of the epidemic it would have been necessary to have reduced the value of I'_o to a much lower level than was in fact achieved.

If the effectiveness of the fungicide had been enhanced by a more severe winter, and if temperatures had been lower in early May the delay in the development of the epidemic in the treated area would almost certainly have been greater. It will be obvious, however, that the benefits of delaying the epidemic in early spring are likely to be greatest under just those conditions in which delay is most difficult to achieve - ie conditions which enable the mildew to reach such high levels as to damage the crop in the early stages of growth.

It was noticeble that mildew development on spring barleys was influenced more by proximity to winter barley crops than by the treatment which those winter crops had received. This provides further evidence of the importance of nearby sources of inoculum in the early stages of the epidemic. As had been found in previous studies (Yarham and Pye 1969) the levels of mildew in the spring crops later in the season were not related to proximity to winter barley, but by this time the levels on the top leaves were much lower, and presumably far less damaging, than the levels recorded earlier when the differences were apparent.

It is difficult to gauge the extent to which the yields of spring barley were affected by the slight delay in mildew development consequent upon the seed treatment of the nearby winter barley, or by the longer delay resulting from the spring crop being distant from winter barley. It is impossible to draw firm conclusions from 'between field' comparisons and the yield data obtained from fields which had shown early mildew gradients must be treated with caution. Since soil conditions are so variable, data obtained from only three fields is insufficient to allow firm conclusions to be drawn. Moreover, since the components of yield were examined in detail in one field only, one cannot rule out the possibility that brown rust spreading from the winter barley was contributing to the yield gradients detected in the other two. Wolfe (personal communication) has however adduced evidence which suggests that under conditions of severe attack the early stages of the epidemic may be responsible for a considerable proportion of the total yield loss caused by mildew. It might be expected therefore that yield losses would be reduced by any delay in disease build up occurring at this stage. More work is needed to confirm this contention. The effect of delaying the development of mildew on the optimal timing of fungicidal sprays for spring barley has been discussed by Evans and Hawkins (1971).

Hall (1971) has shown that yields of winter barley can be substantially increased by the use of ethirimol seed dressing. It is therefore fair to assume that, however small its effect on the spring mildew epidemic, the application of the seed dressing did benefit the winter barley crops themselves. This is likely to have been especially true to the early sown crops which became so heavily infected with mildew in the autumn.

Acknowledgements

The authors wish to express their thanks to the staff of Plant Protection Ltd and the Miln Marsters Group, and to all the farmers whose co-operation made this study possible. We are also indebted to our colleagues in the ADAS who gave such valuable assistance in the execution of the work and to all the volunteers who so assiduously recorded meteorological data in the area. The excellent co-operation received from the Local Education Authority was especially appreciated.

References

BROOKES, D. Jealott's Hill Res. Sta., Bracknell (personal communication).

EVANS, E. J. & HAWKINS, J. H. (1971) Timing of fungicidal sprays for controlling mildew on spring barley. Proc. 6th Br. Insectic. Fungic. Conf. (these proceedings).

EVANS, S. ADAS, Wye (personal communication).

FINNEY, A. R. and HALL, D. W. (1971) Effect of autumn mildew on the growth and development of winter barley. Proc. 6th. Br. Insectic. Fungic. Conf. (these proceedings).

GREGORY, P. H. (1961) The microbiology of the atmosphere. 252 pp. London and New York.

HALL, D. W. (1971) Control of mildew on winter barley with ethirimol. Proc. 6th Br. Insectic. Fungic. Conf. (these proceedings).

HERMANSEN, J. E. (1968) Studies on the spread and survival of cereal rust and mildew diseases in Denmark. Friesia 8 (3), 1-206.

ROSSER, W. R. (1969) Spray timing and the control of mildew in spring barley. Proc. 5th Br. Insectic. Fungic. Conf. 1, 20-24.

STAPEL, C. and HERMANSEN J. E. (1968) Tidsskr. Landokon 155, 218.

STEPHAN, S. (1958) Concerning the epidemiology of cereal mildew (*Erysiphe graminis* D.C.) in Germany. Nachr Bl. dtsch. Pfl Sch. Dienst, Berl. N.F. 11, 9, 169-177.

VAN DER PLANK J. E. (1960) Analysis of Epidemics. Plant Pathology III 230-287 London and New York.

WOLFE M. PBI, Cambridge (personal communication).

YARHAM D. J. and PYE D. (1969) Winter barley as a source of mildew for spring barley crops. Proc. 5th Br. Insectic. Fungic. Conf. 1 25-33.

Proc. 6th Br. Insectic. Fungic. Conf. (1971)

CONTROL OF MILDEW IN WINTER BARLEY WITH ETHIRIMOL

D.W. Hall
Plant Protection Limited,
Jealott's Hill Research Station, Bracknell, Berks

Summary Ethirimol applied as a seed dressing to control mildew in winter barley was examined in 18 field experiments during the period 1969-71. The chemical gave almost complete control of mildew in the autumn and was sufficiently persistent, in the single year where comparisons were made, to be as effective as a spring spray in controlling the spring mildew attack. Overall yield responses were in excess of 6%. Where autumn mildew was serious they were normally 12% resulting from improved crop vigour during autumn and winter which, in a number of experiments persisted until harvest.

INTRODUCTION

Powdery mildew (Erisyphe graminis D.C.) is widely recognised as one of the most serious diseases of barley. Recent Ministry of Agriculture surveys showed that yield losses from this disease frequently exceed 15% in spring barley (James, 1968). In contrast, winter barley, a less important crop has received little attention although it, too, is highly susceptible to mildew and provides the main overwintering 'green bridge' for the disease (Yarham, 1971). For this reason the growing of winter barley in Denmark was recently banned. Most published data (e.g. Yarham and Pye, 1969) examines only the carryover of mildew onto spring crops rather than any direct effects on growth and yield of the winter crop itself.

The etiology of mildew in winter barley is not yet fully understood and the disease/plant relationship is more complex than in spring-sown crops. There are normally two distinct periods of attack, one in autumn and a second in spring, with a lull caused by cold weather during winter. All current winter barley varieties are susceptible to the disease.

The discovery of the systemic fungicide ethirimol ('MILSTEM')* at Jealott's Hill (Bebbington et al, 1969) and its subsequent development as a seed dressing for spring barley is well documented (Brooks, 1970). This paper describes the continuation of the studies on winter barley and discusses the importance of control of powdery mildew in this crop.

METHOD AND MATERIALS

Eighteen replicated field experiments were carried out in south and east England during 1969/70 and 1970/71 to examine the control of mildew in winter barley by ethirimol seed dressings and sprays. Three experiments in the former season studied methods of application. A further 15 experiments during 1970/71 selected the seed dressing as the main method of application with particular emphasis on application rates. For this paper, data were taken from treatments at normal levels (usually 0·70 kg a.i./ha) with the aim of highlighting the agronomic features of disease control.

*'MILSTEM' is a trade mark of Plant Protection Limited.

In both series of experiments, a number of treatments were replicated five times in randomised block designs. Plot sizes were 35 m by 8-11 m depending upon drill width. All on-farm operations were carried out at farmer specified times with farmer equipment. Seed dressing was carried out by the Machinery Department of Plant Protection Limited using commercial equipment. Spray treatments, in 1970, were applied by the field teams using normal farm sprayers. The spray was applied in 225 l. water/ha as soon as mildew appeared in spring.

Mildew assessments were commenced as soon as the disease appeared and continued at least until growth stage 10·5 (Feekes scale . In the initial trials when the major mildew attacks occurred in spring, most of the assessments, a minimum of four per experiment, were made in spring but in the 1970/71 trials when autumn mildew was prevalent, emphasis was given to this period. Assessment of mildew on leaf 3 was used as a standard at most growth stages including growth stage 10·5. It was, however, not suitable at other times particularly in autumn when the plants had few leaves. Then, whole plant assessments were made. Assessments of other foliar diseases were made as and when they appeared.

Estimates of yield were made at harvest by taking a single combine cut from each plot. Prior to this, counts were made of grain numbers per ear and ear bearing tillers per m. After harvest, grain size was assessed by counting and sieving.

In a number of trials, detailed studies were made of early plant growth. Particular emphasis was given to root development. The results of some of this work will be reported elsewhere (Finney and Hall, 1971).

RESULTS

Mildew There was a marked contrast between the pattern of mildew attack in the two years of trials. The 1969/70 season was typified by light or moderate attacks in autumn followed by severe attacks in spring. The reverse situation, with heavy autumn mildew and relatively light spring attacks occurred in 1970/71. Almost all combinations of intensity of autumn and spring attack were encountered. Only one experiment failed to contract mildew at any stage. As an indication of the severity of mildew in winter barley, a large percentage of the experiment developed severe mildew in autumn and a similar number, not necessarily the same, in the spring. The criterion for judging a severe attack was taken as an excess of 50% mildew on untreated plots on leaf 3 at one growth stage within the period.

Where mildew appeared in autumn, control with ethirimol applied as a seed dressing exceeded 95% until at least the end of November when spread of the disease effectively ceased in the 1969/70 experiments. In a number of early sown experiments in 1970/71 where mildew appeared early and where levels were high on untreated adjacent areas during November, the level of disease sometimes increased on treated plots. Control, however, still averaged 64% during December and the disease became inactive at the end of that month. This figure was considered highly satisfactory taking into account the level of the spore pressure from the surrounding field. The mean results of the autumn assessments are presented in Table 1.

Table 1

Effect of ethirimol on autumn mildew in winter barley

Year	Period	Assessments	Untreated control % mildew	Ethirimol % mildew	Ethirimol % disease control
1969/70	November	2	41·2	0·4	99
1970/71	October/November	6	36·8	0·3	99
1970/71	December	7	52·2	18·6	64

Almost all the experiments were drilled in late September and early October, perhaps near normal for this crop. In these experiments where drilling was delayed until late October, mildew appeared relatively later and was much slower in building up.

Control of mildew in autumn with ethirimol seed dressing gave highly significant improvements in crop colour, growth and general vigour compared to the untreated areas which remained yellow and weak. This effect persisted well into spring and where autumn mildew was most severe through until harvest.

Mildew re-appeared in mid-May in the 1969/70 experiments. It attached much later in 1970/71 even though surrounding fields of spring barley were heavily infected and it developed only to measurable levels where autumn attacks had been light or absent. All trials were examined at growth stage 10·5 and the mean results are given in Table 2. Trials with less than 5% mildew on leaf 3 on untreated plots were not assessed.

Table 2

Effects of ethirimol on spring mildew in winter barley

Year	Assessments	% mildew on leaf 3: Untreated control	Ethirimol seed dressing	Ethirimol spray
1969/70	3	40·8	2·7 (93)	4·5 (89)
1970/71	15	29·5	17·4 (42)	-

% mildew control in brackets

In 1969/70, mildew control with the seed dressing exceeded 90% at growth stage 10·5, a level as least as good as single spring spray. In the 1970/71 experiments, control of mildew in spring particularly during the later stages of growth (i.e. growth stage 10·5) was not as good. No spray treatments were included in this year for comparison. Where earlier assessments were made i.e. at growth stage 6·8, disease control was somewhat higher particularly where autumn mildew attacks were light.

Growth stage 10·5 may not be a suitable stage for critical assessment in winter barley as the crop is normally senescing rapidly at this time. Third leaves and below were fully senesced in a large number of the trials. When a single spring spray was included, control of mildew also reached its peak just before growth stage 10·5.

The level of brown rust measured on the trials was relatively low in both years and is unlikely to have had any major effect on yield. Winter barley normally completes its life cycle before peak levels of this disease are reached.

Grain yield and components The mean grain yield data are presented in Table 4. 3 experiments were excluded from the 1970/71 series because of severe lodging.

Table 3

Effect of mildew control with ethirimol on yield of winter barley

(kg/ha at 85% dry matter)

Year	Experiments	Untreated control	Ethirimol Seed dressing	Ethirimol Spray
1969/70	3	3176	3578	3452
1970/71	12	4469	4739	-

Yields in 1971 were considerably higher than in 1970. Consequently larger percentage yield responses were obtained in 1970, as shown in Table 4. The actual yield increase obtained from a seed dressing was substantial in both years (402 and 270 kg/ha in 1969/70 and 1970/71 respectively). The spring spray gave approximately 50% of the response of the seed dressing in the single-year that it was tested.

In both years, the seed dressing, which caused marked improvements in crop growth over winter and into the spring, leading to improved tillering, gave significantly more ear-bearing heads at harvest. Grain number per ear and individual grain weights were less affected by treatment in the 1969/70 trials although both were relatively lower in the 1970/71 series. The effect was due either to considerable compensatory growth on untreated plots in the spring or more likely because the overall tiller production was already very high even on untreated plots in this year averaging 118·1 heads/m at harvest. These data plus yield data are presented in Table 4.

Table 4

Grain yields and grain yield components (as % of untreated)

Year	Component	Untreated control	Ethirimol Seed dressing	Ethirimol Spray
1969/70	Yield (kg/ha)	100 (3176)	112·7	108·7
	Ears/m	100 (105·6)	113·0	105·3
	Grains/ear	100 (27·3)	100·0	101·8
	Grain wt. (g)	100 (25·5)	105·9	104·3
1970/71	Yield (kg/ha)	100 (4469)	106·0	-
	Ears/m	100 (118·1)	113·8	-
	Grains/ear	100 (30·4)	93·9	-
	Grain wt. (g)	100 (26·9)	100·4	-

Figures in brackets indicate untreated means

The effect of autumn mildew on yield. It is not unreasonable to suppose that maximum yield responses will be obtained if mildew is controlled as it appears. There were two sources of evidence to show the importance of controlling autumn mildew in winter barley quite aside from reducing inoculum levels of crops.

The first of these came from the 1969/70 trials, where, on average, a single spray applied in spring gave only 68·5% of the response of an equivalent seed dressing (Table 4) over 3 trials. When the data were divided into two groups on incidence of autumn mildew, it was evident that autumn mildew was exerting a large effect on yield response as shown in Table 5.

Table 5

Effect of controlling autumn mildew on yield response in winter barley

(kg/ha at 85% dry matter)

Autumn mildew	Spring mildew	Ethirimol Seed dressing	Ethirimol Spring spray
Moderate	Moderate/severe	439 (112)	226 (106)
Nil	Moderate/severe	314 (116)	364 (119)

Figures in brackets indicate yield response as per cent of control

In this series, spring mildew was moderate/severe on all trials. In one trial where only spring mildew occurred, the spray treatment applied in spring was as effective as the seed dressing. However, in experiments where both autumn and spring attacks occurred, the seed dressing was twice as effective as the spray in terms of increasing yield.

The second source of information came from the 1970/71 series when the major mildew attacks were in autumn; it was fairly clear that not only was autumn mildew having a large effect on yield but that the size of the yield response obtained was closely related to the date of initial mildew attack and its duration as shown in Table 6. Mildew in these experiments was largely inactive by late December.

Table 6

Effect of intensity of autumn mildew on yield response

Period of initial attack	Severity	Yield response (kg/ha)	% of control
Late September	V. severe	705	120
October	Severe	254	106
November	Moderate	238	105
-	Nil	138	103

DISCUSSION

Eighteen experiments carried out during 1969/70 and 1970/71 showed that large yield increases could be obtained by controlling mildew in winter barley using ethirimol as a seed dressing. It gave a high level of control of mildew appearing in autumn with sufficient persistence into the spring to give similar mildew control to a single spring spray in one year where both methods were compared. Although little is known about the effects of mildew on yield in winter barley, it is fairly clear from the data presented that the effect of the disease is complex and that no single relationship linking mildew at a specific stage and yield, such as was proposed by Large and Doling (1962) for spring barley, is appropriate. Mildew can occur at almost any period in autumn or spring and each attack varies from year to year, even area to area, in intensity and duration. Moreover, there is some evidence that a mildew attack at one specific time influences subsequent attacks. In the trials described, severe autumn attacks were usually followed by light spring attacks. It was possible that some form of induced resistance appeared in the plants after the early attacks. Alternatively, the winter barley was at a non-infectable growth stage. The latter theory is difficult to understand when the source of inoculum for surrounding spring barley was possibly the winter barley itself.

Although the data presented stressed the importance of autumn mildew, insufficient data was available to show the relative importance of autumn and spring attacks. This may be unimportant as both normally occur. It is difficult to comprehend how mildew in winter barley could be effectively controlled using a single spray applied either in spring or in autumn. Whilst winter barley undoubtedly has considerable ability to compensate from sustained disease attacks, it is clear that major advantages in this crop, and possibly also by reduction of inoculum in adjacent spring crops, will only be obtained if the disease is controlled from the onset.

Acknowledgments

The author would like to acknowledge the assistance given by members of the Field Trials Unit at Jealott's Hill in carrying out the work.

References

BEBBINGTON, R.M. et al. (1969). Chem. Ind., 1969, 1512.

BROOKS, D.H. (1970). Outl. Agric. 6, (3), 122-127.

FINNEY, J.R. and HALL, D.W. (1971). In prep.

JAMES, W.C. (1968). Ann. Appl. Biol., 63, 253-263.

LARGE, E.C. and DOLING, D.A. (1962). Plant Path. 11, 47-57.

YARHAM, D.J. and PYE, D. (1969). Proc. 5th Br. Insectic. Fungic. Conf. 1, 25-33.

YARHAM, D.J. (1971). Proc. 6th Br. Insectic. Fungic. Conf.

Proc. 6th Br. Insectic. Fungic. Conf. (1971)

TIMING OF FUNGICIDAL SPRAYS FOR CONTROL OF MILDEW ON SPRING BARLEY

E J Evans and J H Hawkins
Agricultural Development and Advisory Service, Shardlow Hall, Shardlow, Derby

Summary Trials were carried out to determine the best time to apply a single spray of fungicide to achieve optimum mildew control and yield response in spring barley. In 1970 at Gleadthorpe EHF, single sprays of drazoxolon on 4 June and 18 June gave the most effective control of mildew on Zephyr barley. In 1971, significant control of mildew and increased yields were achieved with tridemorph. At Gleadthorpe EHF highest yields were obtained with single sprays applied on 11 May and 18 May and at Osgathorpe, Leicestershire on 25 May and 2 June. The highest yield responses were achieved with sprays applied prior to, or during the early stages of epidemic development and coincident with levels of less than 5% infection on leaf 3 of unsprayed plants. The earlier development of mildew at Gleadthorpe was attributed to an adjacent crop of winter barley acting as a source of inoculum for early infection of the trial.

INTRODUCTION

In recent years it has been demonstrated (Evans, 1969; Rosser, 1969) that the timing of fungicide sprays markedly influences the degree of control of mildew (*Erysiphe graminis*) on spring barley. This paper describes the continuation of work begun in the East Midlands by Rosser in 1968 and designed to :-

a) determine whether a single well-timed spray would yield an economic return in different seasons and with varying times of epidemic development of the disease and,

b) identify the optimum time of application for such a spray.

METHOD AND MATERIALS

1970 Trials were carried out at Gleadthorpe EHF and on a commercial farm at Osgathorpe, Leicestershire. At Gleadthorpe 2 duplicate series of plots were employed each consisting of 3 randomised blocks of 7 plots, each treatment replicated once per block. 5 of the 7 plots in a block were sprayed once only on the following dates, 7 May, 22 May, 4 June, 18 June and 2 July. A further plot received a complete schedule of 5 sprays, one applied on each of those dates and the remaining plot was left unsprayed. Plots measured 50 yd x 3 yd (45·7 m x 2·74 m) and were sown with Zephyr barley on 28 March at a rate of 8 stone/ac. Drazoxolon (4 - (chlorophenylhydrazono) - 3 - methyl - 5 - soxazolone) was employed as the spray material for the first series of plots (Trial 1), tridemorph (N - tridecyl - 2, 6 dimethyl morpholine) for the other (Trial 2). Sprays were applied by means of a hand boom supplied by a hose from the headland. Drazoxolon was applied at a rate of 2 pints (1 lb a.i.)/ac. (1·12 kg/ha.), tridemorph at $\frac{1}{2}$ pint/ac (0·70 l/ha.). Disease incidence was determined at fortnightly intervals by assessing the top 3 leaves of 10 tillers per plot using an area diagram key (Key 5) produced by the ADAS and Plant Pathology Laboratory, Harpenden. In the text of this paper leaves are numbered from the apex of the plant, the top fully expanded leaf being referred to as leaf 1. Growth stages conform with the Feekes Scale (Large, 1954). Total yield was determined by combine harvesting each plot and 1000 grain weights from an oven-dried sub sample.

At Osgathorpe an attempt was made to compare degree of mildew control and yield response achieved by applying single sprays of a "systemic" and non-systemic fungicide following the weather criteria suggested by Rosser (1969). The following treatments were employed :-

a tridemorph at ½ pint/ac.

b wettable sulphur at 5 lb/ac. (5·6 kg/ha)

c unsprayed

Treatments were replicated once in each of 4 randomised blocks. Plots measured 60 yd x 3 yd (54·84 m x 2·74 m) and were sown with Zephyr barley on 20 April at 8½ stone/ac. Spray treatments were applied on 9 June following a period of 7 days (30 May - 5 June) during which the mean of the maximum daily temperatures exceeded 20°C as recorded at the nearest Meteorological Station (Sutton Bonington).

<u>1971</u> Trial 2 was repeated at Gleadthorpe EHF with the following modifications, 4 randomised blocks were employed and the number of single spray applications increased to 6. Plots were sown with Zephyr barley on 19 February, the site situated adjacent to a commercial crop of Maris Otter winter barley. The trial was duplicated at Osgathorpe, sown with Sultan barley on 13 March at a site having no winter barley in its immediate vicinity.

A further trial was carried out at Navenby, Kesteven to assess the degree of mildew control and yield response achieved by applying "early" and "late" fungicide sprays to spring barley in a predominantly winter barley area. This trial consisted of 4 randomised blocks, each composed of 3 plots. Treatments were replicated once per block and were as follows :-

a "early" tridemorph spray, applied shortly after the first appearance of mildew on leaf 3

b "late" tridemorph spray, applied a month later than a

c unsprayed

Plots were sown with Sultan barley on 4 March at a rate of 8 stone/ac. Tridemorph was applied at ½ pint/ac, the "early" spray on 20 May, the "late" spray on 17 June.

RESULTS

1970 - Gleadthorpe EHF

Mildew appeared on the lower leaves of all plants during May and was first recorded on leaf 3 on 1 June. The disease developed rapidly during the following 4 weeks particularly in Trial 1 where it reached a level of 58% infection of leaf 3 on unsprayed plants by 1 July. The equivalent mildew score in Trial 2 was considerably lower at 13%, a reflection of high leaf necrosis attributed to drought.

An excellent control of mildew was achieved by the complete schedule of 5 sprays. Of the single spray treatments the most effective were those of drazoxolon applied on 4 June and of tridemorph applied on 4 June and 18 June. Figure 1 illustrates the progress of mildew on plants given the above spray treatments. Yield and grain quality were analysed (Table 1). A prolonged drought during June/early July contributed to yield variations. As a consequence, no firm conclusions can be drawn from this data.

Table 1

Yield and Grain Quality - Gleadthorpe EHF 1970

Treatment	TRIAL 1 - Drazoxolon Sprays			TRIAL 2 - Tridemorph Sprays		
	Total Yield cwt/ac.	(kg/ha)	1000 Grain Weight (g)	Total Yield		1000 Grain Weight (g)
1 Complete schedule	21·0	(2631)	39·3	16·5	(2067)	37·1
2 7 May only	20·4	(2556)	39·3	17·9	(2243)	37·2
3 22 May only	20·3	(2544)	38·1	16·9	(2118)	37·6
4 4 June only	20·1	(2519)	38·1	16·9	(2118)	36·8
5 18 June only	20·5	(2569)	38·3	16·3	(2042)	37·2
6 1 July only	18·8	(2536)	38·0	15·1	(1892)	36·3
7 Unsprayed	18·3	(2293)	37·2	16·4	(2055)	37·3
s.e. per plot	1·54	(7·71%)	1·86 (2·55%)	0·84	(5·09%)	0·93 (2·53%)

1970 - Osgathorpe

At Osgathorpe the pattern of mildew development was similar with a rapid build-up of the disease from mid-June onwards (Table 2). Both tridemorph and wettable sulphur gave satisfactory control of mildew when applied on 9 June immediately prior to epidemic development of the disease. Tridemorph was the more persistent material giving good control up to 8 July. This was reflected in a 10% increase in yield (Table 3) accompanied by improvement in grain quality.

Table 2

Mean % Mildew on Leaf 3 - Osgathorpe 1970

Treatment	Date of Assessment				
	2 June (G.S.6)	15 June (G.S.8)	25 June (G.S.10·1)	8 July (G.S.11·1)	15 July (G.S.11·1)
Tridemorph	0·7	0·6	1·3	13·7	40·5
Wettable sulphur	0·7	0·8	7·5	25·8	55·4
Unsprayed	0·7	3·7	8·6	38·7	64·2
s.e. per plot	-	-	-	8·61 (32·9%)	-

Fig. 1

Barley Mildew Progress Curves,

Gleadthorpe E.H.F., 1970

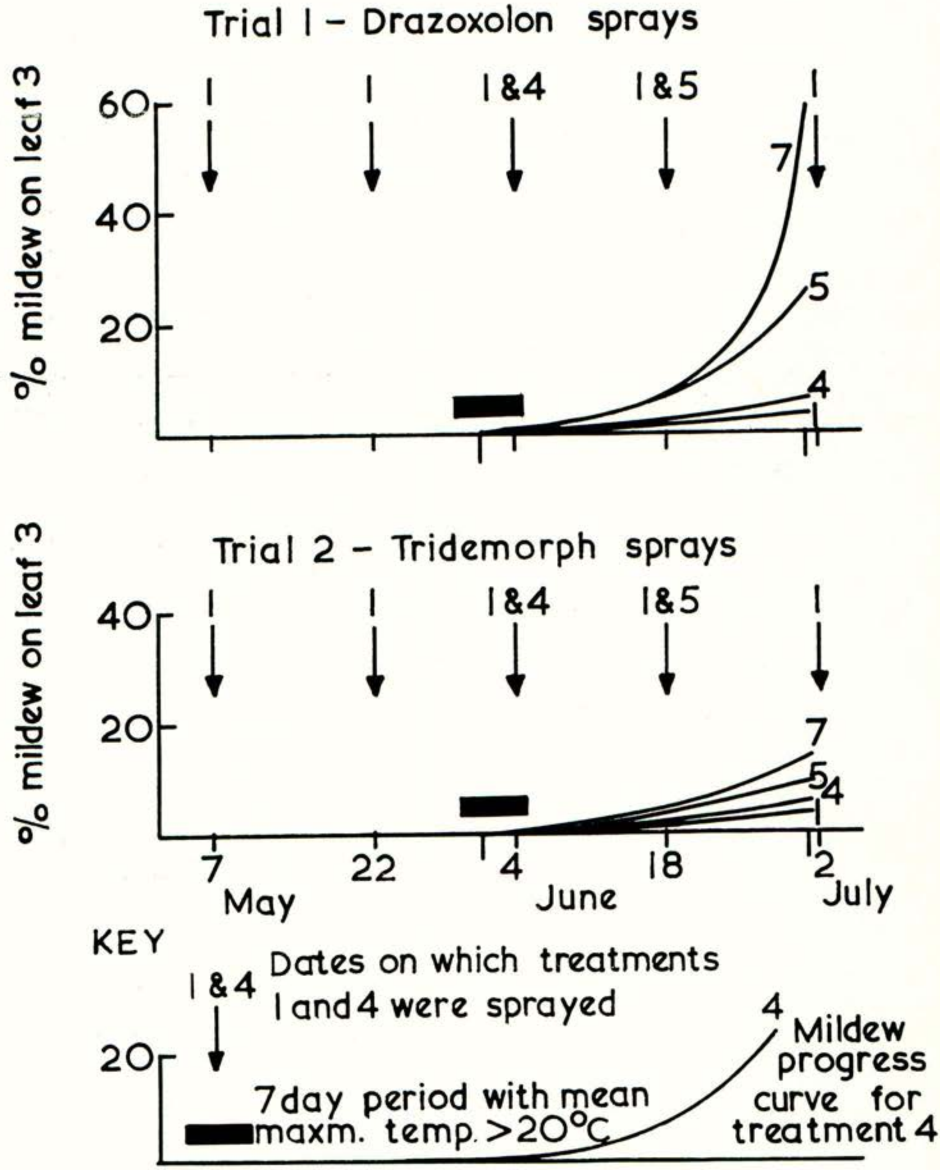


Table 3

Yield and Grain Quality - Osgathorpe 1970

Treatment	Total Yield cwt/ac. (kg/ha)	1000 Grain Weight (g)
Tridemorph	48·4 (6064)	40·5
Wettable sulphur	45·7 (5726)	39·9
Unsprayed	44·1 (5526)	38·8
s.e. per plot	5·25 (3·10%)	0·36 (0·90%)

1971 - Gleadthorpe EHF

Mildew build-up was earlier than in season 1970 and the lower leaves became infected during the last week of April. Infection was first noted on leaf 3 as early as 12 May and by 26 May had reached 6% level on unsprayed plants. The relative levels of disease showed a marked increase between 26 May and 29 June. In terms of mildew control the most effective single spray treatments were those applied on 25 May and 2 June (Figure 2). Yield data is presented in Table 4. Single sprays applied on 11 May, 18 May, 25 May and 2 June all gave significant increases in yield, the earlier the spray application the greater the yield benefit. These sprays gave yield increases of 22%, 20%, 16% and 16% respectively.

1971 - Osgathorpe

The mildew pattern was very different at Osgathorpe. Here mildew development was later than at Gleadthorpe with the first appearance of the disease on leaf 3 occurring on 25 May. Subsequent build-up in June was slow and by 5 July had reached only 24% infection of leaf 3 on unsprayed plants. Early single applications of tridemorph on 11 May and 18 were relatively ineffective in controlling mildew and inferior to applications on 2 June and 15 June. (Figure 2). The highest yield benefits were attained from single sprays by applying tridemorph on 25 May and 2 June. These increased yield by 7% and 8% respectively.

Fig 2

Barley Mildew Progress Curves
1971

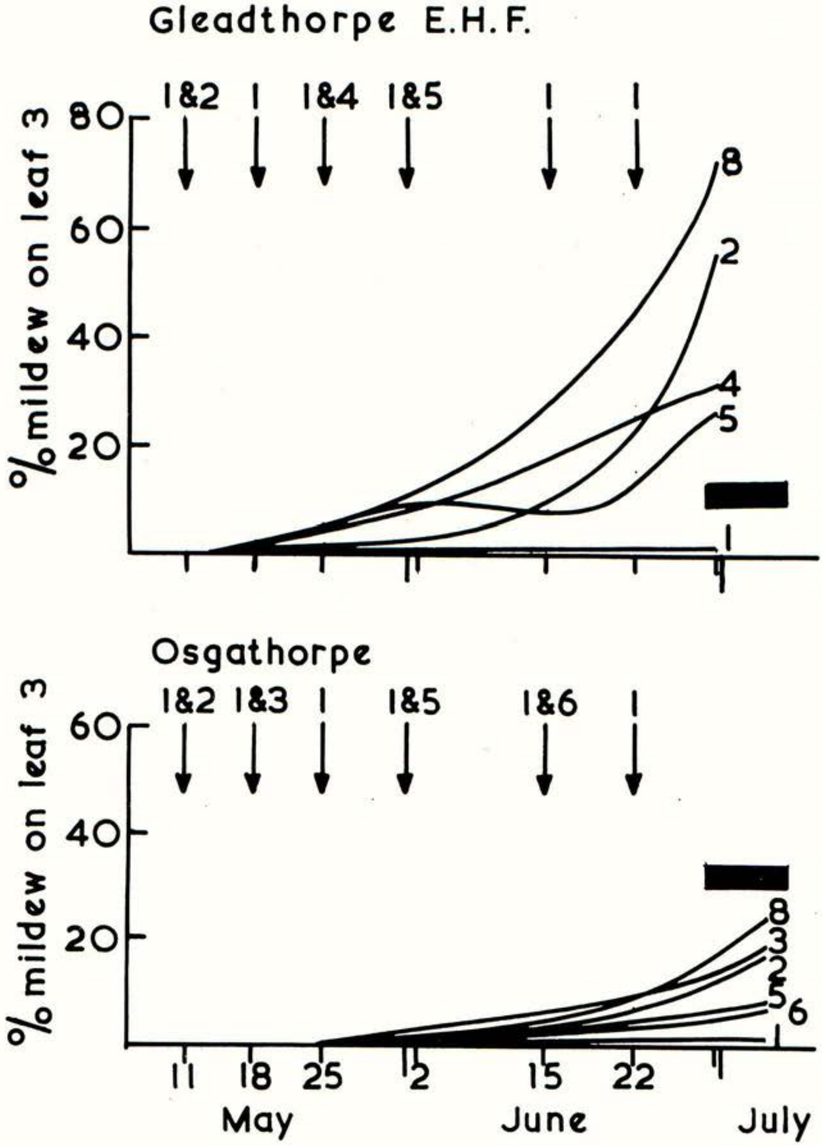


Table 4

Yield and Grain Quality - Gleadthorpe EHF and Osgathorpe 1971

		Gleadthorpe EHF			Osgathorpe		
		Total Yield cwt/ac.	(kg/ha)	1000 Grain Weight (g)	Total Yield		1000 Grain Weight (g)
1	Complete schedule	37·0	(4636)	35·2	31·4	(3934)	33·3
2	11 May only	33·8	(4235)	35·0	27·1	(3396)	30·7
3	18 May only	33·1	(4147)	34·1	28·6	(3584)	32·6
4	25 May only	32·1	(4022)	34·6	29·5	(3696)	32·5
5	2 June only	31·9	(3997)	33·8	29·3	(3671)	32·1
6	15 June only	28·5	(3571)	36·1	28·4	(3559)	32·3
7	22 June only	28·8	(3609)	34·4	28·3	(3546)	32·6
8	Unsprayed	27·6	(3458)	34·3	27·4	(3433)	31·9
s.e. per plot		1·78	(5·64%)	1·18 (3·42%)	1·22	(4·25%)	1·22 (3·76%)

1971 - Navenby

Here the pattern of mildew development was similar to that at Gleadthorpe with early build-up of the disease in May. The "early" tridemorph spray (20 May) was found to be superior to the "late" one (17 June) both in terms of mildew control (Table 5) and yield response (Table 6).

Table 5

Mean % Mildew on Leaf 3 - Navenby 1971

Treatment	Date of Assessment 13 May (G.S.6)	27 May (G.S.7)	10 June (G.S.9–10)	24 June (G.S.10·5)
Tridemorph (early)	1·7	2·4	1·4	12·9
Tridemorph (late)	1·7	8·0	5·1	12·7
Unsprayed	1·5	7·2	6·9	22·0

Table 6

Yield and Grain Quality - Navenby 1971

	Total Yield cwt/ac.(kg/ha)	1000 Grain Weight (g)
Tridemorph (early)	22·0 (2757)	37·5
Tridemorph (late)	19·3 (2418)	36·3
Unsprayed	18·6 (2331)	36·1

DISCUSSION

The effective performance of a fungicide in controlling foliar diseases is dependent upon many factors. Of these, timing of application has been shown to be of considerable importance. Evans (1969) showed that single sprays of benomyl applied at G.S.7-10 tended to give a greater yield benefit than those applied earlier at G.S.4-5. Rosser (1969) working in the East Midlands, found that in 1968-69 single sprays of drazoxolon, gave good control of mildew when applied following a period of 7 days during which the mean of the maximum daily temperatures exceeded 20°C. In both seasons this period of warm weather was considered operative in triggering off epidemic development of the disease.

The results described in the present paper indicate that in 1970 epidemic development of mildew at both trial sites occurred in mid-June. The most effective single sprays in terms of disease control were those applied following Rosser's weather parameter (based on meteorological data recorded at Gleadthorpe EHF and Sutton Bonington). At Osgathorpe a spray of tridemorph applied following these criteria gave significant mildew control and an economic return on yield.

In 1971 at Gleadthorpe and Navenby where trials were situated in close proximity to mildew infected winter barley, epidemic development of mildew on the spring barley occurred at the end of May. Early infection of these trials was attributed to inoculum derived from the adjacent winter barley acreage (Yarham and Pye, 1969). At Osgathorpe, where no winter barley occurred in the immediate vicinity of the trial epidemic development of the disease occurred 3 weeks later than at Gleadthorpe. The Rosser weather parameter was not achieved at any site until the first week of July and played no part in initiating epidemics. Nevertheless the most effective sprays were again those applied immediately prior to epidemic development: with early and mid-May sprays at Gleadthorpe, late May and early June sprays at Osgathorpe giving the highest yield benefits. These sprays were all applied between G.S.7 and G.S.10 confirming Evans' results.

It appears from an examination of the 1970-71 data that the highest yield responses were achieved from sprays applied when mildew was at a low level (< 5%) of infection on leaf 3. Mildew control and yield response declined rapidly when spraying was delayed until the disease had become established on the top 3 leaves of plants. Economic yield responses of between 7% and 22% were achieved with single sprays of tridemorph applied immediately prior to epidemic development of the disease. These results compare favourably with those obtained by Kradel, Pommer and Effland (1969) using the same fungicide.

Acknowledgements

The authors wish to express their thanks to Dr I F Storey for useful discussions and to ADAS staff at Shardlow, Gleadthorpe and Sleaford for their assistance. We are also grateful to those farmers who willingly co-operated in the work.

References

Evans, E Rickard, M and Whitehead, R (1969)
Proc. 5th Brit. Insectic. Fungic. Conf. 610 - 619

Kradel, J Pommer, E H and Effland, H (1969)
Proc. 5th Brit. Insectic. Fungic. Conf. 16 - 19

Large, E C (1954). Pl. Path. 3, 128

Rosser, W R (1969). Proc. 5th Brit. Insectic. Fungic. Conf. 20 - 24

Yarham, D J and Pye, D (1969). Proc. 5th Brit. Insectic. Fungic. Conf. 25- 33

Proc. 6th Br. Insectic. Fungic. Conf. (1971)

STUDIES OF POWDERY MILDEW CONTROL IN SPRING BARLEY USING CHLORANIFORMETHAN*

M. E. Davis, S. M. Weeden and T. J. Martin
Bayer Agrochem Ltd, Eastern Way, Bury St. Edmunds, Suffolk

Summary Chloraniformethan, 1-(3,4-dichloroanilino)-1-formylamino-2,2,2,trichloroethane, Malz et al (1968), is a chemical which can effectively control powdery mildew in spring barley. Glasshouse studies showed the chemical to possess good curative and protective properties. Although capable of distal movement within a leaf and uptake by plant roots it does not appear to move from sprayed to unsprayed foliage.

In field trials single sprays of chloraniformethan gave good disease control with yield responses on a wide range of spring barley varieties. Optimum benefits were obtained when application was made between crop growth stages 6-8. Barley plants grown from seed drilled at weekly intervals covering a period of five weeks, ending in mid April, reached these growth stages between mid May and early June, a period when infection is encouraged by climatic conditions and rapid plant growth. During 1971 chloraniformethan was used extensively by barley growers for the control of mildew. Some successful usage on wheat and oats has been recorded.

INTRODUCTION

The importance of powdery mildew (*Erysiphe graminis*) as a foliar disease of spring barley is well established, James (1969), Large and Doling (1962). In recent seasons a considerable amount of research work has proceeded in an attempt to provide the farmer with a spray chemical which will control the disease sufficiently to enable the crop to yield its true potential. This paper describes work carried out, under glass and in the field in 1970 and 1971, with chloraniformethan, a chemical which exhibits a strong and specific action against powdery mildews. Chloraniformethan (Bayer 79770) is the common chemical name for 1-(3,4-dichloroanilino)-1-formylamino-2,2,2, trichloroethane, Malz et al (1968). It is a practically odourless, white crystalline powder virtually insoluble in water but soluble in organic solvents.

The molecular weight is 336.5; melting point 134-135°C and vapour pressure 10^{-4} to 10^{-2} mm. hg at 80-130°C. The acute oral toxicity (LD_{50}) is as follows:- male rats, > 2,500 mg/kg; female rats, > 1,000 mg/kg; dogs, > 500 mg/kg; guinea pigs, 250-500 mg/kg; Kimmerle (1967). In order to support the notification of the chemical to the Pesticide Safety Precaution Scheme several studies on wild life have been initiated. Tests on soil fauna using ten times the commercial dose rate have been completed with no depression in numbers of earthworms or *Collembola* spp. or in the feeding activity of soil organisms.

* Proposed common name

FUNDAMENTAL EXPERIMENTS

Experiments were carried out in the glasshouse to determine some aspects of the mode of action of chloraniformethan. Test plants were spring barley, cultivar Zephyr. The first formed leaf was referred to as leaf 1, subsequent leaves in order of appearance 2, 3 and 4.

Infection was carried out in an inoculation chamber as described by Kirby and Frick (1963). Jets of air were blown through heavily infected leaves, into the chamber which was then left sealed for 24 hours, to allow spores to settle onto the plants.

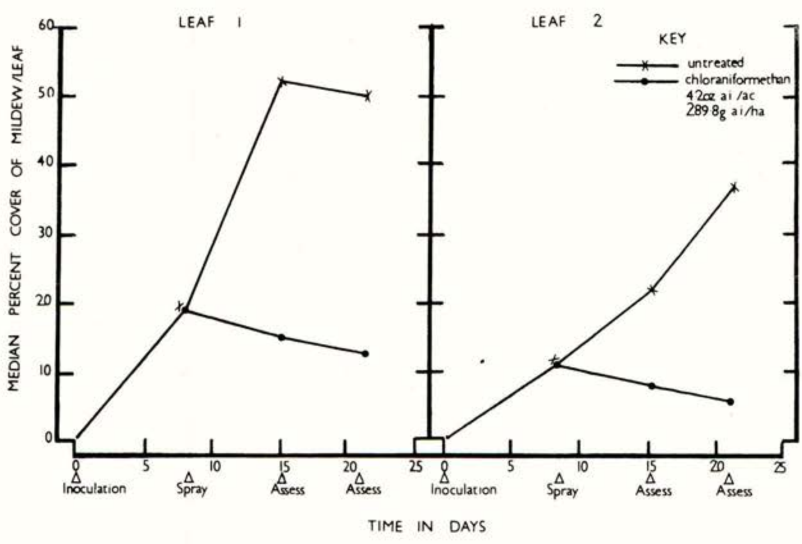
The pots of plants were sprayed by means of a modified Van der Weij sprayer fitted with a single nozzle and using a volume equivalent to 40 gallons/acre, to simulate field conditions as closely as possible. Subjective assessments were made of the per cent cover of living pustules on a leaf by one experimenter.

Curative action tests

Plants were infected at the three leaf stage and sprayed as soon as a good infection had developed. A typical set of results is illustrated graphically below:

Figure 1

Curative action of chloraniformethan



Protective action tests

Plants were sprayed at the three leaf stage and a number were infected at intervals of several days after treatment. Percentage levels of mildew were assessed when the infection was well developed on untreated plants. A set of results is shown in Table 1 below:

Table 1

Protective action of chloraniformethan

% cover of pustules on leaf 2

Days infected after treatment	0	5	10	15
Treatment				
Chloraniformethan 4.2 oz a.i./ac (289.8 g a.i./ha)	0.0	0.0	0.0	2.5
Untreated control	11.5	45.0	22.5	22.5

Other glasshouse studies included an experiment to discover whether the chemical was capable of movement within a leaf. The basal or distal 2 cm length of leaf was painted with a 0.034% emulsion of chloraniformethan. Plants were inoculated 1, 2 or 3 days before or 1 day after treatment. Assessments were made by observing the extent of infection on the untreated area of the leaf.

When the distal part of a leaf was painted only this portion remained free from infection but basal painting caused 3 day old infections to be eradicated over all but the most extreme twenty five percent of leaf area. Younger infections were invariably prevented from establishing over the entire leaf.

Chloraniformethan was also found to be taken up by the roots of barley plants in sufficiently active concentrations to considerably reduce mildew infection on the leaves. However, when applied as a spray, the chemical did not prevent infection on unsprayed foliage.

FIELD TRIALS

Preliminary trials with earlier formulations of chloraniformethan were undertaken in 1968 and 1969. Following this introductory work a rigorous series of small plot replicated trials and large scale non-replicated grower trials were carried out throughout the United Kingdom in 1970 and 1971. From the results of this work extensive information was obtained concerning the mildew control and yield responses achieved with a single treatment of chloraniformethan. Full trials results, tabulated in Table 2 and Table 3, are arranged in order of mildew infection on untreated plots. A summary, to indicate means and ranges of these results, is given in Table 4.

Table 2

Mildew control and yield response with chloraniformethan from small plot replicated trials in 1970 and 1971

Site (year)	Barley Cultivar	Crop* stage at applic.	% mildew infection untreated	% mildew control 4.2 oz a.i./ac (289.8 g a.i./ha)	Yield on untreated (cwt/ac)	Yield in cwt/ac 4.2 oz a.i./ac (289.8 g a.i./ha)
Rowhill, Kent (70)	Zephyr	5	5	53	-	-
Diss, Norfolk (70)	Zephyr	9	9	36	37.6	38.2
Bury St. Edmunds, Suffolk (70)	Proctor	9	9	15	25.3	27.4
Yaxley, Lincs. (70)	Proctor	6	10	62	28.2	29.0
Sevenstoke, Worcs. (70)	Midas	5	11	71	34.7	38.7
Frittenden, Kent (70)	Zephyr	6	13	48	-	-
Knaresborough, Yorks. (70)	Zephyr	5	15	49	29.6	30.0
Fornham, Suffolk (70)	Proctor	9	15	39	16.2	18.0
Norwich, Norfolk (70)	Proctor	9	18	53	37.3	34.9
Tenbury, Worcs. (70)	Zephyr	7	20	83	28.6	45.9
Stamford, Lincs. (70)	Sultan	6	21	72	24.8	21.8
Cupar, Fife (71)	Golden Promise	8	23	79	56.4	57.1
Diss, Norfolk (70)	Zephyr	6	25	29	-	-
Corbridge, Northumberland (71)	Julia	5	32	78	28.2	31.4
Ledbury, Hereford (71)	Sultan	7	37	65	30.5	32.0
Woolpit, Suffolk (71)	Sultan	8	43	84	16.0	17.5
Marden, Kent (71)	Zephyr	8	52	53	27.5	28.9
Rowhill, Kent (71)	Golden Promise	7	58	75	-	-
Bardwell, Suffolk (71)	Proctor	7-8	70	93	21.9	21.6

* Feekes-Large Key

Table 3

Mildew control and yield response with chloraniformethan from non-replicated grower trials in 1970 and 1971

Site (year)	Barley Cultivar	Crop* stage at applic.	% mildew infection untreated	% mildew control 2.8 oz 193.2 g	% mildew control 5.6 oz (a.i./ac) 386.4 g (a.i./ha)	Yield on untreated (cwt/ac)	Yield in cwt/ac 2.8 oz 193.2 g	Yield in cwt/ac 5.6 oz (a.i./ac) 386.4 g (a.i./ha)
Diss, Norfolk (70)	Zephyr	6	3	76**	32**	35.6	42.7	37.9
Willingham, Cambs. (71)	Sultan	7	3	-	67+	-	-	-
Warrington, Lancs. (70)	Zephyr	4	4	36	61	28.3	29.8	33.7
Ingham, Suffolk (70)	Gerkra	6	5	26**	47**	15.4	12.9	15.4
Risby, Suffolk (70)	Proctor	6	6	41**	49**	14.6	17.8	17.2
Wickham, Cambs. (70)	Proctor	9	6	17	27	-	25.6	26.8
Fornham, Suffolk (70)	Proctor	9	7	16**	7**	-	29.2	30.2
Reevsby, Lincs. (70)	Julia	6	8	64	83	-	25.8	27.2
Bury St Edmunds, Suffolk (70)	Proctor	6	11	80	89	29.1	27.3	26.8
Pocklington, Yorks. (70)	Sultan	5	11	72	50	31.9	28.0	27.2
Newark, Notts. (70)	Vada	5	12	37	66	-	24.8	22.0
Kilmarnock, Aye (70)	Golden Promise	7	17	84	99	37.5	40.9	43.1
Coldstream, Berwick (70)	Golden Promise	8	22	48**	77**	42.6	46.5	48.1
Deal, Kent (70)	Proctor	5	23	25	40	-	30.4	26.4
Kernoway, Fife (70)	Golden Promise	7-8	25	94	-	-	-	-
Wormsley, Yorks. (70)	Zephyr	5	26	54	62	35.3	38.6	37.7
Market Rasen, Lincs. (70)	Deba Abed	4	45	86	82	-	25.4	30.8
Blairgowrie, Perth (71)	Golden Promise	10	-	-	-	38.6	-	45.0+
Dunbar, E. Lothion (71)	Golden Promise	8	-	-	-	46.8	-	51.4+
Ely, Cambs. (70)	Zephyr	9	-	-	-	36.5	38.8	38.1
Hitchin, Herts (70)	Vada	5	-	-	-	27.9	30.6	29.3
Lawshall, Suffolk (70)	Proctor	9	-	-	-	19.1	22.8	24.2
Ullingswick, Hereford (70)	Sultan	9	-	-	-	37.4	39.7	40.8
West Wretton, Norfolk (70)	Zephyr	9	-	-	-	9.5	16.0	15.4

* Feekes-Large Key ** Morestan or Wettable Sulphur treatments taken as control plots.

\+ 4.2 oz a.i./ac (289.8 g a.i./ha)

Table 4

A summary of the control of mildew and yield results in 1970 and 1971 trials

Year and treatment	Crop stage at applic.	No of trials	Median control %	Range of disease control obtained %	No of trials	Mean yield in cwt/ac on untreated	Mean yield in cwt/ac on treated
			Small plot replicated trials				
1970 4.2 oz a.i./ac (289.8 g a.i./ha)	4 - 9	12	52.4	15 - 83	9	29.14	31.54
1971 4.2 oz a.i./ac (289.8 g a.i./ha)	6 - 8	7	69.0	33 - 93	6	30.08	31.92
			Non-replicated grower trials				
1970 2.8 oz a.i./ac (193.2 g a.i./ha)	4 - 9	16	53.5	16 - 94	20	28.62	29.68
1970 5.6 oz a.i./ac (386.4 g a.i./ha)	4 - 9	15	58.0	7 - 99	20	28.62	29.92
1971 4.2 oz a.i./ac (289.8 g a.i./ha)	7	1	67.0	-	2	42.70	48.20

The severe drought during May, June and early July of 1970 caused losses in yield in many areas of the country. Nevertheless, in trials where extreme weather conditions did not affect the crop but mildew infection was at a higher level, particularly good yield responses were recorded.

This relationship may be exemplified by the results of a 1971 trial in which several different cultivars were drilled in duplicated strips (Table 5). Part of each strip was treated with chloraniformethan at 4.2 oz a.i./ac (289.8 g a.i./ha) and the remainder left untreated. Deba Abed and Brevia, with reasonably high levels of infection, responded well to treatment, but the results also emphasise the variable responses, perhaps a result of innate differences between cultivars.

The chemical was tested on a wide range of spring barley varieties during trials work and no symptoms of phytotoxicity were observed.

Timing of the application of chloraniformethan varied between crop growth stages 4 and 9 (Feekes-Large Key) in 1970 trials (Tables 2 and 3). However the most effective control of mildew and the highest yield responses were obtained when application was made between crop growth stages 6 - 8 (Table 6). Results from specific timing trials supported this conclusion and this timing is now recommended for commercial application.

Table 5

Mildew control and yield effect on a range of spring barley varieties

Rowhill 1971

Barley Cultivar	Resistance to mildew*	% level of mildew infection on untreated	% mildew control with chloraniformethan 4.2 oz a.i./ac (289.8 g a.i./ha)	Increase in yield as % of untreated plots
Deba Abed	6	15.5	77.0	122.16
Vada	6	0.8	0.0	103.00
Julia	5	6.7	82.3	102.73
Gerkra	4	11.5	60.0	105.20
Imber	4	6.5	80.9	102.10
Midas	4	5.8	65.5	108.20
Sultan	3	3.1	47.6	102.85
Zephyr	3	1.1	40.5	104.97
Proctor	2½	6.6	49.3	100.16
Brevia	-	29.1	54.5	119.45

* NIAB ratings

Table 6

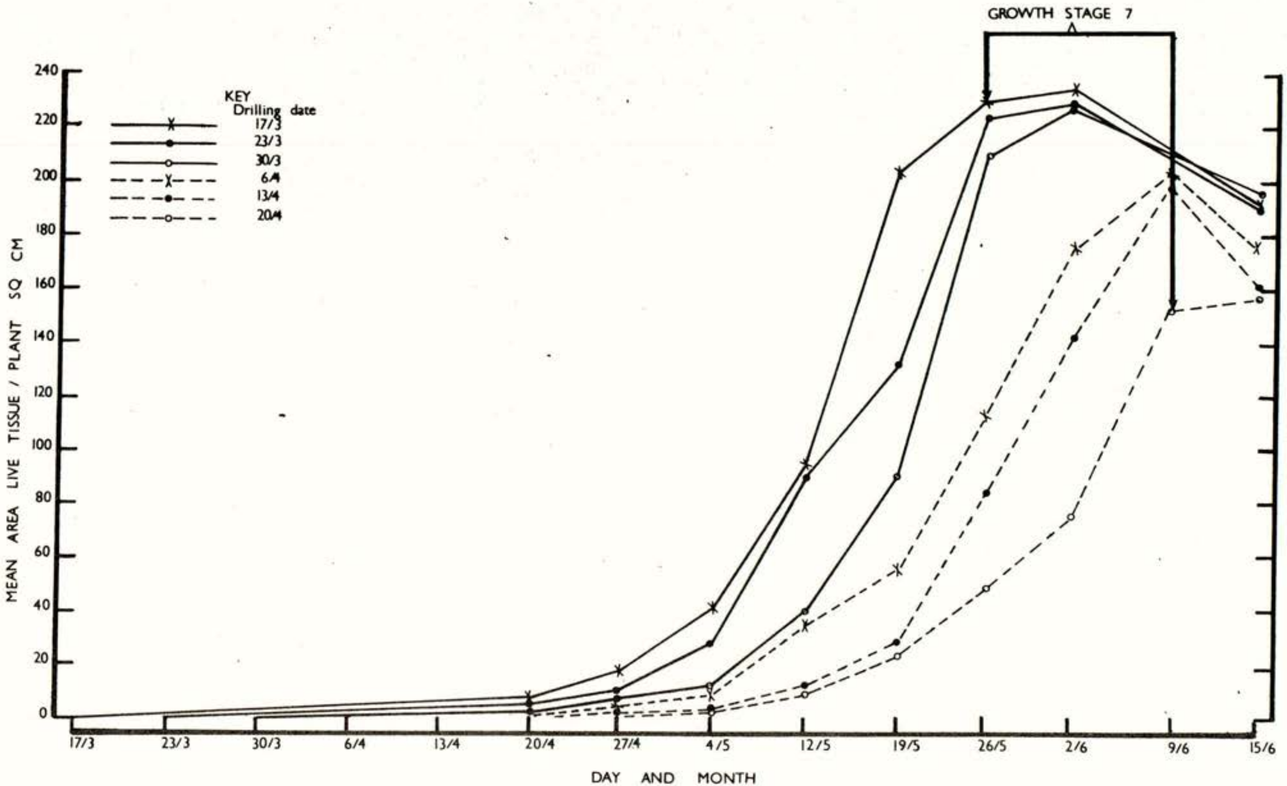
A summary of results from all 1970 trials grouped to show the effect of spray timing

Crop stage at applic.	No of observations	% control of mildew by chloraniformethan at 2.8 oz a.i./ac (193.2 g a.i./ha)	5.6 oz a.i./ac (386.4 g a.i./ha)
up to 5	10	53.8	59.9
6 - 8	12	57.3	65.5
9 and over	6	30.5	32.5
		Yield response cwt/ac as % of untreated plots	
up to 5	7	102.8	102.5
6 - 8	11	108.3	111.0
9 and over	6	105.8	108.3

A trial was conducted in 1971 to determine the practicability of a growth stage recommendation for crops sown on different dates in the same locality. Seed was sown between mid March and mid May, at weekly intervals. Crops drilled between mid March and mid April reached growth stages 6 - 8 between mid May and early June, a period when climatic conditions are often highly conducive to the spread of mildew infection. Growth curves are illustrated in Figure 2.

Figure 2

Growth Curves of spring barley (cv. Golden Promise) drilled at different times



Commercial Usage

During 1971 chloraniformethan was used extensively, in the main, against mildew on barley, but also against mildew on wheat and oats. A survey carried out among 50 users indicate highly satisfactory results, with yield increases where records were kept. Trials with chloraniformethan applied from the air were also satisfactory. The majority of commercial applications were made at barley growth stages 6-8.

DISCUSSION

Fundamental glasshouse tests provided much information on the mode of action of chloraniformethan. The chemical exhibited good curative action although it did not entirely eradicate an established infection (Figure 1). Even under the severe infective conditions in the glasshouse it showed exceptional protective properties (Table 1).

Chloraniformethan moved to a limited extent within a leaf and was taken up by plant roots in sufficient quantities tc suppress mildew infection. However, bio-assay tests showed that the material did not move from sprayed to unsprayed barley foliage.

Under field conditions, mildew control was successfully achieved in 1970 and 1971. Treatments were applied over a wide range of crop growth stages in 1970 and gave an average of 52.4% control in small plot replicated trials (Table 4). In 1971 when application was restricted to the 6-8 growth stages, the average control in these trials was 69.0% and the variation in control less.

Although, in both years, yield results were variable it is clear that in the majority of trials substantial responses were obtained with single applications of chloraniformethan (Tables 2 and 3). Increases were particularly marked when crops were heavily infected and when the spray application was made between growth stages 6-8. Benefits from spraying at other growth stages have been obtained but appear less reliable.

During development work a wide range of spring barley cultivars were treated with the chemical and no adverse symptoms were recorded in any trial.

Applications at growth stages 6-8 are practicable even when crops are sown over a period of time. Figure 2 shows that barley sown at six drilling dates covering a period of five weeks, ending in mid April, reached growth stages 6-8 between mid May and early June. Thus the final stages of rapid plant growth coincided with a period when climatic conditions and spore build-up frequently combine to encourage infection of epidemic proportions.

It is tempting to conclude that by spraying at growth stages 6-8, optimal use is made of the curative action in reducing infection already present, and of the protective action by covering a large area of young, susceptible leaf tissue.

References

JAMES, W. C. (1962) A survey of foliar diseases of spring barley in England and Wales. Pl. Path. 63 (2), 253-263.

KIMMERLE, G. (1967) Toxicological studies on active ingredient Bayer 79770. Report No 411, Farbenfabriken Bayer AG, Institut für Toxikologie, Wuppertal-Elberfeld.

KIRBY, A. H. M. and FRICK, E. L. (1963) Greenhouse evaluation of chemicals for control of powdery mildews I. A method suitable for apples and barley. Ann. Appl. Biol., 51, 51-60.

LARGE, E. C. and DOLING, D. A. (1962) The measurement of cereal mildew and its effect on yield. Pl. Path., 11 (2), 47-57.

MALZ, H. et al (1968) Farbenfabriken Bayer AG, Belgian Patent 701322, application filed on July 13, 1967, published on January 15, 1968; German priority; July 14, 1966.

Proc. 6th Br. Insectic. Fungic. Conf. (1971)

CONTROL OF BARLEY POWDERY MILDEW USING TRIARIMOL

B. L. Rea and P. A. Brown
The Boots Company Ltd., Lenton Research Station, Nottingham

Summary Results of a series of field trials carried out in 1970 and 1971 show triarimol to be highly active against powdery mildew of barley, *Erisyphe graminis f.sp hordei*; when used as a foliar spray.

Triarimol was tested in a number of replicated rate and timing experiments in both years and gave excellent mildew control when applied over a wide range of rates and growth stages. In all cases triarimol was applied when the crop was already suffering from mildew attack.

Increases in final grain yield were consistently obtained with all rates of triarimol, the highest statistically significant increases occurring with rates in excess of 0.3 l/ac (0.75 l/ha). It was found that treatments made at Growth Stage 5 gave yield increases of a similar order to those obtained from applications made at later growth stages.

A number of grower reliability trials carried out in 1971 confirmed the efficacy of triarimol for the control of powdery mildew of barley.

INTRODUCTION

Gramlich *et al* first described the properties of triarimol (EL 273) in 1969.

Preliminary investigational trials carried out in 1969 indicated triarimol to have activity against barley powdery mildew when applied as a foliar spray.

In 1970 trials planned to evaluate further the potential of this chemical as a cereal mildewicide confirmed work in other European trials where the effectiveness of triarimol was demonstrated. As a result, a more extensive trial programme was devised for 1971.

METHOD AND MATERIALS

The formulation of triarimol used in 1970 and 1971 trials was a 4.5% emulsifiable concentrate.

The experimental procedure adopted in the replicated trials was identical in both years. A fully randomised replicated block design was used. Plot size was 44 x 3 yd (40.2 x 2.7 m) and treatments were replicated six times. A full size untreated control plot was included in each replicate. Applications were made by the Lenton Small Plot Sprayer capable of spraying a nine foot width. Fan jet nozzles were used at a pressure of 30 p.s.i. and volume of application was 20 gal/ac (225 l/ha). This gave a spray cover similar to that obtained by conventional farm spraying equipment. Yield determinations were made by combine harvester modified for experimental plot harvesting. Harvest plot size was 40 x 2 yd (36.6 x 1.8 m).

Treatment effectiveness was measured by quantitative assessment of mildew control by measurement of per cent leaf area infected with reference to the Plant Pathology Laboratory Mildew Key. Ten leaf or twenty leaf samples, as deemed necessary, were taken from each plot, and a mean per cent infection result obtained for each treatment. In 1970 these measurements were made at Growth Stage 11.1, but in 1971 they were taken at Growth Stage 10.5 at all sites, and also where possible at other growth stages so that the progress of the early applied treatments could be recorded.

Qualitative visual assessment of mildew control over the whole plant was also carried out at each site on several occasions during the progress of the trials.

The triarimol treatments included in the 1970 and 1971 trials were as follows:-

1970 Trials

Three replicated trials were carried out in spring barley in the East Midlands.

Two application timings were examined, triarimol treatments being made at either:-

1) Growth Stage 4-5 (pre-jointing)
or 2) Growth Stage 10 - 10.3 (late jointing to partial heading out of the crop).
or on both occasions 1) and 2).

In all cases mildew was infecting the crop before the early applications were made.

The treatments made at each time of application were as follows:-

i)	Triarimol	0.75 l/ac	(1.9 l/ha)	formulated product
ii)	"	1.0 l/ac	(2.5 l/ha)	" "
iii)	"	1.5 l/ac	(3.8 l/ha)	" "
iv)	Standard treatment, Tridemorph 0.5 pt/ac (0.7 l/ha) formulated product.			

No double applications were made of the standard treatment.

1971 Trials

a) Replicated Trials

A number of replicated trials in spring barley were carried out in the East Midlands, results of seven of these are reported in this paper. In four of these trials three application timings were examined as follows:-

1) Growth Stage 5 (pre-jointing)
2) Growth Stage 6-8 (early - mid-jointing)
3) Growth Stage 9 - 10.3 (late jointing - partial heading out of the crop)

In the other three trials applications were made at the two later stages only i.e. 2) and 3).

At all sites mildew was present in the crop when the first applications were made.

At five sites the treatments at each time of application were:-

i)	Triarimol 0.2 l/ac	(0.5 l/ha)	formulated product		
ii)	" 0.3 "	(0.75 ")	"	"	
iii)	" 0.4 "	(1.0 ")	"	"	
iv)	" 0.5 "	(1.25 ")	"	"	
v)	" 0.75 "	(1.9 ")	"	"	
vi)	Standard treatment, Tridemorph 0.5 pt/ac (0.7 l/ha) formulated product.				

At the remaining two sites rates were similar with the exception that the rate of 0.25 l/ac (0.63 l/ha) was substituted for 0.2 l/ac (0.5 l/ha).

b) Reliability Trials

Grower reliability trials in spring barley were carried out throughout the United Kingdom in 1971. In each case two one acre packs of triarimol containing 0.3 and 0.4 litres respectively were supplied to farmers. The fungicide was applied through farm spraying equipment at not less than 20 gal/ac (225 l/ha) when mildew was present in the crop. The trials were assessed following application using assessment methods employed in the replicated trials. Yield measurements were taken by farmers' combine harvesters where these could be accurately carried out.

RESULTS

1970 Trials

The level of mildew infection was low at Winkburn and Cropwell Butler at the time of the first application, and remained so throughout the season so that by Growth Stage 11.1 only leaves three and four respectively were diseased. At Balderton however there was a high infection level at Growth Stage 4 which persisted throughout and severely affected the later development of the untreated crop.

Visual assessment of mildew control following application showed all rates of triarimol to be extremely effective at both application timings.

Assessment of mildew control by measurement of per cent leaf infected at Growth Stage 11.1 is shown in Table 1. At Balderton, where there was a high incidence of disease, reinfection of the crop in the Growth Stage 4 applied treatments occurred by Growth Stage 11.1, whilst the double application plots were still giving a high level of control. The mildew levels at the other two sites were too low to draw conclusions other than that all treatments gave excellent mildew control.

Yield results in Table 1 show emphatically at Balderton the advantages of treatment at Growth Stage 4. Highly significant results were obtained with all early applied treatments and yield increases were no greater in the twice sprayed plots. The second stage treatments (Growth Stage 10 - 10.3) gave little yield benefit. Significant yield increases were also achieved at Cropwell Butler where the level of infection on the variety Vada remained low throughout. Again the largest increases were obtained from treatments applied early or those applied on both occasions and there was no dose response pattern. Yield increases at Winkburn were not statistically significant.

Table 1

Replicated trials 1970 - Site location. Application dates and cereal growth stages. Assessment dates and mildew control measured as % leaf area infected at Growth Stage 11.1. Yield results expressed as mean % of untreated control.

Site Location	BALDERTON			WINKBURN			CROPWELL BUTLER	
	% Leaf Infection		Yield	% Leaf Infection		Yield	% Leaf Infection	Yield
Leaf Number	2	3		3	4		4	
Treatments								
Application 1								
Triarimol 0.75 l/ac	4.0	16.3	117.3***	0.1	0.1	101.1	0.9	106.6**
Triarimol 1.0 l/ac	2.5	14.3	122.7***	0.0	0.1	103.4	0.9	105.3*
Triarimol 1.5 l/ac	2.8	12.4	126.3***	0.0	0.1	104.0	0.4	105.2*
Tridemorph	3.3	11.2	118.0***	0.2	0.1	110.5	1.4	107.6**
Application 2								
Triarimol 0.75 l/ac	2.3	8.7	100.3	0.2	1.3	99.1	0.1	103.4
Triarimol 1.0 l/ac	3.9	16.1	102.9	0.5	4.0	105.7	0.2	106.0**
Triarimol 1.5 l/ac	0.4	10.6	103.7	0.2	1.5	102.3	0.1	101.9
Tridemorph	0.7	10.3	98.4	0.9	1.3	97.7	0.4	101.9
Application 1 and 2								
Triarimol 0.75 l/ac	0.5	6.6	118.8***	0.0	0.0	105.7	0.0	105.7**
Triarimol 1.0 l/ac	0.0	5.6	118.2***	0.0	0.0	102.6	0.1	105.7**
Triarimol 1.5 l/ac	0.6	5.2	126.4***	0.0	1.4	104.9	0.0	106.2**
Untreated	5.6	21.6	100.0	6.9	9.3	100.0	6.0	100.0
Application dates								
Application 1	29.5.70			8.6.70			2.6.70	
Growth stage	4			5			5	
Application 2	22.6.70			23.6.70			10.6.70	
Growth stage	10.3			10.2			10.0	
Assessment date	10.7.70			7.7.70			8.7.70	
Variety	Zephyr			Deba Abed			Vada	
Yield/ac of untreated control in cwts	30.9			32.6			33.8	

KEY * ** *** Significantly different from untreated control at 5%, 1% and 0.1% levels respectively

1971 Trials

Table 2 gives details of the trials carried out including application dates, crop growth stages and mildew infection levels at each time of application. In 1971 mildew spread into spring barley in early May in the East Midlands.

First applications were made when the disease was affecting at least two leaves. The per cent mildew affecting the lowest green leaf was recorded on each spraying occasion at each site.

a) Replicated Trials

Table 2

Replicated trials 1971 - Site location, application dates and cereal growth stages. Incidence of mildew on lowest green leaf at time of application

Site location	Thrumpton	Barton	Ruddington	Balderton	Cropwell Butler	Croxton Kerrial	Cromwell
Variety	Sultan	Zephyr	Julia	Julia	Vada	Sultan	Crusader
Application 1 (Growth Stage 5)							
Date	12.5.71	12.5.71	14.5.71	15.5.71			
Crop growth stage	5	5	5	5			
Mildew level	20.5(3)	6.2(4)	11.9(5)	8.6(6)			
Application 2 (Growth Stage 6-8)							
Date	19.5.71	19.5.71	21.5.71	21.5.71	27.5.71	28.5.71	17.5.71
Crop growth stage	6-7	6-7	7-8	7	7	6	6-7
Mildew level	69.6(4)	31.5(5)	21.5(5)	16.0(5)	8.1(4)	7.5(6)	7.5(4)
Application 3 (Growth Stage 9 - 10.3)							
Date	1.6.71	1.6.71	15.6.71	5.6.71	17.6.71	22.6.71	7.6.71
Crop growth stage	8-9	8-9	10	9-10	10	10.3	10
Mildew level	43.5(4)	49.5(5)	7.8(4)	10.0(4)	7.4(4)	23.2(4)	14.5(6)

Level of mildew as mean % leaf area infected on the lowest green leaf at time of spraying.

( ) Leaf no. in brackets after % infection score.

Visual assessments of mildew control were made at each site following application. The results showed clearly the effectiveness of triarimol over a wide range of rates, and demonstrated that time of application has little effect on the standard of control achieved. Overall however the most consistently effective rates were those in excess of 0.3 l/ac (0.75 l/ha), mildew control with the three lower rates i.e. 0.2 l/ac (0.5 l/ha), 0.25 l/ac (0.63 l/ha) and 0.3 l/ac (0.75 l/ha) being erratic in some instances. With these higher rates reinfection of the crop did not take place until some 4-5 weeks after spraying.

At the four sites where sprays were applied at Growth Stage 5 there was a very marked improvement in crop vigour following treatment due to control of mildew infection. It was observed that treatment at that time effectively delayed senescence of at least one of the lower leaves on tillers by eradication of disease. This contrasted markedly with untreated plots where senescence of diseased leaves occurred prematurely.

Similar but less pronounced effects were seen following the Growth Stage 6-8 series of treatments, which were generally applied one week after the first application date. By the time the sprays were applied at Growth Stage 9-10 the untreated crop at most sites was looking much thinner and less vigorous than the early treated plots. The level of infection had increased during the weeks following the first application date, particularly at Thrumpton and Barton where the trials were being carried out on Sultan and Zephyr respectively. Infection levels were somewhat lower at Ruddington and Balderton on the variety Julia.

At the three sites where there were two application dates mildew did not infect the crops until after Growth Stage 5. The first sprays were applied at Growth Stage 6-7 as soon as mildew had spread onto at least two leaves. Results were similar to those obtained in the three stage trials.

Measurement of per cent leaf area infected at Growth Stage 10.5 (see Table 3) shows that considerable reinfection of the Growth Stage 5 and Growth Stage 6-8 application timings had taken place by that stage. This however was some 6-7 weeks after the first applications had been made and the breakdown in control only began to show after 4-5 weeks.

The flag leaf was virtually uninfected at all sites when the Growth Stage 10.5 assessments were made.

Table 4 shows the degree of mildew control obtained at Thrumpton by triarimol treatments as measured by per cent leaf area infected during the weeks immediately following application. This shows the progress of treatment effect and illustrates the point where the maximum mildew control is achieved by each treatment following application.

Additionally it indicates when reinfection of the first two applications, started to take place i.e. some five weeks after spraying. Thus by Growth Stage 10.5 leaves 2, 3 and 4 in the first application treatments were reinfected to approximately 50% of the untreated control level with the second application treatments marginally less infected. Throughout the progress of the trial a high degree of mildew control was achieved by all rates at all three stages, but there was a dose response between the 0.2 l/ac (0.5 l/ha), 0.4 l/ac (1.0 l/ha) and 0.75 l/ac (1.9 l/ha) rates.

It was noticeable at Thrumpton as at other sites that the level of mildew in the untreated control fell during the first two weeks of June due to heavy rainfall occurring in the area and in some instances did not regain the May levels of infection.

Table 3

Replicated Trials 1971 - Mildew control with triarimol expressed as % leaf area infected at Growth Stage 10.5

Site Location	THRUMPTON		BARTON		RUDDINGTON●		BALDERTON●		CROPWELL BUTLER		CROXTON KERRIAL		CROMWELL	
Assessment Date	28/6/71		2/7/71		30/6/71		1/7/71		14/7/71		14/7/71		5/7/71	
Leaf Number	2	3	3	4	2	3	2	3	2	3	2	3	2	3
Treatments														
Application 1 (Growth Stage 5)														
Triarimol 0.2 l/ac	4.2	11.1	2.8	5.0	1.3	2.8	1.5	3.6						
Triarimol 0.3 l/ac	5.1	11.1	3.0	5.6	1.2	3.2	3.2	6.8						
Triarimol 0.4 l/ac	4.2	12.3	3.6	6.0	0.9	3.0	3.5	6.8						
Triarimol 0.5 l/ac	5.5	11.4	3.4	5.4	0.9	3.0	3.0	4.2						
Triarimol 0.75 l/ac	4.5	12.2	4.0	4.5	1.2	3.3	1.8	3.3						
Tridemorph	4.5	12.6	3.7	3.0	1.0	3.2	1.0	3.1						
Application 2 (Growth Stage 6-8)														
Triarimol 0.2 l/ac	5.0	10.6	6.0	3.4	1.3	4.8	2.2	3.7	7.9	5.0	23.9	31.2	3.4	3.5
Triarimol 0.3 l/ac	3.8	9.1	3.9	3.3	1.6	3.9	2.2	4.8	6.2	6.9	26.2	33.7	1.5	3.1
Triarimol 0.4 l/ac	3.8	10.4	3.9	3.3	1.1	3.3	4.0	5.4	4.6	4.0	35.0	15.0	5.5	5.0
Triarimol 0.5 l/ac	3.2	8.1	1.5	2.4	0.8	3.6	1.5	3.4	5.8	5.7	26.8	21.5	1.8	2.8
Triarimol 0.75 l/ac	3.3	6.8	2.9	2.4	0.4	2.7	1.5	3.0	3.1	6.8	26.5	6.3	6.0	4.2
Tridemorph	3.8	11.8	3.0	4.4	1.8	3.5	1.7	4.8	6.5	6.9	12.7	17.0	5.6	5.5
Application 3 (Growth Stage 9-10.3)														
Triarimol 0.2 l/ac	1.8	4.1	2.1	4.5	0.2	2.6	0.3	0.5	4.4	6.8	16.6	16.0	2.8	4.1
Triarimol 0.3 l/ac	1.3	3.5	1.7	3.7	0.3	2.4	0.5	2.8	5.8	8.0	15.7	12.8	0.8	3.4
Triarimol 0.4 l/ac	1.4	1.7	1.8	1.5	0.5	1.9	0.5	0.5	3.3	8.0	7.2	5.8	0.9	1.0
Triarimol 0.5 l/ac	0.7	1.2	0.8	2.1	0.3	1.7	0.5	0.9	1.9	3.4	7.7	6.7	1.0	2.8
Triarimol 0.75 l/ac	0.2	0.6	0.2	0.8	1.0	4.2	0.3	0.5	7.3	5.0	9.3	12.4	0.1	0.6
Tridemorph	1.0	2.7	1.4	2.0	0.5	2.0	0.5	0.5	2.5	3.8	11.0	16.5	0.6	2.3
Untreated	10.6	30.9	7.2	11.5	3.0	9.6	3.0	7.0	12.0	50.0	53.7	40.0	9.2	5.3

KEY ● 0.25 l/ac rate substituted for 0.2 l/ac

Table 4

Replicated Trials 1971

Assessment of mildew control at Thrumpton showing progress of triarimol treatments up to and including Growth Stage 10.5 (expressed as mean % leaf area infected)

Assessment Date	19/5/71			1/6/71			14/6/71			28/6/71		
Growth Stage	6-7			8-9			10.3			10.5		
Leaf Number	2	3	4	2	3	4	2	3	4	2	3	4
Treatment												
Application 1 (Growth Stage 5) Spraying date: 12/5/71												
l/ac												
Triarimol 0.2				3.0	2.6	19.5	0.3	2.8	6.3	4.2	11.1	10.3
Triarimol 0.4	0.0	9.0	35.0	1.7	0.1	13.3	0.4	2.8	5.0	4.2	12.3	12.4
Triarimol 0.75	0.3	8.3	29.5	1.6	0.0	3.8	0.4	1.7	4.1	4.5	12.2	12.3
Application 2 (Growth Stage 6-7) Spraying date: 19/5/71												
l/ac												
Triarimol 0.2							0.5	2.8	4.7	5.0	10.6	11.7
Triarimol 0.4				0.3	3.0	18.2	0.2	1.7	1.7	3.8	10.4	8.9
Triarimol 0.75				0.0	0.0	6.5	0.3	1.6	2.3	3.3	6.8	3.4
Application 3 (Growth Stage 8-9) Spraying date: 1/6/71												
l/ac												
Triarimol 0.2							0.1	2.5	8.4	1.8	4.1	7.1
Triarimol 0.4							0.1	1.0	4.4	1.4	1.7	4.4
Triarimol 0.75							0.0	1.0	5.3	0.2	0.6	3.0
Untreated	5.4	32.8	69.6	15.3	66.8	43.5	0.6	5.8	11.2	10.6	30.9	17.3

Measurement of final grain yield showed often highly significant yield increases over untreated following mildew control by triarimol treatment. Table 5 shows that the increases were generally in order of increasing rate with the 0.75 l/ac (1.9 l/ha) treatment almost always giving the greatest yield benefit, there being little to choose between the 0.4 l/ac (1.0 l/ha) and 0.5 l/ac (1.25 l/ha) rates. The 0.2 l/ac (0.5 l/ha) and 0.3 l/ac (0.75 l/ha) rates also on occasion gave highly significant yield increases but these were generally of a lower order than those achieved with the higher rates.

Yield benefits from the Growth Stage 5 application timing were overall as great as those from the other two stages, indicating that a delay in spraying would give no extra yield advantage. In fact at Balderton and Cropwell Butler spraying at the third stage was too late to give any yield benefit.

Table 5

Replicated trials 1971 - Yield results expressed as mean % of untreated control

Site Location	THRUMPTON	BARTON	RUDDINGTON●	BALDERTON●	CROPWELL BUTLER	CROXTON KERRIAL	CROMWELL
Treatments							
Application 1 (Growth Stage 5)							
Triarimol 0.2 l/ac	105.1	104.0*	106.2***	106.6			
Triarimol 0.3 l/ac	104.9	106.7***	106.7***	105.7			
Triarimol 0.4 l/ac	109.3***	106.1***	107.1***	109.1**			
Triarimol 0.5 l/ac	106.5*	107.4***	110.5***	107.9*			
Triarimol 0.75 l/ac	105.3*	110.7***	108.2***	108.2*			
Tridemorph	108.6**	107.4***	110.5***	105.7			
Application 2 (Growth Stage 6-8)							
Triarimol 0.2 l/ac	102.3	101.4	107.3***	102.8	103.2*	114.3***	108.2
Triarimol 0.3 l/ac	106.0*	103.4	105.6***	104.7	105.4***	118.5***	110.4*
Triarimol 0.4 l/ac	109.0***	106.3***	106.7***	105.0	105.4***	119.4***	111.1*
Triarimol 0.5 l/ac	109.5***	107.4***	107.3***	107.6*	106.4***	120.8***	110.9*
Triarimol 0.75 l/ac	112.0***	107.0***	109.7***	109.1**	107.8***	126.5***	110.2*
Tridemorph	108.3**	103.8*	108.6***	108.2*	106.6***	121.7***	108.8*
Application 3 (Growth Stage 9-10.3)							
Triarimol 0.2 l/ac	106.0*	102.5	102.2	102.2	100.0	101.8	108.4
Triarimol 0.3 l/ac	107.9**	103.4	103.7*	98.7	98.4	105.1*	112.0**
Triarimol 0.4 l/ac	110.4***	106.1***	104.1**	102.8	98.6	105.4*	112.2**
Triarimol 0.5 l/ac	110.2***	107.0***	106.7***	103.8	100.8	108.6***	107.7
Triarimol 0.75 l/ac	110.2***	110.3***	107.3***	108.2*	100.6	107.7***	110.7*
Tridemorph	108.6**	101.5	104.1**	104.4	100.1	101.2	106.4
Untreated	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Yield/acre of untreated in cwts.	38.9	42.8	42.0	42.9	45.3	30.3	39.7

KEY ● Triarimol 0.25 l/ac rate substituted for 0.2 l/ac

* ** *** Significantly different from untreated control at 5.0%, 1.0% and 0.1% levels respectively

b) Grower Reliability Trials

Results of sixteen grower trials carried out throughout the United Kingdom with 0.3 l/ac (0.75 l/ha) and 0.4 l/ac (1.0 l/ha) rates of triarimol in spring barley are shown in Table 6.

Table 6

Grower trials 1971 - Application and assessment dates, crop growth stages; assessment of % leaf area infected

Site Location	Variety	Application date & crop growth stage	Assessment date & crop growth stage	Leaf no.	Triarimol 0.3 l/ac	Triarimol 0.4 l/ac	Untreated
1) Taunton, Somerset	Proctor	4/6/71 7	14/7/71 11.1	2 3	2.0 16.0	4.3 11.9	28.7 81.8
2) Williton, Somerset	Ruby	18/5/71 4-5	14/7/71 11	2 -	31.3 -	16.5 -	28.5 -
3) Wadebridge, Cornwall	Ruby	27/5/71 5	21/6/71 10.4	3 4	0.4 0.2	1.8 0.2	18.6 8.8
4) Chepstow, Mon.	Ruby	21/5/71 6	16/7/71 11.1	1 2	9.5 15.7	4.8 6.8	28.6 58.3
5) Banbury, Oxon.	Sultan	28/5/71 5-6	15/7/71 11.1	1 2	8.8 25.8	7.1 23.8	29.1 58.0
6) Kettering, Northants.	Sultan	1/6/71 6	24/6/71 10	2 3	1.6 2.3	1.5 1.8	4.1 21.0
7) Newmarket, Cambs.	Proctor	14/5/71 5	8/6/71 10	3 4	0.4 3.4	0.2 1.1	2.2 39.1
8) Moulton, Northants.	Sultan	7/6/71 9	24/6/71 10.4-10.5	2 3	4.6 16.8	0.6 10.8	12.0 33.0
9) Woodborough, Notts.	Rika	15/5/71 5	3/6/71 8-9	3 4	0.8 2.7	0.2 2.4	3.6 10.4
10) Stoke Ferry, Norfolk.	Sultan	17/5/71 5-6	9/6/71 10	3 4	0.5 2.6	0.2 1.4	3.8 35.5
11) Gainsborough, Lincs.	Sultan	3/6/71 9	15/6/71 10.1	3 4	1.7 4.8	1.0 3.0	10.3 16.0
12) Ellerdine, Salop.	Proctor	1/6/71 5-6	1/7/71 10.1	2 3	2.3 7.6	1.2 8.5	6.0 32.0
13) Ellerton, Yorks.	Proctor	25/6/71 10	28/7/71 11.1	1 2	1.9 15.0	0.6 12.9	1.4 33.2
14) Ormskirk, Lancs.	Deba Abed	12/5/71 5	30/7/71 11.1	1 2	2.9 9.3	3.1 13.1	12.2 29.0
15) Bishopton, Durham.	Zephyr	10/6/71 5-6	28/7/71 11.1	1 2	1.9 13.5	0.7 10.7	14.0 57.0
16) Freuchie, Fife	Golden Promise	4/6/71 8	29/7/71 11.1	1 2	6.9 17.3	3.0 9.5	11.1 58.0

The mildew control data obtained demonstrates the effectiveness of triarimol when used in varying conditions of crop growth and climate. The results also confirm the evidence of the replicated trials that 0.4 l/ac (1.0 l/ha) generally gives better and more acceptable control than the 0.3 l/ac (0.75 l/ha) rate.

Table 7

Grower Trials 1971 - Results expressed as % of untreated control

	Triarimol 0.3 l/ac	Triarimol 0.4 l/ac	Yield/ac untreated in cwts
1) Taunton, Somerset	100.0	106.6	33.3
2) Williton, Somerset	110.7	114.3	28.0
3) Newmarket, Cambs.	107.1	110.0	35.0
4) Woodborough, Notts.	112.9	112.9	31.0
5) Banbury, Oxon.	101.2	103.9	38.5
6) Freuchie, Fife.	102.5	107.5	40.0

Yield data from trials where measurements could be accurately made are shown in Table 7. Because the treatments were not replicated no statistical significance can be drawn from the results but they support those obtained from the replicated trials.

DISCUSSION

The effectiveness of triarimol at rates $>$0.3 l/ac (0.75 l/ha) for the control of powdery mildew of barley has been clearly demonstrated in the two years work carried out. The 1971 trial programme designed to elucidate the range of activity of the chemical has shown that it will control mildew equally well at all of the growth stages at which spraying took place.

Yield increases from spraying at Growth Stage 5 were similar to those obtained from later applications, and although reinfection of the crop did often occur 4-5 weeks after spraying the practical advantages of applying the fungicide at Growth Stage 5 on infected crops are considerable.

It is significant that yield increases due to triarimol treatment in nearly all the 1971 replicated trials were in the region of 5-10% above untreated control. Despite the heavy mildew infection, the untreated crop in these trials yielded in the region of 2 tons/ac (5,000 kg/ha) and over, thus a 10% yield increase represents at least a 4 cwt/ac (500 kg/ha) benefit. At the one site where untreated yield was 30 cwt/ac (3,750 kg/ha) increases due to triarimol treatment were in the region of 20% and above.

Acknowledgements

The authors wish to acknowledge the collaboration of the Lilly Research Centre Ltd and Elanco Products Limited who also supplied the fungicide. Thanks are due to their colleagues at Lenton Research Station, and Boots Farm Sales Ltd. fieldstaff for their valuable assistance in carrying out the trial programme; and to the many farmers who kindly co-operated.

References

1. GRAMLICH, J.V. et al (1969). Proc. 5th Br. Insectic. Fungic. Conf., 576

2. Plant Pathology Laboratory Guide for the assessment of cereal diseases.

Proc. 6th Br. Insectic. Fungic. Conf. (1971)

FUNGICIDAL CONTROL OF MILDEW ON SPRING BARLEY IN SOUTH-EAST SCOTLAND

James Gilmour
Edinburgh School of Agriculture

Summary Ethirimol seed treatment at 2.1 - 2.8 lb a.i./ac (2.4 - 3.1 kg a.i./ha) gave effective control of mildew in 15 small plot trials during 1969, 1970 and 1971, and mean yield responses of 0.9, 4.3 and 7.3 cwt/ac (113, 540 and 916 kg/ha) for Golden Promise, -0.3, 2.7 and 3.2 cwt/ac (-38, 339 and 402 kg/ha) for Ymer, and -1.3 and 1.5 cwt/ac (-163 and 188 kg/ha) for Julia in 1969 and 1970 only. Phytotoxic effects occurred on the more resistant cultivars when mildew levels were very low in 1969. Responses of 3.6 - 8.2 cwt/ac (452 - 1029 kg/ha) were obtained in 1971 where ethirimol treated Golden Promise seed (0.75 lb a.i./ac, 0.84 kg a.i./ha) was sown in 1 - 2 ac (0.4 - 0.8 ha) plots.

Single spray applications of tridemorph (1970 and 1971) and chloraniformethan (1971) gave the best mildew control and yield response when applied at GS 10 - 10.1. A single spray of benomyl (1970) in one trial gave a comparable response at GS 10.1, but in another trial the greater yield response at GS 7 was not related to mildew control. An examination of temperature in relation to mildew control and yield response indicated that Rosser's criterion (spray after a period when the mean of the daily maximum temperature for seven consecutive days equalled or exceeded 20°C) could have been used to predict the timing of the sprays which gave the greater responses in 1970, but not in 1971. An index of seasonal warmth (accumulated day-degrees in excess of 15°C from 1 May) is suggested to distinguish effective and non-effective critical periods.

Crop losses due to wheel tracking in these trials averaged 0.65 cwt/ac (82 kg/ha), 1.6 per cent of the mean yield of untracked plots. Tracking trials indicated that wheeling losses due to herbicide application alone could be 0.6 cwt/ac (75 kg/ha) and that in some circumstances standard tyres, 11 in (279 mm) wide, caused no more yield loss than narrow tyres, 6 in (152 mm) wide. The interactions of tyre width and row spacing are discussed.

INTRODUCTION

Some 750,000 acres of barley are now grown in Scotland (DAFS 1971a), of which perhaps a half is Golden Promise, the most mildew-susceptible cultivar to gain recent commercial acceptance. In some areas of south-east Scotland Golden Promise is almost the only cultivar grown, its popularity being enhanced by its suitability for malting although only a quarter of the Scottish barley production is currently used for this purpose (DAFS 1971b). Golden Promise also has a number of desirable agronomic characters, in particular, earliness of ripening, stiffness of straw, resistance to grain splitting and resistance to wind loss. It can give a high yield under suitable conditions, but is the lowest yielding cultivar on the current recommended list issued by the Scottish Agricultural Colleges. Before the introduction of Golden Promise in 1966 Ymer was the dominant cultivar and mildew (*Erisyphe graminis*) on spring-sown barley was generally considered to be a "serious" problem only once or twice in ten years. Since then mildew has become an increasing problem, due in part to the change in cultivar pattern and in part to the intensification of barley growing. In addition there has been an unusual sequence of seasons of mildew-favourable weather in the past five years.

A collaborative project involving several organisations throughout Scotland was begun in 1969 to determine the potential crop response to the control of mildew following the release of ethirimol as an experimental seed treatment. Only the results of the trials sponsored by the Edinburgh School of Agriculture will be reported here; a more detailed report of the project will appear elsewhere. With the introduction of fungicides formulated for spray application, trials were also made to determine the optimum time for a single treatment with special reference to the typically late development of mildew in south-east Scotland.

SEED TREATMENT TRIALS

MATERIALS AND METHODS

Seed of three barley cultivars of differing susceptibility to mildew (Golden Promise - very susceptible, Ymer - susceptible, and Julia - moderately resistant) was treated with ethirimol, applied as a powder at 1.4 lb a.i./cwt (12.5 g a.i/kg) in 1969 and as a liquid at 1.1 and 1.0 lb a.i./cwt (10 and 9 g a.i./kg) in 1970 and 1971 respectively. An organo-mercury fungicide was applied before or after ethirimol treatment. Seed of the same stocks without ethirimol treatment was used for the control plots. The trials were laid out in three, four or six randomised blocks and were sown at the same time as the surrounding farm crop, usually early in April, with the exception of one trial in 1971 where sowing was delayed by three weeks. The plot size was 1/40 ac (1/100 ha), typically 3 yd (3 m) wide, except for two trials in 1971 where the plot size was reduced to 1/60 ac (1/150 ha), 2 yd (1.8 m) wide. Seed rates varied from 1.5 to 2 cwt/ac (185 to 250 kg/ha) except for one trial in 1971, when only 1 cwt/ac (125 kg/ha) was sown. Fertilisers and herbicides were applied in accordance with local farm practice. Disease assessments were made with the aid of area diagram keys (ADAS 1971) on the top three leaves (flag leaf = leaf 1) of ten main tillers from each plot at either GS 10.5 or GS 11.1 or both. Non-green tissue which could not be associated with any recognised disease on simple visual examination was assigned to "dead tissue". The trials were harvested by combine when, at most sites, the whole of each plot was cut. Although the trials were in the same areas of south-east Scotland each year, only trial 3 was on the same farm each year. No data are available for Julia in 1971 owing to a high level of varietal contamination in the seed supplied which was not discovered until after the trials had been sown.

RESULTS AND DISCUSSION

(Table 1) In 1969 the incidence of mildew was generally slight. Leaf blotch (*Rhynchosporium secalis*) was the principal disease in trials 69.4 and 69.5; there were no treatment effects on this disease. In 1970 mildew levels were much higher throughout south-east Scotland, the disease first appearing early in June, but developing rapidly only after ear emergence. In 1971, following a mild winter, appreciable levels of mildew were present in untreated plots in May. The disease developed only slowly during June, but built up rapidly thereafter. In 1970 and 1971 leaf blotch and brown rust (*Puccinia hordei*) were rarely seen, very few leaves having even 1 per cent infection with either disease.

The mildew data in the table relate to leaf 2 except for trial 69.1 where leaf 3 has been used and trial 71.4 where field plot observations have been substituted because the full disease assessment was made at GS 10.5 when the highest level of mildew was 7 per cent. The very high levels of mildew in trial 71.5 undoubtedly arose because the plots were sown three weeks later than the surrounding farm crop of Golden Promise. Wherever appreciable levels of mildew occurred, ethirimol treatment gave a significant reduction, but better control was achieved on the more resistant cultivars, as noted by Wolfe (1969).

Table 1

Disease assessment (mean percentage leaf area) and yield responses (cwt per acre at 15 percent moisture) of 3 cultivars with(+) and without(-) ethirimol seed treatment

	Percentage Mildew							Yield Response		
	G Promise		Ymer		Julia			Golden	Ymer	Julia
Trial	-	+	-	+	-	+	GS	Promise		
69.1	1	0	1	0	0	0	10.5	1.1	-1.8	-1.9
2	traces in some control plots							-1.7	2.9	0.0
3	10	5	4	1	0	0	11.1	4.7	1.5	2.1
4	traces in some control plots							0.8	-1.9	-2.9
5	traces in some control plots							-0.3	-2.0	-3.7
mean								0.9(2.5%)	-0.3(-0.7%)	-1.3(-3.3%)*
70.1	33	8	19	2	8	1	11.1	4.8	0.9	2.1
2	12	1	8	1	3	0	10.5	4.9	6.2	0.1
3	8	0	1	0	0	0	11.1	2.2	2.7	2.6
4	12	2	5	1	1	0	10.5	3.3	2.4	1.2
5	9	0	6	2	1	0	10.5	6.3	1.3	1.5
mean								4.3(11.0%)	2.7(7.6%)	1.5(3.8%)
71.1	33	5	30	4			11.1	6.0	5.1	
2	31	3	18	0			11.[illegible]	7.5	3.7	
3	56	13	34	5			11.1	5.3	3.3	
4	20	1	10	1			10.54	6.2	-0.6	
5	72	20	70	7			11.1	11.6	4.7	
mean								7.3(15.7%)	3.2(7.9%)	

Statistically significant responses to treatment are underlined ($P \leqslant 0.05$).

* Yield response as percentage mean yield of treated plots.

In 1969 the only significant yield response of Golden Promise to ethirimol treatment occurred where there was an appreciable mildew attack (trial 69.3). The significant positive response of Julia in the same trial where no mildew was recorded on the untreated Julia plots, must be regarded as a chance result in view of the opposing trend in the other trials in that year. Such a result is quite possible because of the total number of comparisons made at this level of probability ($0.5 \leqslant P < 0.01$). The other Julia results in 1969 indicate that ethirimol was phytotoxic at the high dose rates applied (1.4 lb a.i./cwt, i.e. 2.1 - 2.8 lb a.i./ac), at least on a resistant cultivar in the absence of appreciable mildew attack. Similar phytotoxicity was reported by Wolfe (1969), but at lower dose rates (0.75 lb a.i./ac). High dose rates had, however, been found necessary to achieve satisfactory mildew control in relatively small plots where there could be no effective isolation and treated plots were continuously exposed to inoculum from adjacent untreated plots (Dr. D. H. Brooks, pers. comm.).

In 1970 the mean yield responses to treatment followed the established pattern of cultivar susceptibility to mildew and there was no evidence of phytotoxicity. In trial 70.1 the ethirimol treated plots of Ymer were sown at a lower seed rate than the others because the treatment restricted grain flow to a greater extent than had been anticipated. This led to a thinner plant stand which may have reduced the response. Severe lodging occurred in trial 70.2: Golden Promise was the worst affected and to such an extent that about 10 per cent of the crop was lost.

Yield responses in 1971 were generally greater than previously owing to the higher levels of mildew recorded. Quite severe lodging and harvest difficulties in trials 71.4 and 71.5 resulted in yield coefficients of variation of 10 per cent.

Doodson and Saunders (1969) found that the yield response of Julia to ethirimol treatment was often greater than that estimated from the level of mildew by the method of Large and Doling (1962). The data presented here do not confirm this although no allowance has been made for possible phytotoxic effects. With the exception of Ymer in 1971 (due probably to the negative response in trial 71.4), the general levels of the mean yield responses of all three cultivars in 1970 and 1971 are very much in line with those predicted from the Large and Doling formula, although there is great variation between individual trials.

Analyses of grain samples from some of the 1969 and 1970 trials have shown that ethirimol treatment had no significant effect on the nitrogen content of the grain.

It is not possible to predict directly from the results of these trials the response to ethirimol treatment on a field scale for several reasons: a) the high dose rate used; b) the possible reduction of response by phytotoxicity; c) the lack of effective isolation of the treated plots from continual reinfection; and d) the possible inflation of the response by plot "edge effects", where there may have been differential responses to reduced competition for light and nutrients. Comparable responses were, however, obtained in three evaluation trials this year where ethirimol treated Golden Promise seed (0.75 lb a.i./ac, 0.84 kg/ha) was sown in 1 or 2 acre (0.4 and 0.8 ha) unreplicated plots: 3.6 cwt/ac (0.45 tonne/ha) at Kelso in Roxburghshire, 7.0 cwt/ac (0.88 tonne/ha) at Gifford in East Lothian and 8.2 cwt/ac (1.03 tonne/ha) at Friockheim in Angus.

SPRAY TIMING TRIALS

METHODS AND MATERIALS

<u>1970 Trials</u> Two trials were laid down in commercial Golden Promise crops sown in mid-march at 1.5 cwt seed/ac (185 kg/ha). Nitrogen fertiliser was applied at 70 - 80 units N/ac (90 - 100 kg N/ha). At Monikie in Angus, the fungicides were applied with the farm sprayer (30 ft (9 m) boom) to plots measuring 30 yd by 30 yd (27.4 m), the direction of spraying being parallel with the direction of sowing. At Kincardine in Fife, a contractor's sprayer (49.5 ft (15 m) boom) was used on plots 33 yd (30 m) wide and 27 yd (25 m) long, at right angles to the direction of sowing. At both sites four replicates were arranged with plots at right angles to the direction of herbicide application to avoid confounding any effect of the associated wheel tracking with the treatments. The fungicides, benomyl, at 0.5 lb a.i./ac (0.56 kg a.i./ha), and tridemorph, at 0.47 lb a.i./ac (0.53 kg a.i./ha), were applied in approximately 25 gal water/ac (280 l/ha). A non-ionic wetter was included at 0.03 per cent v/v in the benomyl spray. Treated plots were sprayed once either at GS 7 or at GS 10.1 - 10.2. Disease assessments were made at either GS 10.5 or GS 11.1 on ten main tillers taken along a diagonal between the pairs of wheel tracks within each plot; a corresponding area was sampled in the control plots. At harvest a strip 6.5 ft (2 m) wide was cut with a combine from an untracked area near the centre line of each plot. To assess wheeling losses, a 6.5 ft (2 m) strip was cut to include both wheel tracks from one pass of the sprayer across each treated plot at Kincardine.

<u>1971 Trials</u> To obtain more information about the effects of very late spraying a programme of four sprays at approximately weekly intervals during June was used for two trials in commercial Golden Promise crops in Perthshire. Both crops were sown

during mid-March at 1.5 cwt seed/ac (188 kg/ha). 52 units N/ac (65 kg N/ha) were applied at Forteviot and 80 units N/ac (100 kg N/ha) at Meigle. Plots 36 yd (33 m) wide and 25 yd (23 m) long were laid out in four randomised blocks at right angles to the direction of sowing and herbicide application. A contractor's sprayer with a 53 ft (16 m) boom was used with 25 gal/ac (280 l/ha) nozzles working at a spraying pressure of 40 lb/in^2 (2.76 bar), to apply approximately 30 gal/ac (337 l/ha). The tractor-mounted sprayer weighed 70 cwt (3.6 tonne) gross and was fitted with 8.3 in x 44 in (211 mm x 1118 mm) rear tyres. Each treated plot was sprayed only once, with tridemorph (0.47 lb a.i./ac, 0.53 kg a.i./ha) at Forteviot and (1-3,4-dichloroanilino)-1-formyl amine-2,2,2trichloroethane (proposed common name chloraniformethan) (0.26 lb a.i./ac, 0.29 kg a.i./ha) at Meigle. Disease assessments were made at both GS 10.5 and GS 11.1. At harvest a 6.5 ft (2 m) strip was cut with a combine from an untracked area near the centre-line of each plot and a similar strip cut to include one wheel track from one pass of the sprayer across each treated plot at both sites. Two untracked strips were cut from each control plot and the mean plot yield determined.

RESULTS AND DISCUSSION

1970 Trials At the time of the first spray application very little mildew was seen in these crops. By 10 June, GS 8-9, leaf 5 was less than 5 per cent infected, while only occasional lesions could be found on leaf 4. There was no noticeable increase in the level of mildew up to the time of the later application, but the disease developed very rapidly during late June and early July.

At Monikie (Table 2) all treatments reduced the levels of mildew, but the reduction was significant only with the later tridemorph spray. All treatments increased yield, the later applications of both fungicides giving significantly higher yields. The greatest response, 6.7 cwt/ac (840 kg/ha) given by the later tridemorph application, was very similar to that obtained from Golden Promise with ethirimol in one of the seed treatment trials in the same area, 6.3 cwt/ac (790 kg/ha).

Table 2

Disease assessment (mean percentage leaf area) at GS 10.5 on 9 July and yield of grain (cwt per acre at 15 per cent moisture), Monikie 1970

Date sprayed		-	29 May		19 June		
Growth stage		-	7		10.1		
Fungicide		control	benomyl	tridemorph	benomyl	tridemorph	se
Untracked yield		36.1	39.2	38.0	41.7	42.8	±1.54
Mildew	leaf 1	14	12	9	7	3	±2.2
	leaf 2	23	23	16	17	9	±1.8

At Kincardine (Table 3) only the later application of tridemorph reduced the mildew level significantly. There were no significant effects on yield. The failure of the later treatments to give appreciable mildew control may have been due to the more advanced stage of growth at which these applications were made compared with that at Monikie. The crop was, however, affected by drought and this may have affected treatment responses.

The yields of the tracked strips followed the expected pattern, those of the later sprayed plots being lower, but within treatments there was an unusual amount of variation from plot to plot in the comparison between untracked and tracked yields, reflected in a coefficient of variation of 15 per cent. Although the growing crop looked quite uniform, small differences in the severity of the effect of drought might have contributed to the yield variations recorded within plots. Some of this variation may also have been due to the difficulty of including the area affected by both wheel tracks uniformly within a single 6.5 ft (2 m) combine swath.

Table 3

Disease assessment (mean percentage leaf area) at GS 11.1 on 15 July and yield of grain (cwt per acre at 15 per cent moisture), Kincardine 1970

Date sprayed		-	29 May		19 June		
Growth stage		-	7		10.2		
Fungicide		control	benomyl	tridemorph	benomyl	tridemorph	se
Untracked yield		37.7	41.6	35.2	35.5	40.5	±1.53
Tracked yield		-	37.4	39.2	34.2	33.3	±1.92
Crop yield		37.7	41.1	35.7	35.3	39.5	
Mildew	leaf 1	14	17	15	17	9	±1.8
	leaf 2	28	26	26	27	21	±1.4
Dead	leaf 1	8	8	9	6	11	±1.7
Tissue	leaf 2	12	14	13	13	13	±1.2

The crop yield has been calculated as

crop yield = ((6.5 x tracked yield) + (43 x untracked yield))/49.5

on the assumptions that all of the area damaged by wheel tracking was included within the 6.5 ft combine swath and that this represented 6.5/49.5 of the area covered by a single pass of the sprayer. Average wheeling losses for the later sprays have thus been assessed at 0.6 cwt/ac (75 kg/ha), i.e. 1.6 per cent of the mean untracked yield for those treatments.

Although some benomyl-treated plots in both trials had lower levels of mildew than the controls, the results suggest that yield responses to this fungicide occurred where no effective reduction was achieved and were due primarily to other factors. In this connection it was noted that the straw and heads of plants in the benomyl-sprayed plots were virtually free of the discolouration normally associated with the parasitic pre-harvest development of such fungi as *Cladosporium* spp. and *Alternaria* spp.

Spray Trials 1971 (Table 4) Mildew was well established at low levels, 5 per cent on leaf 5, at both sites by 31 May, GS 7-8, rather earlier than in the 1970 spray trials. The levels of mildew did not increase greatly during June, but the disease spread to the upper leaves. Slightly more rapid development occurred during the first fortnight of July, but the final levels were well below those of the 1971 seed treatment trials. Disease assessment at all stages was characterised by the large amounts of dead tissue recorded. At the later assessment many leaves from some treated plots at Forteviot had more than half of their area taken up by necrotic flecks on which no disease was apparent, while at Meigle unusually high proportion of chlorosis were recorded. There were no significant treatment effects on mildew levels, except for those on leaf 1 at GS 11.1 at Meigle, but the spray applications on 4 and 14 June at both sites gave the greatest reduction in"non-green tissue", i.e. mildew plus dead tissue.

Of the untracked yields, only the greatest response at Meigle was statistically significant, but all treatments gave an increase over the controls except the last spray at Meigle. The pattern of yield response to treatment followed the pattern of reduction in total non-green tissue. The greatest yield responses in these two trials were obtained from sprays applied on different dates, 14 and 18 June, but at the same stage of crop growth, GS 10 - 10.1. The greater responses to tridemorph in the 1970 spray trials were also obtained from applications at this growth stage, indicating the importance, in south-east Scotland, of the late development of mildew.

Table 4

Yield of grain (cwt per acre at 15 percent moisture) and disease assessment (mean percentage leaf area), Forteviot and Meigle 1971

Date sprayed		control	4 June	14 June	18 June	25 June	
FORTEVIOT tridemorph		Growth stage	9-10	10-10.1	10.1-10.4	10.5	se
Untracked yield		42.6	43.0	45.5	44.7	44.0	± 1.75
Tracked yield		-	43.0	43.3	40.9	40.5	± 2.40
Crop yield		42.6	43.0	44.9	43.8	43.1	
Disease assessment		23 June GS 10.5					
Mildew	leaf 3	8	5	7	6	9	± 1.1
	leaf 4	5	4	6	5	5	± 0.7
Dead tissue	leaf 3	25	22	5	10	29	± 8.8
	leaf 4	84	71	56	71	81	± 9.4
Disease assessment		12 July GS 11.1					
Mildew	leaf 1	4	5	3	4	1	± 1.5
	leaf 2	13	17	9	12	8	± 3.7
	leaf 3	8	11	7	9	13	± 1.3
Dead tissue	leaf 1	30	29	30	17	32	± 6.3
	leaf 2	37	34	51	29	30	±10.0
	leaf 3	75	78	91	66	54	±12.0
MEIGLE chloraniformethan		Growth stage	8-9	9-10	10-10.1	10.1-10.4	se
Untracked yield		38.9	40.3	40.0	44.5	38.3	± 1.57
Tracked yield		-	38.8	38.9	39.7	36.2	± 1.13
Crop yield		38.9	40.0	39.7	43.3	37.8	
Disease assessment		23 June GS 10.2					
Mildew	leaf 3	3	3	3	4	2	± 0.3
	leaf 4	5	4	4	5	3	± 0.4
Dead tissue	leaf 3	0	0	1	2	0	± 0.5
	leaf 4	22	24	9	34	24	± 0.4
Disease assessment		12 July GS 11.1					
Mildew	leaf 1	4	3	1	1	2	± 0.5
	leaf 2	11	5	7	7	7	± 1.5
	leaf 3	0	2	7	4	3	± 1.9
Dead tissue	leaf 1	16	14	12	14	14	± 5.3
	leaf 2	44	39	35	35	40	± 8.6
	leaf 3	100	89	82	92	88	± 4.6

The yields of the tracked strips followed a similar pattern to that in the 1970 trials, those of the later sprayed plots being lower. The effect of tracking on Golden Promise is to cause a total loss of the tillers damaged, owing to the brittle nature of the plants. Compensation may occur in the adjacent rows as a result of the reduced competition for light, this effect being greatest with pre-heading sprays. If the wheeling is done at a sufficiently early stage new tillers will grow from the damaged plants, but these are not likely to make much contribution to yield because they are typically about half the height of normal tillers, have fewer grains per head and are immature at harvest. The numbers of such tillers, as percentages of the numbers of original tillers, for the successive sprays were 100, 20, 10 and 0 at Forteviot and 20, 10, 10 and 1 at Meigle. Field observations on the effects of post-tillering herbicide or fertiliser applications have shown that there is marked seasonal variation in the extent of this regrowth, but it is a factor which must be considered in the production of high quality grain samples for seed and malting purposes.

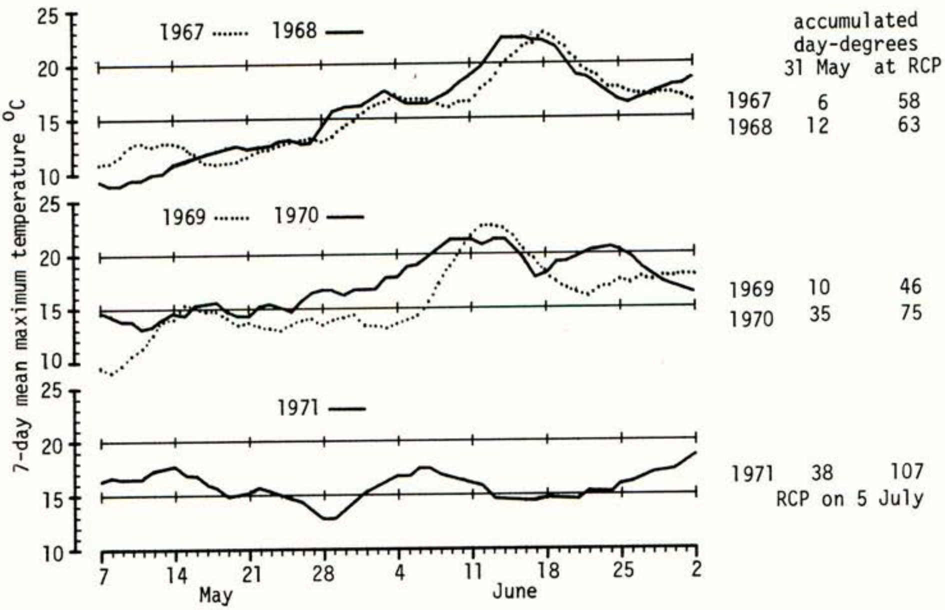
The crop yields are given by:

crop yield = ((13 x tracked yield) + (40 x untracked yield))/53

as the tracked strips (6.5 ft) in these trials represented only half of the area damaged at each pass of the sprayer (53 ft wide). An average over several treatments probably gives a better estimate of actual wheeling losses than the result for any one treatment alone and so wheeling losses for the three later applications have been assessed at 0.8 cwt/ac (100 kg/ha) at Forteviot and 0.7 cwt/ac (88 kg/ha) at Meigle, i.e. 1.8 per cent and 1.7 per cent respectively of the untracked yields for those treatments.

Rosser (1969) found that single sprays of drazoxolon applied when, or soon after, the mean of the daily maximum temperature for seven consecutive days equalled or exceeded 20°C ("Rosser Critical Period, RCP") gave effective reductions in the incidence of mildew in trials in 1968 and 1969, and he suggested that this criterion might indicate when an economic response to treatment was likely. An examination of temperature data from the City of Perth Meteorological Station showed that a Rosser Critical Period had occurred on 8 June 1970 and that such conditions persisted until 15 June (Figure 1).

Fig. 1 Seven-day means of maximum daily temperature, Perth 1969-1971



In the 1970 trials sprays were applied on 29 May at GS 7 and on 19 June at GS 10.1 - 10.2. The better control of mildew and the greater yield response to tridemorph applied on the second date in those trials and the similar response to benomyl in the trial at Monikie may support Rosser's findings. In 1971, however, an RCP was not recorded until 5 July, but sprays applied at GS 10 - 10.1, on 14 and 18 June, again gave the greatest responses.

Rosser Critical Periods also occurred during mid-June at Perth in 1967, 1968 and 1969. Subsequent analysis of temperature data from twentyeight other Meteorological Stations throughout south-east Scotland has shown that RCPs occurred at most inland sites on approximately the same dates as those at Perth. Data from coastal Meteorological Stations rarely included daily maximum temperatures as high as 20°C during June owing to the effects of on-shore winds. An examination of the temperature data from Perth for the 30 year period 1941 to 1970 showed that the occurrence of four consecutive years when an RCP was recorded in mid-June was very unusual, and that in only half of the years during this period did an RCP occur between 1 June and 20 June (Table 5. One of the RCPs recorded in May was followed by a further RCP on 12 June.). Even within the four-year sequence 1967-1970 it is necessary to distinguish "effective" and "non-effective" RCPs as the data from the seed treatment trials reported here and data from barley variety trials in south-east Scotland indicate that in 1967 and 1969 levels of mildew were generally very low, while in 1968 and 1970 mildew caused widespread losses.

Table 5

Number of years out of 30 during which a Rosser Critical Period first occurred between the stated dates, Perth 1941-70

May	June			July
1-31	1-10	11-20	21-30	1-31
3	8	6	6	5

no RCP occurred in 1954 and 1965

From Figure 1 it can be seen that the seven-day mean daily maximum temperature in 1970 rose fairly steadily from 14 May until the RCP on 8 June. In contrast, May in 1969 was cool and the temperature mean did not begin to rise until 5 June, with an RCP on 10 June. To characterise these patterns the areas under the curves have been calculated by accumulating the day-degrees in excess of 15°C from 1 May, giving an index of seasonal warmth. Relevant values are tabulated in Figure 1. Similar, but smaller differences were found between 1967 and 1968. At some other sites, e.g. Kelso, the contrast between "mildew" and "non-mildew" years was much greater in terms of this parameter. Last (1963) and others have shown that the incubation period of mildew decreases with increasing temperature up to 20°C. The index of warmth calculated here can thus give an indication of the extent to which mildew may have become established on the lower leaves within a crop, and of the general level of disease activity before the onset of conditions favourable to full endemic development, characterised by an RCP. The local significance of this index may, however, be changed if an unusually early infection occurs, for example, from nearby infected winter barley. To cover such variations and those revealed in the seed treatment trials, where some crops gave an economic response to treatment while others in the same season did not, it will be necessary to define an additional crop-based parameter. Ideally, such a parameter should also be of use in seasons like 1971, when no RCP was recorded before heading but economic responses to spray treatment were obtained.

WHEEL TRACKING TRIALS

METHODS AND MATERIALS

When the final spray had been applied to the timing trial at Forteviot the sprayer was driven away from the trial along the wheel marks resulting from the herbicide application. At harvest two 6.5 ft (2 m) strips were cut to include one wheel track from this damaged area. For comparison two similar strips were cut from adjacent wheel tracks due to herbicide application alone, and from an untracked area between these two sets of marks.

In conjunction with the School's Engineering Department, a tractor weighted to 47.5 cwt (2.4 tonne) was driven parallel to the direction of sowing through a crop of Ymer barley on one of the School of Agriculture farms (Boghall) on 11 June at GS 9 - 10 and on 28 June at GS 10.4 - 10.5. Four sets of tracks were made on each occasion, two with the tractor on 6 in x 36 in (152 mm x 914 mm) rear tyres and two on 11 in x 28 in (279 mm x 711 mm) rear tyres. At harvest two 6.5 ft (2 m) strips were cut from each set of trackings, including only one wheel track of each pair, and from untracked areas between them. The crop was sown with 4.5 in (114 mm) coulter spacing.

RESULTS AND DISCUSSION

At harvest the tillers in the herbicide application tracks at Forteviot were mature but 1 - 2 in (2.5 - 5 cm) shorter than tillers in untracked areas. No regrowth occurred in the tracks which had been run over again at GS 10.5. The yields of strips cut from both sets of tracks were considerably lower than those of strips cut from the untracked area (Table 6). Crop yields have been calculated in the same way as those for the main trial. The theoretical loss due to the total destruction of two rows in 53 ft at 7 in spacing is 2.2 per cent if tracking has no deleterious effects on adjacent rows and no compensation occurs.

Table 6

Yield loss (cwt per acre at 15 per cent moisture) due to tracking, Forteviot 1971

	untracked	tracked at herbicide application	tracked additionally at GS 10.5
strip yield	42.6	40.2	37.4
strip loss	-	2.4 (5.6%)*	5.2 (12.2%)
crop yield	42.6	42.0	41.4
crop loss	-	0.6 (1.4%)	1.2 (2.8%)

* loss as percentage untracked yield

These results, although based on only two replicate samples, indicate that wheeling losses due to herbicide application alone (0.6 cwt/ac) were almost equal the average loss due to the later fungicide applications in the spray timing trials (0.7 cwt/ac). The effect of the double tracking cannot be compared directly with the sum of the crop losses from each occasion separately as no fungicide was applied, but there are indications that these effects may not be additive, in which case there will be a real advantage in tracking the same rows for herbicide and fungicide applications.

The wheeling losses in this trial are much greater than those reported by Holmes and Lang (1965), who tracked two rows at 7 in spacing in 10 row plots of Ymer barley with a light tractor in a series of trials from 1960 to 1964. For comparative purposes crop yields based on a 53 ft sprayer width have been calculated from the yields of their harvested plots, which included both wheel tracks, but no allowance has been made for plot edge effects. No loss was caused by tracking up to four weeks after seedling emergence. Tracking at six weeks after seedling emergence caused a crop loss of 0.1 cwt/ac (0.25 per cent) and at eight weeks, at GS 10 - 10.1, a crop loss of 0.6 cwt/ac (1.5 per cent), which is similar to the average crop loss in the spray timing trials. The differences between the losses from the earlier trackings may be due in part to varietal differences in growth habit and in part to the use of an unladen tractor by Holmes and Lang.

In the trial at Boghall, tracking with narrow and standard width rear tyres caused similar yield losses, the damage being significantly greater on the later occasion (Table 7). For comparative purposes crop yields have again been based on a 53 ft sprayer width.

Table 7

Yield loss (cwt per acre at 15 per cent moisture) due to tracking, Boghall 1971

		tracked at GS 9-10			tracked at GS 10.4-10.5		
	untracked	narrow	standard	untracked	narrow	standard	se
strip yield	37.0	34.5	34.7	37.4	31.9	31.7	±1.35
strip loss	-	2.5(6.8%)	2.3(6.2%)	-	5.5(14.7%)	5.7(15.2%)*	
crop yield	37.0	36.4	36.4	37.4	36.1	36.0	
crop loss	-	0.6(1.6%)	0.6(1.6%)	-	1.3(3.5%)	1.4(3.7%)*	

strip yield standard error is only approximate owing to systematic arrangement of treatments

* loss as percentage untracked yield

The theoretical loss due to the total destruction of four rows in 53 ft at 4.5 in spacing is 2.8 per cent. The tillers of Ymer, however, unlike those of Golden Promise, are not irrecoverably damaged by tracking, and this, together with compensation in adjacent rows, probably accounts for the smaller losses from the earlier tracking. The larger losses from the later tracking are probably related to the less upright growth habit of Ymer which permitted the loss of tillers from rows other than those directly under the tractor wheels.

The similarity of the losses caused by narrow (6 in) and standard (11 in) rear tyres indicates that on both occasions two rows of plants were damaged by each tyre. This could have been achieved by steering the front wheels of the tractor between the rows. If the tractor had been driven so that it crushed one row under each front wheel, the narrow rear tyres would have severely damaged only one row, while the standard tyres would have damaged three adjacent rows at 4.5 in spacing. Holmes et al (1971) have recently shown that there is a small, but consistent yield advantage (0.7 cwt/ac, 88 kg/ha, 2 per cent) for barley sown in narrow rows in south-east Scotland. If narrow row drills become more popular as a result, more attention will have to be given to this interaction between row spacing, tyre width and tracking pattern (i.e. on the rows or between the rows). The tiller density within the row is lower in narrow rows and so for some combinations of tyre width, row spacing and tiller density, tracking parallel to the rows will cause less yield loss, while for other combinations damage will be minimised by tracking at right angles to the rows.

Acknowledgements

I wish to thank many colleagues in the School of Agriculture who have contributed to the work reported here, in particular Mr. J.B.A. Rodger, Mr. W.D. Gill and

Mr. R.W. Lang and their Assistants who did much of the trials work, and Mrs. C. Anderson for assistance with the data processing. I am grateful to the farmers who provided sites for our sometimes large and unsightly trials and to the chemical manufacturers who provided the fungicides. I would also thank the Superintendent and staff of the Meteorological Office, Edinburgh, for access to the Monthly Returns of Daily Observations for Meteorological Stations in south-east Scotland.

References

ADAS (1971) (and earlier editions). Guide for the assessment of cereal diseases. Ministry of Agriculture, Fisheries and Food, Plant Pathology Laboratory, Harpenden.

DAFS (1971a) Agricultural Census June 1971. Summary for counties, regions and Scotland. Department of Agriculture and Fisheries for Scotland, Economics and Statistics Unit, Edinburgh.

DAFS (1971b) Scottish Agricultural Economics, 21. Edinburgh. H.M.S.O.

DOODSON J.K. and SAUNDERS P.J.W. (1969) Observations on the effects of some systemic chemicals applied to cereals in trials at the N.I.A.B. Proc. 5th Br. Insectic. Fungic. Conf. (1969), 1 - 7.

HOLMES J.C. and LANG R.W. (1965) Damage to barley by tractor wheels. Edinb. Sch. Agric. expl Wk. 1964.

HOLMES J.C., LANG R.W., GILL W.D. and RODGER J.B.A. (1971) A comparison of two row widths for spring barley and winter wheat at varying seed and nitrogen rates. Expl. Husb. (in press).

LARGE E.C. and DOLING D.A. (1962) The measurement of cereal mildew and its effect on yield. Pl. Path. 11, 47 - 57.

LAST F.T. (1963) Effect of temperature on cereal powdery mildews. Pl. Path. 12, 132 - 133.

ROSSER W.R. (1969) Spray timing and the control of mildew in spring barley. Proc. 5th Br. Insectic. Fungic. Conf. (1969), 20 - 24.

WOLFE M.S. (1969) Pathological and physiological aspects of cereal mildew control using ethirimol. Proc. 5th Br. Insectic. Fungic. Conf. (1969), 8 - 15.

Proc. 6th Br. Insectic. Fungic. Conf. (1971)

THE EVALUATION OF APPLICATION TIME OF TRIDEMORPH FOR THE CONTROL OF MILDEW IN BARLEY AND OATS IN THE UNITED KINGDOM

K. U. Jung and J. L. Bedford
BASF United Kingdom Limited, St. Francis Tower, Greyfriars, Ipswich

Summary Results of trials comparing application time of tridemorph for the control of mildew in barley and oats are described. In spring barley the best yield response was obtained with applications of tridemorph between growth stages 4 to 6.

In winter barley, autumn applications of tridemorph although resulting in good mildew control have not given any positive yield response, whilst spring applications to infected crops have shown yield increases.

In oats, good control of mildew was obtained with tridemorph, resulting in yield increases. Timing of single applications between growth stages 4-9 does not appear critical in determining the yield response. Double applications generally gave greater yield increases. A mixture of tridemorph and chlormequat gave the greatest yield increase of all treatments in winter oats. In spring oats this mixture did not give as great a yield increase as two applications of tridemorph.

INTRODUCTION

Tridemorph was found in laboratory tests and field trials to have prophylactic and eradicant activity against mildew (Erysiphe graminis) in barley (Pommer et al 69).

Trials carried out on the Continent and in the U.K. have shown that 0.47 lb a.i. per acre (0.52 kg a.i. ha) is the most suitable rate for use in cereals.

In order to obtain the maximum benefit from a single application of tridemorph timing is considered important and a series of trials were conducted in the U.K. to investigate this factor. 58 trials carried out in Germany between 1961-64 suggested that the best response is obtained when treatment commences at growth stages 5-6 provided that build up of mildew occurs at this stage (Kradel et al 69). Growth stage 5-6 was therefore chosen as a basis for the timing in the spring barley trials.

Further trials were laid down on winter barley to evaluate the effect of controlling cereal mildew in the autumn compared with spring applications.

Trials were also carried out on spring and winter oats evaluating tridemorph in the spring at varying timings and in a tank mixture with chlormequat. The latter mixture was included to test biological compatability as this was considered a possible commercial application.

METHODS AND MATERIALS

In the BASF trials a randomised block design with four replicates was used. Plot sizes measured 4.3 yd by 13.7 yd (4 m by 12.5 m). Treatments were applied with a Van der Weij knapsack sprayer fitted with cone nozzles.

The trials were harvested using a "Hege 125" small plot combine harvester. A strip measuring 1.36 yd by 12.33 yd (1.25 m by 11.25 m) was cut from each plot.

In the trials carried out by Boots Pure Drug Company Limited, a randomised block design with 6 replicates was used. Plot sizes measured 44 yd by 3 yd. The treatments were applied using the "Lenton" wheeled small plot sprayer.

In all trials tridemorph was applied at 0.47 lb/ac a.i. in 20 gals of water (0.52 kg a.i. in 250 l ha). In the mixture of tridemorph and chlormequat the application rate was 0.47 lb/ac a.i. of tridemorph and 0.75 lb a.i. of chlormequat per acre (0.52 kg a.i. and 0.84 kg a.i./ha respectively).

Mildew assessments were carried out using the cereal mildew key No. 5, draft 2, devised by the Plant Pathology Laboratories, Harpendon.

Cereal growth stages are expressed using the Feekes-Large scale (Large, 1954).

Formulations: Tridemorph (75% a.i. w/v emulsifiable concentrate)
Chlormequat (40% a.i. w/v aqueous solution)

RESULTS

Trials were laid down by BASF in 1970 to examine whether applications of tridemorph at early growth stages would give better yield increases than later applications. The results obtained in two of these trials are shown in Table 1. Four other trials results are not included as they all suffered severely from drought which depressed yields below 20 cwt/ac. However, early applications of tridemorph between growth stages 5-8 gave greater yield increases than later applications at growth stage 9-10 in three of these results.

Table 1

Results of trials on spring barley comparing early and late applications of tridemorph

Trial number and variety	Growth stage at application	Date of application	% leaf infection Leaf 3	Leaf 4	Yield in cwt/ac
1 Zephyr	Untreated		5.6	21.6	30.9
	4	29.5.70	3.3	11.2	36.5**
	10.3	22.6.70	0.7	10.3	30.4
2 Vada	Untreated		1.0	6.0	33.8
	5-6	2.6.70	0	1.3	36.4**
	10	10.6.70	0	0.4	34.4
3 Deba Abed	Untreated		6.9	9.3	32.6
	5-6	8.6.70	0.2	0.1	36.0
	10.2	23.6.70	0.9	1.3	31.9
4 Proctor	Untreated		2.1	15.0	24.7
	5-6	6.6.70	0	0.4	27.7
	10	17.6.70	1.2	11.2	24.7
5 Proctor	Untreated		1.8	28.3	22.3
	5-6	6.6.70	0.1	0.6	23.4
	10	16.6.70	0.9	12.3	21.6

** Significantly different from untreated plots at 1.0%

Trials 1-3 were carried out by Boots Pure Drug Co. Limited in 1970 and mildew assessments were made at growth stage 11.1 between the 7th and 10th July. Trials 4 and 5 were assessed for mildew at growth stage 10.1-5 on the 23rd June.

The results of an initial trial on winter barley in 1970 showed that spring applications of tridemorph also gave control of cereal mildew on this crop (see Table 2).

Table 2

Results of a spring application of tridemorph on winter barley in 1970

	% leaf infection on 12.6.70 at GS 10.5			% leaf infection on 24.6.70 at GS 11			Yield in cwt/ac
	Flag	2nd	3rd	Flag	2nd	3rd	
Untreated	1.1	17.5	38.1	2.8	29.8	48	29.6
Tridemorph	0	0.6	1.2	1.0	2.9	2.3	34.4***

*** Significantly different from untreated plots at 0.1%

Tridemorph was applied on the 20th May at growth stage 5-6.

A further series of trials was started in the autumn of 1970 to compare autumn applications of tridemorph with spring applications for the control of mildew in winter barley. The results are shown in Table 3. No mildew assessments were made in trials 1-3 in the spring due to the fact that mildew had disappeared.

Table 3

Results comparing autumn and spring applications of Tridemorph on winter barley, 1970-71

Site Number and Variety	Date of application and assessment	Assessments	Untreated	Tridemorph Autumn	Tridemorph Autumn and Spring	Tridemorph Spring	Tridemorph Spring Twice
1 Malta	26.10.70) 10. 3.71) 12. 5.71)	GS at application		3	3 & 4	9	4 & 9
	13.11.70	% at GS 3	11.6	0			
		Yield in cwt/ac	26.5	27.3	28.0	26.9	28.6
2 Maris Otter	23.10.70	GS at application		2-3			
	11.11.70	% at GS 2-3	2.2	0.8			
		Yield in cwt/ac	30.2	30.2			
3 Senta	23.10.70	GS at application		1-2			
	9.11.70	% at GS 2-3	1.7	0.3			
		Yield in cwt/ac	43.3	43.4			
4 Maris Otter	12.11.70) 22. 4.71) 18. 5.71)	GS at application		2-3	2-3 & 5	5	5 & 9-10
	3.12.70	% at GS 2-3	2.8	0.3			
	5. 5.71	% at GS 6	0.01	0.05	0.01	0.003	
	24. 5.71	% at GS 10-10.5	0.6	0.7	0.1	0.2	0.1
		Yield in cwt/ac	28.2	27.1	27.9	29.2	29.0

% refers to percentage leaf infection of middle leaf of each tiller at assessment.

The results of trials carried out on spring and winter oats evaluating tridemorph at varying timings in the spring and in a tank mixture with chlormequat are shown in Table 4.

Table 4

Results of tridemorph trials in winter and spring oats in 1971

Site number and variety	Date of application and assessment	Assessments	Untreated	Tridemorph early	Tridemorph twice	Tridemorph late	Tridemorph + Chlormequat
1	17.4.71 & 18.5.71	GS at application		4-5	4-5 & 7	7	7
Winter Oats	27.4.71	% at GS 5-6	12.1	2.0	2.0	7	
Maris Quest	2.6.71	% at GS 9	2.2	0.2	0.03	0	0.1
	16.6.71	% at GS 10	8.9	5.3	0.05	0.2	0.1
		Yield in cwt/ac	42.2	43.8	45.9 *	44.1	48.3 *
2	30.4.71 & 21.5.71	GS at application		5-6	5-6 & 8	8	5-6
Winter Oats	10.5.71	% at GS 6-7	6.0	3.7	3.7		3.5
Maris Quest	3.6.71	% at GS 10	3.4	1.5	0.9	1.1	1.2
		Yield in cwt/ac	46.9	57.9***	56.9***	53.7 *	58.1***
3	28.4.71 & 28.5.71	GS at application		5-6	5-6 & 8-9	8-9	5-6
Winter Oats		No mildew assessments due to low level of mildew					
Peniarth		Yield in cwt/ac	28.5	29.7	27.3	26.8	32.9**
4	21.5.71 & 13.6.71	GS at application		6	6 & 8	8	8
Spring Oats	24.6.71	% at GS 9	2.5	2.0	0	0	0.1
Condor	9.7.71	% at GS 10.5	17.6	18.3	3.0	7.5	6.4
		Yield in cwt/ac	37.6	40.4**	47.0***	41.8***	42.2***
5	28.5.71 & 21.6.71	GS at application		6-7	6-7 & 9	9	6-7
Spring Oats	24.6.71	% at GS 9	3.5	1.8	1.8		1.1
Astor	9.7.71	% at GS 10.5	9.4	8.0	0.1	0.2	4.1
		Yield in cwt/ac	30.7	31.5	34.2	31.3	33.1

* ** *** - Significantly different from untreated plots at 5.0%, 1.0% and 0.1% respectively.

Trials 2 and 3 yield results are the mean of only three replicates. % refers to percentage leaf infection of the 3rd leaf in trials 1-2 and the 2nd leaf in trials 4-5. The whole of the trials area in No. 4 had lodged.

DISCUSSION

The interpretation of these results should be treated with some reserve as they are based on a limited number of trials over one or two years.

In the spring barley trials early applications of tridemorph gave good control of mildew for 3-5 weeks in small plots under severe inoculum pressure. Applications at growth stage 10-10.3 gave poor control of mildew in trials with a heavy infection. Yield increases were obtained with early applications of tridemorph but not from the later applications even where good mildew control had occurred. Similar yield responses are reported for 1970 by the Norfolk Agricultural Station (Norfolk Agricultural Station, 1970-71). An application in mid May at growth stage 5 to Proctor barley when mildew was just detected resulted in greater yield increases than later applications at early and mid June. The yield trends in a similar trial in 1971 were comparable but the variety Proctor used in the trial was severely affected by brown rust (Mundy, 1971).

In winter barley a spring application of tridemorph at growth stage 5-6 in 1970 resulted in very good mildew control and significant yield increase under a high incidence of mildew (Table 2). Good control was also obtained with autumn applications in 1970 at growth stage 2-3 but did not result in any positive yield response (Table 3). Spring applications made in two of these trials resulted in marginal yield increases although the initial high incidence of mildew had declined to a very low level in spring.

Applications of tridemorph to both winter and spring oats gave good control of mildew. The mixture of tridemorph and chlormequat showed a similar degree of mildew control as obtained with a single application of tridemorph applied at the same growth stage. Two applications of tridemorph gave a greater and more prolonged control of mildew than single applications. Applications of tridemorph increased yield in all the oat trials in which mildew was prevalent. Two applications resulted in greater yield increases than single applications, except in trial No. 2 (Table 4) where one early application gave a slightly greater yield increase.

Timing between growth stages 4-9 did not appear critical in terms of the increase obtained. In trial No. 2 the early treatment gave the greater yield increase, whilst in trial No. 4 the later application gave a high response. (Table 4) In winter oats the mixture of tridemorph and chlormequat gave greater yield increases than either single or double tridemorph treatments. This mixture also gave a significant yield increase in trial 3 where the incidence of mildew was very low. However, in spring oats this mixture did not result in as great a yield increase as given by double applications of tridemorph.

Acknowledgements

The authors wish to thank Boots Pure Drug Co. Ltd. for providing data from their trials for inclusion in this paper. We should also like to thank Mr. A.J.P. Frost and Mr. H.C. May for their help in the trials, and the farmers who co-operated.

References

Kradel J. and Pommer E.H. (1970) The chemical control of leaf and ear diseases in cereals. Zeitschrift fuer Pflanzenkrankheiten und Pflanzenschutz 77 443-454 (8th edition).

Large, E.C.(1954) Pl. Path. 3, 128.
Mundy, E., Norfolk Agricultural Station (1971) private communication.
Norfolk Agricultural Station (1970-71) Sixty-third Annual Report. "Experiments in Progress" 63, 17-18.
Pommer, E.H., Otto, S. and Kradel, J. (1969) Some results concerning the systemic action of tridemorph. Proceedings of the British Weed Control Conference 2, 347-353.

Proc. 6th Br. Insectic. Fungic. Conf. (1971)

RESULTS OF SEVERAL YEARS OF TESTING THE SYSTEMIC FUNGICIDE CELA W 524 AGAINST MILDEW AND RUST OF CEREALS

P. Schicke, K.G. Adlung and Chr.A. Drandarevski
C. H. Boehringer Sohn and Cela GmbH, Ingelheim

Summary Triforine* (Cela W 524) is a systemic fungicide against powdery mildew, rust fungi and other organisms causing leaf spot diseases. When applied as a 20 % e.c. using 200 g active material per hectare, triforine is a potent agent against mildew of cereals, at the same time reducing attacks of rust and net blotch disease. The yield is raised by 5 - 20 % and the percentage of grain over 2.5 mm is improved. An effect against mildew which, however, depends on soil humidity, is also obtained after seed treatment. From the toxicological point of view triforine can be considered acceptable for use in cereals.

INTRODUCTION

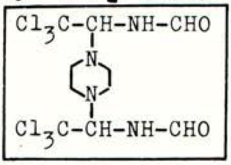
The large expansion of barley acreages which have taken place in the Federal Republic of Germany during the past 10 years, the mixed cultivation of spring- and winter barley - with 60 % of the latter in Northern Germany, as well as efforts to raise the yield to 7 tons per hectare have favoured the occurrence of barley mildew and encouraged the development of a large infection potential (Kradel et al. 1969). At the same time the development of new biotypes of mildew has occurred - 70 types were counted in 1968 (Nover et al. 1968), and even in valuable barley varieties a break down of resistance to mildew is observed (Plate, Fischbeck, 1969).

Severe attacks of mildew cause substantial reductions in yield and quality. In cases of an early attack which are relatively rare, the loss may amount to 30 - 40 % and in the more usual cases of late attack, i.e. the occurrence of mildew at ear emergence the losses may be 5 - 15 %.

There are years in which, apart from mildew, rusts of cereals are also of great importance. However, rust epidemics are less frequent than mildew epidemics. The times of infection partly coincide with those of mildew, so that by means of late spraying, carried out during the period of tillering rust infections can also be controlled. Due to the fact that the upper leaves and the ears are likely to be attacked, further sprayings may be required (Bohnen, 1963).

* proposed common name

Among other new products, piperazine-1,4-diyl-bis [1-(2,2,2-trichlorethyl)formamide] (=Cela W 524, proposed common name "triforine") can be used effectively.



Basic research results for triforine are reported by Ebenebe, *et al.* (1971); Fuchs, *et al.* (1970); Fuchs, *et al.* (1971 a); Fuchs, *et al.* (1971 b); Ost, *et al.* (1971); Schlüter, Weltzien, (1971). Schicke and Arndt (1971) reported on its practical use in ornamental plants; Adlung and Drandarevski (1971) on fruit crops.

METHOD AND MATERIALS

In preliminary greenhouse trials triforine was tested by application to leaves and roots for an effect against mildew (*Erysiphe graminis*) and certain rusts - (*Puccinia coronata*, *P. graminis*, *P. triticina*). Tests were made with several formulations: triforine 5 % e.c., 10 % e.c., 20 % e.c.; in comparison with tridemorph 75 % e.c.; chloraniformethane 27,5 % e.c.

All the doses quoted refer to active material.

For field screening we used the logarithmic sprayer (Haefliger, 1965) which is a well known technique for herbicide evaluation. The use of this sprayer was made possible by a very even infection of the cereal crop. Field trial details are as follows:

Plots 20 - 25 m^2; 3 - 4 replicates in latin square or randomized blocks; spraying at stages G - I according to BBA (1964); assessment: 10 and 21 days after treatment (logarithmic trials: only 21 days). All the tests were evaluated for leaf infection and phytotoxicity, using the BBA-code (BBA 1966): 1=0 %; 2=<2,5 %; 3=<5 %; 4=<10 %; 5=<15 %; 6=<25 %; 7=<35 %; 8=<67,5 %; 9=<100 % infected or damaged area of the leaf. The upper 4 leaves of 25 plants were examined for each plot. In addition to yield the 1000-grain-weight and the percentage of seeds over 2,5 mm was measured. The mildew incidence is given as percentage mildew cover on the leaves.

The figures in the tables are averages from several trials, because the number of single tests was too large to report individually. A statistical analysis of all trials in one calculation was not biometrically possible. So we cannot quote any overall significance levels. In these single tests the significant differences for mildew infestation were between 1 and 10 % mildew cover, for yields between 2 and 8 %. And for the seed measurements they were between 1,5-2 %.

RESULTS

1. Greenhouse experiments

(a) Experiments on fungicidal effect

The first tests (Schicke, Veen 1969) with triforine against powdery mildew and rust on cereals were continued. A detailed study of the dependence of efficiency on formulation is reported by Drandarevski (1971). In this paper only the efficacy of triforine against mildew and rusts was discussed. Table 1 shows results of foliar and root treatment against mildew and rust.

Table 1

Efficacy of triforine against mildew and rust after leaf- and root treatment; dose in ppm a.i. needed for 90 % fungicidal effect

Treatment		powdery mildew		rust	
		barley	rye	wheat	oats
foliar	ec 10	15-20	5-10	100	150
spray	ec 20	5-10	1- 5	150	200
root	ec 10		1- 2	50-100	500
treat.	ec 20	0.5-1		40- 50	100-200

In the development of a formulation for outdoor use the washing effect of rain is very important.

In table 2 the results of an experiment with artifical rain are summarized. The behaviour of two formulations of triforine were be examined under rain influence. By dry and humid exposure after application the influence of "time of drying" of the spray film was also studied. (Time of humid setting: 48 h). Measurement was by mildew infestation on rye, ascertained as % of the rained and unrained untreated control.

Table 2

Washing effect of rain on triforine formulations; mildew assessment as % of the rained and unrained control on rye

		without rain								20 mm rain							
		dry				humid				dry				humid			
ppm a.i.		250	64	16	4	250	64	16	4	250	64	16	4	250	64	16	4
Trifo-	ec 10	2	8	13	36	0	6	0	39	0	2	0	35	0	0	0	15
rine	ec 20	0	0	7	40	3	0	0	52	2	3	15	59	0	6	3	72
Tridemorph		0	2	78	94	0	0	121	102	0	38	85	95	0	0	99	83

The results show, that the adherence of triforine formulations is very good; even 20 mm rain do not cause any lost of efficacy.

(b) Crop safety

No leaf damage to cereals occurred in any of the numerous tests including those under glass. Therefore, the assessment of safety for various formulations which is necessarily involved in such a development, was carried out using more sensitive test plants and more unfavourable conditions (moist chamber). The phytotoxicity on beans (Phaseolus) and tomato after treatment with the test formulations between 4000 and 250 ppm and standards were the criteria for judgement of phytotoxicity. All results show excellent plant safety. Comparison of relevant dosages shows that plant tolerance of triforine is 4 times as good as the tolerance of other cereal fungicides.

2. Field experiments using the logarithmic sprayer

The results from 12 logarithmic field trials are combined in table 3. The ED-values show, that there is a considerable dependence of efficacy on the degree of infection present. According to the values determined in 1970 the ratio of the effective dosage "triforine : tridemorph : chloraniformethane" is 1 : 3 : 1. Within the same range we carried out plot tests.

Table 3

Powdery mildew on spring barley, ED_{15}-doses *)
g/ha a.i.; check = % mildew

No of tests	year	Triforine (W 524) EC 5	EC 10	EC 20	Tridemorph	Chloraniformethane	check mildew %
6	68/69	123			420		26
4	69/70		220		540		31
2	1970		280	280	800	250	42

In another logarithmic test against brown rust in spring wheat, an ED_5 *) of 500 g/hectare was apparent for triforine. These findings confirm the results obtained in greenhouse tests, which indicate that doses required to control rust are higher than those to control mildew.

3. Plot tests - treatment of the leaves

(a) Mildew and yield

The results of plot trials with spring- and winter barley, spring- and winter wheat and winter rye, carried out over a period of 3 years, are compiled in tables 4 and 5.

---

*) $ED_{15/5}$ = doses which gives a reduction of the infection to 15/5 % of the leaf area.

Table 4

Powdery mildew on barley and wheat: % mildew cover on the leaves, 1st and 2nd assessment; yields as % of check (=100); no. of tests in brackets; 1969-triforine e.c. 10, 1970/71 e.c. 20

Treatment	rate a.i. g/ha	spring barley									winter barley					
		1969 (5)		1970 (15)		1970 (7)		(7) 1971 (17)			1970 (3)			(4) 1971 (1)		
		mildew	yield	mildew			yield	mildew		yield	mildew		yield	mildew		yield
		2.	%	1.	2.	2.	%	1.	2.	%	1.	2.	%	1.	2.	%
Triforine	70	5	105													
	100	4	101													
	150	4	105	7	10	8	105				8	12				
	200			5	10	8	107	4	8	111	6	10	114	4	7	109
	250			5	10	8	104				5	10	120			
Tridemorph	375	3	105	4	7	5	105				4	6	116			
	562			2	6	4	107	3	5	111	3	4		3	4	112
Chlorani-	138			5	10	8	105				7	8	109			
formethane	206			5	9	6	105				6	7				
Check		12	100	16	22	15	100	28	31	100	25	29	100	13	20	100
yield t/ha			=4.2				=3.0			=3.6			=5.0			=4.8

		winter wheat									spring wheat					
		1969 (1)		1970 (15)		1970 (8)		(3) 1971 (2)			1970 (4)			1971 (2)		
Triforine	100	14	110													
	150	11	100	10	10	10	104				3	3	104			
	200			8	8	10	106	5	36	111	2	2	107	9	1	111
	250			7	8	8	103				2	3	107			
Tridemorph	375	22	106	5	6	6	107				2	2	107			
	562	26	106	3	5			3	20	107	1	2		5	0	112
Chlorani-	138			7	8	8	105				2	2	102			
formethane	206			5	8						2	5				
Check		36	100	16	20	19	100	19	79	100	8	6	100	49	20	100
yield t/ha			=4.6				=3.7			=4.1			=4.1			=4.0

Table 5

Powdery mildew on winter rye: % mildew cover of the leaves; yields as % of check (=100); No. of tests in brackets

	1970 (3)				1971 (2)			
treatment	rate a.i. g/ha	mildew 1.	mildew 2.	yield %	rate a.i. g/ha	mildew 1.	mildew 2.	yield %
Triforine	150	3	5	104				
	200	3	4	111	200	5	4	108
	250	2	3	105				
Tridemorph	375	2	4	107				
	562	1	3		562	5	2	107
Chlorani-formethane	138	3	4	104				
	206	2	4					
Check		10	9	100		15	15	100
yield t/ha				4.2				3.4

These data show that with all three cereals triforine has an effect on mildew which is comparable to that of the standard preparations and which clearly manifests itself in an increase in yield. In spite of the fact that the plots treated with triforine are slightly more infected, the rise in yield is the same as that obtained with the standard preparations.

(b) Rust

It has already been mentioned that in Germany rust of cereals occurs less frequently and not so regularly as mildew. Where rust occurred in the trials it was also assessed. The results are compiled in table 6.

Table 6

Rust on barley, wheat and rye; % rust cover on the leaves

Treatment	rate a.i. g/ha	brownrust						yellowrust	
		w.-barley		spring-barley			w.-wheat		w.-rye
		1969	1970	1969	1970	1970	1970	1969	1970
Triforine	70	24		15					
	100	15		12					
	150	10	16	12	2	18	21	24	15
	200		15		3	16	24		12
	250		13		2	15	20		12
Check		64	34	28	9	18	29	34	24

As can be seen from the data given in table 6, triforine exerts a distinct action on yellow rust and brown rust. This effect, however is comparatively less pronounced than the action against mildew.

(c) Net blotch disease (Helminthosporium teres)

In three tests carried out in 1970, triforine was found to be an effective agent against net blotch disease. From the results given in table 7 it can be seen that under conditions of low infection a reduction in the disease was obtained.

Table 7

Net blotch disease on barley; % disease cover on the leaves

Treatment	rate a.i. g/ha	w.-barley	s.-barley	s.-barley	mean
Triforine	150	1.0	3.6	2.9	2.5
	200	1.2	3.4	2.9	2.5
	250	1.2	3.0	2.3	2.2
Check		5.0	10.0	7.0	7.3

(d) Yield and quality

The prevention of mildew in cereals leads to a better development of the grains, manifesting itself in the 1000-grain-weight and in the percentage of grain retained by a 2,5 mm mesh sieve. With prevention of early mildew attacks an increase in the ear-bearing tillers can also be achieved. Thus, we can say that the economic effect of the control of mildew is manifested in an increased yield and in an improvement of the grain quality. In 31 field experiments, we have found an increase of the percentage of grains > 2,5 mm from 86,7 to 90,3 % (1969), 85,6 to 87,9 (1970) and 84,0 to 87,0 (1971). The 1000-grain-weight increased from 39,2 g to 41,4 g. The germination of the seeds and the protein content were not influenced.

In the three test years triforine, as had been expected, raised quality and percentage of grain over 2,5 mm by a margin of 2,5 - 4%, as was reached in the tests carried out by other autors (Klasen, 1970; Kradel et al., 1969).

4. Seed dressing treatments with triforine

The systemic effect of triforine, found in the greenhouse, justified seed dressing applications against foliar diseases on cereals. An average of 26 field trials showed control of mildew and rust and important yield increases in some cases. The results were nevertheless inconsistent and seed treatment showed low control in several trials. Greenhouse tests subsequently demonstrated, that poor performance can be related to low soil moisture conditions.

5. Miscibility with herbicides; crop tolerance

Mixtures of triforine 20 % e.c., with herbicides (dicamba + CMPP, ioxynil + 2,4-DP, mecoprop, MCPA + 2,4-D, MCPA + 2,4-D + urea) were sprayed without any loss of effectivness or any lasting crop damage. It should also be mentioned that triforine, applied to cereals without any admixture is extremely well tolerated by the plants.

6. Residues and toxicological data

Generally, following treatment of barley plants at stage H (begin of tillering) using 200 g of a.i. per hectare, residues of triforine in grains at harvest were found to be less than 0,01 ppm which is the detection limit of the method of analysis. In some cases, traces of the active ingredient could be found in the grains which, however, did not exceed a value of 0,06 ppm. In view of the low toxicity of the substance evident from 90 day-feeding-studies in dogs and rats, the small residues which occurred in isolated cases, are of negligible significance.

DISCUSSION AND CONCLUSION

Triforine employed as a 20 % e.c. and used at 200 g active substance per hectare, proved to be an effective agent against powdery mildew of cereals and also against rusts and net blotch disease. In winter- and springbarley as well as in winter-and spring wheat and in rye, it gives an increase in yield and quality. Although in the actual control of mildew in cereals triforine is slightly less effective than other preparations, no significant difference was observed with regard to the increase in yield. In our opinion there is a correlation between effect against mildew, excellent plant tolerance and resultant crop yield. In addition the side effects i.e. some control of other infections - rusts and net blotch - also contribute to the increase in yield.

As is shown in the papers by Ost et al. (1971), Fuchs et al. (1971 b) and Ebenebe et al. (1971), triforine is readily absorbed by plants; it is acropetally distributed and has an therapeutic effect. According to Schlüter and Weltzien (1971) the development of the disease in the case of barley mildew is interrupted at the stage of forming haustoria. In the view of Drandarevski (1971), the ability of the active substance to stop a pathogen at such an advanced stage can be regarded as an explanation of the good curative effect which allows the preparation to be administered even after infection.

The strong systemic properties of triforine contribute significantly to its efficacy in the control of important leaf diseases in cereals.

Acknowledgement

The conscientious work of our fieldtestingstaff and the assistence of Mr. S. Arndt in the evaluation of the extensive data is gratefully acknowledged.

REFERENCE

Adlung, K. G., Drandarevski, C. A. (1971), Proc 6th Br. Insectic. Fungic. Conf.

Biol. Bundesanst. Land- u. Forstwirtsch., Berlin-Dahlem (1966)

—, (1964), Merkblatt v. 27. 6. 1964 "Entwicklungsstadien"

Bohnen, K., (1963), Mitt. Biol. Bundesanst. Berlin-Dahlem 108, 125-129

Drandarevski, C. A., (1971), 38. Deutsch. Pflanzenschutz-Tagung, Bln.

Ebenebe, C., Fehrmann, H., Großmann, F. (1971), Plant. Dis. Reptr. 55, (8)

Fuchs, A., Viets-Verweij, M., Vörös, J., & Vries, F. W. de, (1970), Proc. Conf. biochem. ecol. Aspects Plant-Parasite Relations, Budapest, Hungary (to be published).

Fuchs, A., Doma, S., Vörös, J., (1971 a), Neth. J. Pl. Path. 77, 42 - 54

Fuchs, A., Viets-Verweij, M., de Vries, F. W., (1971 b), Phytopath. Z. (in the press)

Haefliger, E., (1965), Z. Pflanzenkh. Pflanzensch., Sonderheft 3, 115 - 122

Klasen, M., (1970), Landw. Z. Rheinland 137, 58

Kradel, J., Pommer, E. H., Effland, H., (1969 a), Meded. Landbouwwetensch. Gent 34, 772 - 778

Kradel, J., Pommer, E. H., Effland, H., (1969 b), Proc. 5th Br. Insectic. Fungic. Conf. 16 - 19

Nover, J., Brückner, F., Wiberg, A., Wolfe, Z., (1968), Z. Pflanzenkrankh. Pflanzensch., 350 - 353

Ost, W., v. Bruchhausen, V., Drandarevski, C. A., (1971), Pestic. Science (in the press)

Plate, D., Fischbeck, G., (1969), Z. Pflanzenzüchtg. 61, 225 - 231

Schicke, P., Veen, K. H., (1969), Proc. 5th Br. Insectic. Fungic. Conf., Brighton, 569 - 575

Schicke, P., Arndt, S., (1971), 23^e^ Intern. Symp. Fytofarm. Fytiatrie, Gent (in the press)

Schlüter, K., Weltzien, H. C., (1971), 23^e^ Intern. Symp. Fytofarm. Fytiatrie, Gent (in the press)

Proc. 6th Insectic. Fungic. Conference (1971)

THE COMPARISON OF YIELDS OF SOME SPRING BARLEY VARIETIES IN THE PRESENCE OF MILDEW AND WHEN TREATED WITH A FUNGICIDE

R. Little and J.K. Doodson
N.I.A.B. Huntingdon Road, Cambridge.

Summary. The yields of eight spring barley varieties at eight sites were assessed in the presence and absence of mildew by the use of a mildew fungicide.

The ranking of all varieties on the mean yields did not significantly alter in the absence of mildew. This suggests that the NIAB yield rankings are representative of a wide range of conditions including the presence and absence of mildew. The control of mildew on only the very susceptible varieties would nevertheless improve their position in the ranking order.

The moderately resistant varieties Julia and Vada (also resistant to brown rust) gave significant increases in the absence of mildew and were the highest yielding varieties, probably because brown rust infections decreased the yields of the other varieties. The major gene resistant variety (Feronia) gave no response. At sites where high levels of mildew were recorded the most susceptible varieties Golden Promise, Proctor, Zephyr and Sultan gave the largest increases in yield. Where mildew levels were lower the incidence of brown rust was a complicating factor. In some cases the treated plots of brown rust susceptible varieties tended to be more severely infected than the untreated.

INTRODUCTION

The recent development of semi-systemic fungicides for the control of barley powdery mildew (*Erysiphe graminis f. sp. hordei*) has made possible the simultaneous assessment of yields in the presence and absence (or at least near absence) of mildew. Under field conditions different varieties become infected to different extents (NIAB Farmers' Leaflet No. 8, 1971). Yield data in the absence of mildew would be of considerable interest and would indicate those varieties which are likely to respond most to fungicide treatment.

In 1969 and 1970 seed of sixteen spring varieties was dressed with ethirimol and a single plot of each variety was planted in random order adjacent to unrandomised, untreated demonstration plots at fourteen NIAB Regional Trial Centres (Doodson and Saunders, 1969). Further control of mildew on the treated plots was obtained by applying more ethirimol as a foliar spray if and when required. Yield data and mildew levels were extremely variable and due to lack of replication there were no significant differences in yield between treated and untreated plots for any of the varieties.

In 1971 fully replicated trials were carried out and the number of varieties and sites were considerably reduced to bring the programme to manageable proportions. The trials were intended to measure the yields of spring barley varieties in the absence of mildew or at least at very low levels of mildew and not the efficiency of the fungicide.

METHODS AND MATERIALS

Seed of eight spring barley varieties was treated with three times the normally recommended dose of ethirimol, ie. 0.75 lb/bushel (13.4g/kg). The eight varieties were the five varieties recommended for general use on the NIAB Farmers' Leaflet No. 8 (1971), ie. Sultan, Julia, Zephyr, Vada and Proctor, as well as Midas which is provisionally recommended. Also included were Feronia with major gene resistance to the mildew races in the U.K. and Golden Promise which is very susceptible.

These eight varieties were planted in a factorial trial of two (treated and untreated) x eight (varieties) in four replications at nine sites viz. Cambridge, Harper Adams (Shropshire), Morley (Norfolk), Rosemaund (Hereford), Seale-Hayne (Devon), Sparsholt (Hants.), Sutton Bonington (Leics.), Terrington (Norfolk) and Wye (Kent). The seed was drilled at approximately 140lb/acre (157kg/ha) in plots of approximately 1/100 acre (1/250 ha) at Cambridge and Sparsholt and of approximately 1/50 acre (1/125 ha) at all other sites.

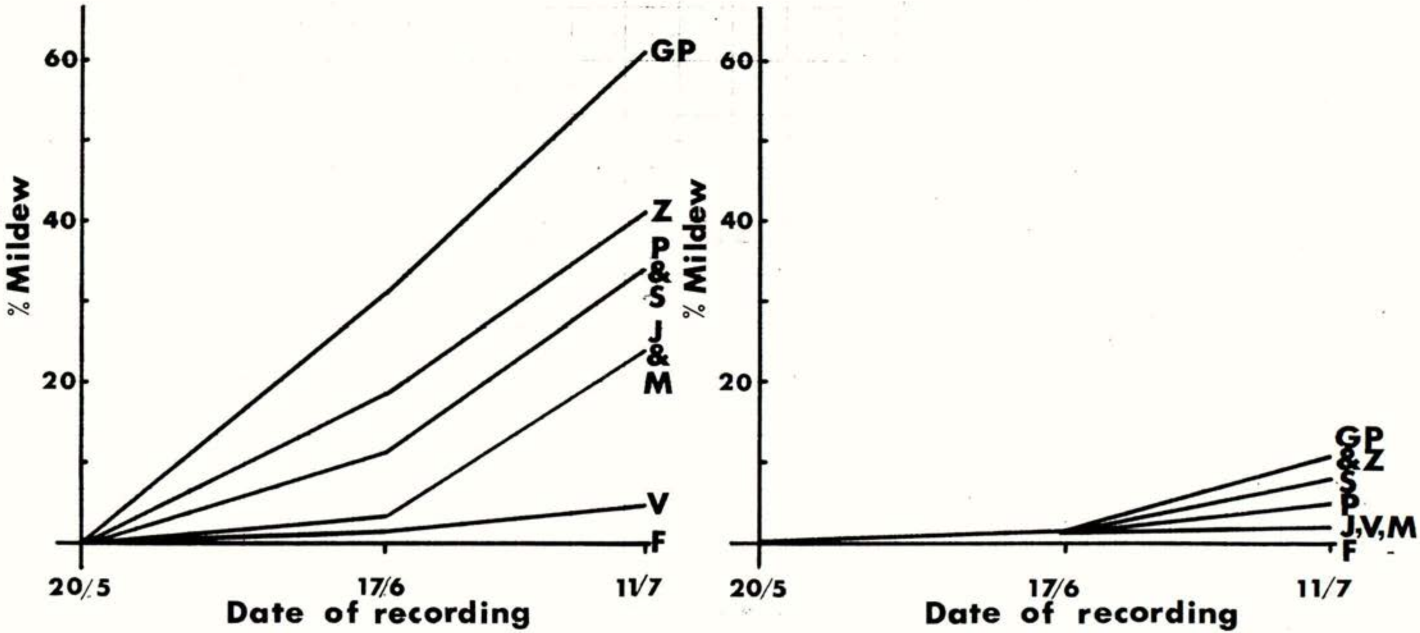
Records of mildew and brown rust (Puccinia hordei) infections were kept throughout the season on both the treated and untreated plots. At Rosemaund and Sutton Bonington further mildew control was required and the plots were sprayed with tridemorph at ½ pt/acre (560 ml/ha) at approximately growth stage 9 (Large, 1954). At the other sites except Cambridge and Harper Adams, no further control was necessary. Lodging at Cambridge and Harper Adams made further control by spraying impracticable and low levels of mildew developed on the treated plots at these sites. All trials were harvested with a combine harvester and yield measured as weight of grain per plot at 15% moisture content. The trial at Seale-Hayne suffered from drought and was heavily infected with barley yellow dwarf virus (BYDV). Data from this trial has therefore been omitted from the results presented here.

RESULTS

Progress of the mildew epidemic in treated and untreated plots - Harper Adams

Since no additional control of mildew was possible at Harper Adams this trial provided the opportunity of comparing the development of the mildew epidemic in treated and untreated plots. (At Cambridge mildew levels declined due to unfavourable weather conditions). The level of mildew on the untreated plots for all varieties except Feronia was approximately one fifth of that in the untreated plots when recorded at growth stage 10.5.4. (Fig. 1). The varieties rank on their susceptibility to mildew in virtually the same order in the treated and untreated plots and this order is that to be expected from the figures given for mildew resistance in the NIAB Farmers' Leaflet No. 8 (1971). The treatment (at three times the recommended rate) contained the mildew level below 5% on Golden Promise (the most susceptible variety) for about fifteen weeks from planting and the level finally increased to only 12%. It was also interesting to note that mildew appeared first in Golden Promise followed by Zephyr, Proctor and Sultan; then in the more resistant varieties Midas and Julia and finally in Vada.

Fig 1 Progress of mildew epidemic in plots of eight spring barley varieties with and without treatment with ethirimol (Harper Adams, 1971)



Variety Key:

GP - Golden Promise
Z - Zephyr
P - Proctor
S - Sultan
J - Julia
M - Midas
V - Vada
F - Feronia

Yield data - all centres. Table 1 summarises the significant differences in yield for variety (mean of treated and untreated), treatment (mean of all varieties), treatment within variety and treatment x variety interactions at each centre together with the mildew (on untreated plots) and brown rust levels at these centres. Significant treatment x variety interactions occurred at those sites where mildew levels were high or moderate and were absent from those sites where mildew levels were low, ie. at high levels of mildew infection varieties tended to react differently to the treatment whereas at low levels of mildew they reacted similarly. The effect of the treatment (meaned over all varieties) was significant at only four centres and it bore no particular relationship to mildew levels but more to low or medium levels of brown rust infection except at one centre (Morley). Conversely at three of the four centres where there were no significant treatment differences there were high brown rust levels and there was a tendency for the ethirimol treated plots to be infected with brown rust to a greater extent than the untreated plots thus eroding any yield advantage obtained by mildew control. At the remaining centre (Sparsholt) where there was no significant treatment effect both brown rust and mildew infection levels were low.

Table 1

Analysis of yield increases obtained by mildew control at each site and the disease levels

Site	Coeff. of Var.	Variety	Treat-ment	Treatment within Variety	Treatment *Var. Interact.	Mildew	Brown Rust
Cambridge	7.01	***	NS	*	**	Mod.	High
Harper Adams	5.10	***	*	*	*	High	Mod.
Morley	4.25	***	*	*	*	Mod.	High
Rosemaund	3.30	***	NS	*	***	High	High
Sparsholt	6.07	***	NS	NS	NS	Low	Low
Sutton Bonington	4.13	***	**	**	**	High	Low
Terrington	6.60	***	NS	*	NS	Low	High
Wye	4.92	***	*	*	NS	Low	Mod.

*** Significant at 0.1% probability   * Significant at 5% probability
** Significant at 1% probability   NS Not significant

Effect of treatment on varieties. There were significant differences caused by the treatment within varieties at all sites except Sparsholt. Different varieties have responded differently at different sites. Golden Promise, Zephyr and Vada gave yield increases at five sites, Julia at four sites, Proctor and Sultan at three sites, Midas at one site and Feronia at none.

The largest and most frequent yield responses occurred at Harper Adams, Rosemaund and Sutton Bonington where mildew levels were high. The percentage increase in yield of the treated plots over the untreated for each variety is given in Table 2 for these three sites together with the means over all nine sites. The highest individual yield increases were at Sutton Bonington (Zephyr, 23.5%) and at Rosemaund (Golden Promise and Proctor, 20.3%).

Table 2

Percentage increase in yield of eight spring barley varieties with almost complete mildew control at three sites where mildew infection was high in the untreated plots

	Sites with severe mildew				
	Harper Adams	Rosemaund	Sutton Bonington	Mean of 8 sites	Estimated increase ≠
Sultan	13.9*	19.7*	19.7**	5.2	14.2
Julia	16.2*	16.0*	12.4*	7.1	7.0
Zephyr	15.9*	9.9	23.5**	9.8	13.8
Vada	14.7*	6.4	9.4*	8.3	5.2
Proctor	13.4*	20.3*	12.1*	6.8	15.6
Midas	-0.7	10.2	9.1*	3.3	11.1
Golden Promise	17.4*	20.3*	17.1**	14.2	18.9
Feronia	6.1	1.9	-0.5	1.1	0
Sig. diff. over untreated	12.5	14.5	8.0		
S.E.	±3.5	±3.6	±2.5		
Coeff. of Var.	5.10	3.80	4.13		

≠ based on Large & Doling (1962) formula. Loss = 2.5 x $\sqrt{\text{mildew}}$

DISCUSSION

The varieties can be classified into four groups on their reaction to mildew and brown rust. Their response to mildew control is strongly related to these factors. The groups are:-

1. Very resistant to mildew, very susceptible to brown rust - Feronia.

2. Moderately resistant to mildew, very susceptible to brown rust - Midas.

3. Moderately resistant to both mildew and brown rust - Julia and Vada.

4. Susceptible to both mildew and brown rust - Golden Promise, Zephyr, Proctor and Sultan.

1. Feronia gave no response to treatment. This was to be expected of a variety with a major gene giving resistance to the mildew races in the U.K.

2. Midas was heavily attacked by brown rust and even in the treated plots yielded seventh of the eight varieties when meaned over all nine centres. At three centres (Harper Adams, Morley and Sparsholt) the treated plots of Midas were infected to a greater extent by brown rust than the untreated plots which would tend to counteract the effect of mildew control. Only at one centre where mildew levels were high and brown rust levels low (Sutton Bonington) did Midas respond to mildew control. It is obvious that care must be taken, in the selection of varieties most likely to respond to fungicide treatment, to exclude those varieties very susceptible to other diseases.

3. Julia and Vada both gave yield increases with treatment; Julia at four sites (maximum 16.2%) and Vada at five sites (maximum 17.4%). Since these varieties are more mildew resistant than the others one might expect less response but in a year such as 1971 they have the added advantage of brown rust resistance. From calculations of yield losses using the formula of Large and Doling (1962) predicted yield increases can be calculated and are shown in Table 2. Julia responds as predicted (cf. Doodson & Saunders, 1969 where a much greater response than predicted was found for Julia), but Vada has responded rather better than expected but probably not significantly so. It is interesting to note that all other varieties (except Feronia) have responded less well than predicted since losses from brown rust have not been taken into consideration.

4. Golden Promise, Zephyr, Proctor and Sultan are susceptible to mildew and have given the largest yield increases at some sites. Golden Promise and Zephyr have responded particularly well but results with Sultan were inconsistent; three sites gave significant increases, four sites gave no increase and one site, Cambridge, gave a significant decrease in yield. The decrease at Cambridge can be attributed to the fact that brown rust infection on the treated plots was double that on the untreated plots. Proctor responded considerably less than might be expected from its mildew susceptibility (Table 2). However, the three sites at which it did respond were those with the highest mildew levels.

Ranking of the varieties on yield in the presence and absence of mildew

Treatment x variety interactions were significant at the five sites where mildew levels were high or moderate. At these five sites Golden Promise increased its ranking most, followed closely by Julia and then Zephyr and Proctor. Midas and Feronia showing virtually no response fell in rank.

The ranking of the varieties on mean yields over all eight sites on treated and untreated plots is shown in Table 3.

Table 3

Mean yield over eight sites of eight spring barley varieties and their ranking on yield in the presence and absence of mildew

Correction: The headings to columns (Treated and untreated) should be reversed

	Mean Yields			Rank		
	Treated †	Untreated †	% Increase	Treated	Untreated	Change
Sultan	100.4	105.6	5.2	5	6	-1
Julia	118.0	125.1	7.1	2	2	0
Zephyr	107.9	117.7	9.8	4	3	+1
Vada	120.1	128.4	8.3	1	1	0
Proctor	100.0	106.8	6.8	6	5	+1
Midas	98.9	102.2	3.3	7	8	-1
Golden Promise	89.0	103.2	14.2	8	7	+1
Feronia	110.1	111.2	1.1	3	4	-1

† expressed as % Proctor (untreated)

The treatment has no significant effect on the order of the ranking. This means that with almost complete mildew control of all varieties the ranking does not significantly change. If these sites are representative of the whole country such use of mildew fungicides would not significantly alter the ranking of the varieties on the NIAB Farmers' Leaflet No. 8. The yield data going into these leaflets is a mean of results under very varied conditions eg. high and low mildew infections and one would not expect that by controlling mildew this mean yield figure would be greatly influenced. However farmers are likely to treat only those varieties mostly likely to respond to fungicide treatment. Golden Promise, Zephyr and Proctor are likely to show the most response if a high degree of mildew control is obtained from mildew fungicide treatment.

Acknowledgements

The authors wish to thank Dr D Brooks for treating the seed with ethirimol, the Regional Trials Officers and the Cereals Section at Cambridge for carrying out the trials and Miss M H Tonkin for statistical analyses.

References

DOODSON J K and SAUNDERS P J W (1969). Observations on the effects of some systemic chemicals applied to cereals in trials at NIAB. Proc. 5th Br. Insectic. Fungic. Conf. 1969 1; 1-7.

FARMERS' LEAFLET No. 8 (1971). Recommended varieties of cereals, NIAB, Cambridge.

LARGE E C (1954). Growth stages in cereals. Pl. Path. 3; 128-129.

LARGE E C and DOLING D A (1962). The measurement of cereal mildew and its effect on yield. Pl. Path. 11, 47-57.

Proc. 6th Br. Insectic. Fungic. Conf. (1971)

EFFECT OF FUNGICIDES ON INOCULUM POTENTIAL OF APPLE CANKER DISEASE (NECTRIA GALLIGENA)

Margery Bennett
East Malling Research Station, Maidstone, Kent

Summary Fungicides were tested as high-volume sprays on cankers of Nectria galligena on stems of young c.v. Cox's Orange Pippin. When benomyl (0.025% a.i.) and captan (0.1% a.i.) were applied at 14-day intervals throughout summer 1970, captan had a continuous effect on spore germination and benomyl markedly suppressed spore production. When phenylmercuric chloride (0.006% Hg), a proprietary wettable Bordeaux (0.188% Cu), benomyl (0.05% a.i. and 0.25% a.i.), pyridinitril (0.05% a.i.) and thiabendazole (0.1% a.i.) were applied twice at 30-day intervals in autumn 1970, benomyl, mercury and copper suppressed sporulation but viability of spores was diminished only by mercury and copper.

INTRODUCTION

Apple canker disease (Nectria galligena) can be controlled by copper or mercury fungicides but these can be used only as post-harvest applications (Moore and Bennett, 1960; Byrde et al, 1965); however, abundant inoculum and many infection sites are present before such fungicides can be applied (Burmeister and Kennel, 1967; Bennett, 1971). Young cankers that have developed from infections occurring the previous autumn produce many conidia during the late summer months. Wet, windy weather during August and September promotes infection of prematurely exposed leaf scars several weeks before the application of the post-harvest sprays. Either copper or mercury sprays applied in the autumn diminish the production of conidia, and this effect was sought in fungicides suitable for application before harvest.

In autumn 1969 preliminary tests were made on young cankers producing abundant conidia. Although variation in sporulation between cankers was found to be high, results from cankers treated with captan, benomyl, pyridinitril and thiabendazole were sufficient to justify further investigation.

METHOD AND MATERIALS

Single spore cultures of Nectria galligena were grown from ascospores and conidia collected in the field and maintained on PDA and V8 agar media. One and two-year old stems of cv. Cox's Orange Pippin were inoculated in bark wounds with mycelium on agar discs, using two isolates in each wound. Inoculations (Marsh, 1939) were successful in March, April and July 1970. Sprays were applied from a Shandon Laboratory spray gun, wetting thoroughly the surface of the cankers and surrounding bark. To obtain samples of spores, 5 or 10 ml sterile distilled water was sprayed onto cankers and the run-off collected on 1 in polythene tape encircling the stem and led into a glass boiling tube (Corke, 1958). Spore-concentrations were determined on a haemocytometer (Mod-Fuchs Rosenthal), and viability assessed by germination of spores streaked on a slide in a damp petri-dish held at room temperature for 24 hours.

Summer application trial

A comparison was made between ten fortnightly sprays of (a) captan (75% w.p.) at 0.1% a.i. or (b) benomyl (50% w.p.) at 0.025% a.i., (c) five sprays at four-week intervals of benomyl at 0.025% a.i. and (d) no sprays. The first spray was applied on 7th May 1970 and the last on 11th September and 27th August, respectively. There were five replicates of each treatment.

Autumn application trial

Two sprays were applied on 15th September 1970 and 14th October 1970, with four replications each of the following treatments:-

1. Unsprayed controls
2. Standard control, phenylmercuric chloride (40% w.p.) at 0.01% PMC (0.006% Hg)
3. A proprietary wettable Bordeax (15% Cu) at 0.188% Cu, i.e. $\frac{3}{4}$ normal rate
4. Benomyl (50% w.p.) at 0.05% a.i.
5. Benomyl (50% w.p.) at 0.025% a.i.
6. Pyridinitril (75% w.p.) at 0.05% a.i.
7. Thiabendazole (75% w.p.) at 0.1% a.i.

RESULTS

Summer application (1970)

During the period when the sprays were applied at 14-day intervals, there was a marked reduction in viable spores from cankers receiving either captan or benomyl. The effect of 0.025% benomyl sprays every 14 days was so pronounced that analysis of variance was carried out on the other three treatments only. Results from two samples taken on 12th August and 21st September showed that both 0.1% captan at 14-day and 0.025% benomyl at 28-day intervals reduced the numbers of viable spores compared with unsprayed ($P<0.001$) (Table 1). This was achieved primarily by a reduction in spore germination with 0.1% captan sprays ($P<0.01$) and by a reduction in total spores with the 0.025% benomyl spray ($P<0.01$). Numbers of viable spores increased more rapidly following the captan sprays than after the benomyl sprays.

Autumn applications (1970)

In the few days following the first spray all the fungicides had reduced spore viability, but this effect was persistent only with the copper and mercury sprays. Comparison with control samples at 3 weeks after applying the first spray and again after the second showed that there was substantial reduction ($P<0.001$) in number of viable spores collected from the cankers receiving 0.01% PMC (0.006% Hg) and 0.188% Cu sprays. Cankers receiving benomyl at 0.05% or 0.025% yielded fewer viable spores following the first spray ($P<0.01$) and even less following the second spray ($P<0.001$) compared with the unsprayed controls (Table 2).

DISCUSSION

The technique employed in this work appears to be satisfactory for testing the inoculum potential for infection with conidia of apple canker. A fungicide reducing the concentration of viable spores below that necessary for 10% leaf scar infection, i.e. c 2000 spores/ml (Bennett, 1971) should be effective in field control. The results from the tests with a proprietary wettable Bordeaux and PMC support this. However, protective action, which is not tested in this technique, will improve the performance of fungicides in the field.

In the tests reported, captan 0.1% a.i. and benomyl 0.025% a.i. pyridinitril 0.05% a.i. and thiabendazole 0.1% a.i. all reduced numbers of viable spores immediately after application but the effects of pyridinitril and thiabendazole did not persist beyond a few days. As Byrde (1970) found a marked reduction in leaf scar infections with pyridinitril 0.035% a.i. its action may be chiefly protective.

Fortnightly applications of captan 0.1% a.i. during the dry summer of 1970 resulted in very low viability of spores for two weeks after each spray, whereas benomyl 0.025% a.i. had no such effect but showed a high degree of spore suppression. On cankers sporulating well at the first spray application, in the autumn trial in 1970, reduction in sporulation by benomyl was possibly insufficient to lower inoculum concentration enough to prevent leaf scar infection. A second spray at least appears to be necessary. This interpretation of the results may be incorrect, however, and benomyl may have a delayed action on spore production.

Sprays of 0.006% mercury and 0.188% copper reduced both numbers of spores and germination, the effect of the former being more persistent especially on viability. In a previous trial, 0.006% mercury sprays gave better control of apple canker than copper sprays of 0.25% in the autumn and 0.125% in the spring (Bennett, 1971), but the copper sprays were slightly more effective as antisporulants. Hislop (1969) found that some fungicides are redistributed better than others, thus affecting field control. In the current tests the sprays were applied to the cankers and adjacent areas, giving little chance of redistribution.

Examination of other fungicides in current use in the apple spray programme might prove profitable; reduction of inoculum at any period during a wet season would reduce infection without any increase in cost; however, the tests for spore production potential must continue into the autumn when the majority of leaf scars are vulnerable, as a reduction at one stage may be compensated by an increase later.

References

Bennett, Margery. (1971) Comparison of a copper and a mercury spray programme against apple canker disease (Nectria galligena Bres.). Pl. Path., 20, 99-105.

Burmeister, Von P. and Kennel, W. (1967) Infektionsversuche mit Nectria galligena, Gloeosporium perennans und G. album an Fruchtansatzstellen des Rels in Verbinduna mit chemischen Bekampfungsversuchen. Z. PflKrank., 74, 615-626.

Byrde, R.J.W., Evans, S.G. and Rennis, R.W. (1965) The control of apple canker disease in two Somerset orchards by a copper-spray programme. Pl. Path., 14, 143-149.

Byrde, R.J.W. and Slowley, Celia. (1970) Reseach Report. Rep. Long Ashton Res. Stn for 1969, 102.

Corke, A.T.K. (1958) A trap for water-borne spores. Pl. Path., 7, 56.

Hislop, E.C. (1969) Splash dispersal of fungicides and fungus spores. Ann. appl. Biol., 63, 71-80.

Marsh, R.W. (1939) Observation on apple canker. II. Experiments on the incidence and control of shoot infections. Ann. appl. Biol., 26, 458-469.

Moore, M.H. and Bennett, Margery. (1960) Experiments on the control of apple canker by spraying. Rep. E. Malling Res. Stn for 1959, 85-91.

Table 1

Effect of summer fungicide applications † on spore production
Nectria galligena

Treatments	12 August Spores/ml	12 August % germination	12 August Viable spores/ml	21 September Spores/ml	21 September % germination	21 September Viable spores/ml
1) Unsprayed	308.2	59.5	261.8	210.5	53.4	165.4
2) 0.1% captan every 14 days	194.6	8.5	28.5	119.5	8.8	28.2
3) 0.025% benomyl every 14 days	16.6	84.3	16.6	4.7	45.0	1.0
4) 0.025% benomyl every 28 days	85.7	48.7	57.5	48.4	48.6	32.7
S.E. (for 1, 2 and 4)	±36.45	±7.17	±24.31	±28.29	±5.40	±18.42

† Dates of spraying:-
14-day intervals - 7, 20 May, 4, 18 June, 1, 16, 28 July, 13, 27 August, 11 September.
28-day intervals - 7 May, 4 June, 1, 28 July, 27 August.

Treatments were compared by analysis of variance using a square root transformation for nos. spores/ml and an angular transformation for % germination. Figures shown are the transformed data. Because of low spore numbers treatment 3 was not included in the analysis.

Table 2

Effect of fungicides† on short-term sporulation of *Nectria galligena*

Treatments	Sample 6-7 October (3 weeks after first spray)			Sample 3-4 November (3 weeks after second spray)		
	Spores/ml	% germination	Viable Spores/ml	Spores/ml	% germination	Viable spores/ml
Control unsprayed	350.6	56.6	285.8	285.9	50.0	215.9
0.006% Hg	49.7	33.3	28.3	20.3	14.3	7.9
0.188% Cu	107.4	33.4	61.8	47.3	51.1	34.4
0.05% benomyl	146.6	60.2	125.5	24.6	65.2	30.0
0.025% benomyl	115.1	62.4	103.8	44.0	41.2	35.0
0.05% pyridinitril	327.3	71.0	309.9	346.9	58.7	291.7
0.1% thiabendazole	269.2	48.1	201.7	240.0	48.9	180.6
S.E.	±37.03	±5.11	±35.25	±35.19	±7.75	±28.27

† Dates of spraying:- 15 September and 14 October, 1970.

Treatments were compared by analysis of variance using a square root transformation for nos. spores/ml and an angular transformation of % germination. Figures shown are the transformed data.

Proc. 5th Br. Insectic. Fungic. Conf. (1971)

THE CONTROL OF POWDERY MILDEW, CANKER AND OTHER DISEASES OF APPLE WITH BENOMYL

W.S. Catling
Du Pont Co. (U.K.) Ltd.

Summary Benomyl (Benlate*) at 8 oz a.i./ac (0.55 kg/ha) applied at 14-day intervals from bud-burst until the cessation of extension growth has controlled several apple diseases. The chemical reduced infection by powdery mildew of leaves and buds and apparently eradicated primary infections. Apple scab has been controlled particularly on the fruit, and on dessert varieties an extended 21-day schedule was adequate. The scab/mildew programme suppresses sporulation of *Nectria* and *Gloeosporium* and reduces the spread of cankers. Storage rots have been reduced but additional late-season sprays have been shown to improve control.

INTRODUCTION

Since initial field tests in the United States in 1966 (Delp & Klopping, 1968) and preliminary trials in the United Kingdom in 1967 (Catling, 1969) many trials have been carried out to demonstrate the activity of benomyl against powdery mildew (*Podosphaera leucotricha*), apple scab (*Venturia inaequalis*), bitter rot (*Gloeosporium* spp.), canker (*Nectria galligena*) and blossom wilt (*Sclerotinia laxa f. mali*).

METHOD and MATERIALS

Throughout the trials and commercial usage a wettable powder containing 50% benomyl has been used.

In small scale trials using lance application and in high volume commercial applications (over 200 gal/ac) the material has usually been applied at 4 oz a.i. per 100 gal(25 g/100l). In the low-volume applications (20 gal - 200 gal/ac) the material has been applied at 8 oz a.i./ac (0.55 kg/ha). A non-ionic wetting agent was added to the pre-blossom applications.

Sprays were usually applied at 14-day intervals, but some trials have been carried out with shorter intervals for powdery mildew control and longer intervals for apple scab control.

In all trials spraying commenced at bud-burst and continued until the cessation of extension growth, usually in mid-July. In the storage rot trials, sprays were applied in late summer (August, September).

*"Benlate" is the Trademark of E.I. du Pont de Nemours & Co. (Inc.)

RESULTS

Powdery Mildew

In trials carried out in the United Kingdom in 1968 and 1969 (Catling, 1969, Evans 'et al' 1971) 8 oz a.i./ac (0.55 kg/ha) or 4 oz a.i./100 gal (25 gm/100l) of benomyl on a 14-day schedule starting at bud-burst was shown to give generally better control of secondary mildew than standard protectants and to have some effect on primary mildew. Subsequent information (Fung. & Nem. tests 1969, Fung. & Nem. tests 1970) has confirmed the effectiveness of benomyl at the 0.025% a.i. rate.

In 1970 both replicated and grower applied trials were carried out on dessert orchards to examine the effect of benomyl applied at different rates and time intervals on the control of powdery mildew. In addition full commercial applications were made by growers.

The results from the replicated trials are shown in Table 1.

Table 1

The effect of benomyl on the control of powdery mildew - 1970 trials

Treatment	Rate oz a.i./ac (kg/ha)	Spray Interval in days	% Diseased Leaves Hereford	Suffolk	Essex	Notts.	Notts.	Cambs
benomyl	4(0.28)	14	9.2	20.8	12.8	-	-	-
benomyl	6(0.42)	14	10.4	13.5	8.2	20.0	52.6	28.6
benomyl	8(0.55)	14	5.4	10.5	10.8	19.8	32.0	27.6
benomyl	8(0.55)	28	10.2	17.8	18.4	-	50.0	41.3
binapacryl	16(1.1)	14	12.4	9.2	6.0	30.6	39.3	41.0
dinocap	8(0.55)	14	10.8	8.2	7.0	-	51.3	-
Untreated	-	-	18.6	25.0	13.0	49.3	80.0	48.0

The results of these trials show 8 oz a.i./ac (0.55 kg/ha) benomyl to be as effective as binapacryl and dinocap in controlling secondary mildew. Control was not good where benomyl was applied on a 28-day schedule.

In grower applied trials on 15 sites, early season secondary mildew assessments (June/July) indicated that the low rate of 6 oz a.i./ac (0.42 kg/ha) of benomyl applied every 14 days reduced the level of control. Assessments in August/September however showed the difference between the 6 oz a.i. and the 8 oz a.i./ac (0.42 and 0.55 kg/ha) to be less marked. In these trials benomyl at 8 oz a.i./ac (0.55 kg/ha) applied every 14 days was equivalent to the standard treatments. In some trials a reduced rate of benomyl at 4 oz a.i./ac (0.28 kg/ha) was applied at 7-day intervals and this resulted in an improvement in disease control. In all the trials benomyl appeared to suppress sporulation of primary mildew on blossom trusses and vegetative shoots.

Nine out of the fifteen grower applied trial sites that had received benomyl at 8 oz a.i./ac (0.55 kg/ha) in 1969 were treated during 1970 at a similar rate and time interval starting at bud-burst. Plots receiving the standard treatments of binapacryl or dinocap were also sprayed in 1969 and 1970. The incidence of primary and secondary mildew is shown in Table 2.

Table 2

The incidence of primary and secondary mildew - 1969/70 trials

Site	Fruit bud		Vegetative bud		Secondary mildew	
	Benomyl	Standard	Benomyl	Standard	Benomyl	Standard
Cambs.	2.3	12.5	3.9	13.0	8.6	20.1
Essex	2.5	4.8	2.2	4.2	2.8	12.4
Essex	1.4	7.4	1.2	8.7	1.4	7.2
Kent	1.4	2.7	2.7	3.6	2.0	1.8
Kent	0.7	1.9	2.2	5.2	4.1	4.5
Glos.	1.2	7.2	5.5	14.7	27.1	56.6
Hereford	0.3	1.2	0.9	0.8	17.2	24.4
Suffolk	0.6	2.2	2.3	4.6	11.7	8.8
Suffolk	2.4	3.8	2.4	3.8	8.9	11.7

It was apparent in the first year of treatment (1969), benomyl had some effect on the development of primary infections. The most marked effect is seen however in the extent of primary mildew infection developing on trees sprayed for the two years with benomyl, in that it reduced both fruit and vegetative bud infection, and later when combined with further benomyl sprays resulted in a high standard of secondary mildew control.

In 1970, benomyl was used commercially in many dessert orchards for the first time on a limited acreage. It was applied at 8 oz a.i./ac (0.55 kg/ha) on a 14-day schedule from bud-burst with a non-ionic wetting agent added to the spray tank for pre-blossom applications. The control of secondary mildew achieved was variable. In orchards in dry areas and free-draining soils, control was generally poor as compared with the standard protectants which, in many cases, were being applied on a 7-day schedule. In orchards in the less dry areas and on the more moisture retaining soils however the control of secondary mildew was satisfactory. It was also observed that where orchards were receiving irrigation, control was also good.

In 1971, seven grower applied trials were carried out in which the standard 8 oz a.i./ac (0.55 kg/ha) applied every 14 days was compared with 8 oz and 4 oz a.i./ac (0.55 and 0.28 kg/ha) applied every 7 days. In some cases a standard protectant (dinocap or binapacryl) was also included in the comparison.

The benomyl treatments were as effective or superior to the standard protectants in both primary and secondary mildew control. The reduced interval 7-day application only marginally improved mildew control and little difference could be detected between the 8 oz and 4 oz a.i./ac rates.

Commercial use during 1971 with the 8 oz a.i./ac (0.55 kg/ha) 14-day schedule from bud-burst has resulted in good powdery mildew control with an ameliorating effect in primary infections.

Apple Scab

The trials carried out in the United Kingdom in 1968 and 1969 (Catling, 1969, Evans 'et al' 1971) indicated that benomyl at either 8 oz a.i./ac (0.55 kg/ha) or 4 oz a.i./ac (25 gm/100l) applied at 14-day intervals from bud-burst was achieving good control of scab in both dessert and culinary varieties. Effective control was also obtained when the interval was extended to 28 days. Comprehensive further work (Fung. & Nem. tests 1969, Fung. & Nem. tests 1970) has confirmed the high activity of benomyl against scab and has demonstrated the promise of extended schedule spraying.

In 1970 both replicated and grower applied trials were carried out in England and Northern Ireland to investigate the efficiency of extended schedule spraying on the culinary variety Bramley's Seedlings. The incidence of scab was low in 1970 but at those sites where the disease developed the 14 and 21-day schedules gave excellent control. When applied at 28-day intervals benomyl although giving control comparable to a standard protectant of either dithianon or dodine acetate programme was not as effective as the shorter interval programmes.

Further trials in 1971 on Bramley's Seedling in which 21-day schedules were compared with 14-day schedules indicated that in areas where scab infection was severe a 21-day schedule was insufficient to control the disease. The 14-day schedule however remained effective especially on the fruit.

In dessert orchards grower experience using a 14-day schedule at 8 oz a.i./ac (0.55 kg/ha) was that in 1970 and 1971 excellent control of both leaf and fruit infections was obtained.

Bitter Rot

In the 1968 apple trials some control of Gloeosporium spp. rots was achieved by the scab/mildew summer programme of benomyl (Catling, 1969). This result was confirmed in trials at Long Ashton where Gloeosporium spp. and other storage rots were reduced from 31.8% on trees receiving a summer captan/binapacryl programme to 9.3% on trees sprayed with benomyl (Long Ashton, 1970).

The spore suppressant activity of benomyl against Gloeosporium perennans was demonstrated by Corke on a trial at Long Ashton in which 1.0% a.i. applied at the end of March to cankers effectively reduced spore production (Long Ashton, 1969). This result was confirmed in 1970 and it was also shown that the rate of canker development was reduced (Long Ashton, 1970).

Protective spraying on Cox and Sunset at East Malling in July, August and September with benomyl at 0.025% a.i. gave promising control of Gloeosporium spp. (East Malling, 1970).

In 1969 a number of replicated trials on Cox were carried out to investigate the activity of benomyl against Gloeosporium spp. storage rots. One (Sept.) two (Sept. Sept.) and three (Aug. Sept. Sept.) late benomyl [8 oz a.i./ac (0.55 gm/ha)] sprays were compared with three captan (Aug. Sept. Sept.) [39 oz a.i./ac(2.68 gm/ha)] sprays following benomyl and captan/dinocap summer programmes. In one of these trials a 17.2% loss was reduced to 7.2% following 3 late captan sprays and 0.4% following 3 late benomyl sprays; this trial was treated with captan/dinocap during the summer for scab/mildew control. In another trial both 3 and 2 late sprays of benomyl were superior to 3 late sprays of captan in controlling storage rots; there was an indication that the summer programme of benomyl was reducing the number of storage rots.

Grower experience in 1970 with two late sprays of benomyl at 8 oz a.i./ac (0.55 kg/ha) added to a summer programme of benomyl for scab/mildew control or alternatively three late sprays to a summer programme of standard protectants effectively reduced losses from storage rots.

Trials with a 0.05% a.i. post-harvest dip following experiment by Edney (East Malling, 1969) with a 0.03% a.i. dip have indicated that late infections of Gloeosporium spp. may be controlled by this treatment. Some reduction of brown rot (Sclerotinia spp.) was also observed in these trials.

Canker

Studies at Long Ashton by Byrde in which he applied benomyl at 0.025% a.i. in comparison with copper oxychloride (0.25% Cu) and pyridinitril at 0.03% a.i. showed that two post-harvest pre-leaf fall and one bud-break sprays were disappointing in the control of leaf scar infection (Long Ashton 1969).

In work at East Malling, Bennett has shown that autumn application of benomyl at 0.025% a.i. showed some promise in reducing the numbers of spores produced from viable cankers. Further work indicated that benomyl at 0.025% compared with captan at 0.1% a.i. on a summer 14-day schedule reduced sporulation without affecting germination; captan had little effect on sporulation but did diminish viability. In addition benomyl was tried as a canker paint, a 1% a.i. suspension showed some promise in 1968, but the effects were less promising in 1969. In 1970 a 1% petroleum jelly formulation gave good control for up to four months after application of the treatment on the cankers; 6/10 benomyl-treated cankers bore no sporing pustules compared with 1/10 on the controls with a mean of two pustules/canker on those treated with benomyl compared with 40 pustules/canker on the untreated controls (East Malling, 1970).

The most important cause of post harvest decay of apples in Ireland has been Nectria galligena. Benomyl at 0.025% a.i. applied either as single pre-harvest spray or as a post-harvest dip effectively reduced this fruit decay in Laxton's Superb during a five month storage period (McDonnell, 1970).

Canker control is difficult to detect in a short period in commercial orchards, but there have been strong indications that the spread of canker within orchards treated for more than one year with a benomyl scab/mildew programme has been suppressed.

Blossom Wilt

Trials on Cox and Lambourne in Devon in 1968 with benomyl at 4 oz a.i. per 100 gal (25 gm/100l) showed that blossom wilt could be controlled with two sprays applied at an interval of 7-days from first flower. Further trials in 1969 indicated that both sprays were necessary (Byrde and Melville, 1971).

Commercial experience has confirmed this result in that 8 oz a.i./ac (0.55 kg/ha) applied at first flower and subsequently at 7 days has controlled the disease.

Crop Yield and Fruit Appearance

Initial trials (Catling, 1969) had indicated no detrimental effect of benomyl on the quality of the harvested fruit. Subsequent trials (Evans '*et al*' 1971) have demonstrated no adverse effects on fruit except in the case of cv Worcester Pearmain where there is some evidence that fruit "colouring" was delayed. In the same trials there were some indications of increased yield as a result of improved fruit set.

Some increases in fruit russet on dessert varieties have been reported (East Malling, 1970, Long Ashton, 1970) as a result of applying benomyl on a regular schedule, but replicated and grower applied trials carried out in commercial orchards over the last three years have not detected any increase.

In some trials increases in yield have been observed and some explanation has been afforded by the work of Williams (Long Ashton, 1970) who has shown that benomyl used for scab/mildew control caused an increase in both initial and final fruit set.

DISCUSSION

Early experiments with benomyl suggested that it's systemic properties and activity against a wide number of pathogens might make it a useful fungicide for the control of a number of diseases of apple.

Powdery mildew trials (Catling, 1969) in which the percentage of secondary mildew was assessed demonstrated the eradicant nature of the fungicide in addition to its protectant activity. Variable results were obtained under commercial conditions in 1970 with control being poor in those areas that had a particularly low rainfall and free-draining soils; a 7-day schedule was necessary for good control. This experience was at variance with that of preceding years and in 1971 when control was uniformally good. 1970 was peculiar in that May and June were the driest since 1940 (East Malling 1970) and many apple trees were at moisture stress during this period. It is reported by Butt (East Malling, 1969) that this is also the period of highest mildew spore release. It is possible that in these conditions of moisture stress benomyl is not being absorbed by the leaf and is acting only as a protectant. Hence the need to reduce the interval between sprays to 7 days. The 1971 trials indicate that in this event a half standard rate, 4 oz a.i./ac (0.28 kg/ha) is sufficient.

The successful control of powdery mildew is dependent upon reducing infected buds and thereby primary mildew. The extent of secondary mildew developing in an orchard is determined by the number of bud infections and their production of primary mildew (Baker, 1962). Butt (1971) demonstrated that developing fruit buds need protection from the green cluster to the early fruitlet stage in the year before they flower. The critical period for the protection of terminal buds is later and in 1968 was between 10 June and 12 July (East Malling, 1969).

Trials with benomyl have shown that post bud-burst applications have a suppressing effect on primary mildew thereby reducing the spore load available for leaf and bud infection. Furthermore, the good eradicant properties of benomyl are of value in protecting the developing fruit and vegetative buds during the critical periods of spring and early summer. Assessment of bud infections in the year subsequent to benomyl applications have demonstrated this marked effect.

Apple scab control with benomyl on the 14-day schedule has been excellent. The eradicant properties of the fungicide prompted investigation of extended schedule spraying. Initial trials showed promise with a 21-day schedule on both culinary and dessert varieties and control with a 28-day schedule was effective particularly on the fruit. 1971 was a particularly favourable year for the disease and under these conditions the 21-day schedule gave incomplete control on the culinary variety Bramley's Seedling although control remained good on dessert varieties.

Benomyl was shown to be effective in suppressing spore production from cankers caused by Nectria galligena and Gloeosporium perennans. Trials have shown that in the case of the former disease this activity resulted in a retardation in the spread of canker in the orchard, and in the latter a reduction in storage rots where only a benomyl scab/mildew summer programme has been applied. Field trials have also shown the value of July, August and September applications of benomyl in further improving the control of storage rots.

In trials over a 4-year period, it has been shown that benomyl applied on a regular 14-day schedule starting at bud-burst is a promising fungicide for the control of many of the diseases of apple particularly if used for more than one season.

Acknowledgements

The author wishes to thank Boots Pure Drug Co., Ltd., Farm Protection Ltd., Fisons Agrochemical Division Ltd., and Pan Britannica Industries Ltd., for providing data from their trials for inclusion in this paper.

References

Baker, June V. (1961) The life history of apple mildew and the field assessment of the disease. Proc. Br. Insec. Fungic. Conf. 173 - 178.
Butt, D.J. (1971) The role of the apple spray programme in the protection of fruit buds from powdery mildew. Ann. apple Biol., 68, 149-157.
Byrde, R.J.W. and Melville, S.C. (1971) Chemical Control of Blossom Wilt of Apple. Pl. Path., 20, 48 -50.
Catling, W.S. (1969) Benomyl - A broad spectrum fungicide. Proc. Br. Insectc. Fungic. Conf. 2, 298-309.
Delp, C.J. and Klopping, H.L. (1968) Performance attributes of a new fungicide and mite ovicide candidate. Pl. Dis. Reptr., 52, 95-99.
East Malling Res. Stn. (1969) Ann. Rep.
East Malling Res. Stn. (1970) Ann. Rep.
Evans, E., Marshall, J. and Hammond, C. (1971) An Evaluation of Benomyl as a scab/ mildew Fungicide in the United Kingdom. Pl. Path. 20, 1-9.
Fungicide and Nematocide Tests (1969) American Phytopathalogical Society 25
Fungicide and Nematocide Tests (1970) American Phytopathalogical Society 26
Long Ashton Res. Stn. (1969) Rep.
Long Ashton Res. Stn. (1970) Rep.
McDonnell, P.F. (1970) Control of Nectria decay of apple fruits by benomyl. Pl. Dis. Reptr., 54, 83-85.

Proc. 6th Br. Insectic, Fungic. Conf. (1971)

EVALUATION OF APPLE SCAB (Venturia inaequalis) AND CANKER (Nectria galligena) CONTROL PROGRAMMES IN IRELAND 1961-1971

T. Kavanagh
Agricultural Institute, Kinsealy Research Centre, Dublin, 5,

N.D. O'Kennedy
Pomology Research Station, Ballygagin, Co. Waterford, Ireland.

Summary Attempts at reducing the number of sprays necessary for the control of apple scab (Venturia inaequalis) in Ireland by applying dodine acetate after Mills' infection periods were not consistently successful. In 1971 four applications of benomyl used in this way controlled the disease but the season was not favourable for scab development. Used as protectants benomyl and triarimol gave good control.

Cuprous oxide and mercurized copper oxychloride sprays were most effective of six fungicides tested for their defoliating properties in the control of apple canker (Nectria galligena). Four canker paints based on mercury, tin and phenyl phenol were examined for their effectiveness in controlling canker and promoting callousing. Of these 2- phenyl phenol, although less effective, has the advantage of ease of application and low mammalian toxicity.

INTRODUCTION

Apple scab and apple canker are the most important diseases affecting fruit trees in Ireland. At the Pomology Research Station, Agricultural Institute, Ballygagin, Co. Waterford unsprayed trees in fungicide trials for the control of scab developed up to 100% infection of leaves and fruit. Apple canker, despite good management and the removal of diseased areas in winter, continues to re-appear. Scab outbreaks are encouraged by the climatic conditions of relatively cool moist growing seasons and canker by the high rainfall, the high nitrogen content of Irish soils, mild winters and windy conditions during the growing season which cause injuries to leaves and branches. Control of both diseases was under investigation at Ballygagin during the 1960's.

EXPERIMENTAL AND RESULTS

I Apple Scab Investigations

Curative spraying: In Ireland protectant applications at 10-day intervals commence at bud-burst and continue until the end of July entailing a total of 12 to 14 sprays. O'Kennedy (1962) showed that ascospore release ceased about the third week in May. If control was complete at that time, further sprays would be unnecessary. Spraying after Mills' infection periods would reduce the number of applications in most seasons, particularly if treatments ceased at the end of May. An alternative approach was to spray with a curative-protectant fungicide only when infection periods were separated from each other by at least 10 days. Experiments at Ballygagin using phenyl mercury acetate were discontinued because of phytotoxicity to the foliage and fruit and because the use of this material in the post-blossom period is unacceptable on dessert trees. Dodine acetate was substituted because of its curative and protectant properties. The treated trees were bush type, cv. Laxton's Superb and were sprayed with a mist blower at 50 gal/ac (562 l/ha). Because of their large size and the limited number of trees available and because the type of spray machinery used necessitated large plots, adequate replication of the treatments was not possible.

The proximity of severely scabbed unsprayed trees to some of the other treatments in 1964 affected the final result (Table 1). The protectant programmes did not provide effective control in 1965 and 1966. In 1965, wire boxes of scabbed leaves which were used for ascospore release studies were inadvertently left in the orchard, and furthermore, some of the trees had been unsprayed controls in the 1964 experiments and were therefore heavily infected. In 1966 the weather in April was exceptionally wet - a total of 9 in. (229 mm) of rain fell in 22 days. However a good programme should have kept scab at a low level particularly in 1966 when other complicating factors were absent. The results show that apple scab spray programmes based on applications of dodine acetate after all infection periods or alternatively after infection periods separated by at least 10 days are not reliable under Irish conditions.

In 1971, a one acre block of central-leader-trained trees of the cultivars Golden Delicious, Cox's Orange Pippin and Laxton's Superb was sprayed with benomyl at 0.5 lb a.i./ac (0.56 kg/ha) after Mills' infection periods separated by at least 20 days. Four sprays were applied between April and the end of July compared with 9 and 7 sprays of benomyl applied at 14-day and 20-day intervals respectively. No leaf or fruit scab was detected in this area up to early September.

Protectant spraying & fungicide testing: From 1961 to 1969, 22 fungicides were tested for the control of scab mainly on the cultivar Laxton's Superb at Ballygagin (O'Kennedy, 1961-65, O'Kennedy & Kavanagh, 1966-69). Most of these gave satisfactory control but some caused severe russeting at the rates used. In 1969, benomyl and triarimol were tested and gave satisfactory control the former being used at 20-day intervals. Benomyl at 14-day and 20-day intervals gave excellent scab control and did not cause russeting of Laxton's Superb in 1970 but the season was very unfavourable for scab development. This experiment was repeated in 1971. Up to early September, negligible leaf scab ($<1\%$) was present at either the 14- or 20-day interval but russeting was more prevalent than in 1970.

In a comparison of triarimol, benomyl and captan on Cox's Orange Pippin and Golden Delicious in 1970 no scab occurred. Russeting data taken on the cv. Golden Delicious showed that it was mostly slight and was approximately the same for all three fungicides at the calyx and stalk end of the fruits. Though slight, benomyl caused more russeting of the cheek of the fruits than either of the other fungicides.

Triarimol was applied at 1.3 oz/ac (92 g/ha) by mistblower in 50 gal water/ac (562 l/ha) to Cox's Orange Pippin, Golden Delicious, Laxton's Fortune, Laxton's Superb, Lord Lambourne, Tydeman's Late Orange and Worcester Pearmain at 10-day intervals in 1970. No scab occurred and most fruits were russet-free. In 1971, the same cultivars were sprayed with triarimol at 10-day intervals. Scab control was again excellent. All the cultivars were russet-free except Tydeman's Late Orange on which slight russeting occurred.

II Apple Canker Experiments

Autumn spraying at leaf fall: Moore & Bennett (1960) showed the value of an autumn copper spray programme in preventing leaf-scar infection by *Nectria galligena*, and this was confirmed by Byrde *et al* (1965). In both these investigations a proprietary Bordeaux powder was used but, as this material was not readily available in Ireland, several proprietary copper fungicides, an organo-tin and an organo-mercurial fungicide were examined for their defoliating properties. The fungicides were applied to the cultivars Lord Lambourne and Laxton's Fortune at the beginning of natural leaf-fall and again when about 50% of the leaves had fallen. The experimental design was a randomized block with three replications of the seven treatments. Before spraying, five shoots were tagged on each of 21 trees of each cultivar and counts were made of the number of leaves on these shoots and the number which had already fallen. After spraying to run off with an hydraulic knapsack sprayer counts were made at weekly intervals (Table 2).

There were some differences between cultivars but in general the order of the fungicides based on their defoliating efficiency was the same with mercurized copper oxychloride and cuprous oxide producing the most rapid defoliation. Proprietary Bordeaux powder was the next most effective defoliant on cv. Lord Lambourne but was surpassed by copper oxychloride on cv. Laxton's Fortune. Hislop (1966) also found proprietary cuprous oxide more effective as a defoliant than proprietary Bordeaux powder.

Comparison of Canker Paints: In 1968 and 1969, four paints were compared for their effectiveness in controlling canker and in promoting callousing around the treated areas. These were 2% mercury in anthracene oil, 2-phenyl phenol, 3% yellow mercuric oxide and 0.4% fentin hydroxide. The cultivars treated and the effects of the chemicals are shown in Table 3. The treatments were applied between February 12 and 17, 1968. In the case of 3% yellow mercuric oxide and 0.4% fentin hydroxide the cankered area was pared away before the paint was applied. All cankers treated with 2% mercury in anthracene oil were wire brushed beforehand. Cankers to be painted with 2-phenyl phenol received no prior treatment.

In 1969, the four paints were applied to cankers on the cultivars Cox's Orange Pippin and Lord Lambourne. In addition to applying the paints as in 1968, 3% yellow mercuric oxide and 0.4% fentin hydroxide were diluted 50/50 with water and were applied to unpared cankers. 2% mercury in anthracene oil was applied to unbrushed as well as wire-brushed cankers and an attempt was made to apply 2-phenyl phenol as a spray. The treatments were applied in March 1969 and assessments made December 1969, (Table 4).

Table 4

The effect of applying four canker paints, each by two methods on canker development and callousing of two apple cultivars

Treatments		Cox's Orange Pippin			Lord Lambourne		
		No. treated	No. calloused	Perithecia present	No. treated	No. calloused	Perithecia present
3% yellow mercuric oxide *	unpared	6	2	2	6	4[+]	2
	pared	6	5	0	6	6	0
0.4% fentin hydroxide*	unpared	6	3	5	6	3	4
	pared	6	4	0	6	5[+]	0
2% mercury in anthracene oil	unbrushed	6	4[+]	1	6	3[+]	1
	wire brushed	6	3	1	6	4	0
2-phenyl phenol	applied with paint brush	6	4	2	6	1[+]	2
	sprayed on	6	2	5	6	3[+]	3

* Diluted 50/50 with water when applied to unpared cankers.

[+] One of the unhealed cankers was on a branch which had been killed.

In 1968 both 3% yellow mercuric oxide and 0.4% fentin hydroxide gave complete control and good callousing. 2% mercury in anthracene oil was almost as effective. No prior treatment was given to the cankers treated with 2-phenyl phenol, nevertheless, this paint also gave good results although inferior to the other three. The 1969 tests indicate that 3% yellow mercuric oxide and 0.4% fentin hydroxide will give some control if applied in a diluted form to unpared cankers. Wire brushing before the application of 2% mercury in anthracene oil appeared to make little difference to the result, confirming the maker's recommendation that only rough cankers need this treatment. 2-phenyl phenol proved too viscous as a spray and this method of application was unsatisfactory. The results obtained from brushing 2-phenyl phenol on to cankers on cv. Lord Lambourne were disappointing.

DISCUSSION

Scab control is a major cost in commercial apple production. The possibility of reducing the number of protectant sprays necessary for the control of apple scab was examined for several seasons at Ballygagin. Attempts to achieve this reduction by applying dodine acetate sprays according to Mills' infection periods were not consistently successful. The use of large trees and the inclusion of unsprayed controls complicated the experiments. Benomyl applied at 14- and 20-day intervals gave excellent control in both 1970 and 1971. However, neither of these seasons was favourable for the development of scab and further experiments under more severe conditions are necessary. The possibility of reducing the number of applications even further by applying this fungicide after certain Mills' infection periods only is attractive and merits further examination. Benomyl caused none or only slight russeting in 1970 but this condition tended to be more prevalent in 1971 particularly on fruits from branches close to the sprayer. Triarimol controlled scab and caused no russeting of several cultivars in two seasons.

Protecting leaf scars with a copper fungicide in autumn is still one of the few methods of preventing invasion by N. galligena. As leaf-scars remain susceptible to invasion for several weeks after leaf-fall, it is desirable to shorten the leaf-fall period so that more leaf-scars can be directly protected by the second spray (Moore et al 1960). Ideally, therefore, the protectant fungicide should also accelerate defoliation. The present results show that a number of possible protectants tested differ greatly in this respect. There may also be a cultivar interaction, copper oxychloride being more effective on cv. Laxton's Fortune than cv. Lord Lambourne. Furthermore, it is possible that chemicals which accelerate defoliation may not be the most effective for protecting leaf scars. The latter possibility was not examined in the present experiments. Control with paints was improved if the cankers were pared before the chemical was applied. However, paring out disease areas is an operation which growers are unlikely to continue for much longer because of the cost and the shortage of labour. Hence the good control obtained with 2% mercury in anthracene oil on wire-brushed and unbrushed cankers is interesting as are the promising results with 3% yellow mercuric oxide or 0.4% fentin hydroxide in a diluted form on unpared cankers. No prior treatment is recommended where 2-phenyl phenol is used and generally, this paint gave very good results. However, where it ran down the stems of young Cox's Orange Pippin and Golden Delicious trees, it caused a superficial scorching resulting in a non-progressive lesion. Its ease of application and low mammalian toxicity make it attractive particularly with the current trend towards the use of less toxic chemicals.

Acknowledgments

The authors thank the staff of the Department of Statistics & Biometrics for advice on experimental design and statistical analysis; Mr. P. Casey, Mr. E. Kelly and Mr. P. Power for technical assistance.

References

BYRDE, R. J. W., EVANS, S. G. and RENNISON, R. W. (1965) The control of apple canker in two Somerset orchards by a copper-spray programme. Pl. Path. 14, 143.

HISLOP, E. C. (1966) The redistribution of fungicides on plants II. Solution of copper fungicides. Ann. appl. Biol. 57, 475.

MOORE, M. H. and BENNETT, M. (1960) Experiments on the control of apple canker by spraying. Rep. E. Malling Res. Stn. for 1959, 85.

O'KENNEDY, N.D. (1961-1965) Apple scab (*Venturia inaequalis* (Cooke) Wint.) Res. Reps. Hort. & For. Div., Agricultural Institute, Ireland for 1961-1965.

O'KENNEDY, N.D. and KAVANAGH, T. (1966-1969) Apple scab (*Venturia inaequalis* (Cooke) Wint.) Res. Reps. Hort. & For. Div., Agricultural Institute for 1966-1969.

Table 1

A comparison of protectant and curative programmes, based on dodine acetate, for the control of apple scab.

Treatments (dodine acetate lb a.i./ac)	No. of sprays and % fruit scab											
	1962		1963		1964		1965		1966		1967	
	Sprays	Scab	Sprays	Scab	Sprays	Scab	Sprays	Scab	Sprays	Scab	Sprays	Scab
0.65 @ 10 days	-	-	-	-	-	-	13	6.0	14	7.0	13	0.8
0.98 pre-, 0.65 post-blossom	-	-	-	-	-	-	11[+]	7.3	14	7.2	13	0.5
0.98 after I.P.* more than 10 days apart	9	0.1	7	0	7	10.3	7	13.6	7[‡]	22.6	9	0.5
0.98 after all I.P.* to May May 30	-	-	9	0	7	66.1	-	-	-	-	-	-
0.98 after all I.P.* to July 31	-		12	1	14	7.3	11	10.0	12	10.0	13	0.2
Unsprayed	0	11.8	0	40	0	100	-	-	-	-	-	-

* I.P. denotes scab infection period.

[+] at 14-day intervals.

[‡] Weather exceptionally wet in April so changed at the end of June to a 10-day dodine-captan protectant programme.

Table 2

Effect on rates of defoliation of applying fungicides at the beginning of and at 50% leaf-fall to two apple cultivars

	% leaves remaining on trees																			
	Lord Lambourne										Laxton's Fortune									
	Days after first fungicidal application																			
	7	14	21	28	35	42	7	15	21	28	7	14	21	28	35	42	10	14	22	28
	1966						1967				1966						1967			
Proprietary Bordeaux w.p. at 0.25% Cu.	99	94	74	29	15	4	87	68	27	0	81	61	36	19	13	5	82	51	22	3
Mercurized Cu oxychloride at 0.25% Cu	97	95	51	6	2	0	87	61	30	0	80	54	16	7	3	0	85	47	12	2
Cuprous oxide at 0.25% Cu	98	94	63	9	1	0	88	63	30	0	83	52	25	6	3	1	72	32	9	2
Copper oxychloride at 0.25% Cu	98	95	84	53	27	11	86	65	42	0	89	63	38	13	4	3	73	45	9	0
Fentin hydroxide @ 0.06% a.i.	96	92	82	61	33	12	87	76	48	2	82	59	46	39	24	8	90	50	27	15
Phenyl mercury acetate at 0.008% a.i.	98	93	74	59	36	14	88	70	40	0	85	68	50	30	22	8	84	47	17	4
Unsprayed	99	96	89	80	47	17	89	74	39	3	93	69	56	44	25	7	81	51	30	14
SE (df = 12)	1.1	1.8	4.6	8.0	8.7	4.4	2.6	3.2	6.7	0.9	3.1	4.4	5.3	4.8	3.7	1.7	3.3	6.1	3.5	3.0

* Second spray applied when about 50% of the leaves had fallen in the proprietary Bordeaux treatment.

Table 3

The effect on canker control and callousing of applying canker paints to eleven apple cultivars

	3% yellow mercuric oxide		0.4% fentin hydroxide		2% mercury in anthracene oil			2-phenyl phenol		
Cultivar	No. treated.	No. calloused+	No. treated.	No. calloused+	No. treated	No. calloused	Perithecia present	No. treated	No. calloused+	Perithecia present
Exter Cross	10	10	11	11	8	8	0	13	12	4
Red Delicious	9	9	-	-	8	6 + 2*	3	7	7	0
Ingrid Marie	13	13	4	4	13	12 + 1*	0	11	11	1
Cox's Orange Pippin	5	5	8	8	8	8	0	5	5	0
Cox's Orange Pippin	6	6	7	7	4	4	0	9	7 + 1*	6
Ellison's Orange	6	6	5	5	8	8	2	5	4 + 1*	3
Worcester Pearmain	9	9	6	6	12	10 + 2*	1	6	4 + 2*	0
Red Ellison	5	5	1	1	1	1	0	7	7	3
Belle de Boskoop	5	5	3	3	6	6	0	7	7	1
Bramley Seedling	12	12	6	6	14	14	0	8	8	0
Exquisite	-	-	4	4	-	-	-	11	8 + 3*	4
Laxton's Fortune	6	6	-	-	10	9 + 1*	2	-	-	-

+ - no perithecia present

* - callousing possibly incomplete.

Proc. 6th Br. Insectic. Fungic. Conf. (1971)

THE CONTROL OF DISEASES OF APPLES AND PEARS IN THE UNITED KINGDOM WITH THIOPHANATE METHYL

R.J. Cole, A.J. Gilchrist and D. Soper
May & Baker Ltd., Ongar Research Station, Essex

Summary Trials with thiophanate methyl (NF44) have shown that a dose rate of 1 lb a.i./ac applied at 14 day intervals from bud-burst/green cluster to cessation of shoot growth provides effective control of apple powdery mildew and apple and pear scab. Two applications of thiophanate methyl made in mid-August and early September gives control of storage rot diseases (*Gloeosporium* spp.) superior to that given by three applications of captan. Preliminary experiments on apple canker indicate good control with solvent and paint preparations of thiophanate methyl when applied to established lesions in the dormant period.

INTRODUCTION

Following greenhouse and small plot trials by May & Baker in the United Kingdom in 1969, (Mercer, 1970) a series of replicated experiments were carried out in commercial orchards in 1970 to evaluate thiophanate (NF35) and thiophanate methyl (NF44) for the control of diseases of apples and pears (mildew, scab and storage diseases).

Results from Nippon Soda and others indicated thiophanate methyl to be the more active of the two products (Formigoni *et al*, 1970, Aelbers, 1970 and Ishii, 1970). Both materials were included in the 1970 trials however, because thiophanate (NF35) was already an established product in Japan (trade names "Cercobin" and "Topsin") and Italy ("Enovit").

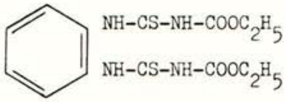
In 1971, approximately 50 grower trials with thiophanate methyl (trade name 'Mildothane'*) were carried out in the main fruit growing areas of the United Kingdom to evaluate the product when used in a seasonal programme alongside recognised standard mildew and scab fungicides.

Further replicated experiments were conducted in 1971 to evaluate the product against apple scab and apple canker.

* Registered trade mark of May & Baker Ltd.

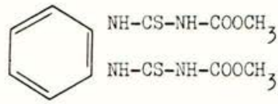
METHOD AND MATERIALS

thiophanate (NF35)



1,2-bis(3-ethoxy-carbonyl-2-thioureido) benzene

thiophanate methyl (NF44)



1,2-bis(3-methoxy-carbonyl-2-thioureido) benzene

In the 1970 top fruit trials, wettable powder formulations of thiophanate (NF35 - 50% w/w) and thiophanate methyl (NF44 - 70% w/w) were used. In 1971, a 50% w.p. formulation (ARD/31/03) of NF44 replaced the 70% material. Further experimental formulations of apple canker paints and solutions were also prepared for use in 1971.

Both low volume and high volume replicated orchard trials were carried out in 1970/71. Low volume spray applications were made using a tractor-mounted Victair air-assisted sprayer operating at 50 gal/ac. Plot sizes were of 9 or 12 tree blocks replicated three times. In the high volume work, one or two tree randomised plots replicated three to six times were sprayed either with a landrover-mounted high volume sprayer or a mini-tractor mounted high volume sprayer - both operated via the power take-off. Sprays were applied using hand lances, the trees being sprayed to run-off with spray volumes of the order of 200-300 gal/ac. Significance of treatment means was expressed using Duncan's Multiple Range Test. (Duncan, 1955).

In the grower trials rates of 1 lb and $1\frac{3}{8}$ lb a.i./ac (1.1 and 1.5 kg a.i./ha) low volume or 0.5 lb and 0.7 lb a.i. per 100 gal of water (0.5 and 0.7 kg a.i./100 litres) high volume were applied at 14 day intervals, or pro-rata at reduced intervals down to 7 days, starting at pre-blossom and continuing until about the end of July. The two experimental treatments were compared with standard captan/dinocap or a similar scab/mildew spray at the same time-interval, all treatments being applied by means of the growers' own machinery. The main variety treated was Cox's Orange Pippin.

RESULTS

Apple powdery mildew (*Podosphaera leucotricha*) trials 1970

A dry, warm season during 1970 gave rise to high levels of powdery mildew infections in most of the trial orchards enabling a thorough evaluation of dose rates/formulations/timing intervals of both NF35 and NF44 to be made against this disease. Primary mildew infected blossom trusses were recorded in those orchards with high levels of infection and at these sites, assessments of the intensity of blossom truss mildew showed that NF44 suppressed development and sporulation of mildew on the infected trusses.

Assessments of secondary mildew on the leaves were made in July/August using the method described by Baker (1961). Table 1 shows key treatments, from the full trials, all sites being sprayed at 14 day intervals from bud burst.

Table 1

Control of secondary mildew on leaves

Material	Dose Rate a.i./ac	% mildew on leaves mid-season										
		Site 1	Site 2	Site 5	Site 6	Site 8	Site 11	Site 13	Site 15	Site 16	Site 17	Site 18
NF35	1.0 lb	1.6a	1.2a	18.9a	10.4 ab	3.7ab	14.8a	18.4a	18.6a	11.6a	5.1a	7.8 b
NF44	1.0 lb	1.5a	0.5a	18.6a	8.1 a	1.9a	14.8a	14.0a	14.7a	12.1a	4.4a	4.0ab
benomyl	0.5 lb	1.5a	0.5a	24.1a	8.7 a	3.4a	16.4a	20.6a	12.4a	10.5a	3.9a	3.1a
dinocap	0.5 lb	2.8a	0.8a	22.3a	13.1 ab	8.0 bc	16.6a	13.7a	17.2a	14.8ab	4.3a	7.7 b
control	-	5.5 b	2.9 b	34.5 b	16.0 b	11.3 c	26.7 b	34.6 b	30.2 b	28.3 b	18.8 b	15.0 c
Variety		Cox	Cox	Cox	Cox	Cox	Cox	Cox	Jonathan	Cox	Jonathan	
Spray Volume		LV	HV	LV	HV	HV	HV	LV	LV	HV	LV	HV

Figures suffixed by the same letter are not significantly different at the 5% level (Duncan's Multiple Range Test)

In all cases, NF44 was more effective than NF35 and dinocap, although differences between NF44 and benomyl were less marked. A visual assessment of tree health, related to mildew level (see Table 6 for key) was carried out in August on the low volume sprayed sites. The results confirmed the secondary leaf mildew assessment results and showed that NF44 was slightly more effective than benomyl and clearly superior to NF35 and dinocap in controlling this disease.

Fruit finish (russet)

Russet assessments were carried out at harvest (mid-late September) on one bushel samples of fruit from each plot, obtained either by sub-sampling from the full tree yield or by picking unselectively along individual limbs of the tree. The fruit was then graded by teams of assessors according to the following categories:-

Negligible russet: no russet on circumference, possible small patch around eye or stem.

Light russet: smooth russet on up to 25% of circumference.

Moderate russet: smooth russet on over 25% and rough russet on up to 25% of circumference.

Severe russet: all cracked fruit. Rough russet on over 25% of the circumference.

N.B. Smooth russet: skin rough but no incipient cracking
Rough russet: skin harsh in feel and appearance, cracks beginning to form although skin not broken.

Results shown in Table 2 indicate percentage russeted fruit in moderate PLUS severe categories at various sites.

Table 2

Degree of fruit russet

Material	Dose Rate a.i/ac	% russeted fruit Site 4	Site 8	Site 9	Site 13	Site 14	Site 15	Site 16
NF 35	1.0 lb	7.4	1.5a	26.6abc	53.3ab	42.0a	7.6a	40.4ab
NF44	1.0 lb	6.0	1.1a	11.1a	47.6a	38.1a	8.8a	26.2a
benomyl	0.5 lb	9.3	4.1ab	32.4 bc	44.0a	50.5a	15.9ab	45.7ab
dinocap/ captan	0.5/ 2.0 lb	8.5	1.5a	42.0 bc	61.0 bc	45.4a	12.5a	66.1 b
control	-	6.7	8.3 b	48.4 c	70.9 c	66.7 b	26.4 b	64.0 b
variety		Conference	Cox	Cox	Cox	Cox	Jonathan	Cox
spray volume		HV	HV	HV	LV	HV	LV	HV

Figures suffixed by the same letter are not significantly different at the 5% level (Duncan's Multiple Range Test).

Levels of russet on the unsprayed controls were largely due to mildew, whereas that on treated plots may have been due to mildew or chemicals or most likely a combination of both. Both NF44 and NF35 treated plots showed only low levels of russet, these levels being generally lower than those on dinocap and benomyl treated plots.

Storage Rot trials - 1970

Investigations of the control of storage rots with NF35 and NF44 were carried out in 1970 in five orchards which had received seasonal applications of the same materials, and in one orchard which had received a dinocap/captan seasonal programme. Additional spray applications were made in late July (captan only) mid-August and early September in the selected orchards, the variety in each case being Cox's Orange Pippin. Fruit was harvested in mid-September and placed in cold store (except site 21a which was barn stored). Sub-samples of apples (one bushel per plot) were examined when the fruit was removed from store (January/February). Table 3 shows percentage of fruit infected with 'bitter rot' (*Gloeosporium* spp.) and brown rot.

Table 3

Control of Storage Rots

Material	Dose Rate a.i./ac	% bitter rot					% brown rot				
		Site 3	Site 13	Site 14	Site 21a	Site 21b	Site 3	Site 13	Site 14	Site 21a	Site 21b
NF35	1.0 lb	2.0	8.4	1.8	4.3	2.7	3.7	8.4	4.4	6.9	2.7
NF44	1.0 lb	0.9	4.3	0.9	1.9	0.8	2.1	6.7	2.6	4.7	8.8
benomyl	0.5 lb	0.8	3.1	3.1	0.8	2.1	3.7	5.2	1.2	6.9	6.4
captan	2.0 lb	1.4	7.8	6.6	4.7	3.6	3.7	32.2	7.1	7.4	11.5
control	-	8.3	28.5	19.9	33.3	36.7	17.7	42.4	11.3	32.1	27.0
Spray volume		LV	LV	HV	HV	HV	LV	LV	HV	HV	HV

The results show that two applications of NF44 following seasonal programmes of either NF44 or dinocap/captan gave better control of both bitter rot and brown rot than the conventional three sprays of captan or two sprays of NF35.

Blossom phytotoxicity, fruit set and fruit size

Applications of the experimental fungicides were made during full bloom in both the 1970 and 1971 series of trials. Assessments made of blossom scorching showed that neither NF35 nor NF44 caused any significant damage to the petals compared to controls, whereas dinocap caused light petal spotting and slight necrosis. Follow-up assessments after 'June-drop' of degree of fruit set, and at harvest of fruit size showed no significant differences between experimental treatments, standards and controls.

Apple and pear scab (*Venturia inaequalis* and *Venturia pyrina*) trials - 1971

Following a relatively dry season in 1970, replicated trials were repeated in 1971 to investigate the control of apple scab with NF44. It was decided to locate these trials in Somerset in order to obtain the best chance of the disease occurring. For the same reason, some sites were located in cider apple and perry pear orchards.

Eight sites were sprayed high volume at 14 day intervals from bud burst, and one site was sprayed at 28 day intervals. Assessments of leaf scab were made in early September (approximately 8 weeks after the last spray application) and also of fruit scab (on the tree) using the methods described by Croxall et al (1952). Results are shown in Table 4.

Table 4

Control of apple and pear scab

Material	Dose Rate a.i./100 gal.	% scab on leaves					% scab on fruit		
		Site 5	Site 6	Site 7	Site 8	Site 9	Site 5	Site 6	Site 7
NF44	0.5 lb	0.003a	0.48 b	0.007a	0.02a	0.07a	0.0	0.0	0.0
NF44	0.7 lb	0.007a	0.15a	0.008a	0.01a	0.07a	0.0	0.0	0.0
captan	1.0 lb	0.00 a	0.40 b	0.007a	0.05a	0.2 a	0.007	0.0	0.02
benomyl	0.25lb	0.00 a	0.23ab	0.006a	0.01a	0.1 a	0.003	0.0	0.001
control	-	0.14 b	50.0 c	0.642 b	0.83 b	1.5 b	17.02	62.5	9.17
variety		Dabinett	Bulmer Norman	Red Pear		Helens Early	Dabinett	Bulmer Norman	Red Pear
spray interval (days)		14	14	14	14	28	14	14	14

Figures suffixed by the same letter are not significantly different at the 5% level (Duncan's Multiple Range Test)

Apple canker (Nectria galligena) trial - 1971

Three formulations of NF44 were chosen as candidate preparations for the treatment of established cankers on apple trees.

The trial was carried out on cankers of approximately similar ages, without prior wire brushing of the lesions. Treatments were applied in early March and assessments made in July and again in October to determine the efficacy of the formulations in the suppression of sporulation.

Table 5

Control of apple canker (Nectria galligena)

Material	Formulation and % a.i.		% treated cankers bearing conidial pustules	
			14.7.71.	4.10.71.
NF44	aqueous suspension	3%	22.2	44.4
NF44	" "	6%	22.2	66.7
NF44	solution concentrate	3%	0.0	7.1
NF44	" "	6%	0.0	35.7
NF44	bitumastic paint	3%	16.6	28.6
NF44	" "	6%	0.0	0.0
2-phenyl-phenol	solution concentrate		0.0	57.1
Mercuric oxide paint	paste	3%	8.3	8.3
Bitumastic paint control		-	23.1	57.1
Untreated control		-	46.2	66.7

Four months after application, the highest level of spore suppression was given by the solution concentrate formulations of NF44 and 2-phenyl-phenol. The paint formulations of NF44 and mercuric oxide were slightly less effective, possibly due to the absence of wire brushing, prior to application. However, after six months the solution concentrate formulations of NF44 and 2-phenyl-phenol had begun to lose effectiveness, while the paint formulations still continued to exert a satisfactory suppressant effect on sporulation. Although the solution concentrate formulation of NF44 showed promise initially, the paint formulation appears to give more persistent protection.

Grower trials - 1971

A total of 48 grower trials (46 apple and 2 pear) were carried out in 1971. Growers were asked to apply NF44 at two dose rates on different orchard blocks, and to compare this with an adjacent area sprayed with their normal programme. NF44 was applied at high and low volume ranging from 25-200 gal/ac. The main variety treated was Cox's Orange Pippin (45 sites) but over 30 apple and 6 pear varieties have been sprayed. In each treated block, ten trees were taken at random and marked, and all assessments were confined to these trees. A visual assessment of tree health based on mildew was made in August with three observers using the following scoring system:-

Score 0 = No mildew - tree healthy in appearance
Score 1 = Isolated mildew on shoots and leaves. Tree basically still healthy in appearance
Score 2 = Primary mildew evident but only light secondary mildew on new growth
Score 3 = Primary mildew evident with moderate secondary mildew on leaves
Score 4 = High level of both primary and secondary mildew with some defoliation
Score 5 = Leaves heavily mildewed and widespread defoliation especially on terminals, apples small.

Table 6

Visual assessment of tree health based on mildew

Region	No. of Sites	Mean Score (0-5) 1 lb/ac NF44	$1\frac{3}{8}$ lb/ac NF44	Standard (dinocap at 30 sites)	Standard error ($\pm$) of treatment means
S.E. & S. England	19	1.89	1.82	2.15	0.0175
East Anglia	13	2.29	2.31	2.48	0.0172
Somerset and W. Midlands	10	1.73	1.72	2.00	0.0372

In the first season's use of NF44 in 42 orchards with a powdery mildew problem, an improvement in control of the disease, compared mainly with dinocap, has already become apparent at 32 (76%) of the sites.

Scab occurred at the two pear sites (variety Williams) where NF44 gave good control compared to thiram and mancozeb/zineb respectively. At all apple sites, scab was excluded by all treatments including the main standard, captan. Effectiveness against blossom wilt was reported from one apple orchard and suppression of apple canker from a further two.

DISCUSSION

The 1970 experiments with NF35 and NF44 demonstrated the superiority of the latter in the control of apple powdery mildew and Gloeosporium rots. Spray applications commenced at bud-burst and although applications were made during the blossom period, negligible browning of the petals occurred and fruit set was unaffected. It was noticed at this time (i.e. full bloom/petal fall) that both NF35 and NF44 appeared to exert a suppression of sporulation on mildew infected trusses, the reduction being greatest on NF44 treated plots. In orchards where NF44 had been used for two successive years, reduction in primary mildew infected trusses was noticed from 10% on dinocap treated plots to 5% on NF44 plots. Assessments of secondary mildew on the leaves made during July/August indicated NF44 to be more effective than NF35 although differences in control between NF44 and benomyl were less marked.

The 1971 grower trials confirmed the findings of the earlier experiments, namely that 1 lb a.i./ac of NF44 applied at 14 day intervals gave excellent control of mildew and scab. The Gloeosporium trials were also encouraging in that two applications of NF44 gave a better control of storage rots than three applications of captan.

Initial experiments with paint formulations of NF44 applied in the dormant season indicate effective canker control with solvent based and bitumastic paint preparations.

Whereas the grower trials showed only small differences in the control of mildew between NF44 and standard materials following one season's use, in the orchards where growers resprayed areas treated with NF44 in the previous year, the standard of mildew control was markedly improved compared to standards. These 'respray' trials are continuing and it is expected that repeated use of NF44 in seasonal scab/mildew programmes will ultimately reduce the amount of fungal inoculum to a low level.

Acknowledgements

We would like to thank all growers who have co-operated with us in providing facilities for these trials.

References

Aelbers, A. (1970) 22nd International Symposium on Crop Protection, Ghent, 126-134.

Baker, Miss J.V. (1961) Plant Path. 10 32-37.

Croxall, H.E., Gwynne, D.C. and Jenkins J.E.E. (1952) Plant Path. 1 39-41.

Ibid (1952) Plant Path. 1 89-92

Duncan, D.B. (1955) Biometrics 11 1-7.

Formigoni, A. Castagna, G. and Ciocca, P.(1970) 22nd International Symposium on Crop Protection, Ghent 96-108

Ishii, K. (1970) VIIth International Congress of Plant Protection, Paris. 200.

Mercer, R.T. (1971) Pestic. Sci. (in press).

Proc. 6th Br. Insectic. Fungic. Conf. (1971)

THE CONTROL OF APPLE MILDEW WITH TRIARIMOL (EL 273)

J.H. Bryant and D.J. Hitchman

Murphy Chemical Limited, Wheathampstead, Herts

Summary In 3 years testing in the U.K. triarimol has proved superior to dinocap and benomyl for the control of powdery mildew on apples. Its performance has been unaffected by changes in variety, spray volume, weather conditions and tree health. Safety to all varieties and absence of incompatibility problems has been demonstrated.

INTRODUCTION

The characteristics and initial field performance of triarimol (α-(2,4-dichloro phenyl)-α-phenyl-5-pyrimidine methanol) were described earlier by Gramlich (1969).

The compound is effective against a range of fungi but its ability to control 'powdery mildews' on apples, blackcurrants, cereals, cucumbers, grapes, roses and other ornamentals is outstanding.

The activity of triarimol against apple scab (*Venturia inaequalis*)and mildew (*Podosphaera leucotricha*)has been reported by Byrde (1970), Burchill (1970) and Butt (1970). Excellent control of powdery mildew (*sphaerotheca mors-uvae*) on blackcurrants has also been demonstrated (Anon 1970).

METHOD AND MATERIALS

In small scale field replicate trials carried out over the period 1969 to 1971, the lay out was of randomised block design with 6 single tree plots per treatment. The variety Cox's Orange Pippin has always been used because it is the main commercial dessert variety and very susceptible to mildew infection and fruit russeting.

All high volume applications were by hand lance from a mobile spraying unit carried in a Land Rover. The volume of individual sprays varied between 150 and 240 gallons of dilute wash per acre depending on stage of growth, tree size and planting density. Low volume sprays were applied with a shoulder mounted mist blower at 40 gallons per acre.

The programme of sprays commenced at early pink bud stage (early May) and continued at 12 to 14 day intervals until mid-July, by which time the flower buds for the following season have usually been formed and 'sealed' in Cox's Orange Pippin.

The control of primary mildew was recorded by examination of 2 x 100 blossom trusses per plot on the 2 and 3 year old shoots immediately prior to treatment and again at the pink bud stage the following year.

Secondary mildew on the current seasons growth was assessed in 1969 and 1970 according to the following method. On each of 10 extension shoots taken at random per plot, 10 leaves were each graded for percentage of area infected by mildew. The grading system is set out below. The starting point on each shoot is the first fully expanded leaf from the growing point and the ten are made up by examining the next nine leaves working towards the base of the shoot.

Grade	% leaf area infected with mildew
0	0
1	1 to 3
2	3 to 8
3	8 to 20
4	20 to 50
5	over 50%

The maximum grading score is therefore 500 per single tree plot. Each assessor was equipped with accurate diagrammatic representations of these grades.

Although this is a time consuming method, one can tell at a glance of the full scoring tables not only whether a particular treatment is effective or not but perhaps just as importantly, if an otherwise effective treatment broke down at a particular stage of growth. This can then be related to dates of application or weather to find the reason for the failure.

In the large scale trials described and in the 1971 replicate trials, the Barratt-Horsfall rating system was used to assess secondary mildew at the end of the spray programme.

RESULTS

1969 replicate trials

Table 1

To show the control of primary and secondary mildew with 7 applications of triarimol commencing at pink bud stage.

Treatment	Rate a.i. per 100 gal.	Primary mildew % blossom truss infection 1969	% change 1970	Secondary mildew Mean rating per plot (Max. infection score = 500)
Site I - Canterbury, Kent				
triarimol	18 g	1.33	-72.5	103.84
triarimol	13.5 g	0.83	-50.6	135.50
dinocap	112 g	1.58	- 5.1	175.17
untreated		1.41	+76.6	324.72
L.S.D. (P=0.001)				±89.45
Site II - Potton, Bedfordshire				
triarimol	18 g	0.42	+97.6	89.33
triarimol	13.5 g	1.00	+67.0	70.16
dinocap	112 g	0.75	+77.3	95.50
untreated		0.46	+750.0	326.66
L.S.D. (P = 0.001)				±109.05

Table 1 (Cont)

Treatment	Rate a.i. per 100 gal.	Primary mildew % blossom truss infection 1969	% change 1970	Secondary mildew Mean rating per plot (Max. infection score = 500)
Site III - Rainham, Kent				
triarimol	18 g	10.41	+15.2	93.00
triarimol	13.5 g	8.16	+47.1	84.01
dinocap	112 g	10.00	+ 9.1	162.67
untreated		10.58	+159.8	420.41
L.S.D. (P = 0.001)				±64.9

1970 replicate trials

These were designed to improve the effectiveness of triarimol even more by applying lower dosage rates at shorter intervals. The effects of these treatments are shown in Tables 2 and 3.

Table 2

To show the control of primary and secondary mildew with triarimol applied high volume at different dosage rates and spray intervals.

Treatment	Rate a.i. per 100 gal.	No. of Sprays	Spray interval in days	Primary mildew % blossom infection 1970	% change 1971	Secondary mildew Mean rating per plot (Max. score = 500)
Site I - Alcester, Worcestershire						
triarimol	9 g	8*	7	2.3	not	241
triarimol	13.5 g	7*	10	1.7	assessed	276
triarimol	18 g	6	14	1.3		144
benomyl	112 g	6	14	1.5		278
dinocap	56 g	8*	7	1.8		266
untreated				1.7		347.5
L.S.D. (P = 0.05)						±65

* Machinery failure resulted in gaps of 18 and 14 days at end of June and early July

Treatment	Rate a.i. per 100 gal.	No. of Sprays	Spray interval in days	Primary mildew % blossom infection 1970	% change 1971	Secondary mildew Mean rating per plot (Max. score = 500)
Site II - Canterbury, Kent						
triarimol	13.5 g	8	10	1.0	+66.0	139.16
triarimol	18 g	6	14	1.33	+75.8	147.33
benomyl	112 g	6	14	1.58	-15.8	139.16
dinocap	84 g	8	10	0.92	+307.6	157.66
untreated				1.33	+326.3	267.50
L.S.D. (P = 0.01)						±65.0
Site III - Rainham, Kent						
triarimol	9 g	11	7	10.75	-29.3	100.17
triarimol	13.5 g	8	10	12.00	-48.4	149.66
triarimol	18 g	6	14	10.66	-23.1	152.00
benomyl	112 g	6	14	9.66	- 3.7	183.16
dinocap	56 g	11	7	10.91	+151.1	114.00
untreated				15.08	+76.4	322.41
L.S.D. (P = 0.01)						±89.6

Table 2 (Cont)

Treatment	Rate a.i. per 100 gal.		No. of Sprays	Spray interval in days	Primary mildew % blossom infection 1970	% change 1971	Secondary mildew Mean rating per plot (Max. score = 500)
Site IV - Tonbridge, Kent							
triarimol	9	g	9	7**	0.16	not assessed	119.2
triarimol	13.5	g	6	10	0.33		92.0
triarimol	18	g	5	14*	0.85		136.8
benomyl	112	g	5	14*	0.41		146.2
dinocap	56	g	9	7**	0.50		165.0
untreated					0.50		311.6
L.S.D. (P = 0.01)							±117

* 19 days gap early June ** Two 10 day gaps late May and early June.

Table 3

To show the control of secondary mildew by triarimol when applied low volume (40 gal/acre).

Treatment	Rate a.i. per acre in 40 gal. water		No. of sprays	Interval in days	Secondary mildew rating Mean rating per plot (Max. infection score = 500)
Site I - Rainham, Kent					
triarimol	18	g	7	11*	198.00
triarimol	27	g	10	8**	164.20
triarimol	36	g	14	6	156.60
dinocap	112	g	7	11*	205.60
untreated					384.80
L.S.D. (P = 0.01)					±122.0

* Gaps of 13 days and 11 days end May and early June
** 15 day gap end May

Treatment	Rate a.i. per acre in 40 gal. water		No. of sprays	Interval in days	Secondary mildew rating Mean rating per plot (Max. infection score = 500)
Site II - Tonbridge, Kent					
triarimol	18	g	7	10**	143.60
triarimol	27	g	10	7	131.60
triarimol	36	g	14	5*	173.00
dinocap	112	g	7	10**	196.00
untreated					296.20
					not analysed

* 19 day gap early June ** Two 10 day gaps late May and early June.

1971 replicate trials

Further trials were designed to compare a 40% w.p. formulation with the 4% w.p. used in previous trials. Dinocap was used as the standard treatment. Seven spray applications were made at 12 to 14 day intervals commencing at early pink bud stage and ceasing about mid July. Secondary mildew was assessed using the Barratt-Horsfall System within 10 days of the last application.

Table 4

To show the level of primary mildew and assessments of secondary mildew.

Treatment	Rate a.i. per 100 gal.	Primary mildew % infected blossom trusses before treatment	Secondary mildew B-H total rating for 6 plots (Max. infection score = 660)	Secondary mildew % infection leaf area
Site I - Cliffe, Kent				
triarimol 4% w.p	18 g	31.0	220	15.5
triarimol 40% w.p	18 g	35.0	216	14.5
dinocap 50% e.c	112 g	34.0	244	19.6
untreated		30.6	271	28.0
L.S.D. (P = 0.01)			7.551	
Site II - Rainham, Kent				
triarimol 4% w.p	18 g	6.2	152	6.6
triarimol 40% w.p	18 g	8.2	147	6.2
dinocap 50% e.c	112 g	27.4	195	11.4
untreated		26.6	208	13.0
L.S.D. (P = 0.01)			8.123	

The level of primary mildew at both sites was extremely high and at Site I was distributed throughout the trial area whereas at Site II it was more variable in distribution.

DISCUSSION

The initial level of primary mildew seen in the 1969 blossom counts (Table 1) was quite low except at Site III. However the growing season was hot and dry, allowing secondary mildew to develop rapidly at all sites. Secondary mildew assessments at the end of the spray programme showed that triarimol at both rates gave excellent control and was statistically superior to dinocap at Site III. No adverse effect occurred on either leaf or fruit finish.

Primary mildew counts in 1971 indicated good control when expressed as percentage change over the initial counts (Table 1). Large reductions occurred at Site I, but increases on all treatments were seen at Site II and III. These increases however were small compared to the rise in the levels on untreated trees.

In 1970 6 trials were carried out to compare triarimol applied at lower dosages at 7 and 10 day intervals since this is the usual commercial practice with standard mildewicides.

At four sites, the treatments were applied high volume and at two of the sites, separate blocks of trees in the same orchard were used for low volume applications. Difficulty was experienced in maintaining the schedules at critical periods at two of the sites but generally the control of secondary mildew (Table 2) with high volume was better at the 7 day interval but not significantly so. At Site I, the regular applications of triarimol at 14 day intervals was significantly better than benomyl on the same schedule and the lower rates of triarimol and dinocap on a shorter interval but slightly erratic programme.

At Site II, there was no significant difference between treatments, or at Site III, although here there is an obvious trend to increased effect both with triarimol and dinocap on a 7 day programme.

At Site IV the best control of secondary mildew was shown by the 10 day programme because of the regularity of the applications.

The level of primary blossom mildew tended to rise at Site II but decrease at Site III where the initial level was much higher. The figures for the dinocap treatment show a very poor control at both sites despite good control of secondary mildew in the growing season.

It is evident from figures in Table 3 that triarimol was also effective for the control of secondary mildew when applied at similar dosage rates and time intervals but in 40 gallons per acre. Unfortunately the scheduled time intervals could not be strictly followed for the 7 day interval so that the treatments with regular applications show up best.

The effect of increasing the concentration of the wettable powder from 4% to 40% does not alter the efficacy of triarimol as seen in Table 4, where again both formulations were statistically superior to dinocap.

The conclusions from the replicate trials outlined were confirmed by 16 large scale trials carried out under normal commercial conditions in 1970. As activity against apple scab was already known, triarimol was tested as a scab/mildew controlling programme from bud burst (early April) to the cessation of extension growth (late July), in comparison with a combination of either dithianon or captan with dinocap or binapacryl. Comparison with a full season's programme of benomyl was also possible at 4 sites.

The plot sizes were usually 1 to 2 acres and the spray volumes varied from 20 to 250 gallons per acre. The formulation used was the 4% w.p. at 900 g (= 36 g a.i.) per acre at 10 - 14 day intervals or 450 g (18 g a.i.) per acre on a 7 day schedule.

The results of mildew assessments are given in Table 5.

Table 5

(Average Percentage Leaf Area Infected with Secondary Mildew)

Location	Spray Volume gals/acre	Spray Interval days	triarimol	benomyl	dinocap	binapacryl
Kent	20	7	1.6	-	1.9	-
Kent	30	14 - triarimol and benomyl 7 - dinocap	5.0	9.4	5.0	-
Kent	50	14	2.8	-	3.3	-
Kent	37	10 to 14	4.0	-	4.7	-
Kent	100	12 to 14	4.0	-	-	6.4
West Sussex	100	13 to 14	1.6	-	-	4.0
Hants	100	14	1.8	5.0	-	4.2
Somerset	150	12	3.0	-	4.4	-
Hereford	50	9 to 20	2.8	-	5.4	-
Hereford	250	9 to 15	4.4	-	10.2	-
Cambs.	100	12 to 16	4.0	-	5.4	-
Norfolk	200	11 to 12	2.2	-	3.6	-
Suffolk	50	12 to 14	1.6	-	2.6	-
Essex	50	10	2.6	-	3.7	-
Essex	200	12 to 14	3.7	-	9.4	-
Herts	100	12 to 14	1.6	3.3	-	3.0

The above figures fully substantiate the efficacy of triarimol and show that even under the conditions of 1970, which were conducive to the spread of mildew, triarimol is superior to other treatments. Excellent leaf and fruit finish was observed on 19 commercial varieties which included Cox's Orange Pippin, Worcester Pearmain, James Grieve, Egremont Russet, Golden Delicious, Jonathan, Laxtons' Superb, Discovery, Crispin, Spartan, Bramley Seedling and Grenadier. The normal complement of insecticides showed no incompatibility problems. While dinocap and binapacryl effectively controlled fruit tree red spider mite during the treatment period, benomyl and triarimol were ineffective and a specific acaricide had to be applied to control this pest on plots treated with these two compounds.

Although very little scab infection occurred in these trials the information available (Gramlich 1971) is such that a recommendation can be made for the use of triarimol as a combined apple scab/mildew treatment.

Acknowledgements

The authors wish to acknowledge the valuable assistance of many colleagues in obtaining much of the data presented in this paper and to the growers who kindly made their orchards available; and some of whom applied the treatments in the large scale trials.

References

ANON with P. WIGGELL and SIMPSON C.F. 20th Ann. Report Luddington E.H.S. 1969. Part I. Fruit 15 - 17.

BARRATT, R.W. and HORSFALL T.G. An Improved Grading System for Measuring Plant Disease. Conneticut Agricultural Experiment Station.

BURCHILL R.T.) Rep. E. Malling Res. Stn. for 1970, 106.
)
BUTT D.J.) Rep. E. Malling Res. Stn. for 1970, 107.

BYRDE R.J.W. HARPER C.W. and HOLEGATE M.E. Ann. Rep. Long Ashton Res. Stn. (1970) 194.

GRAMLICH J.V. SCHWER J.F. and BROWN I.R. Proc. 5th Br. Insectic. Fungic. Conf., (1969) 576.

Proc. 6th Br. Insectic. Fungic. Conf. (1971)

THE CONTROL OF APPLE MILDEW WITH HOE 2873

S. J. B. Hay
Agricultural Chemicals Department, Hoechst U.K. Limited

Summary Hoe 2873 is the trials code number for the new systemic fungicide 2-(0,0-diethyl thionophosphoryl)-5-methyl-6-carbethoxy-pyrazolo-(1,5,a) pyrimidine.

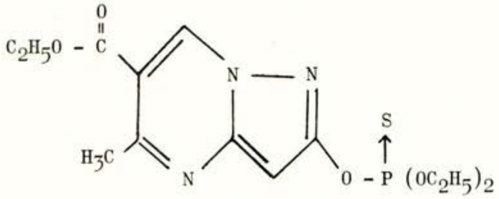
In field trials in the United Kingdom over the period 1969-1970, a 30% e.c. formulation of Hoe 2873 gave control of apple powdery mildew comparable to that of binapacryl and dinocap. Further improvements in effectiveness were obtained following adjustments to the time and rate of application and spray volume.

INTRODUCTION

Developed in Germany by Farbwerke Hoechst A.G., Hoe 2873 is effective against true mildews but possesses only weak insecticidal properties despite its structure.

Physical and Chemical Properties

2-(0,0-diethyl thionophosphoryl)-5-methyl-6-carbethoxy-pyrazolo-(1,5,a) pyrimidine has the following structure:



HOE 2873

$C_{14}H_{20}N_3O_5PS$ M.W. 373

Physical Form:	Colourless, crystalline solid
Melting Point:	50-51°C
Volatility:	Negligible, approximately 10^{-6} mm Hg at 20°C
Solubility:	Soluble in a wide range of organic solvents Solubility in water: 0.33% w/w at 20°C
Formulation:	30% e.c.

Toxicology

For female rats	Route	LD50, Hoe 2873 technical, mg/kg
	Acute oral:	140
	Acute intraperitoneale:	91
	Acute subcutaneous:	131
For fish	An LC100 of 8-16 ppm was established after 24 hours for Carp.	

Mode of Action

Hoe 2873 is absorbed by the foliage and green stem and is translocated by the plant. The uptake by roots is insufficient for its use as a soil application or seed dressing.

Field of Application

Trials with Hoe 2873 have shown the material to be non-phytotoxic to a wide range of crops and excellent control of the powdery mildews *Sphaerotheca humuli*, *S. mors-uvae*, *S.fuliginea* and *Erysiphe graminis* has been obtained. These results suggested that the material might have value in the control of apple mildew (*Podosphaera leucotricha*).

METHODS AND MATERIALS

Field Trials 1969

Technical: Randomised block trials with the inter-site plot size varying from 6-16 trees with 4 replications were used to examine the fungicides. The sprays were applied to run-off every 8-10 days starting at pink bud.

Grower: In additional grower trials Hoe 2873 at 4.8 oz/ac (0.34 kg/ha) was compared with binapacryl and dinocap applied at manufacturers' recommended rates for given spray programmes. The treatments were made with standard orchard spray equipment to unreplicated blocks of 1 or 2 acres (0.4 or 0.8 ha.) at intervals of 8-14 days using 20-180 gal/ac.

All trials were conducted in Kent on areas of 'Cox's Orange Pippin' trees with a wide range of pollinators.

Disease incidence was expressed as the percentage infected leaves on extension shoots calculated as a mean of 40 random shoots per plot in the small trials and 100 shoots per block in the grower trials. The records of diseased shoots refer to terminal bud infection of the current seasons growth.

RESULTS

Technical Trials

Binapacryl gave the best mildew control at all sites but was not significantly better than Hoe 2873 (Table 1).

Table 1

Percentage mildew infection (leaves), 30.7.69

Treatment %	Site Sittingbourne	E. Farleigh	Brenchley
binapacryl w.p. 0.05	7.6	12.1	9.1
binapacryl col 0.05	7.5	12.3	10.5
Hoe 2873 0.015 a.i.	9.6	15.4	12.9
dinocap e.c. 0.03	12.7	22.0	-
L.S.D. (P=0.05)	4.92	4.37	6.43
Number of spray applications	10	9	7

Data relating to the efficacy of Hoe 2873 are somewhat misleading however since the degree of infection of given leaves was often noticeably lower with this treatment. Following applications of Hoe 2873, extension growth was more vigorous and the foliage greener and more highly glossed than on binapacryl or dinocap treated trees (Table 2).

Table 2

Scoring of foliage for vigour/colour (10= excellent), June 1969

Treatment	Site Sittingbourne	E. Farleigh	Brenchley
binapacryl w.p.	8.6	9.1	8.7
binapacryl col	8.9	9.4	8.8
Hoe 2873	9.3	9.5	9.3
dinocap	8.6	9.1	-

Work in these technical trials was verified by grower sprayed trials.

Grower Trials

Table 3

Percentage mildew infection (leaves), July 1969

Treatment	Site 1	2	3	4	5	6
binapacryl w.p.	6.9	5.7	13.0	3.3	2.6	6.8
binapacryl col	5.5	5.2	11.7	3.1	2.5	6.0
Hoe 2873	8.8	9.6	14.7	4.4	3.1	8.4
dinocap	-	11.8	-	6.2	3.5	-

Hoe 2873 gave good disease control even at sites 4 and 5 where applications were every 14 days compared with the 8-10 day intervals on the other orchards. Good vigour and colour of foliage was again noted on the Hoe 2873 treated trees and excellent fruit colour and quality was recorded at harvest.

Effect of the treatments on overwintering infection

Shoots at one site were assessed in January 1970 for the incidence of over-wintering infection. Differences found between treatments are shown in Table 4.

Table 4

Percentage dormant shoots with no visible infection

Summer Treatment	Site: E. Farleigh
binapacryl w.p.	31.8
binapacryl col	37.5
Hoe 2873	40.2
dinocap	26.7
L.S.D. (P=0.05)	13.3

The incidence of mildewed flower trusses was assessed at several of the sites in early 1970 and results indicated that Hoe 2873 had been more effective in preventing re-infection than was suggested by the earlier data. Inhibition of sporulation appears to have been a contributory factor in this respect.

Field Trials 1970

Randomised block trials in Kent and Essex were used to evaluate the fungicide on three mildew susceptible cultivars, (Cox, Idared and Jonathan). Two trials consisting of 4 tree plots with 4 replications were laid down on areas of 'Cox' as shown in Table 5.

Table 5

Treatment	Dose/oz/ac First 3 Sprays	Dose/oz/ac Subsequent Sprays	Spray volume, gal/ac Site Cliffe Kent	Spray volume, gal/ac Site Southend Essex
1. Hoe 2873	9.6	4.8	40	25
2. "	9.6	4.8	80	50
3. "	4.8	4.8	40	25
4. "	4.8	4.8	80	50
5. binapacryl	16.0	16.0	80	50
Number of spray applications			8	7

At each site the higher volume was that amount of water required to spray to run-off. The effect of the treatments on mildew incidence is shown in Table 6.

Table 6

Percentage mildew infection

Treatment	Cliffe Shoots June	Cliffe Leaves August	Southend Shoots June	Southend Leaves August
1	10.6	12.1	11.6	10.7
2	20.0	14.0	11.3	14.9
3	13.1	12.7	16.0	18.1
4	23.8	17.8	16.9	16.9
5	22.5	16.9	15.0	15.3
L.S.D. (P=0.05)	13.27	6.88	7.55	13.24

Results indicate that spray programmes incorporating Hoe 2873 at a rate of 9.6 oz/ac (0.68 kg/ha) gave marked reductions of leaf mildew and prevented many terminal bud infections. Full programmes of 4.8 oz/ac (0.34 kg/ha) gave results in line with those obtained in 1969.

The data also suggest that Hoe 2873 was more effective when applied at lower volumes.

These results were confirmed in another trial at Chelmsford, Essex where the treatments 2, 4 and 5 shown in Table 5 were used. Plots consisted of 3 'Idared' and 4 'Cox' trees and had 4 replications. A total of 7 applications were made at 70 gal/ac (790 l/ha) and results obtained are shown in Table 7.

Table 7

Percentage mildew infection

Treatment	Shoots, June 1970		Leaves, August 1970	
	Idared	Cox	Idared	Cox
2	19.4	14.4	20.4	12.6
4	27.3	17.5	-	17.8
5	26.4	16.9	27.4	17.2
L.S.D. (P=0.05)	26.53	10.19	23.74	4.77

Six applications of several rates and combinations of materials were applied to run-off (80 gal/ac, 900 l/ha) to heavily infected 'Jonathan' trees at Brenchley, Weald of Kent. The treatment details and results are shown in Table 8.

Table 8

Percentage mildew infection (leaves)

Treatment %	June	August
Hoe 2873 0.015 a.i.	38.1	37.0
Hoe 2873 0.030 a.i.	14.1	14.0
Hoe 2873 0.009 a.i. plus binapacryl 0.025	29.3	28.3
binapacryl 0.05	38.6	41.9
dinocap 0.03	43.4	42.4
L.S.D. (P=0.05)	19.65	11.41

The full programme of 0.03 a.i. Hoe 2873 gave excellent disease control with no phytotoxicity to the foliage or fruit. The June estimations also showed that trees receiving this treatment had low levels of shoot infection.

DISCUSSION

These experiments have shown that Hoe 2873, used at rates equivalent to 4.8 oz/ac (0.34 kg/ha) in a standard spray programme, gave control of apple mildew comparable to that afforded by the dinitro fungicides. Used at 9.6 oz/ac (0.68 kg/ha) it was more effective than the latter fungicides and gave excellent control of primary and secondary infections particularly when used at relatively low volumes.

In other trials (unpublished) Hoe 2873 had negligible effects on populations of Panonychus ulmi on apple despite its chemical configuration.

Sprayed alone or with commonly used insecticides Hoe 2873 has caused no phytotoxicity and improvements in vigour, colour of foliage, crop quality and yield have often resulted.

Despite its specificity the material would appear to have considerable potential for the control of apple mildew.

Acknowledgements

The author wishes to thank those growers whose co-operation made this study possible and Mr. P. A. Turner for his assistance in the trials described.