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FUNGICIDES FOR CONTROLLING LEAF DISEASES OF WINTER WHEAT: EVALUATION, TIMING AND IMPORTANCE OF VARIETAL RESISTANCE

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by

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Abstract

During the three years 1991-1993, a series of three related collaborative experiments investigated the interaction between fungicides and cultivar resistance to leaf disease to provide guidance on improvements to wheat disease control. The three multi-site experiments evaluated the biological properties of new fungicide molecules, assessed the value of cultivar partial resistance to disease and compared single sprays of new fungicide products with a set of standard programmes.

In the first experiment, the mildew susceptible cultivar Apollo and the septoria susceptible Riband were each grown at two sites in each year. Single sprays of fungicide were applied at successive seven day intervals from early May until mid June. Additional plots were treated with a second application of the same fungicide three weeks later from mid May until late June.

Differences between fungicides for control of *Septoria tritici* were smaller than the differences between spray intervals. For the single treatments disease control and yield increases were greatest in 1992 and 1993 for treatments applied during the second two weeks of May and in 1991 in early June. For the two-spray treatments benefits were greatest when the second spray was applied to plots first treated during May and each of these two-spray treatments gave comparable disease control and yield benefits. They were generally superior to those of the single sprays on Riband but not on the Apollo.

On Riband, severe *S. tritici* developed at each of the sites in each year. The time of infection of each of the final three leaves (the flag leaf and the two leaves below) was related to specific rain splash events at most sites. In each case a single well timed spray gave disease control comparable to the best of the two-spray treatments on each of the final leaves.

The mildew (*Erysiphe graminis*) epidemics on Apollo were generally less severe than the septoria epidemics on Riband at Morley and ADAS Rosemaund. The best single spray treatment generally controlled disease on each of the final three leaves as well as the best two-spray treatment. There was a very small effect of the early single sprays (those applied before the start of flag leaf emergence) on final disease levels of both septoria and mildew on both cultivars. Where mildew was severe later in the season, there was a yield benefit when the first spray of a two-spray treatment was applied before stem extension, in early May.

In the second experiment a set of six standard one, two and three-spray programmes was compared with a targeted disease management treatment using the ADAS Managed Disease Control system on the four cultivars Riband, Beaver, Apollo and Hereward. Each cultivar was selected for their specific differences in host partial resistance. The three-spray programme, with treatment at second node detectable, flag leaf emerged and ear emerged gave the best overall disease control and greatest yield benefit on all cultivars but was the most cost effective treatment only on the disease susceptible cultivar Riband. By contrast, the single flag leaf emerged treatment generally proved to be most cost effective on Beaver and Hereward. On the mildew susceptible Apollo, the reduced dose treatment, incorporating an early (second node detectable) application of a mildew fungicide was the most profitable

treatment. The targeted treatment was the most cost effective programme on 40% of the sites on Riband but on only 20% of the Hereward sites. The results indicate that targeted disease control is difficult. Operators are risk averse and tend to err on the side of overuse of fungicide.

The third experiment used the mildew susceptible Apollo at five sites, Mercia was grown at one site in two years with the septoria susceptible cultivar Riband at seven sites. It provided independent information on new fungicides before they reached the market place and compared their performance as single sprays applied at flag leaf emerged with a set of standard one, two and three-spray programmes.

In each year the new conazole fungicides, tebuconazole and cyproconazole, gave superior disease control and yield response on both cultivars compared with the standard single spray treatment when applied at flag leaf emerged. These products were particularly effective on the Riband sites, where severe epidemics of septoria developed. The yield and disease control following treatment with these products was superior to that provided by the standard treatment and equal to that of either of the two-spray programmes used.

Objectives

1 The project was designed to improve disease control options for winter wheat by integration of the disease resistance characteristics of cultivars with an improved understanding of the properties of fungicides. It had the overall aim of providing the industry with up to date, independent information on new fungicide molecules and their biological properties.

2 It comprised three experiments, the objectives of which were:

Experiment I - to determine the response profile of winter wheat to fungicide treatment in relation to crop growth and development and the eradicant and protectant properties of the candidate fungicides.

Experiment II - to assess the benefits of host partial resistance to disease in relation to timing of fungicide sprays and identify the needs for disease control at selected growth stages.

Experiment III - to compare new fungicide active ingredients with standard spray programmes with established fungicides when applied as single sprays at flag leaf emerged and to identify products for more detailed evaluation.

3 The project sought to improve fungicide targeting to provide the least-cost system of wheat disease control.

Background

4 Fungicides are an accepted part of cereal crop management. Surveys by the Central Science Laboratory (CSL) MAFF and ADAS have shown that over 90% of the wheat crop in England and Wales has been treated with fungicide since the mid 1980s. Recent evidence from cultivar trials shows that although fungicide need varies according to the general level of disease resistance, most cultivars will give an economic response to fungicides in most seasons.

Winter wheat fungicide regimens

5 Experiments on wheat disease control during the last 15-20 years have consistently shown that the most cost effective control of leaf diseases can be obtained by fungicides applied during the critical flag leaf emergence period, at about GS 39 (Tottman, 1987). This is particularly true where single sprays are used, but the results also show that this treatment is an essential element of fungicide programmes, where disease is severe.

6 Despite this conclusion, the disease surveys by CSL and ADAS show that policy for fungicide use on many crops is sub-optimal. These results, some of which are summarised in Table 1, show that the majority of crops receiving one or two sprays are not protected during this critical period of growth.

Table 1. *Frequency of the main one and two-spray programmes applied to winter wheat (% crops treated)*

Treatment stage	1989	1990	1991	1992	1993	Mean
GS 31 only	9.4	7.8	5.5	5.3	5.1	6.6
GS 39 only	4.7	6.0	3.8	5.8	2.7	4.6
GS 59 only	5.4	8.0	8.2	6.6	7.3	7.1
GS 31 + 39	11.1	17.9	8.0	12.3	11.1	12.1
GS 31 + 59	21.2	18.2	30.2	34.5	24.4	25.7

Note: GS 31:GS 29-35; GS 37:GS 36-44; GS 59:GS 45-71
The table excludes other single or multiple spray combinations

7 Table 1 shows a surprising similarity in treatment regimens between years. In most years less than 20% of crops receiving one or two sprays were treated at the critical GS 39. The survey results support the experimental work in that disease levels are lower on crops which received a second spray at GS 39 compared with GS 59 (eg. Cook, Polley and Thomas, 1991).

Table 2 summarises this survey data for the period 1985-1989 and also indicates that, for septoria control, spray programmes commencing in early May were more effective than those starting in April.

Table 2. *Severity of* Septoria tritici *in relation to spray programme and programme start date (% infection leaf 2)*

Programme	April	May 1-15
31 + 39	4.7	0.9
31 + 59	5.6	2.0
Untreated	6.7	

Introduction

8 Considerable work is carried out by the agrochemical manufacturers before new products are launched on the UK market. Much of the work is aimed at fulfilling the requirements of the MAFF Pesticides Safety Directorate agency (PSD) and is, therefore, concerned with crop residues, mammalian toxicity and other factors that have no direct effect on crop responses to the control of fungal diseases. Although efficacy work is undertaken, some independent work is required to confirm and supplement the label recommendations and provide experience on which to base product use in the field.

9 Although modern fungicides provide a high level of effective disease control, when used according to label recommendations, a greater understanding of some aspects of the field behaviour of fungicides could enable growers to make much more cost effective use of products.

10 Different cultivars have different degrees of genetic disease resistance. Many farmers routinely exploit these differences in their selection of cultivars and choice of fungicide programme. Cultivars can be grouped according to their resistance levels and response to fungicides. As cultivars become more widely grown, the pressure on fungal pathogens to adapt increases and the disease resistance ratings frequently fall. As a result, the sensitivity of a cultivar may alter and cause the cultivar to be reclassified. Mercia, for example, has undergone such a change; originally resistant to powdery mildew (*Erysiphe graminis*) it has, in recent years, become susceptible to some races of the mildew fungus.

11 Similar changes have occurred with respect to the resistance of some cultivars to yellow rust (*Puccinia striiformis*). There are many complex races of this pathogen and cultivar resistance can change dramatically from one season to the next as new races of the fungus develop. Slejpner for example is highly susceptible to yellow rust and was, at one stage, almost unique in its susceptibility. The widespread occurrence of the Slejpner race may put other cultivars at risk as new more complex races able to attack other cultivars developed.

12 The project has evolved from MAFF funded work which has demonstrated that there may be potential to exploit the different biological properties of individual fungicides in relation to disease development and crop growth (eg Hims & Cook, 1991, 1992). This work provides a practical outlet for continuing MAFF funded projects as well as new HGCA funded projects which are evaluating appropriate fungicide dose in relation to activity. These projects aim to provide a practical integration of the results of this work to improve disease control options and reduce costs.

Approaches

13 Three distinct experiments were designed to investigate aspects of fungicide timing, the biological properties of fungicides, host partial resistance and to provide information on the comparative activity of new fungicide molecules.

Experiment I: Evaluation of fungicide properties

14 This experiment compared three conazole fungicides, each applied as seven single and five two-spray treatments. The experiment was designed to create differentially phased epidemics of each disease to provide comparative information on fungicide timing and activity.

15 The cultivars Riband and Apollo (at 2 sites each in each year) were selected to provide information on septoria (*Septoria tritici*, conidial state of *Mycosphaerella graminicola*) and mildew (*Erysiphe graminis*) respectively. The cultivars were also selected on the basis of their potential feed, industrial and milling uses.

16 Fungicides representing the new conazoles and products which may be used in mixture with these materials, to broaden the spectrum of activity in specific situations, were evaluated.

Experiment II: Cultivar resistance and disease control

17 In order to evaluate the potential benefits of genetic resistance four cultivars with different levels of host partial resistance were treated with fungicide programmes designed to exploit these differences. The actual 1993 disease ratings, as given by the National Institute of Agricultural Botany (NIAB) Recommended List of the selected cultivars to the target diseases, (Anon, 1993) are shown in Table 3.

18 The individual cultivars were chosen to represent "types" with a range of disease resistance characteristics into which other cultivars with similar disease characteristics could be placed. An example of the way in which cultivars may be grouped in terms of disease characteristics is shown in Table 4.

Table 3. *Characteristics of cultivars used to assess the benefits of genetic resistance (1993 NIAB Recommended List)*

Cultivar	Relative treated yield	Disease ratings				
		Y.rust	B.rust	*S.tritici*	Mildew	Eyespot
Apollo	117	4	4	7	3	5
Beaver	126	4	4	6	7	4
Hereward	115	(4)	8	6	6	5
Riband	126	4	4	3	7	6

() Limited data

Table 4. *Cultivar groups and examples with comparable characteristics to those chosen for Experiment II*

Group	Cultivar used	Comparable cultivars
High yielding, poor disease resistance	Riband	Admiral, Slejpner, Hornet
High yielding, moderate disease resistance	Beaver	Haven
Moderate yield, mildew susceptible	Apollo	Tara, Mercia
Low/moderate yield, good disease resistance	Hereward	Pastiche, Galahad
High yield, good disease resistance	not included in present work	Hussar, Hunter

Experiment III: Fungicide comparison

19 There is overwhelming evidence that the most cost effective time for application of a single fungicide spray to wheat is at, or about, the completion of flag leaf emergence (GS 39). This experiment provided comparative information on the activity of new fungicide molecules and standard spray programmes with a single spray at GS 39.

20 Single applications of candidate materials were applied at a range of sites. Two cultivars, Riband and Apollo, allowed direct comparisons between the other two experiments. These were compared with four standard fungicide programmes, each providing as close as possible to complete disease control at different growth stages. The experiment was made at 12 sites in each year.

Overall method

Experiment details

21 Experiments were established by sowing individual plots during September or early October each year, although at some sites plots were marked into existing crops with Gramoxone 100 (paraquat, 200 g ai/l) during winter or early spring. Each year a new stock of fungicide treated seed, based on phenyl mercury acetate in year 1 and Rappor (guazatine, 300 g ai/l) in years two and three was used. Each site was selected so as to minimise the risk of eyespot (*Pseudocercosporella herpotrichoides*) and take all (*Gaeumannomyces graminis*).

22 Treatments were normally applied using a hand held boom from a gas pressurised sprayer system. Nozzles were of a similar type to those used on commercial sprayers so that treatments were applied in 200-250 l/ha.

Disease assessments

23 Disease was observed at each site at intervals during the season. Each experiment was subject to a site assessment of stem base disease at or immediately after first node detectable (GS 31-32), when 25 potentially ear bearing stems from the untreated plots of each experiment were assessed. The area of the lowest fully expanded leaf with less than 50% senescence was also examined for disease. At GS 75, 25 randomly selected plants per plot were assessed for severity of eyespot, sharp eyespot (*Rhizoctonia cerealis*) and fusarium (*Fusarium* spp). Foliar disease and green leaf area were assessed on leaves 1 and 2 of 10 tillers selected at random from the stem base samples. In each experiment leaf 1 was taken as the top-most fully expanded leaf, ie with the ligule showing. Leaf 2 was the leaf below leaf 1 and so on.

24 All disease assessments were completed according to the guidelines in the ADAS Cereal Disease Compendium, copies of which were supplied to all Site Managers. Leaf disease assessments at other times varied between experiments and are detailed in the sections below. Whole plot assessments of disease, as used at some times in experiments I and II used the ADAS keys which are based on those used by the NIAB.

Weather records

25 Daily maximum and minimum temperature and rainfall were recorded for Experiment I and were used to analyse disease development. Temperature data were used to estimate the latent period for diseases and were integrated with the disease severity at each assessment date to calculate the progressive number of disease degree days for each leaf layer.

Yield

26 Plot yields were harvested by combine harvester and yield components were corrected to 85% dry matter. Specific weight and 1000 grain weight were recorded for all sites

in Experiments I and III. Hagberg falling number (HFN), Sodium dodecyl sulphate (SDS) sedimentation volumes and crude protein (86% dm) were recorded at all sites in Experiment I, but on the milling cultivars only in the other experiments, to reflect the potential market use of the selected cultivars.

Lodging

27 Lodging was assessed when detected in any of the experiments using the following categories:

1. % plot area upright
2. plot area leaning between 30° and 60°.
3. % plot area leaning more than 60° or flat.

28 Where less than 5% of the crop was affected lodging was declared absent at harvest.

Data processing

29 All details and records were input to MINITAB worksheets on pre-formatted diskettes which were processed by ADAS ISU, at Cheltenham.

Experiment I

Method

Sites

30 The individual sites are given in Table 5, with cropping and field details in Annex I, Table A.

Table 5. *Site and cultivar choice for evaluation of fungicide properties*

Site	Cultivar	Collaborator
Rosemaund	Riband	ADAS
High Mowthorpe	Apollo	ADAS
Edinburgh	Apollo	SAC
Morley	Riband	Morley Research Centre

Fungicides and active ingredients

31 Treatments commenced at or around GS 32; subsequent treatments were applied as far as practicable at weekly intervals. The fungicides used in each year are shown in Table 6. Each product was applied at the manufacturer's recommended dose.

Layout and treatment regimens

32 Two randomised blocks were established at each site. Each block comprised of 42 plots, with the three candidate fungicides as the main treatments and timings as sub-plot treatments. There were seven and five one or two-spray programmes respectively. The treatment regimens and spray dates for each site are shown in Table 7. Two untreated sub-plots were included in each main plot for greater untreated baseline stability. The total of 84 plots at each site, were arranged to ensure maximum exposure to disease prior to treatment and to minimise interference between different fungicide treatments. Plot layout is illustrated in Annex I, Table B.

Disease assessments

33 At GS 31 stem base and leaf diseases were assessed on all fully expanded leaves on 25 plants from the untreated plots in each block. *Septoria tritici* and *S. nodorum* were assessed on dead or senescing leaves (which may have been lying on the soil surface). Care was taken to ensure that the two *Septoria* species were distinguished and the percentage area affected by either or both species as well as other leaf diseases was recorded. Eyespot was assessed as the percent tillers affected and the number of leaf sheaths penetrated was noted.

Table 6. *Fungicides used at each site for evaluation of fungicide properties*

Product	Active ingredient (g ai/l)	Rate (l/ha)
1991		
Glint	fenpropimorph + propiconazole (375 + 125)	1.0
Sambarin	chlorothalonil + propiconazole (250 + 62.5)	2.0
UK 264	tebuconazole + triadimenol (250 + 125)	1.0
1992		
Alto Elite (Riband)	chlorothalonil + cyproconazole (375 + 40)	2.0
Alto + Corbel or Mistral (Apollo)	cyproconazole + fenpropimorph (100 + 750)	0.8 + 1.0
Glint	fenpropimorph + propiconazole (375 + 125)	1.0
UK 264	tebuconazole + triadimenol (250 + 125)	1.0
1993		
Glint	fenpropimorph + propiconazole (375 + 125)	1.0
Indar + Corbel	fenbuconazole + fenpropimorph (50 + 750)	1.5 + 0.75
UK 264	tebuconazole + triadimenol (250 + 125)	1.0

34 Subsequent assessments for leaf diseases were made on all leaves on 10 tillers on all sprayed plots, 10 tillers on those plots to be sprayed during a particular week (which were untreated) and 10 tillers on untreated plots at 7 day intervals from the date of first treatment until GS 75. If up to GS 59 disease was absent in any of the untreated plots treated plots were not recorded on that occasion.

Table 7. *Fungicide treatment dates and growth stages for each site in Experiment I*

Week	Rosemaund		High Mowthorpe		Edinburgh		Morley	
no.	GS	Date	GS	Date	GS	Date	GS	Date
1991								
1	31-32	May 7	33	May 22	32-33	May 15	32	May 8
2	32	May 14	43	June 5	33-37	May 22	33	May 15
3	37	May 21	-	-	37	May 29	37	May 22
4	39	May 29	45-55	June 20	41	June 5	37-39	May 29
5	45	June 4	59	June 28	45-51	June 12	43	June 5
6	45-59	June 11	64-72	July 8	57	June 19	57	June 16
7	59	June 18	-	-	59	June 26	59	June 20
8	63-65	June 25	73	July 22	61	July 3	69	June 26
1992								
1	32	May 7	32	May 20	32	May 5	32	May 6
2	32	May 14	41	June 3	32	May 12	33-37	May 13
3	37	May 21	41	June 3	34-37	May 22	37-39	May 20
4	45	May 31	55	June 9	37-39	May 26	51	May 28
5	55	June 4	63-65	June 16	41-45	June 2	65	June 6
6	62	June 10	64-72	June 23	55	June 9	69	June 10
7	69	June 18	69-71	June 30	59	June 16	71	June 22
8	71	June 25	73	July 7	69	July 23	71	June 24
1993								
1	32	May 5	32	May 12	32	May 10	32	April 30
2	32-33	May 12	33	May 19	37	May 19	33	May 6
3	37-39	May 19	33-37	May 25	37	May 25	37	May 13
4	39	May 26	39	June 1	39	May 31	39	May 21
5	45-47	June 2	No spray applied		47	June 7	47-51	May 29
6	59	June 9	55-57	June 13	53	June 14	55	June 3
7	63-65	June 17	61	June 22	57	June 21	65	June 10
8	69-71	June 23	68	June 29	59	June 28	69	June 17

Leaf position

35 The top-most fully expanded leaf was tagged at GS 31 and subsequent leaves were counted as they emerged, so as to obtain a record of leaf development and later to relate leaf position to the flag leaf (leaf 1 = flag leaf).

Fungicide properties

36 In order to gain a more thorough understanding of the biological properties, in terms of both eradicant and protectant activity, of the fungicides used throughout the three years of the experiment, a detailed examination was made of disease progress on the final four leaves (the flag leaf and the three leaves below). In each case the starting point for each epidemic was the date of the imputed infection event for *S. tritici* and one week before the first observation of mildew on each leaf. This enabled:

* Visualisation of disease progress in the untreated plots as an aid to understanding the relationship between rainfall events and subsequent development of septoria.

* Visualisation of the development, in the untreated plots, of mildew to understand the relationship between fungicide activity and the incidence of mildew (and its severity) in the different leaf layers in the crop canopy.

* Calculation of the area under the disease progress curve (AUDPC) for all plots calculated as disease degree days i.e. interpolated daily disease values for each leaf multiplied by the daily mean temperature. For this calculation a base of 0 °C was used, although it was recognized that further examination of the data might reveal that a different base temperature may be more appropriate.

37 For the purposes of this exercise a septoria infection event was taken as 5 mm rain in one day or a total of 10 mm falling on three successive days each with over 1 mm of rain.

38 The AUDPC provides an estimate of the total activity of the fungicide across the whole 10 week period of final canopy development and early grain fill instead of taking a single point in time, usually GS 75, as a measure of fungicide effectiveness.

Results

39 The majority of fungicides were applied according to the spray regime, the exception being High Mowthorpe where very windy and wet weather prevented two treatment applications in 1991 and 1993. All four experiments were harvested successfully in each year and yield and grain quality data were obtained.

Disease development

Mildew

40 Mildew was the major disease at the SAC site in all three years; it also developed to achieve moderately severe levels at High Mowthorpe in 1992 and 1993, but not in 1991. Development at High Mowthorpe and SAC Edinburgh was never spectacular, but steady

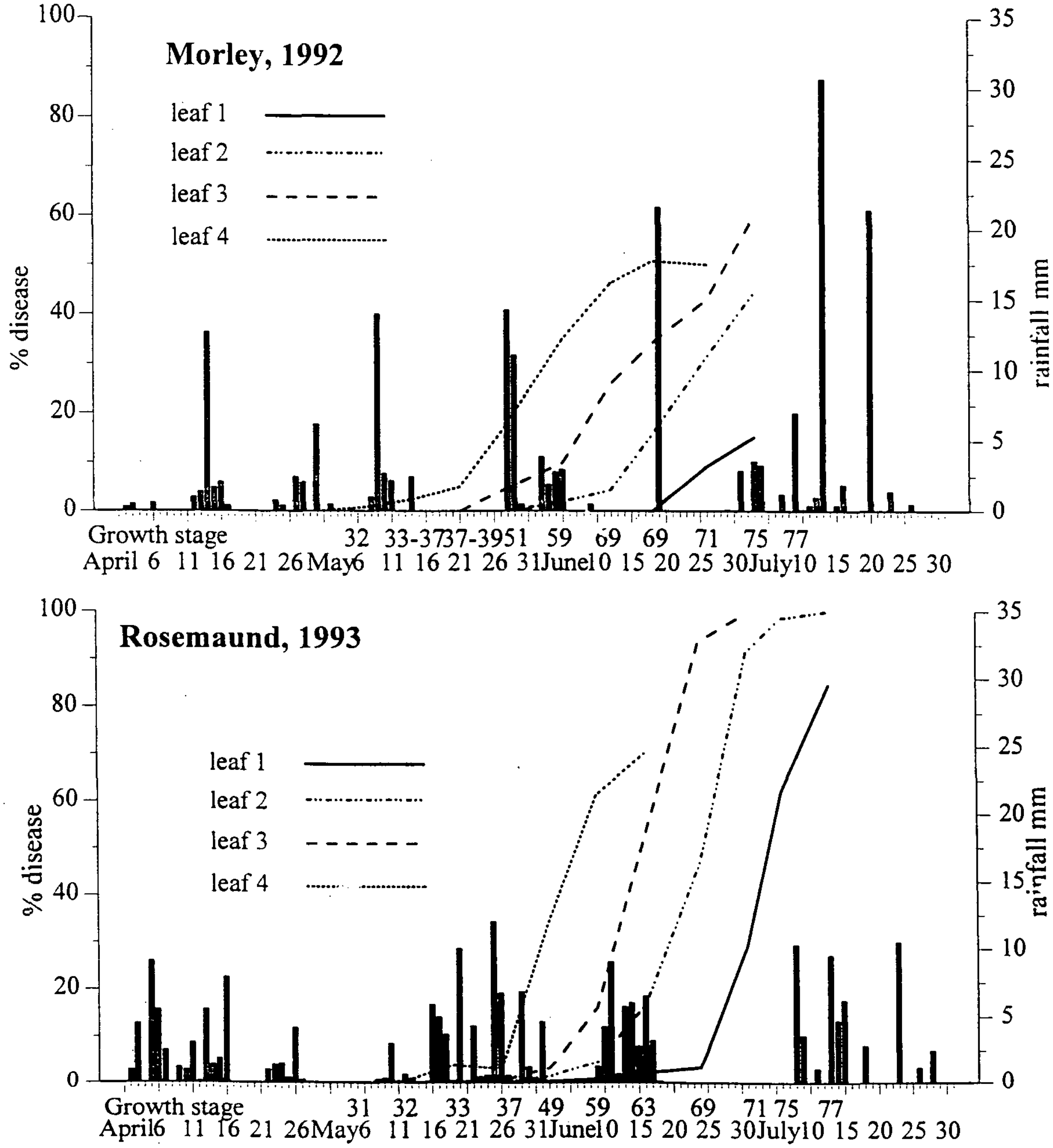
increases from canopy completion (GS 39) onwards meant that the disease achieved levels in the range of 30-40% on the final three leaves at GS 71-85. At each site, infection of each of the final four leaves apparently occurred soon after emergence of the individual leaves but always became more severe following canopy completion. At five of the six site-year combinations mildew ranged up to a maximum of 20-40%, most often on leaf 3 or 4. Leaves 1 and 2 were rarely affected to this degree. Disease development is illustrated in the Annex I Figures A and B (pages 61-65).

Septoria

41 *Septoria tritici* developed to high levels at Rosemaund and Morley and also, to a lesser extent, at the SAC site in 1991, albeit late in the growth of the crop at that site. In contrast to mildew, septoria development at Morley and Rosemaund was dramatic, the disease becoming severe to very severe in untreated control plots at GS 75-85. Despite the common severe attacks there were clear differences in the rates of disease development (Figure 1) and the date of epidemic commencement at the two sites during the three years. This appeared to be almost entirely due to the temporal distribution of rainfall at each site.

42 The two extremes of epidemic development may be illustrated by comparing these two sites. There was a slight difference in the rate of accumulation of day degrees and, if it were meaningful, then Morley should have seen more rapid and intense disease expression as it was approximately 100 day °C warmer than Rosemand by GS 59. Examination of the rainfall distribution at the two sites in 1992 and 1993 indicates that rainfall events (total daily rainfall or total accumulated rainfall during two or more days with >1 mm per day) were considerably more frequent and at higher volume at Rosemaund compared to Morley (30% more rain fell at Rosemaund) and also provided at least 13 potential single rainfall days compared to 6 at Morley. This could have provided at least two more infection opportunities.

Figure 1. *Development of* Septoria tritici *at Morley (1992) and Rosemaund (1993) in relation to rainfall at each site*



43 These experiments have generated significant amounts of data and space does not allow a full presentation of all the results. Individual details of each epidemic at each site are available from the Experiment Leader on request. However, graphs depicting mildew and septoria development, the major diseases at each site, for the 12 site/year combinations (except High Mowthorpe in 1991) during the three years of the project are presented Annex I Figures A to I on pages 61-86. Data from a preliminary analysis of the contrasting septoria epidemics at Morley in 1992 and Rosemaund in 1993 are discussed below.

Fungicide activity

44 Comparisons of fungicide activity are based on the relative reductions in the AUDPC for each of the candidate fungicides. For each individual and clearly identified disease infection event on each leaf, at each site and in each year, the reduction in AUDPC for the candidate fungicides was expressed as a percentage of the AUDPC for the appropriate untreated leaf layer at that site. Each data point was calculated by subtracting the day degree sum (above zero degrees C) for the imputed primary infection event, for each leaf from the day degree sum for each spray day. This provided an estimate of the level of disease control that could be expected if one of the fungicide mixtures was applied within a known number of degree days before or after the imputed infection event. This has been taken as the intersection point of the x and y axes.

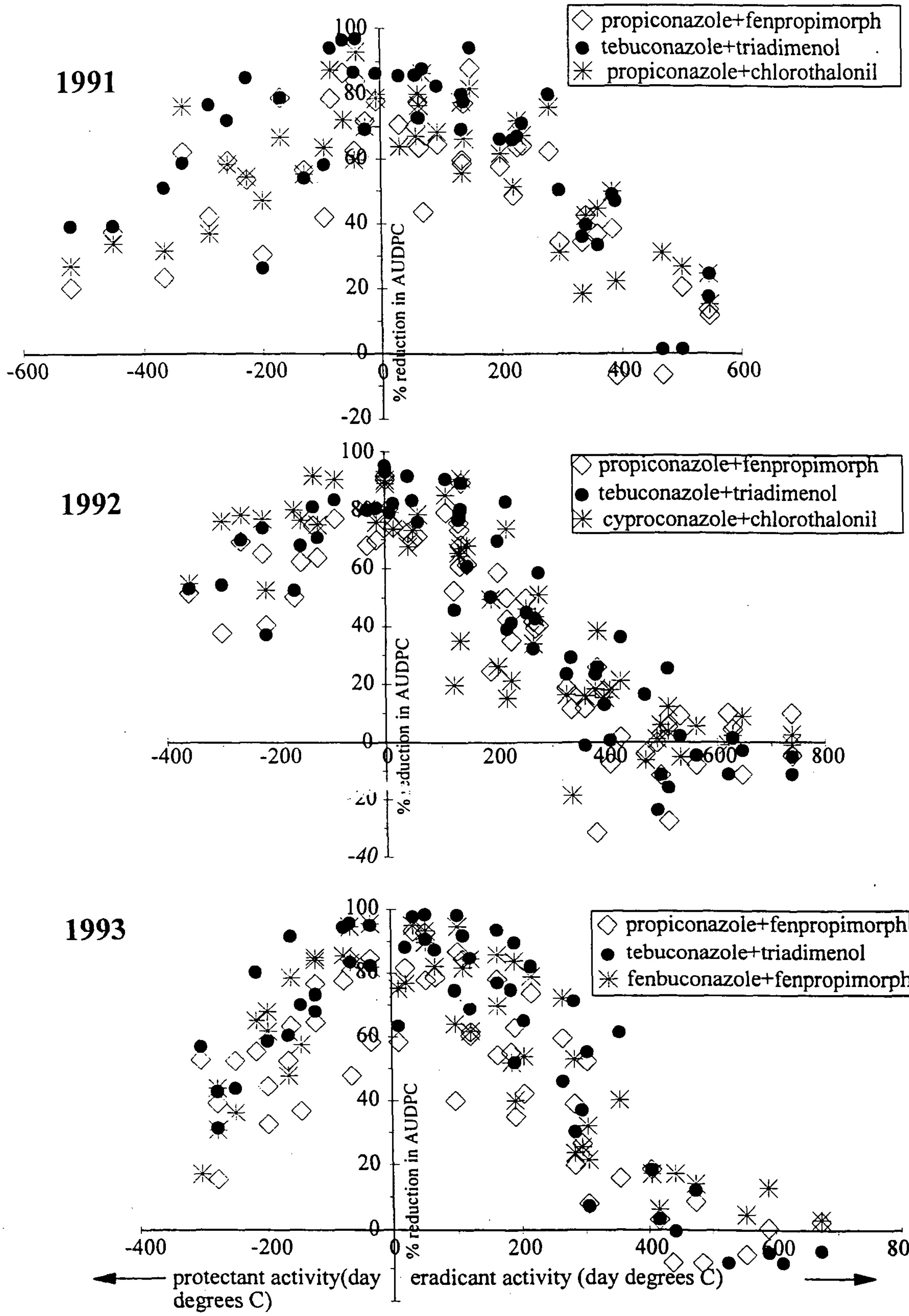
Septoria tritici

45 The severe epidemics at Morley and Rosemaund provided rigorous conditions for testing the properties of the five fungicide mixtures used in Experiment I.

46 The scattergram in Figure 2 indicates that single sprays of all the fungicide mixtures used control at least 50% of *S. tritici* when applied either as a protectant or an eradicant, within 250-300 degree days of leaf infection; moreover 70-80% control was achieved when the fungicide was applied within 100 degree days of imputed leaf infection. Tebuconazole + triadimenol gave the best overall performance, although more sophisticated statistical regression analysis and curve-fitting is needed.

47 Graphs of fungicide activity in relation to infection and disease development on individual leaves at each site are provided in the Annex I Figures C to H (pages 66-83). They indicate how similar the fungicides are in terms of protectant and eradicant activity when applied as two-spray programmes with only 3 weeks between the two-spray treatments. Each fungicide achieved virtually 100% control of disease on a particular leaf when applied within a few days of leaf infection, either before or after the event.

Figure 2. *Protectant and eradicant activity of candidate fungicides against* Septoria tritici *for all site infection events, 1991-1993*



Mildew

48 Generally, the pattern of disease control was less pronounced than for septoria. The 'curves' were much flatter with a much less pronounced peak in the level of control. Moreover, the degree of control was more erratic even with fungicide mixtures containing fenpropimorph (Figure 3) or when treatment was applied close to the imputed infection event. Nevertheless, a single spray applied to a leaf soon after its emergence provided a reasonable to good degree of mildew control with the exception of propiconazole plus chlorothalonil. The two-spray programmes of this mixture gave a similar result. Two-spray programmes of the other mixtures invariably provided good to excellent mildew control with those including an early spray providing the greatest level of control.

49 At each of the mildew sites the first sprays of the two-spray treatments applied in early May reduced mildew at GS 75 in comparison with the single sprays applied at the date of the first spray (Annex I Figures I and J, pages 84-88).

Yield and grain quality

50 Reductions in yield and grain quality were considerable, particularly at the septoria sites. There were critical weeks when fungicides needed to have been applied in order to maintain yield close to that which might be expected when the constraint of disease was avoided. The yield increase following any of the single sprays was significant ($p=0.05$) and in general the response to the single sprays applied in weeks two, three and four were significantly greater than those applied in week one on both cultivars. Similarly, at most sites the two-spray treatments with the first spray in early to mid May provided a significant benefit over the yield response of the comparable single sprays. The Edinburgh site in 1992 provided a notable exception.

51 Reductions in yield and grain quality were well correlated with estimates of disease, particularly so with AUDPC, those for leaves 1, 2 or 3 accounting for 70-90% of the variation in yield and 40-60% for that in grain quality.

52 Graphs to show the effects of each spray on yield are presented in Figures 4 and 5 for the two Riband sites. They show the improved consistency of the two-spray treatments as well as the increased window of treatment opportunity which the two-spray treaments offer.

53 As indicated above, rainfall patterns in 1992 were very different from those recorded in 1991, resulting in somewhat earlier epidemics of *S. tritici*. For this reason the effect of the disease on yield was substantially greater than that recorded in 1991, so that responses of 40-50% were recorded for the best two-spray treatments at Rosemaund and Morley (Figures 4 and 5).

54 Whilst this improved treatment effect was visible at the mildew sites, responses to the single spray treatments were generally more erratic, especially at High Mowthorpe in 1991 (Figure 6) and Edinburgh in 1992 and 1993 (Figure 7). This also shows the relatively small amplitude of response at the site in Scotland.

Figure 3. *Protectant and eradicant activity of candidate fungicides against mildew for all site infection events, 1991-1993.*

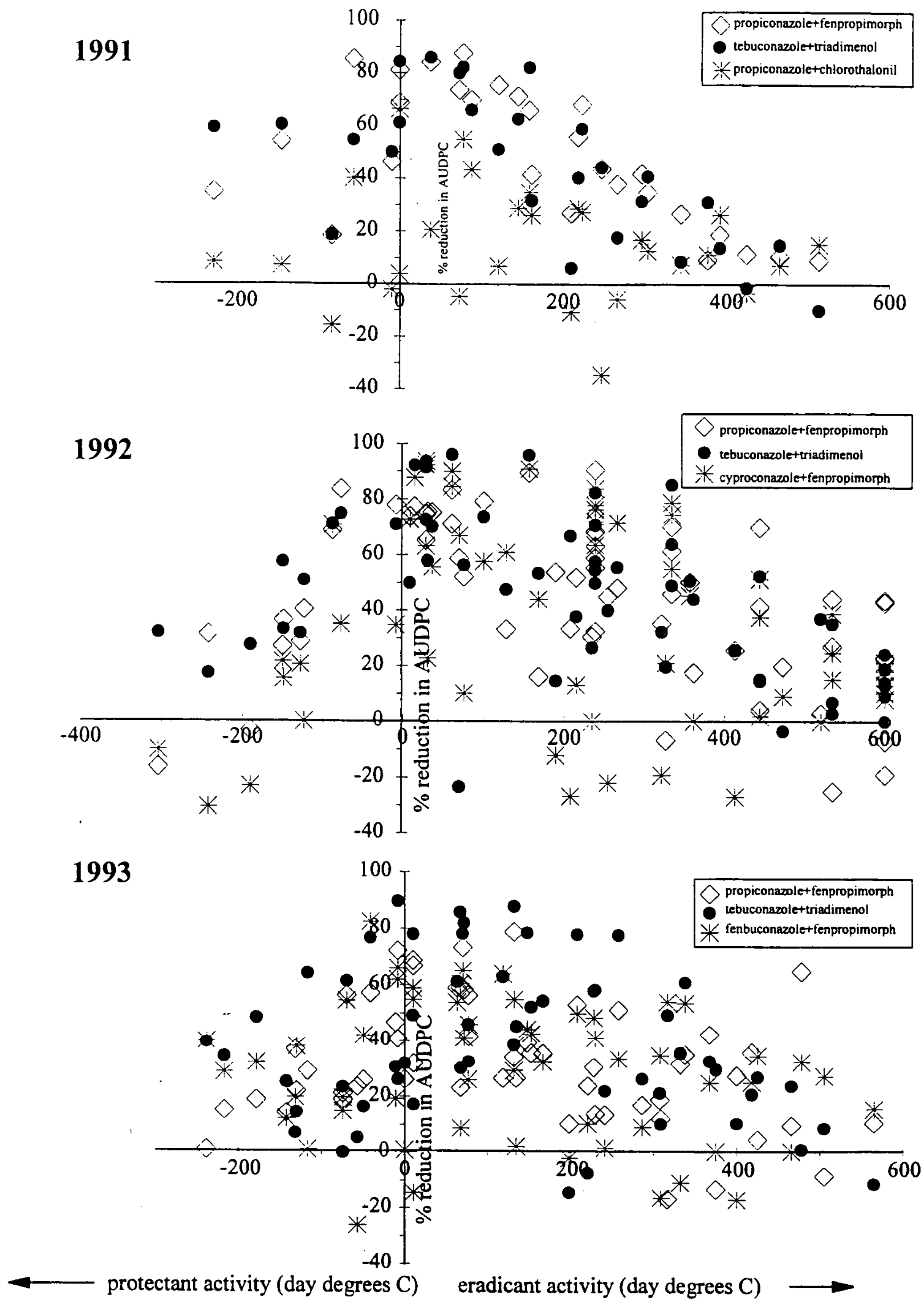


Figure 4. *Pattern of yield response to one and two-spray programmes, Morley Research Centre 1991-1993*

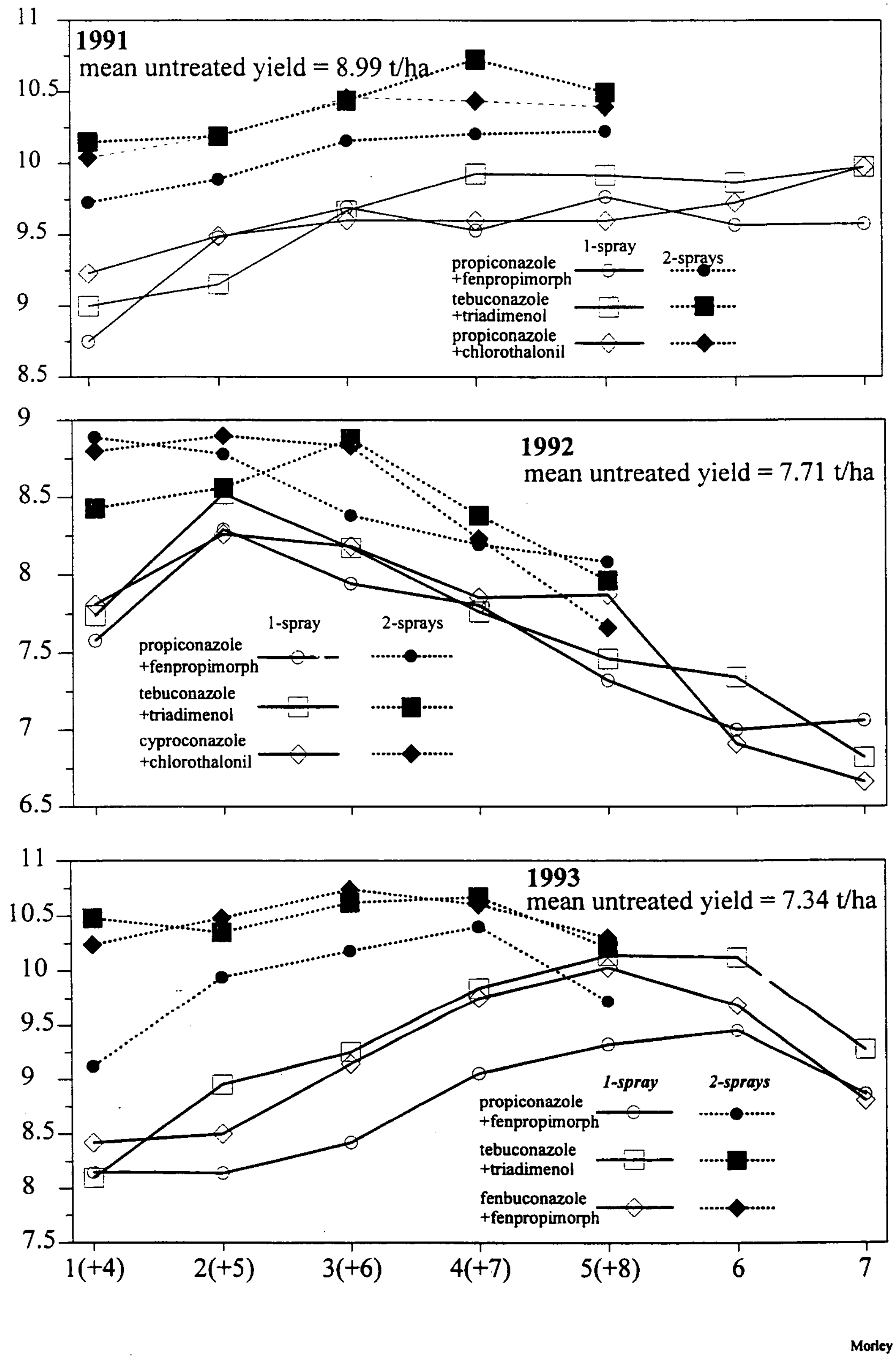


Figure 5. *Pattern of yield response to one and two-spray programmes, ADAS Rosemaund 1991-1993*

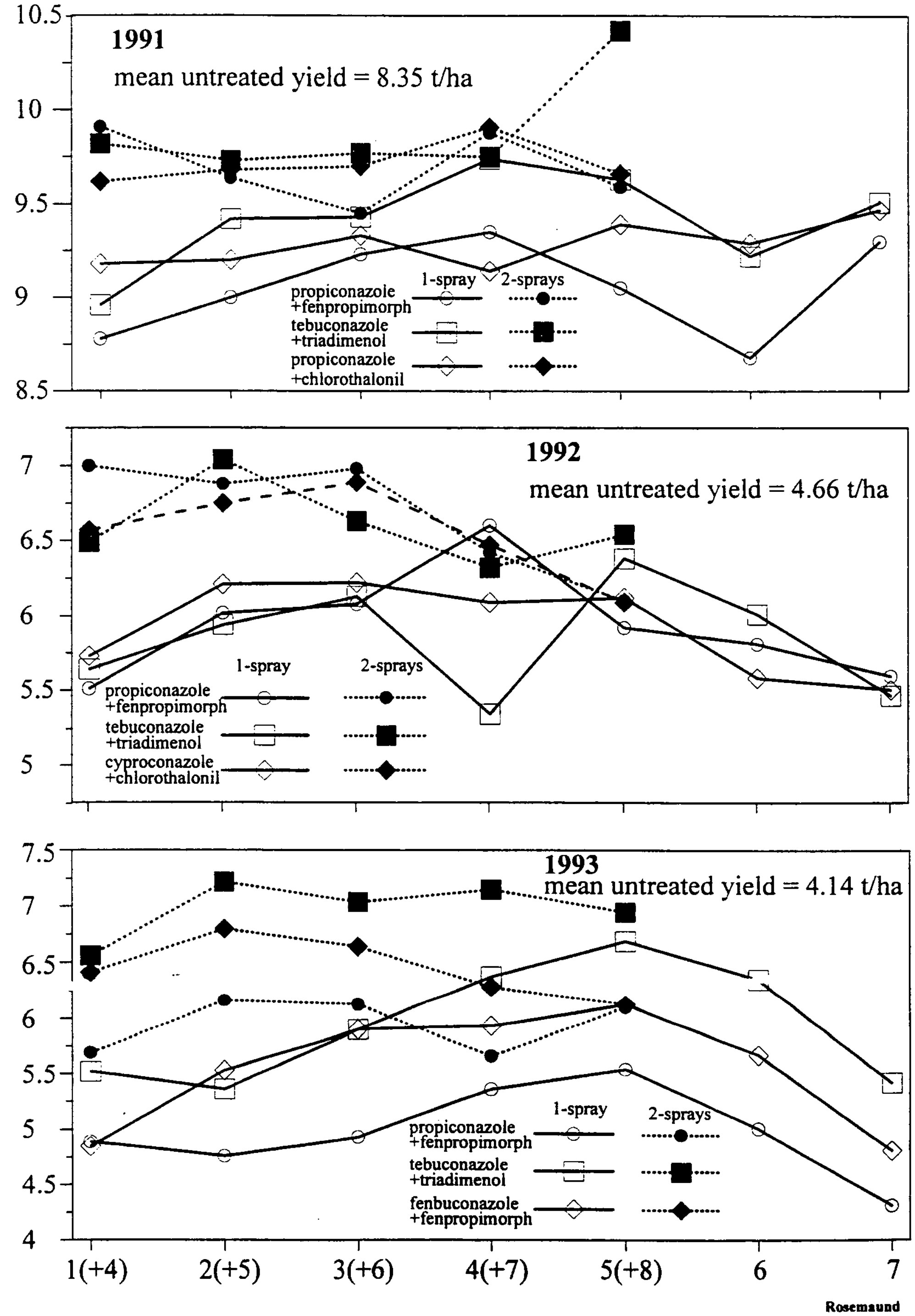


Figure 6. *Pattern of yield response to one and two-spray programmes, ADAS High Mowthorpe 1991-1993*

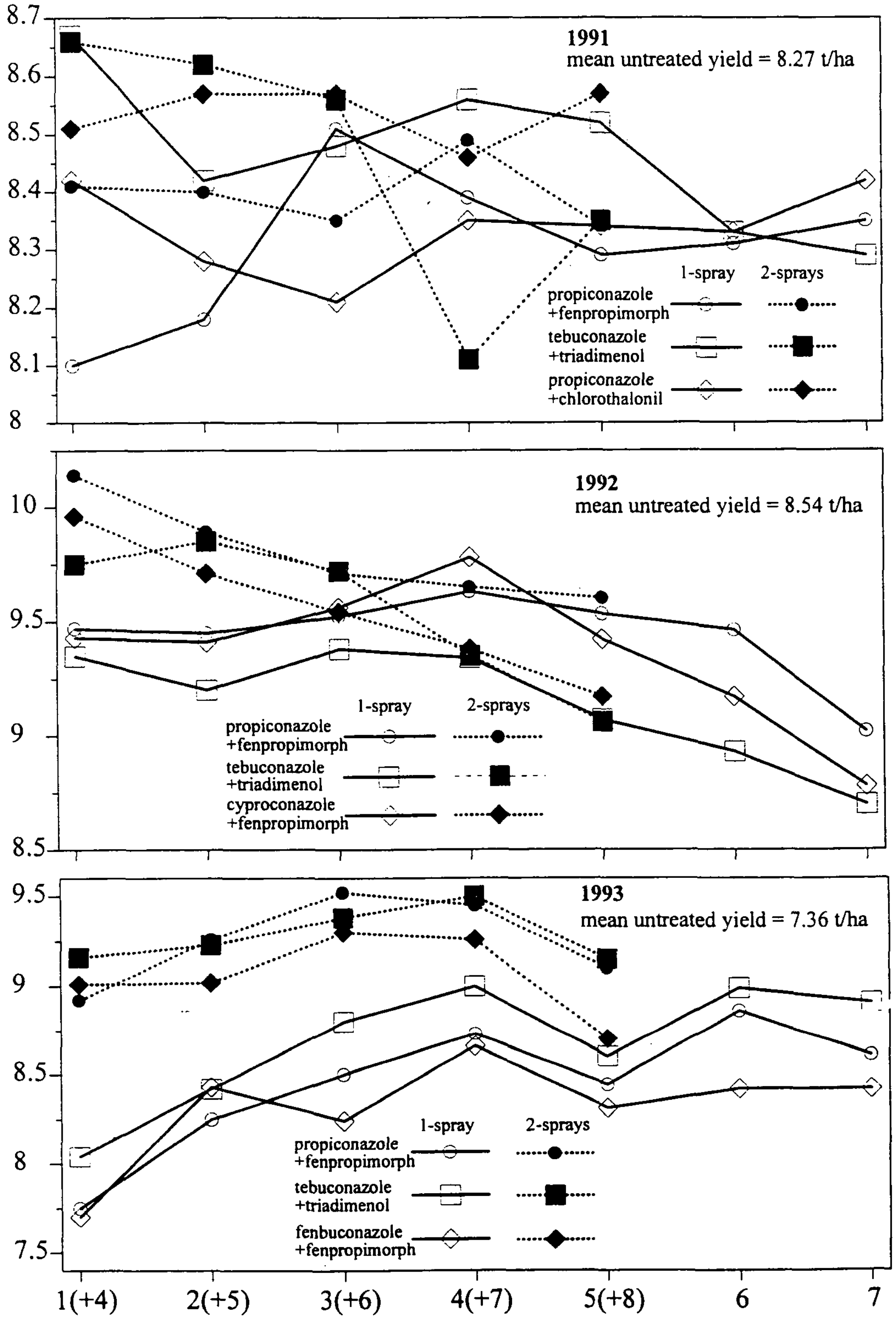
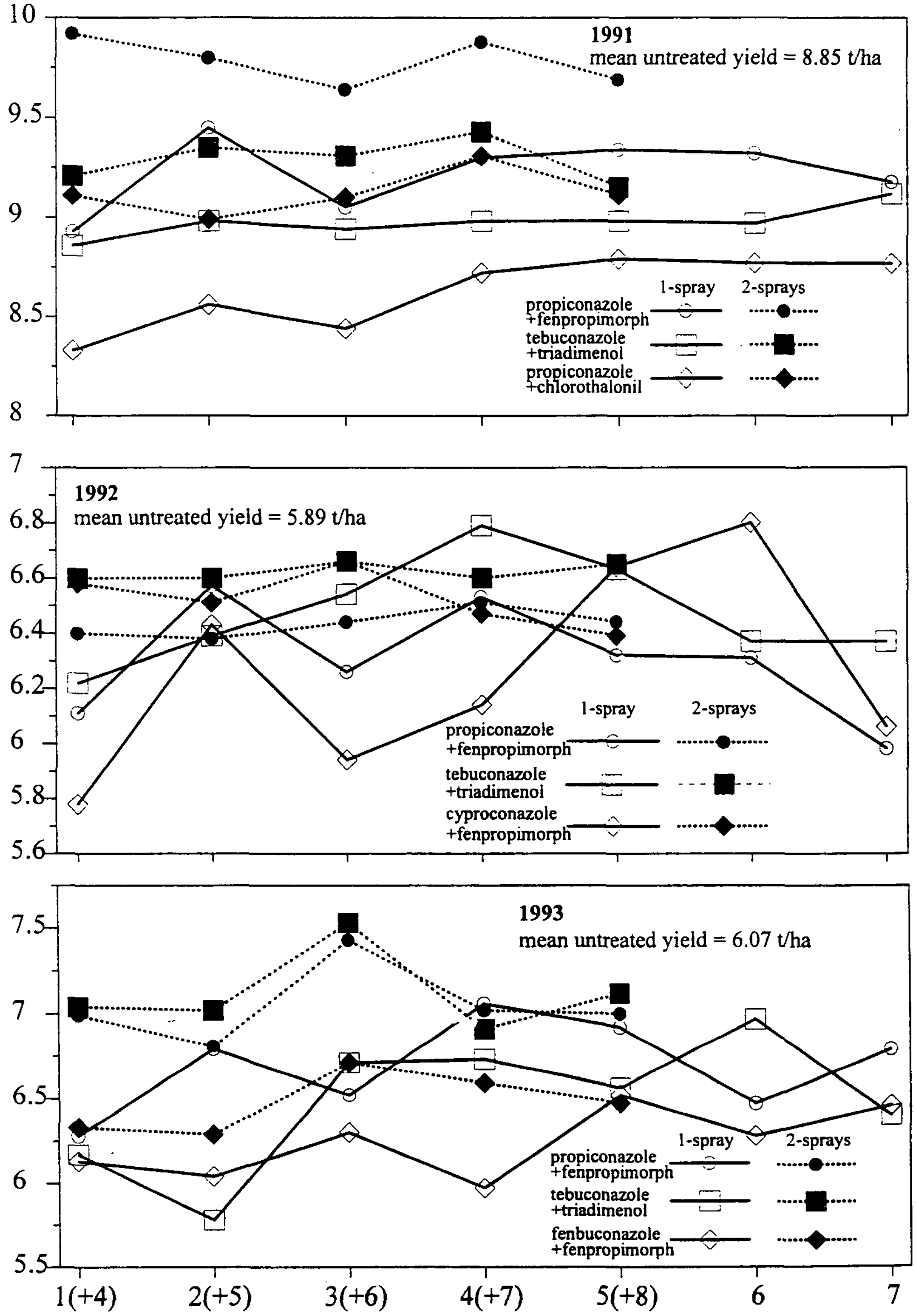


Figure 7. *Pattern of yield response to one and two-spray programmes, SAC Edinburgh 1991-1993*



SAC Edinburgh

55 In 1993, the yield response profile during the treatment period for the Riband sites was comparable to that recorded in the previous two years. At Morley, the peak response for the single sprays occurred at GS 47-51 for the spray applied on May 29 on the same date as in 1991, when the crop was at GS 37-39.

56 Although there were differences between the responses at the septoria sites in each year there was a consistent pattern. For the single sprays, yield response increased from week one to a maximum between weeks three and five. In general terms this was usually between GS 39 and 47-51. In most cases the two-spray treatments gave the greatest yield responses when the first spray was applied between GS 32 and 39. Yield differences between any of the first three two-spray programmes were small.

57 The data showed a consistent effect of treatment on the physical characteristics of grain quality, so that those treatments which gave the best disease control and yield response were those with the best thousand grain weight and specific weight. Highest values were generally recorded for the two-spray treatments with the first applications in early to mid May. There were inconsistent effects on HFN, although at Morley in 1992 there was an inverse relationship between HFN and disease control so that those treatments with the best disease control also gave the lowest HFN.

58 The results require further and continuing analysis. This is in hand and the conclusions will be reported to all collaborators in due course.

Discussion

59 The work has clearly identified those periods in crop growth when disease control is vital. The response profiles generated indicate quite clearly that it is vital to ensure that wheat is well protected from disease during stem extension. In several cases single and two-spray programmes with treatments early in this period have given a significantly reduced yield and disease control compared with treatments commencing closer to flag leaf emergence. It is, however, clear that the two-spray treatments tested in this experiment have increased the flexibility of disease control regimes. This has substantial benefits for disease management strategies.

60 The work has also reaffirmed the need to understand the comparative biological properties of fungicides. Only when such properties are recognised can they be exploited to the best possible advantage to utilise the strengths of fungicides and exclude their weaknesses. This is important in two respects:

60.1 The use of mixtures, possibly of variable ratios of components (depending on disease risk) to avoid the possibility of fungicide resistance arising in populations of cereal crop pathogens.

60.2 The future use of appropriate doses, calculated according to disease risk and taking account of the protectant and eradicant properties of fungicides with respect to imputed infection or the occurrence of disease thresholds.

61 The estimates of latent period for *S. tritici* used for the evaluation of fungicide activity used a base of zero degrees C, although there is some evidence that a higher base may be more appropriate, or that the latent period is about 21 days, irrespective of temperature. Estimates based on the Morley site suggest that a base of 3° C may be more appropriate (Stevens & Nuttall, 1994). This aspect of septoria development needs to be examined in more detail as it will have implications for disease control tactics and fungicide choice.

Experiment II

Method

Sites

62 The experiment was undertaken at six sites in each year, as shown in Table 8. Further details for each site are given in Annex II, Table A. The experiment was arranged in 3 randomised blocks at each site.

Table 8. *Individual sites used in Experiment II, to evaluate genetic resistance*

Site name	Collaborator
Boxworth	ADAS
Bridgets	ADAS
Cirencester	Arable Research Centres
Edinburgh*	SAC
Stowmarket	Morley Research Centre
Rosemaund	ADAS

*1991, Treaton; 1992 Panlathy; 1993, Forfar

63 Details of the fungicide programmes used are shown in Table 9. Treatments 1 to 5 were selected to provide as close as possible to a complete disease control at each of the application stages. In this way the value of disease resistance in each cultivar at each growth stage can be determined. Fungicide dose and active ingredients are shown in Table 10.

64 The fungicides from which selections for the Managed Disease Control (MDC) treatments were made are given in Annex II, Table B. The precise programmes used at each site varied between cultivar and year and are not, for this reason, disclosed. The system tested in this experiment is a shortened version of the programme used by ADAS, involving a reduced number of decisions, in order to simplify its use. Site managers were not given in depth training, so results represent those which competent agronomists would be expected to achieve in the field. The system was revised each year to take into account new trials information, changes in cultivars, fungicide sensitivity shifts and virulence changes.

Table 9. *Fungicide programmes compared on each cultivar*

Treatment	Dose	GS 32	Growth stage GS 39	GS 59	Approx. treatment cost (£/ha)ϕ
1	-	-	-	-	Nil
2	*	-	Bravo+Dorin	-	30
3	*	Sportak 45	Bravo+Dorin	-	50
4	*	Sportak 45	Bravo+Dorin	Patrol+Radar	83
5	*	Corbel+Sportak	Bravo+Dorin	Patrol+Radar	103
6	**	Corbel+Sportak	Bravo+Dorin	Patrol+Radar	57
7	***	Managed disease control			-

*	Recommended dose
**	Reduced dose
***	Dose varies between site and cultivar
ϕ	1993 prices

Table 10. *Fungicides used in Experiment II to evaluate genetic resistance*

Product	Active ingredient (g ai/l)	Full dose (l/ha)	Reduced dose (l/ha)
Bravo 500	chlorothalonil (500)	2.0	1.0
Corbel	fenpropimorph (750)	1.0	0.5
Dorin	triadimenol + tridemorph (125 + 375)	1.0	0.5
Patrol	fenpropidin (750)	0.75ϕ	0.375ϕ
Radar or Tilt	propiconazole (125)	0.5	0.25
Sportak 45	prochloraz (450)	0.9	0.6

ϕ in mixture with Radar

Records

65 All plots were inspected twice a week from GS 31 onwards and the presence of any diseases noted. At GS 39 and GS 59 foliar disease incidence was recorded on both the untreated and previously treated plots using whole plot keys. The Managed Disease Control plots were similarly assessed when sprayed.

Results

66 All treatments were completed according to protocol at all sites and the relevant harvest and grain quality data were recorded. This experiment provided invaluable data on the value of disease resistance and the effect of routine fungicide treatment at predetermined stages of crop development. The disease and yield results for each site are presented below. Abbreviations used in the Tables are also used in Annex Tables for individual sites.

Disease incidence

67 All sites were affected by foliar disease and a summary of the main diseases present at each site is shown in Table 11. Overall, there was a good relationship between disease incidence and yield.

Yield effects

68 Table 12 shows the effects of treatment on yield for each cultivar in the three years of the experiment. The mean responses to the MDC treatments are not given here as the treatments are different for each cultivar and each site. Individual site yields for each year are given in Annex II, Tables C, D and E (pages 97-99).

69 The results in 1992 were very similar to those in 1991, Riband responding best to the three-spray programme (treatment 4). Apollo and Beaver responded best to the reduced dose programme. Hereward also showed the largest response to the three-spray programme. This may reflect the higher disease levels on Hereward during 1992 at some sites when *S. tritici* was reported and there was considerable disease pressure following ear emergence, owing to wet conditions following ear emergence. These generally produced large responses to GS 59 fungicide applications.

70 Hereward has varied in its response to fungicides over the three years of the experiment, the most profitable across site programmes in 1991, 1992 and 1993 being the single GS 39, three-spray and two-spray treatments respectively.

71 The overall mean effect of each programme is given in Table 13. The GS 39 treatment is clearly important on each cultivar. It is also clear that despite the susceptibility of Apollo to mildew there is little economic justification for routine treatment at GS 32.

72 All cultivars at all sites responded to all six fungicide programmes, with mean yield increases over the untreated ranging from 0.49 t/ha (Hereward, GS 39) to 2.70 t/ha (Riband, three-spray with Corbel). The addition of Corbel at GS 32 to the three-spray programme gave only small additional yield responses, none of which was cost-effective. In 1993 the full flag leaf emergence spray, as in 1991 and 1992, produced the largest response for any of the specifically timed single sprays, for all cultivars.

Table 11. *Summary of disease incidence at each site in each year (untreated plots, GS 75)*

Sites	Disease severity			
	S.tritici	Mildew	Y.rust	Eyespot
1991				
Boxworth	***	**	-	-
Bridgets	**	*	-	*
Cirencester	***	***	-	-
Edinburgh	**	**	-	**
Morley	***	*	-	***
Rosemaund	***	*	-	**
1992				
Boxworth	*	*	*	*
Bridgets	**	*	-	*
Cirencester	*	-	-	-
Edinburgh	*	**	-	**
Morley	**	*	-	-
Rosemaund	*	-	-	-
1993				
Boxworth	***	-	**	**
Bridgets	*	**	-	**
Cirencester	***	-	*	-
Edinburgh	*	**	-	-
Morley	***	-	-	-
Rosemaund	**	*	-	-

Disease levels on untreated:

*	Slight disease (5-20%)
**	Moderate disease (21-40%)
***	Severe disease (over 41%)

Table 12. *Effects of fungicide treatment on yield (t/ha, 85% dm)*

Treatment			Cultivar			
GS 32	GS 39	GS 59	Apollo	Riband	Beaver	Hereward
1991						
Untreated			7.71	7.90	8.16	7.61
-	B+D	-	8.19	8.70	8.92	8.17
Sp	B+D	-	8.48	8.91	8.85	8.18
Sp	B+D	P+R	8.53	9.62	9.35	8.25
C+Sp	B+D	P+R	8.71	9.64	9.34	8.41
C+Sp*	B+D*	P+R*	8.59	8.97	9.21	8.19
		Fungicide	Cultivar			
	SED:	0.0740	0.604			
	CV%:	4.6%				
1992						
Untreated			7.89	7.14	7.98	7.96
-	B+D	-	8.46	8.10	8.59	8.63
Sp	B+D	-	9.64	8.58	8.91	8.82
Sp	B+D	P+R	8.94	8.96	9.35	9.17
C+Sp	B+D	P+R	9.07	9.13	9.29	9.21
C+Sp*	B+D*	P+R*	8.90	8.60	9.16	8.73
		Fungicide	Cultivar			
	SED:	0.0693	0.0524			
	CV%:	4.4%				
1993						
Untreated			6.06	6.21	7.10	7.30
-	B+D	-	6.72	7.38	7.91	7.49
Sp	B+D	-	6.65	7.93	8.08	7.57
Sp	B+D	P+R	6.63	8.01	8.12	7.38
C+Sp	B+D	P+R	6.55	7.88	8.05	7.36
C+Sp*	B+D*	P+R*	6.86	7.81	8.29	7.28
		Fungicide	Cultivar			
	SED:	0.0598	0.0488			
	CV%:	4.1%				

* Reduced dose

SED: Standard error of difference/CV % Coefficient of variation: standard error per plot as percent of grand mean.

See Table 9 for key to treatments.

Table 13. *Mean yield effects at specifically timed fungicide applications (t/ha, 85% dm)*

Fungicide and growth stage when applied	Yield response Apollo	Beaver	Hereward	Riband	Break-even response *
Sportak 45 @ GS 32	0.13	0.37	0.28	0.75	0.20
Bravo+Dorin @ GS 39**	0.96	1.11	0.49	1.47	0.30
Patrol+Radar @ GS 59	0.31	0.37	0.14	0.41	0.33
Corbel @ GS 32	0.12	0.13	0.18	0.07	0.20
Totals	1.52	1.98	1.09	2.70	1.03

* Assumes grain worth £100/tonne; no account taken of application costs

** Actual yield response, as distinct from the other 3 treatments where yield responses are derived by subtraction.

Managed disease control

73 Individual site results for yield are given as Treatment 7 in Annex II Tables C, D and E (pages 97-99). Some further details of the 1991 and 1992 results were given by Clark (1993) and the 1993 results by Griffin (1994).

74 The difference in the responsiveness of a cultivar can have a large effect on the success or failure of an MDC strategy. The strategy can be classed as successful if it produces a margin over the chemical and application costs among the best three within any one experiment. Overall, MDC was the most profitable treatment on 38% of occasions and within the top three in 66% of tests. It was most successful (measured as the number of occasions that the treatment was the best) on Riband (83%) which is very susceptible to *S. tritici*. This disease has been intensively studied and good, weather related predictive schemes are available which, together with a knowledge of fungicide properties, facilitated successful decision making. The lowest success rate (55%) was on Hereward which has better disease resistance to most of the economically important foliar diseases. Apollo and Beaver were similar, with success rates of 66% and 61% respectively.

Grain quality

75 Tables 14, 15 and 16 summarise the effects of fungicide use on the quality characteristics of Apollo and Hereward. There were no significant effects of fungicide use on HFN, SDS or protein levels. There were no substantive differences between sites or years so that individual site data are not presented in the Annex.

Table 14. *Effect of fungicide programme on Hagberg falling number (s)*

Fungicide input*	1991	1992	1993	3-year mean
Apollo				
Untreated	347	322	288	317
1-spray programme	341	312	294	314
2-spray programme	329	310	278	304
3-spray programme	337	308	271	303
			Range: -14	
Hereward				
Untreated	319	261	225	266
1-spray programme	312	262	233	267
2-spray programme	310	249	210	254
3-spray programme	308	260	220	260
			Range: -6	

* 1-spray programme: Bravo + Bravo GS 39
2-spray programme: Sportak GS 32; Bravo+Dorin GS 39
3-spray programme: Sportak GS 32; Bravo+Dorin GS 39; Patrol + Radar GS 59

76 The range (i.e. the difference between the three-spray treatment and the untreated) gives an indication of the largest likely effect which would be produced by fungicide application. Fungicide use has relatively small effects on the quality characteristics of the cultivars tested.

Table 15. *Effects of fungicide treatment on SDS (ml)*

Fungicide input*	1991	1992	1993	3-year mean
Apollo				
Untreated	41	49	40	44
1-spray programme	42	48	39	43
2-spray programme	45	48	39	44
3-spray programme	43	46	41	43
			Range: -1	
Hereward				
Untreated	72	72	75	73
1-spray programme	72	75	75	74
2-spray programme	74	74	77	75
3-spray programme	71	77	75	74
			Range: +1	

*See Table 14 for treatment details

Table 16. *Effects of fungicide treatment on protein levels (%)*

Fungicide input*	1991	1992	1993	3-year mean
Apollo				
Untreated	10.2	10.2	10.3	10.2
1-spray programme	10.3	10.1	10.4	10.2
2-spray programme	10.3	10.3	10.4	10.3
3-spray programme	10.3	10.2	10.5	10.3
			Range: +0.1	
Hereward				
Untreated	11.2	10.8	10.3	11.0
1-spray programme	11.3	10.7	10.4	11.0
2-spray programme	11.4	10.8	10.4	11.1
3-spray programme	11.4	10.7	10.5	11.1
			Range: +0.1	

*See Table 14 for treatment details

Profitability of treatment

77 The data from Table 12 have been used to determine the profitability of each treatment (Table 17). The most profitable treatment (excluding application costs) for each cultivar is shown in bold. Where application costs are taken into account (assumed to be at £7/ha), the most profitable treatment is underlined. In many cases the inclusion of application costs does not alter the position of treatment in terms of profitability.

Table 17. *Profitability of treatments as margin over fungicide (£/ha)*

Treatment			Value of yield minus fungicide cost			
			Cultivar			
GS 32	GS 39	GS 59	Apollo	Riband	Beaver	Hereward
1991						
Untreated			694	711	734	761
-	B+D	-	707	753	**773**	**786**
Sp	B+D	-	713	752	746	768
Sp	B+D	P+R	685	**783**	759	742
C+Sp	B+D	P+R	680	764	737	738
C+Sp	B+D*	P+R*	**716**	750	772	762
1992						
Untreated			710	643	718	796
-	B+D	-	731	699	743	833
Sp	B+D	-	728	722	752	832
Sp	B+D	P+R	721	**723**	758	**834**
C+Sp	B+D	P+R	713	719	733	818
C+Sp	B+D*	P+R*	**744**	717	**768**	816
1993						
Untreated			545	558	639	730
-	B+D	-	601	660	708	749
Sp	B+D	-	593	708	722	**757**
Sp	B+D	P+R	588	**712**	722	737
C+Sp	B+D	P+R	579	698	714	735
C+Sp	B+D*	P+R*	**611**	697	**740**	727

* Reduced doses
The most profitable treatment for each cultivar is shown in **bold** and if application costs are included underlined. (Wheat priced at £90/t for Apollo, Beaver and Riband and £100/t for Hereward)
See Table 9 for treatment list.

78 In each year the greatest margin for Riband was achieved by the three-spray programme. For Hereward, the single flag leaf spray was the most cost-effective in 1991. Both Apollo and Beaver responded well to the reduced-dose programme each year. Their relatively high level of general disease resistance allowed flexibility in terms of fungicide dose applied, particularly where disease pressure was relatively low. This was not the case for the disease prone cultivar Riband.

79 Figure 8 clearly demonstrates the cost-effectiveness of a GS 39 fungicide treatment. In each year, all cultivars gave significant and economic yield responses to treatment at this growth stage as shown in Table 17. The yield response to additional treatment at GS 59 is, however, very different for each cultivar. Riband and Beaver responded to treatment at GS 59 in all years whereas Apollo and Hereward only gave yield responses which approached economic justification in 1992. This would agree with the general description of the cultivar types: Riband and Beaver being high yielding with moderate to poor disease resistance; Apollo and Hereward having moderate yields with reasonable to good disease resistance.

The value of 1-, 2- or 3-spray programmes

80 The data generated by the experiments have been used to calculate the value of the response to each spray programme as well as each component, based on the mean of three years' data including application cost of £7/ha.

81 It is clear that although the three-spray programme remains the most profitable as wheat prices fall for Riband, as the wheat price approaches £80/t the differences in profitability of the three programmes become small (Figure 9).

82 The responses of Apollo and Beaver are more complex and the optimal spray programme changes as wheat prices fall. The data for Apollo (Figure 10) show how the one- and two-spray programmes are very similar in their profitability. In practice, a single flag leaf spray would not be wise and although a single unit of fungicide may be optimal it would be better to spread the risk across the early (GS 32) and main (GS 39) timings. Commercially, early mildew pressure would normally demand some fungicide input early. The results of this experiment show that the yield response from such a timing is likely to be small. Both Beaver (Figure 11) and Apollo responded well to the multiple reduced dose programme, indicating the relative flexibility of dose selection on these cultivars. This is indicated in Figures 10 and 11 where the difference between one- and two-spray programmes is small.

83 On Hereward (Figure 12), it is clear that only the single flag-leaf spray is profitable, whatever the wheat price. It is also clear that three-spray programmes are not profitable at any wheat price and even two-spray programmes quickly become unprofitable as wheat prices fall. With the two extreme varietal types of Riband and Hereward, the optimal spray programme remains the same within the price range considered.

Figure 8. *Yield response to fungicide treatment at GS 39 and GS 59 (£100/t; t/ha)*

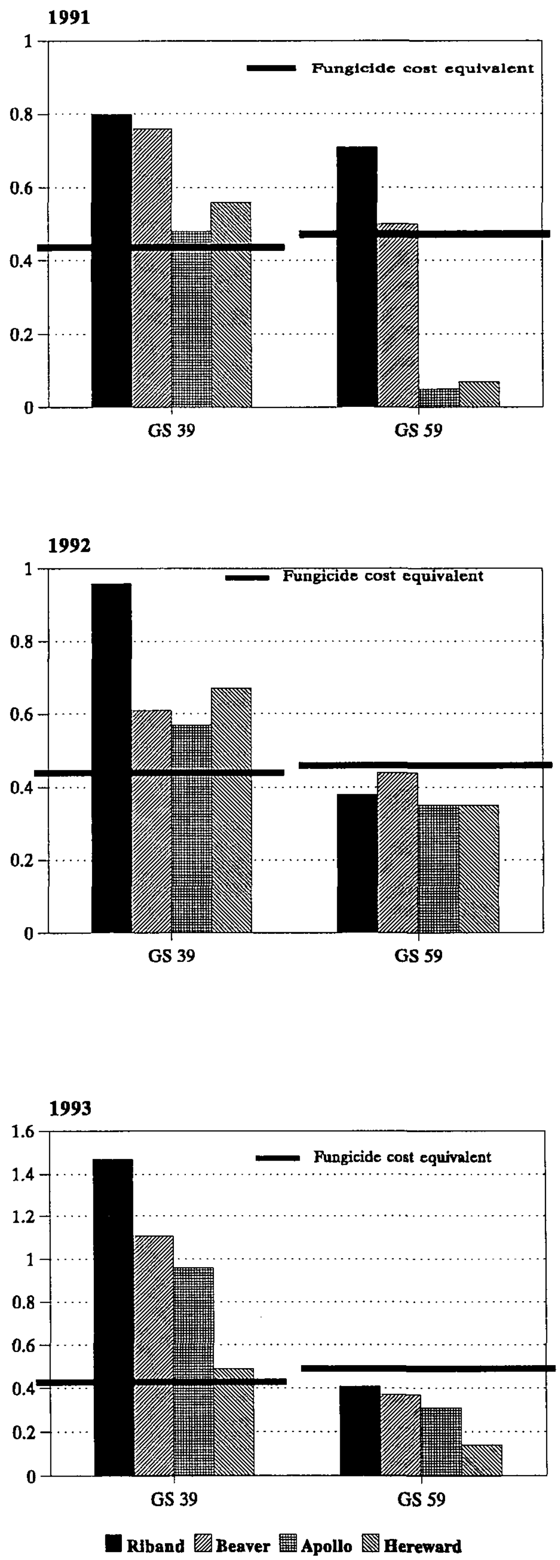


Figure 9. *Profitability of 1-, 2-, and 3-spray fungicide programmes on Riband (3 year mean)*

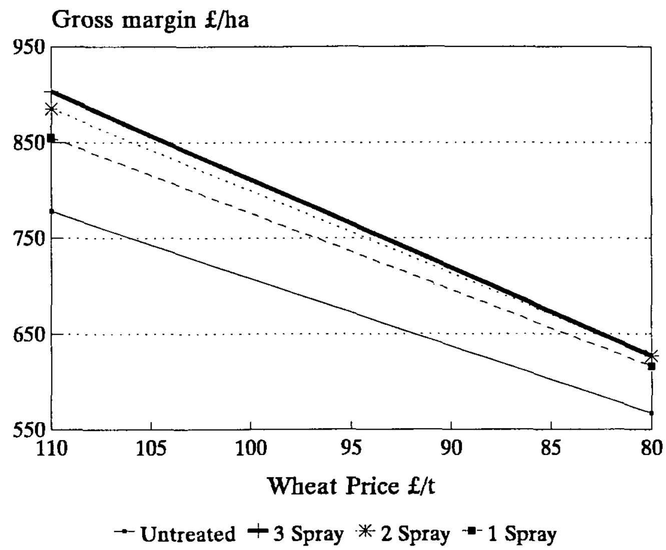


Figure 10. *Profitability of 1-, 2-, and 3-spray fungicide programmes on Apollo (3 year mean)*

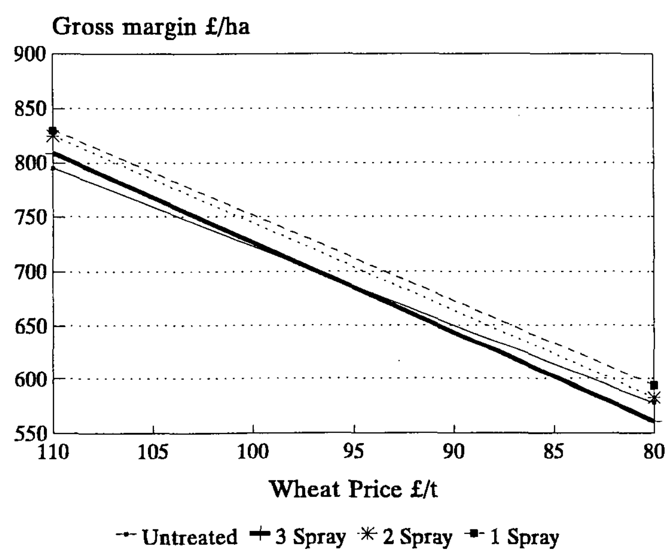


Figure 11. *Profitability of 1-, 2-, and 3-spray fungicide programmes on Beaver (3 year mean)*

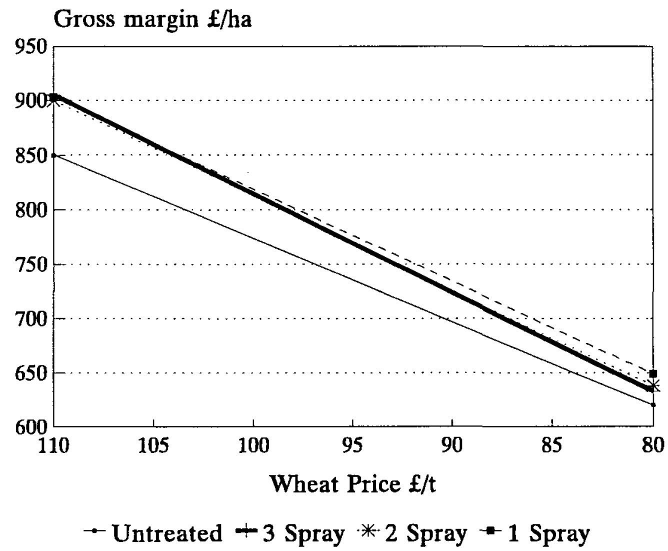
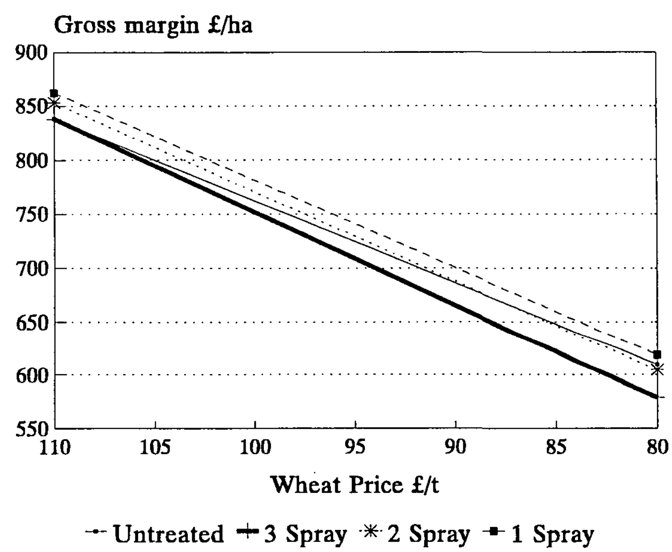


Figure 12. *Profitability of 1-, 2-, and 3-spray fungicide programmes on Hereward (3 year mean)*



Discussion

84 The experiment has demonstrated that there is a very wide range of fungicide requirements for optimum yield, depending on the disease resistance of the cultivar. Riband produced the greatest financial return with a three-spray programme at all sites and is likely to respond to high levels of fungicide use, even if grain prices are reduced by up to 30%. However, at this point, application costs become very significant in determining the value of fungicide application. In the short to medium term, however, it will still be very cost effective to grow high yielding, disease susceptible cultivars such as Riband with a considerable fungicide input.

85 The optimum treatment for Beaver varied from site to site but, in general, the financial return on fungicide use did not differ greatly between treatments. The optimum treatment from the mean result from all sites was the multiple reduced dose application. However, the single flag leaf treatment gave very similar financial returns. Clearly, as wheat prices fall and application costs become a more significant element of treatment cost the optimum treatment for Beaver will very quickly become a single flag-leaf spray.

86 Only a moderate fungicide input was necessary to achieve optimum economic return on Apollo. The responsiveness of Apollo varied according to mildew and, at some sites where disease levels were low, there was very little financial return on fungicide use. Early mildew control (GS 31 to 32) was rarely cost-effective although both this Experiment and Experiment I indicate that early treatment may facilitate control at later stages.

87 Hereward was consistently unresponsive to fungicide treatment other than at the flag leaf stage. Although small increases in yield (mean: 0-0.2 t/ha) were achieved by further fungicide applications, these were rarely cost effective. At five of the six sites the optimum treatment was the single flag leaf spray. At the sixth site the multiple low-dose treatment was the most cost-effective treatment. The effects of falling wheat prices on fungicide use would be less dramatic on cultivars such as Hereward and it would still be profitable to apply flag leaf sprays to such cultivars with wheat prices well below £100/t.

88 The ability to modify a fungicide programme according to disease levels and weather patterns, in order to optimise use, seems to be attractive. This should help to achieve the yield potential of a cultivar, whilst aiming to optimise fungicide use as in MDC. This approach does, of course, involve the extra inputs for crop monitoring, disease identification and assessment on which any targeted system depends. There is also a need to provide a reasonable estimate of potential disease development. Assuming this can be done a managed system should give a satisfactory margin in every situation. It will not always give the highest margin as this can only be known with certainty with the benefit of hindsight.

89 The success of MDC is partly related to the relative responsiveness of the cultivars. It was one of the best three treatments most often on the moderately responsive cultivars Apollo and Beaver. With Riband and Hereward, the system was less successful

although it was still in the top three treatments on 58% of occasions. This is likely to be due to a combination of two factors: firstly the underestimation of the disease resistance of cultivars such as Hereward, leading to the unnecessary use of fungicides; and secondly, the underestimation of the disease susceptibility of cultivars such as Riband.

90 Attempts to be economical with fungicides on high disease-risk cultivars frequently reduces the level of disease control. This result may be expected, as the relatively simple MDC system under test does not tailor itself closely to varietal differences in disease resistance. This feature may be modified in the light of the results of this experiment to allow much more specific recommendations to be given for cultivar types.

91 The testing of targeted disease control in the MDC treatment has highlighted several points of interest. MDC rarely gave the poorest profitability, but although it can be a successful decision system considerable skill is required in its operation. The MDC guidelines provided to collaborators in this experiment were a simplified form of the ADAS system and can be regarded as representative of what would be expected from any agronomist operating the system.

92 The system was developed by the ADAS Cereal Pathology Group as a decision tree. Decisions on the need for fungicide application are made at key points in crop development, and assessments of disease, weather criteria, cultivar, crop structure, time since previous spray, location and growth stage. Simplified earlier versions were published, in flow chart format, as advisory leaflets (Anon, 1986). Updated versions are now used as the basis for ADAS advice on cereal disease control.

93 Despite, or perhaps because of, the simplification of the guidelines, some experimenters found them difficult to interpret. There was a tendency for individual experiment managers to modify the guidelines. Doses of product applied were also modified according to preconceptions about cultivars. This highlights one of the main problems with any set of guidelines - they are often only as good as the individual who is applying them or they need to be used frequently before they become easy to use. This has implications for any crop decision support system.

94 Without very detailed guidelines or a computer-based 'expert system' there will always be scope for the operator to impose his/her interpretation on the guidelines. A set of guidelines which necessitates assessment of disease levels also relies on the user's ability to identify and interpret the threshold levels of disease. User's experience is paramount and there is a tendency to make guidelines more comprehensive, and hence more complicated, or to develop them into a true 'expert system' which would have to be computer-based. The inference from these assessments of a disease management system is that experienced users believe they are more skilled than the guidelines.

Experiment III

Method

95 Apollo and Riband were grown at five and seven sites each to provide information on control of mildew and *Septoria tritici* respectively. Mercia was used at the Yorkshire site in 1992 and 1993. Fungicides were applied as single sprays at flag leaf emergence (GS 39). The experiment had four replicates of the treatments at each site laid out as randomised blocks.

Sites

96 Six organisations co-operated to provide twelve sites spread from the south coast of England to NE Scotland as shown in Annex III, Table A (page 102). Field details for each site are given in Annex III, Tables B, C and D (pages 103-105) for 1991, 1992 and 1993 respectively.

Fungicides and active ingredients

97 Core treatments, shown in Table 18, were based on standard products. A further five test materials were compared with these standards, although they varied from year to year as shown in Table 19. The active ingredients are given in Annex III, Table E.

Table 18. *Core treatments used in fungicide comparison experiments 1991-1993 (dose l/ha)*

GS 32	GS 39	GS 59-69
-	Untreated	-
-	Bravo(2.0)+Dorin(1.0)	-
-	Bravo(2.0)+Dorin(1.0)	Patrol(0.75)+Radar(0.5)
Corbel(0.75)+Sportak 45(0.9)	Bravo(2.0)+Dorin(1.0)	-
Corbel(0.75)+Sportak 45(0.9)	Bravo(2.0)+Dorin(1.0)	Patrol(0.75)+Radar(0.5)

Records

98 At GS 39 and GS 59 untreated plots and treatments applied prior to GS 33 were assessed, using whole plot keys. Eyespot was recorded at GS 75, if the eyespot index exceeded 30 on treatments 4 and 5 as well as all plots to which treatments were applied before GS 33.

Table 19. *Individual test products used in comparison of fungicide experiments 1991-1993*

Treatment code	Commercial product (dose l/ha) Year 1991	1992	1993
6	Silvacur(1.0)	Silvacur(1.0)	Silvacur(1.0)
7	Folicur (1.0)	Folicur(1.0)	Folicur(1.0)
8	Cyclone(1.0)	Indar(1.5)	Indar(1.5) + Corbel (0.75)*
9	Alto Elite(2.0)	Alto Elite(2.0)	Alto Elite(2.0)+Corbel(0.75)*
10	Alto 100SL(0.8)	Alto 100SL(0.8)	Alto 100SL(0.8)

*Corbel added on Apollo and Mercia sites only

Results

Apollo

99 For various reasons, such as lodging, drought or low levels of disease, not every site provided good information in every year. The Tables represent the three year mean only for those sites that were successful each year. Further details of individual sites are presented in Annex III, Tables F-J (pages 107-111).

Disease control

100 When assessed at GS 75 the two best mildew sites had on average almost 25% infection on leaf 2 in the untreated plots (Table 20). Almost 50% control was achieved by the standard flag leaf application but this was improved by the addition of an earlier or later treatment. The additional treatment at GS 59-69 improved late mildew control more than the GS 32 spray and the three-spray treatment gave the best mildew control (76.9%).

Table 20. *Mildew control at GS 75 on Apollo in 1991, 1992 and 1993 (mean of sites Codford and Cockle Park; % control on leaf 2)*

Treatment GS 32	GS 39	GS 59-69	Mildew control (untreated % infection)
Untreated	-	-	(24.8)
-	Bravo+Dorin	-	49.6
-	Bravo+Dorin	Patrol+Radar	70.6
Corbel+Sportak	Bravo+Dorin	-	51.8
Corbel+Sportak	Bravo+Dorin	Patrol+Radar	76.9
-	HGCA 6	-	73.2
-	HGCA 7	-	61.8
-	HGCA 8	-	*
-	HGCA 9	-	**
-	HGCA 10	-	50.3
S.E.D			3.66

* not analysed as products changed
** not analysed as fenpropimorph added in 1993

101 All of the candidate products that were tested for three years equalled or exceeded the performance of the flag leaf standard even though this was a mixture of a conazole and a morpholine fungicide with Bravo. The mixture of conazoles (HGCA 6; Silvacur) gave better mildew control then tebuconazole alone (HGCA 7; Folicur) and this in turn performed slightly better than cyproconazole (HGCA 10; Alto 100SL). Low levels of brown and yellow rust were reported at some sites but these were very well controlled by all candidate fungicides.

102 An assessment of green leaf area on leaf 2 was made at GS 75 and results for this and the mildew assessments are presented as Annex III, Tables F and G (pages 107-108). The mean mildew control and yield are presented graphically in Figure 13.

Yield and quality

103 The three-spray programme resulted in an average yield increase of just over 1.0 t/ha compared to the untreated control (Table 21). At the same time, specific weight was increased by 1.6 kg/hl. Two sprays applied late provided a significantly better specific weight and grain size than two sprays applied early but yields were not significantly different. This is attributed to the later sprays having a greater effect on grain filling while the earlier treatment improved grain numbers. The candidate fungicides were comparable to the standard flag leaf treatment.

Figure 13. *Mildew control on leaf 2, GS 75 (% control) and yield for Apollo sites*

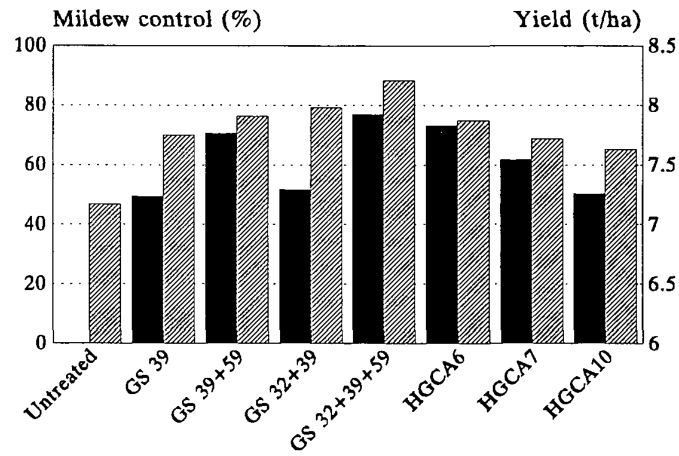


Table 21. *Yield[1], 1000 grain weight[2] and specific weight[3] for Apollo sites in fungicide comparison experiment, 1991-1993 (85% dm)*

GS 32	Treatment GS 39	GS 59-69	Yield (t/ha)	1000 grain weight(g)	Specific weight (kg/hl)
Untreated	-	-	7.17	44.7	77.1
-	Bravo+Dorin	-	7.75	47.1	78.0
-	Bravo+Dorin	Patrol+Radar	7.91	48.7	78.9
Corbel+Sportak	Bravo+Dorin	-	7.98	47.8	78.2
Corbel+Sportak	Bravo+Dorin	Patrol+Radar	8.21	49.1	78.7
-	HGCA 6	-	7.87	47.3	78.1
-	HGCA 7	-	7.72	47.1	77.9
-	HGCA 8	-	*	*	*
-	HGCA 9	-	**	**	**
-	HGCA 10	-	7.63	46.0	77.8
S.E.D.			0.053	0.47	0.23

* not analysed as products changed
** not analysed as fenpropimorph added in 1993
[1] Codford site excluded from 3 year analysis owing to severe lodging in 1992
[2] 1000 grain weight not available for Arthur Rickwood and Lincoln
[3] Specific weight not available for Lincoln

104 Grain quality as measured by HFN, SDS and protein content shown in Table 22 was not affected by treatment. Yields and quality for individual sites are presented in Annex III, Tables H, I and J (pages 109-111).

Table 22. *Milling quality of Apollo*
(Mean of 3 sites - Arthur Rickwood, Wetherby and Cockle Park)

GS 32	Treatment GS 39	GS 59-69	HFN	SDS	% protein at 86% dm
Untreated	-	-	322	45.5	11.2
-	Bravo+Dorin	-	328	44.5	11.3
-	Bravo+Dorin	Patrol+Radar	325	44.5	11.3
Corbel+Sportak	Bravo+Dorin	-	327	45.3	11.4
Corbel+Sportak	Bravo+Dorin	Patrol+Radar	324	44.5	11.4
-	HGCA 6	-	322	45.3	11.2
-	HGCA 7	-	325	44.9	11.2
-	HGCA 8	-	*	*	*
-	HGCA 9	-	**	**	**
-	HGCA 10	-	325	44.5	11.3
S.E.D.			3.8	0.67	0.08

* not analysed as products changed
** not analysed as fenpropimorph added in 1993

Riband

Disease control

105 The rainfall pattern was similar across most of the sites in 1991. Early *S. tritici* infection was recorded at the end of April at most sites when the crops were mainly at the second node stage. It was the major disease at all sites and at many sites it was the only disease recorded. Rainfall differed between sites in 1992 and 1993 so that final infection levels were less uniform. The mean level of disease control for three sites that had consistently high infection each year is shown in Table 23. The standard flag leaf treatment gave an average 55.5% control which was improved to around 67% by the addition of a second spray. There was no difference if this was added at either GS 32 or 59-69. However, adding both to make a three-spray programme further increased disease control.

Table 23. Septora tritici *control on Riband at GS 75, 1991-1993 (mean of Romney Marsh, Charminster and Morley sites; % infection on leaf 2)*

Treatment GS 32	GS 39	GS 59-69	*Septoria tritici* control (untreated % infection)
Untreated	-	-	(44.2)
-	Bravo+Dorin	-	55.5
-	Bravo+Dorin	Patrol+Radar	67.0
Corbel+Sportak	Bravo+Dorin	-	66.8
Corbel+Sportak	Bravo+Dorin	Patrol+Radar	76.7
-	HGCA 6	-	62.3
-	HGCA 7	-	63.3
-	HGCA 8	-	*
-	HGCA 9	-	61.6
-	HGCA 10	-	59.9
S.E.D.			2.34

* not analysed as products changed

106 The candidate materials gave 60% or more control and were superior to the standard flag leaf treatment. There were no significant differences between the candidates in the level of disease control recorded and, although in some sites they matched the performance of a standard two-spray programme, they did not at the high disease sites presented in Table 23. Disease and green leaf records are shown in Annex III as Tables K and L respectively (pages 112-113). Septoria control is presented graphically in comparison with yields in Figure 14 and shows a very good relationship of yield to disease control.

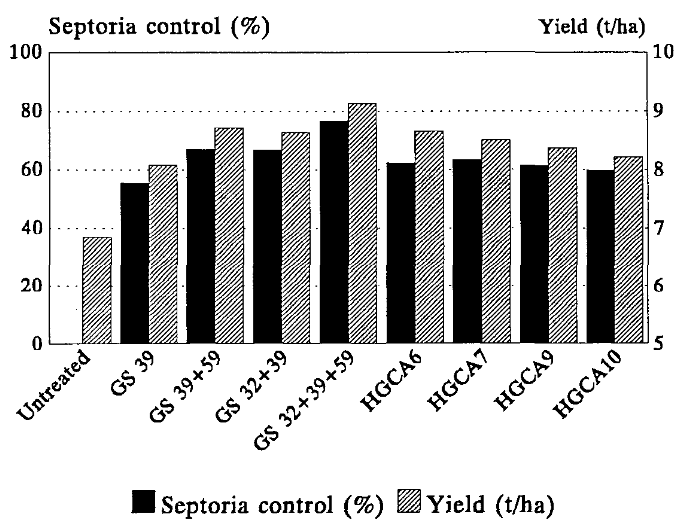
107 The three-spray programme gave an average yield increase of 2.29 t/ha with an increase of 7.7 g in 1000 grain weight and 2.9 kg/hl in specific weight (Table 24). The standard flag leaf treatment recovered 54% of the yield increase resulting from the three-spray programme, 52% of the increase in grain size and 62% of the specific weight. All of the candidate fungicides performed better than the standard with the most effective product (HGCA 6) recovering 79% of yield, 75% of grain size and 90% of the specific weight benefits shown by the three-spray programme. The results for individual sites are presented in Annex III, Tables M, N and O (pages 114-116).

Table 24. *Yield, 1000 grain weight[1] and specific weight on Riband sites 1991-1993 (85% dm)*

GS 32	Treatment GS 39	GS 59-69	Yield (t/ha)	1000 grain weight(g)	Specific weight (kg/hl)
Untreated	-	-	6.84	41.7	69.8
-	Bravo+Dorin	-	8.08	45.7	71.6
-	Bravo+Dorin	Patrol+Radar	8.73	47.8	72.3
Corbel+Sportak	Bravo+Dorin	-	8.64	46.9	72.0
Corbel+Sportak	Bravo+Dorin	Patrol+Radar	9.13	49.4	72.7
-	Folicur	-	8.66	47.5	72.4
-	Silvacur	-	8.51	46.9	72.1
-	HGCA 8	-	*	*	*
-	Alto Elite	-	8.38	46.6	71.8
-	Alto 100SL	-	8.22	46.2	71.8
S.E.D.			0.056	0.37	0.18

* not analysed as products changed
[1] Excluding Terrington and Essex

Figure 14. *Overall control of Septoria tritici on leaf 2 (3 sites) compared with yield at all severe Riband sites (% control)*



Discussion

108 The experiment achieved the objective of obtaining independent information on new fungicides before their commercial launch. It provided growers with information on how to use products when they reached the market during years two and three of the project.

109 The candidate materials HGCA 6 & 7 (based on tebuconazole) and HGCA 10 (cyproconazole) gave mildew control that matched or exceeded that of the standard flag leaf treatment, Dorin + Bravo. Cyproconazole and tebuconazole fully justified their inclusion in Experiment I where their properties were evaluated. The addition of triadimenol to tebuconazole improved the control of mildew on Apollo but failed to give a significant improvement in *S. tritici* control on Riband. The formulated mixture of cyproconazole and chlorothalonil (HGCA 9) gave inferior mildew control compared with cyproconazole alone so in the final year fenpropimorph was added to this mixture, for the mildew sites only. There was no apparent improvement in control of *S. tritici* when using the coformulation at the timing tested in this experiment.

110 Mildew control on leaf 2 at GS 75 was better where the two-spray programme included the late spray than where it included the early spray, but yields were not significantly different. However, the three-spray treatment resulted in significantly higher yields than either of the two-spray treatments, suggesting that mildew needs to be controlled throughout the season on a susceptible cultivar such as Apollo.

111 Candidates HGCA 6, 7 and 10 can contribute to mildew control on a cultivar such as Apollo but they would be expensive if used only for that purpose. In practice they would probably be used (perhaps at a reduced dose) to control rusts and other foliar diseases and in combination with an appropriate dose of morpholine to control mildew. Using a mixture of two unrelated fungicides to control mildew is likely to apply less selection pressure for resistance than relying solely on a single active ingredient.

112 The experiment confirmed the potential of *S. tritici* to cause considerable yield loss. Over all sites and seasons the three-spray programme gave an average 76.7% control of septoria and a yield response of 2.29 t/ha on Riband. The standard flag leaf treatment provided 55.5% control of disease and a yield response of 1.24 t/ha but this was exceeded by candidates HGCA 6, 7, 9 and 10.

113 The tebuconazole based candidates (HGCA 6 and 7) gave the best average performance. It is likely that HGCA 9 (containing chlorothalonil) would require relatively earlier application than those fungicides based entirely on tebuconazole or cyproconazole in order to exploit its protectant activity.

114 Grain size and specific weight were improved by the use of fungicides on both cultivars. Responses were proportional to yield increases and much greater on Riband than Apollo. Further grain quality tests on the Apollo only, showed no significant change in the HFN, SDS values or protein content following treatment.

Conclusions

115 Each of these experiments has confirmed the need to ensure that wheat is well protected from leaf disease between late stem extension and ear emergence. They also show how crucial it is to understand the biological properties of different fungicides, particularly so for the new generation of conazoles. The results have also indicated how cultivar resistance may be manipulated to reduce fungicide input.

116 Timing of fungicide application is far more important than choice of product. An understanding of disease epidemiology will assist in choosing the correct fungicide timing, particularly with *Septoria tritici*. However, we still do not understand precisely what drives this disease in seasons such as 1992 (Rosemaund) when there was little rain during the period GS 32-59 and yet the disease became severe on the top three leaves.

117 With mildew, early control appears to be important in terms of reducing disease development and this may become more important, particularly with the apparent reduction in the efficacy of one or more of the morpholine fungicides. Early control of mildew on the lower leaves prior to canopy completion should be part of a strategy to control mildew, particularly on susceptible cultivars such as Apollo. The data from Experiment II show, however, that this is rarely economically justified on Apollo.

118 The work has reaffirmed the importance of ensuring that the upper leaves of wheat are free of, and protected from, diseases during and after flag leaf emergence. The individual elements of the project have also provided the following specific conclusions:

118.1 High yielding cultivars with poor disease resistance require considerable fungicide input, usually a three-spray programme.

118.2 The fungicide requirement of cultivars with poor disease resistance does not change significantly as wheat prices fall.

118.3 Cultivars with moderate or good disease resistance rarely require more than a single application of the recommended dose of fungicide. Only if mildew establishes early in the growth of the crop is a further fungicide likely to be justified. Such cultivars may lend themselves to the use of reduced-dose fungicide programmes.

118.4 Considerable financial saving can be made by tailoring fungicide use carefully to the disease resistance characteristics of cultivars. Conversely, large financial losses can be incurred if the disease resistance of cultivars is not fully exploited.

118.5 Tebuconazole provided considerable benefit as a protectant and eradicant fungicide for control of *S. tritici* compared with other products tested.

118.6 Addition of chlorothalonil to the conazole fungicides used in these studies seemed to provide benefits when application was made before septoria infection events were recorded.

118.7 Current knowledge, supplemented by these results provides opportunities to integrate cultivar disease resistance with the properties of fungicides to enable growers to develop least cost production systems suited to their own environment. That is the survival route for the future.

Future work

Cultivars

119 The disease resistance characteristics of cultivars change as new races of fungal pathogens arise. Similar experiments will be required as varieties with different disease resistance characteristics are introduced. To some extent, this has already happened. For example, Hussar and Hunter now offer the possibility of high yields and a low fungicide requirement which has not been tested in this experiment. The changes in the CAP, with resulting changes in the pricing structure and quality requirements of cereals, will also have a very significant effect on cultivar choice. It is important that we know the most cost-effective way of growing the newer cultivars in the changing economic climate.

Fungicides

120 The treatments applied in these experiments all used the full manufacturers recommended dose (with the exception of one treatment in Experiment II). This has provided overall information on the properties of the fungicides tested and their response profiles. In practice, however, many crops are treated with a reduced dose of product. There is, therefore, a need to undertake similar experiments with a range of doses to elucidate the interaction between fungicide properties and spray timing. Some of this work is now in hand.

121 These experiments have developed earlier MAFF funded work using the individual active ingredients now used in commercial disease control. This information needs to be supplemented by individual studies to assess the role of fungicide mixtures.

Data generated

122 As indicated above, there is a need for further work to analyse the disease and yield response data provided by Experiment I. This information is an essential adjunct to the data which will be generated in other HGCA funded projects. It will also be incorporated to the proposed LINK project on decision support systems.

Information delivery

123 The conclusions from the tests of MDC provide clear indications as to the needs of decision support systems. They will need to encapsulate user perceptions and provide information for interpretation rather than provide direct advice. They will also need to be easy to use and must have each operator's total trust. Users will, therefore, need to be involved in their planning and subsequent development. The systems will also need a user interface in sympathy with the user's decision processes.

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	Romney Marsh:	A G Thorpe
	Terrington:	C Hayward
	Wetherby:	G Byers and R Kitchen
Arable Research Centres		
	Cirencester:	R Overthrow and M Carver
	Dunmow:	J Smith
	Louth:	D Robinson
Chalkland Cereal Centre		D Miles
Morley Research Centre		D Stevens and M Nuttall.
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SAC	Aberdeen:	S J Wale
	Edinburgh:	S Oxley

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Annexures to HGCA Project Report

Annex I

Evaluation of the biological properties of fungicides

Annex I

Table A. Site location and crop details
Table B. Example fungicide treatment schedule

Figure A. ADAS High Mowthorpe 1992: Mildew development
- Figure Ai. Final four leaves.
- Figure Aii. Disease control, leaf 1
- Figure Aiii. Disease control, leaf 2
- Figure Aiv. Disease control, leaf 3

Figure B. ADAS High Mowthorpe 1993: Mildew development
- Figure Bi. Final four leaves
- Figure Bii. Disease control, leaf 1
- Figure Biii. Disease control, leaf 2
- Figure Biv. Disease control, leaf 3
- Figure Bv. Disease control, leaf 4

Figure C. Morley Research 1991: *Septoria tritici* development
- Figure Ci. Final four leaves
- Figure Cii. Disease control, leaf 1
- Figure Ciii. Disease control, leaf 2
- Figure Civ. Disease control, leaf 3
- Figure Cv. Disease control, leaf 4

Figure D. Morley Research 1992: *Septoria tritici* development
- Figure Di. Final four leaves
- Figure Dii. Disease control, leaf 1
- Figure Diii. Disease control, leaf 2
- Figure Div. Disease control, leaf 3
- Figure Dv. Disease control, leaf 4

Figure E. Morley Research 1993: *Septoria tritici* development
- Figure Ei. Final four leaves
- Figure Eii. Disease control, leaf 1
- Figure Eiii. Disease control, leaf 2
- Figure Eiv. Disease control, leaf 3
- Figure Ev. Disease control, leaf 4

Figure F. ADAS Rosemaund 1991: *Septoria tritici* development
- Figure Fi. Final four leaves
- Figure Fii. Disease control, leaf 1
- Figure Fiii. Disease control, leaf 2
- Figure Fiv. Disease control, leaf 3
- Figure Fv. Disease control, leaf 4

Figure G. ADAS Rosemaund 1992: *Septoria tritici* development
Figure Gi. Final four leaves
Figure Gii. Disease control, leaf 1
Figure Giii. Disease control, leaf 2
Figure Giv. Disease control, leaf 3
Figure Gv. Disease control, leaf 4

Figure H. ADAS Rosemaund 1993: *Septoria tritici* development
Figure Hi. Final four leaves
Figure Hii. Disease control, leaf 1
Figure Hiii. Disease control, leaf 2
Figure Hiv. Disease control, leaf 3
Figure Hv. Disease control, leaf 4

Figure I. SAC Edinburgh 1991: Mildew development
Figure Ii. Final four leaves
Figure Iii. Disease control, leaf 1
Figure Iiii. Disease control, leaf 2
Figure Iiv. Disease control, leaf 3
Figure Iv. Disease control, leaf 4

Figure J. SAC Edinburgh 1992: Mildew development
Figure Ji. Final four leaves
Figure Jii. Disease control, leaf 1
Figure Jiii. Disease control, leaf 2
Figure Jiv. Disease control, leaf 3

Figure K. SAC Edinburgh 1993: Mildew development
Figure Ki. Final four leaves
Figure Kii. Disease control, leaf 1
Figure Kiii. Disease control, leaf 2
Figure Kiv. Disease control, leaf 3
Figure Kv. Disease control, leaf 4

Note in all figures, leaves are numbered from top to bottom so that leaf 1 = flag leaf.

Site details for study of fungicide properties in relation to disease development (Experiment I).

	Collaborator ADAS High Mowthorpe	ADAS Rosemaund	Morley	SAC Edinburgh
1991				
Site	High Mowthorpe	Rosemaund	Morley	-
Soil series	Wold	Bromyard	Ashley	Darvel
Soil texture	ZyCL	ZCL	SC	-
pH	7.5	6.9	7.7	-
Previous crop				
1990	Rape	Rape	W.beans	Potatoes
1989		W.barley	W.wheat	-
1988		W.wheat	Rape	-
Sowing date	19:09:90	09:09:90	08:10:90	09:11:90
Seed rate(seeds/m^2)		350	400	
Total N (kg/ha)	188	151	205	212
Harvest date	15:08:91	31:08:91	30:08:91	05:09:91
1992				
Site	High Mowthorpe	Rosemaund	Morley	North Berwick
Soil series	Wold	Bromyard	Ashley	Kilmarnock
Soil texture	ZyCL	ZyCL	SC	L
pH	7.5	6.9	7.7	6.0
Previous crop				
1991	Potatoes	Linseed	Linseed	Potatoes
1990	S.beans	Wheat	Wheat	S.barley
1989	Wheat	Maize	S.rape	
Sowing date	12:10:91	26:10:91	4:10:91	23:10:91
Seed rate(seeds/m^2)	160 kg/ha	350	400	240 kg/ha
Total N (kg/ha)	200	124	220	150
Harvest date	25:08:92	05:09:92	28:08:92	16:09:92
1993				
Site	High Mowthorpe	Rosemaund	Morley	Dalkeith
Soil series	Panholes	Bromyard	Ashley	-
Soil texture	-	ZCL	SC	-
pH	8.1	7.0	8.2	6.7
Previous crop				
1992	Rape	Grass	Sugar beet	Peas
1991	W.barley	Grass	Wheat	Rape
1990	W.wheat	Grass	W.beans	-
Sowing date	09:10:92	30:10:92	02:10:92	13:10:92
Seed rate(seeds/m^2)	187 kg/ha	375	400	200 kg/ha
Total N (kg/ha)	168	136	220	-
Harvest date	07:09:93	27:08:93	19:08:93	08:09:93

Example fungicide treatment schedule for Experiment I

		May			June			
Date	7	14	21	28	4	11	18	25
Week No.	1	2	3	4	5	6	7	8
1	-	-	-	-	-	-	-	-
2	*	-	-	-	-	-	-	-
3	*	-	-	*	-	-	-	-
4	-	*	-	-	-	-	-	-
5	-	*	-	-	*	-	-	-
6	-	-	*	-	-	-	-	-
7	-	-	*	-	-	*	-	-
8	-	-	-	*	-	-	-	-
9	-	-	-	*	-	-	*	-
10	-	-	-	-	*	-	-	-
11	-	-	-	-	*	-	-	*
12	-	-	-	-	-	*	-	-
13	-	-	-	-	-	-	*	-
14	-	-	-	-	-	-	-	-

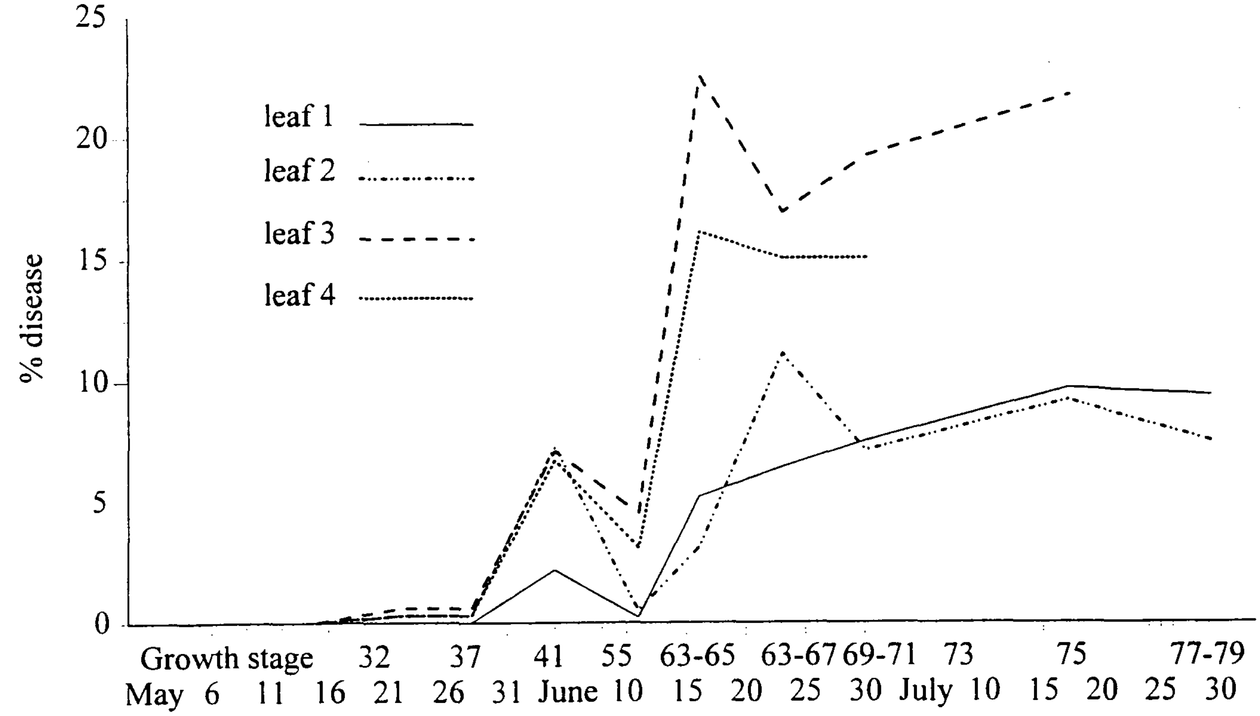
key: * = fungicide application
- = untreated

Note: week 1 was at GS 32 or thereabouts.

Treatments 1 and 14 were untreated controls
Treatments 2, 4, 6, 10, 12 and 13 received one application only of each fungicide
Treatments 3, 5, 7, 9 and 11 received two applications only of each fungicide

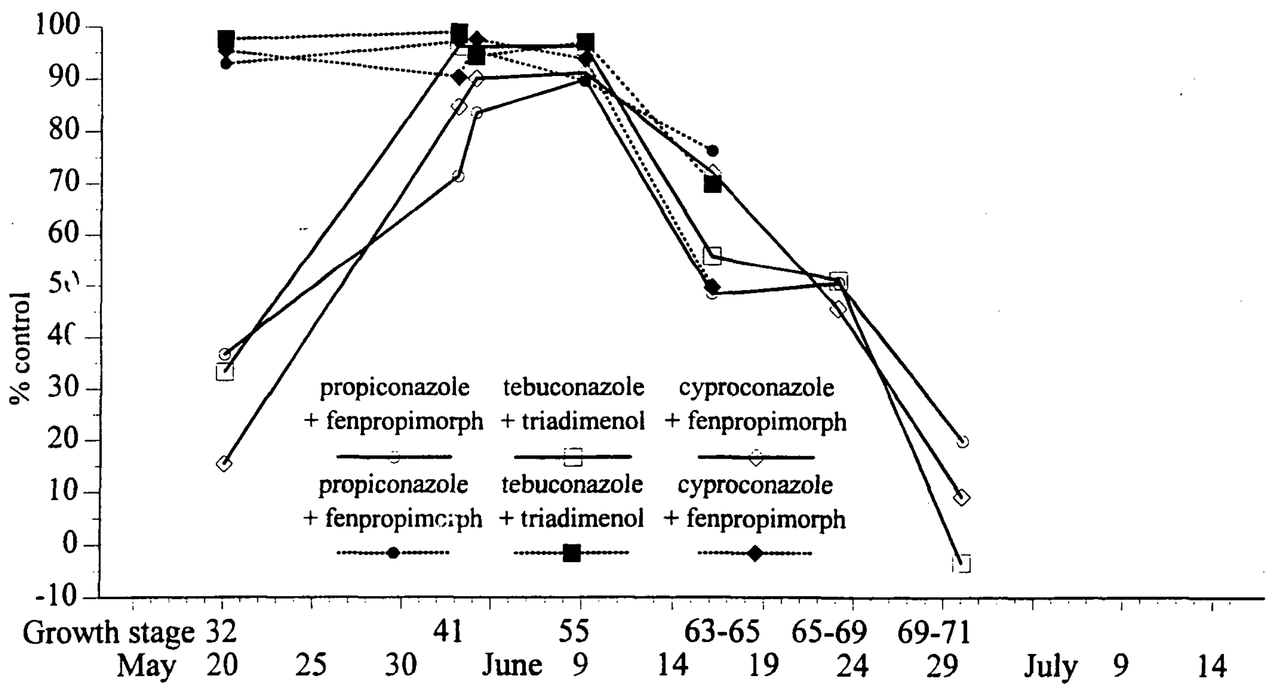
ADAS High Mowthorpe 1992: Mildew

Disease progress on the final four leaves in relation to date and growth stage



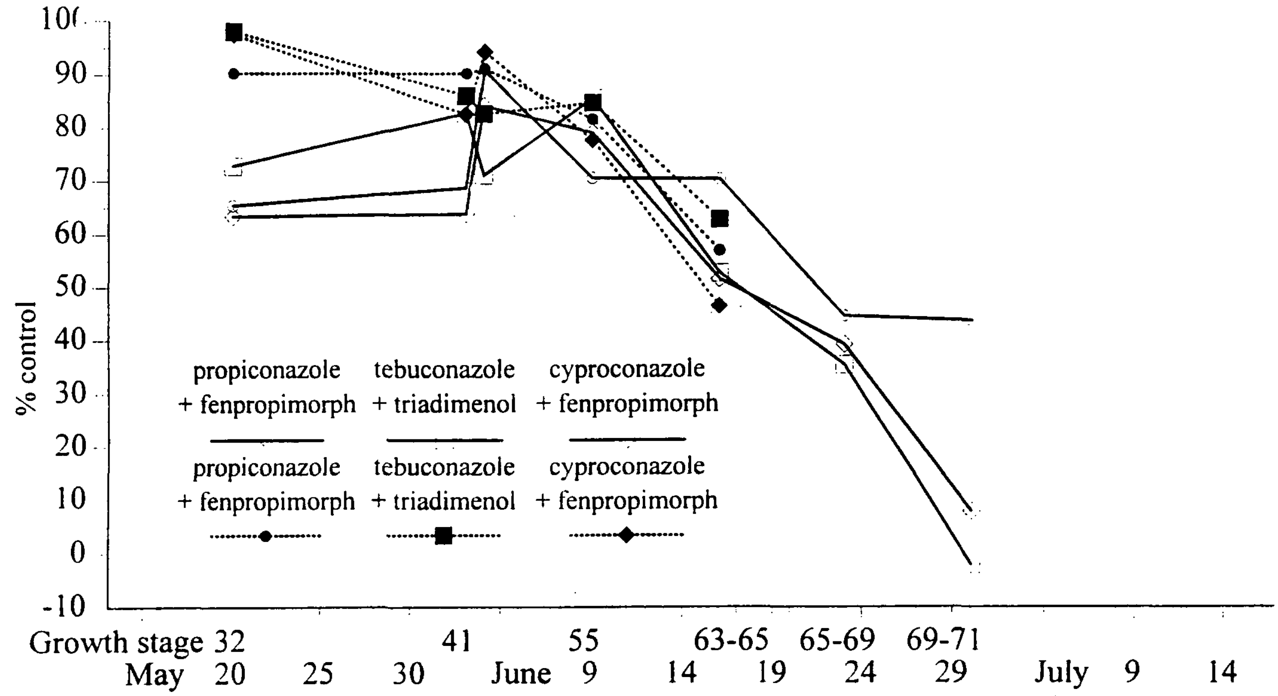
ADAS High Mowthorpe1992: Mildew - leaf 1

% reduction (= control of disease) of accumulated disease at GS77-79 - 29 July in relation to the date and growth stage of fungicide application



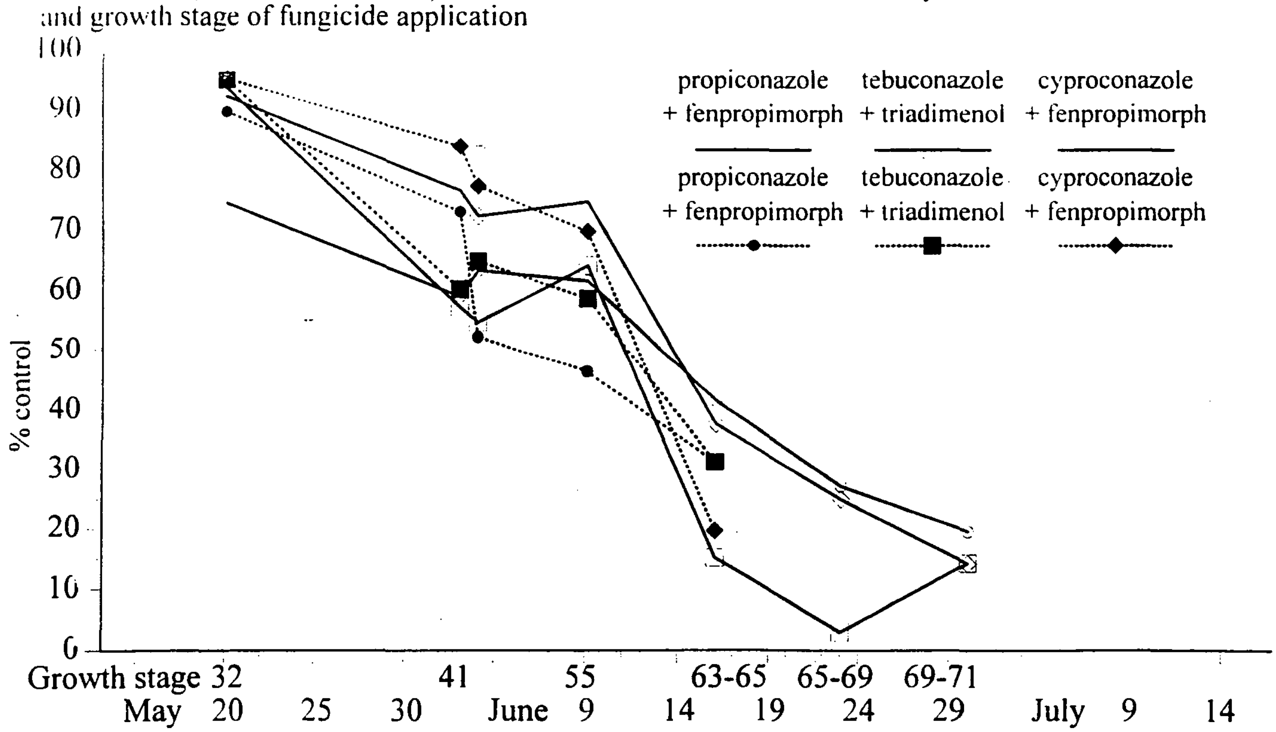
ADAS High Mowthorpe1992: Mildew - leaf 2

% reduction (= control of disease) of accumulated disease at GS77-79 - 29 July in relation to the date and growth stage of fungicide application

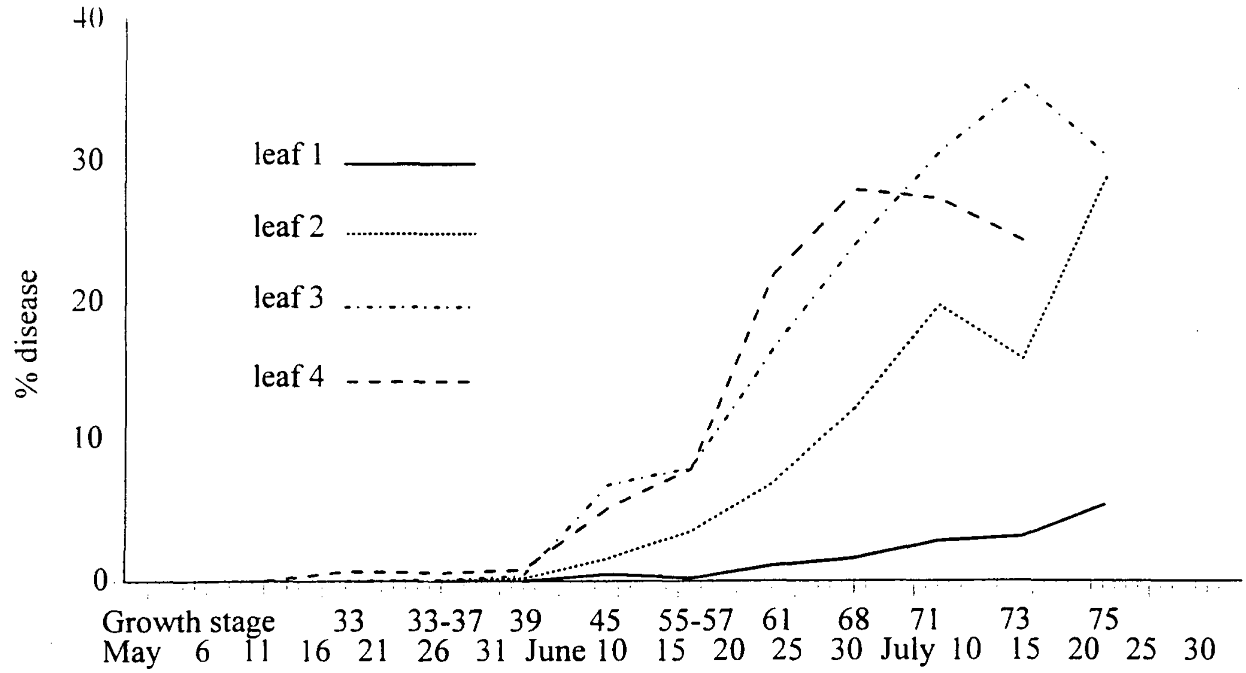


ADAS High Mowthorpe1992: Mildew - leaf 3

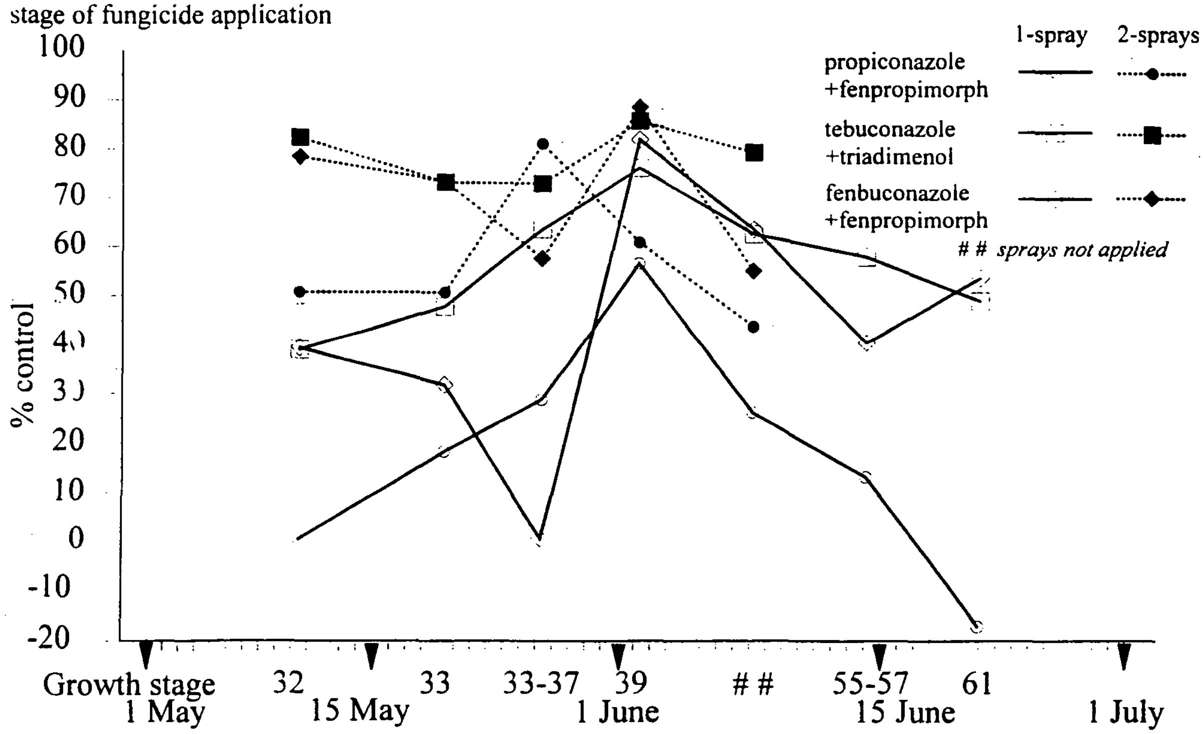
% reduction (= control of disease) of accumulated disease at GS75 - 17 July in relation to the date and growth stage of fungicide application



ADAS High Mowthorpe 1993: Mildew
Disease progress on the final four leaves in relation to date & growth stage

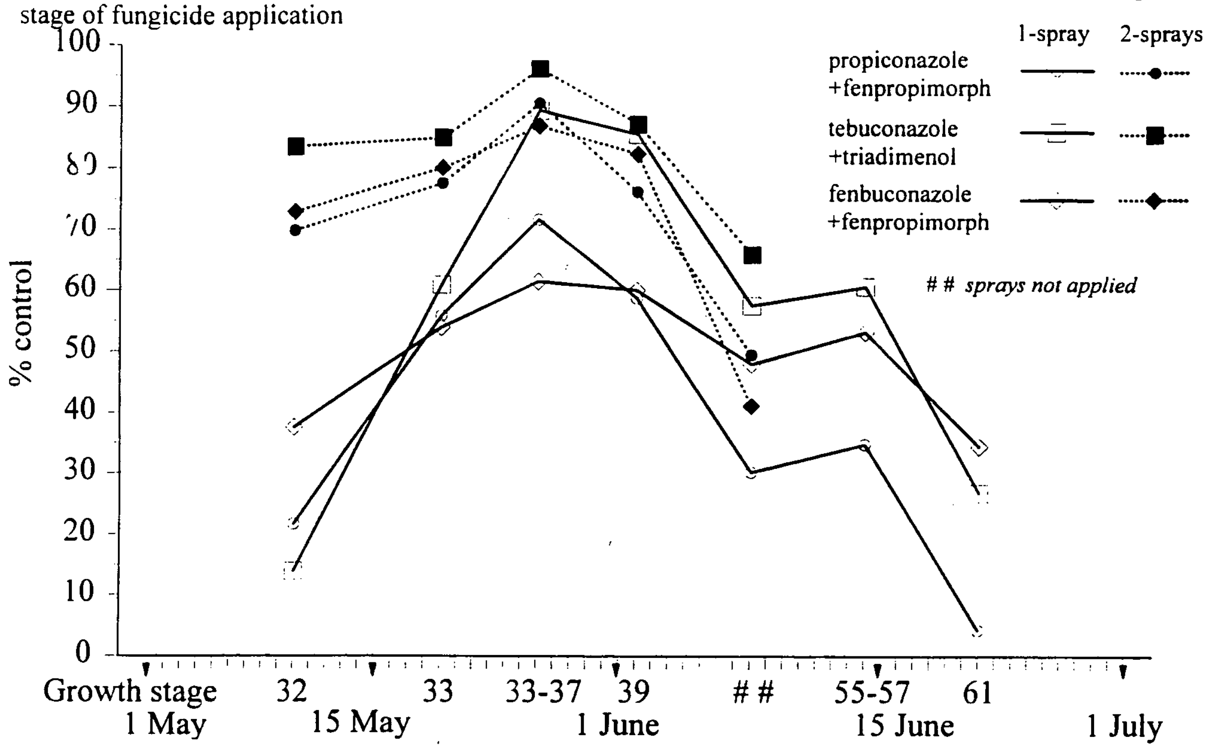


ADAS High Mowthorpe 1993: Mildew - leaf 1
% reduction (= control of disease) of accumulated disease at GS75 - 21 July in relation to the date & growth stage of fungicide application



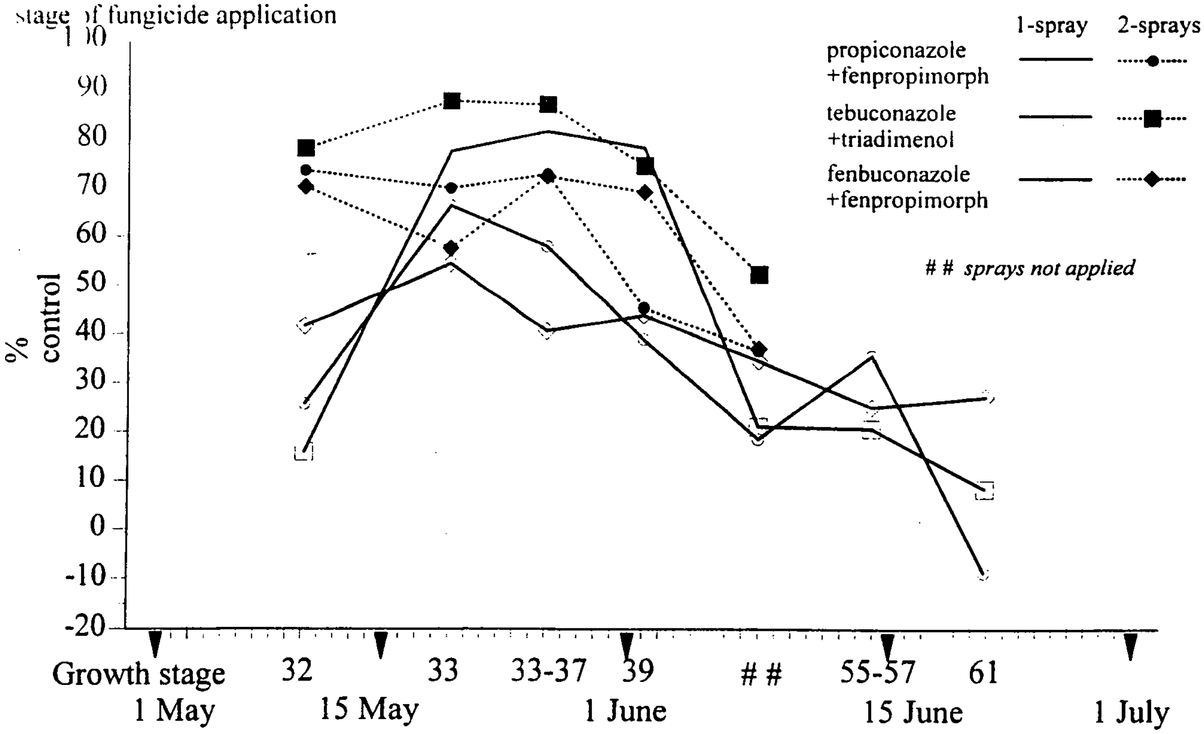
ADAS High Mowthorpe 1993: Mildew - leaf 2

% reduction (= control of disease) of accumulated disease at GS75 - 21 July in relation to the date & growth stage of fungicide application



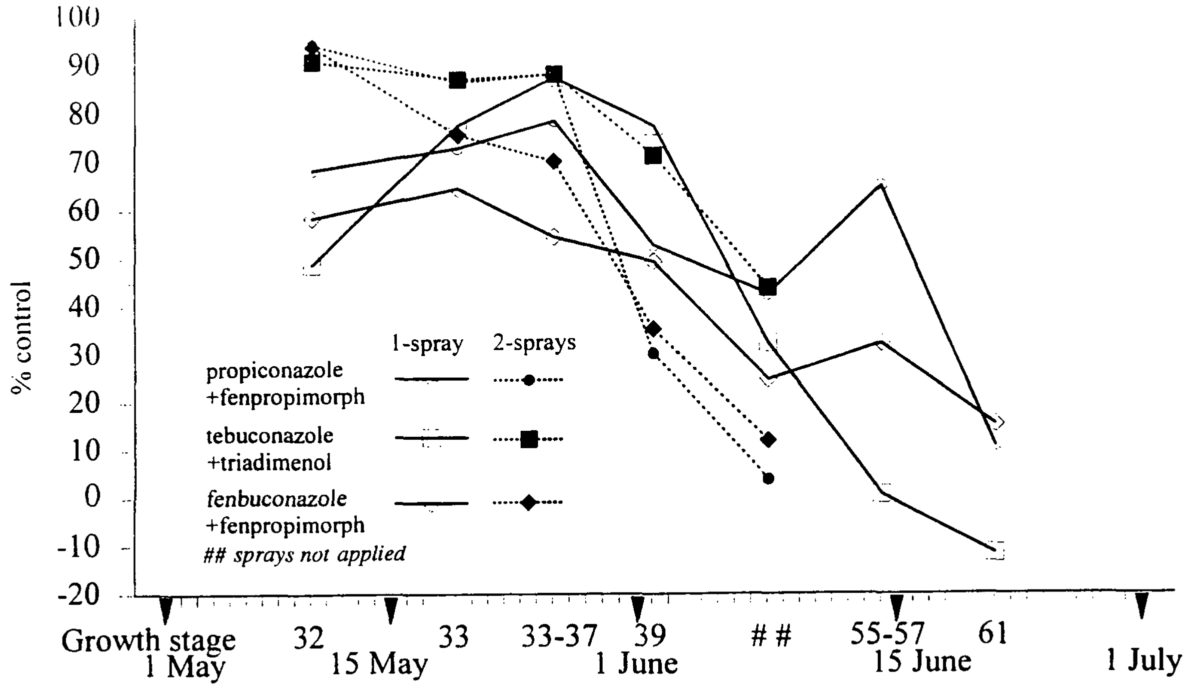
ADAS High Mowthorpe 1993: Mildew - leaf 3

% reduction (= control of disease) of accumulated disease at GS75 - 21 July in relation to the date & growth stage of fungicide application



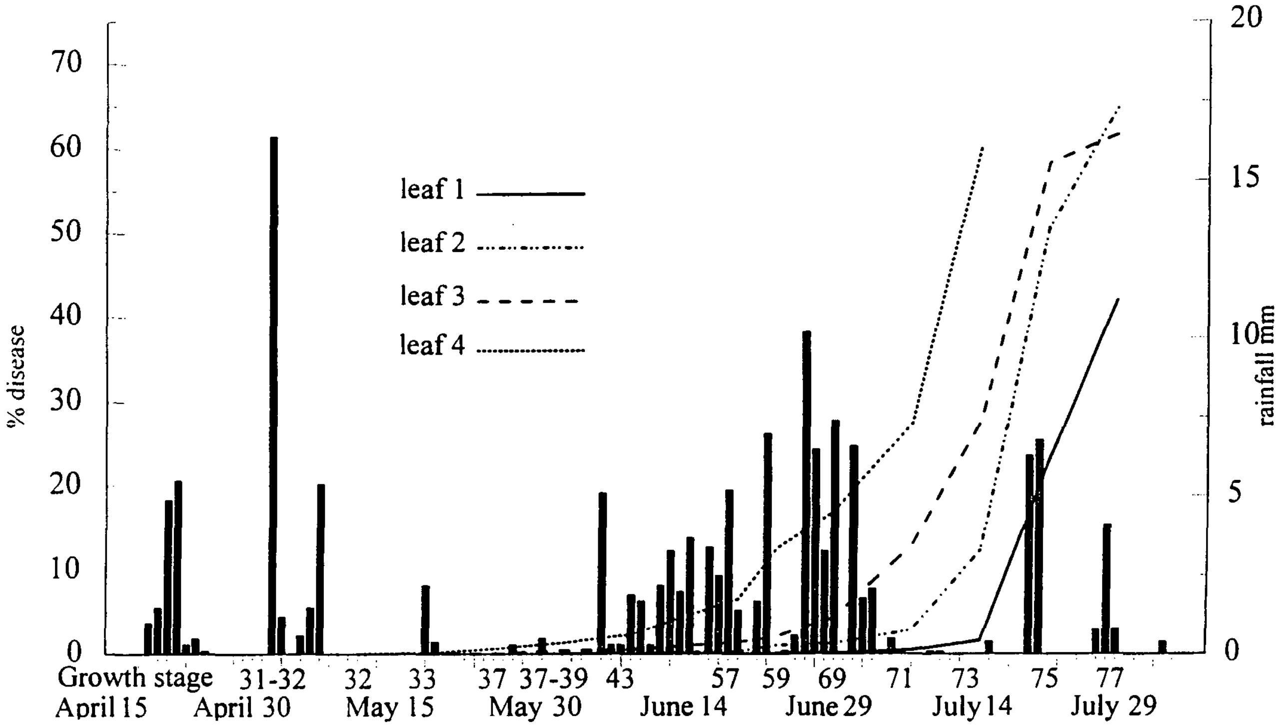
ADAS High Mowthorpe1993: Mildew - leaf 4

% reduction (= control of disease) of accumulated disease at GS73 - 14 July in relation to the date and growth stage of fungicide application



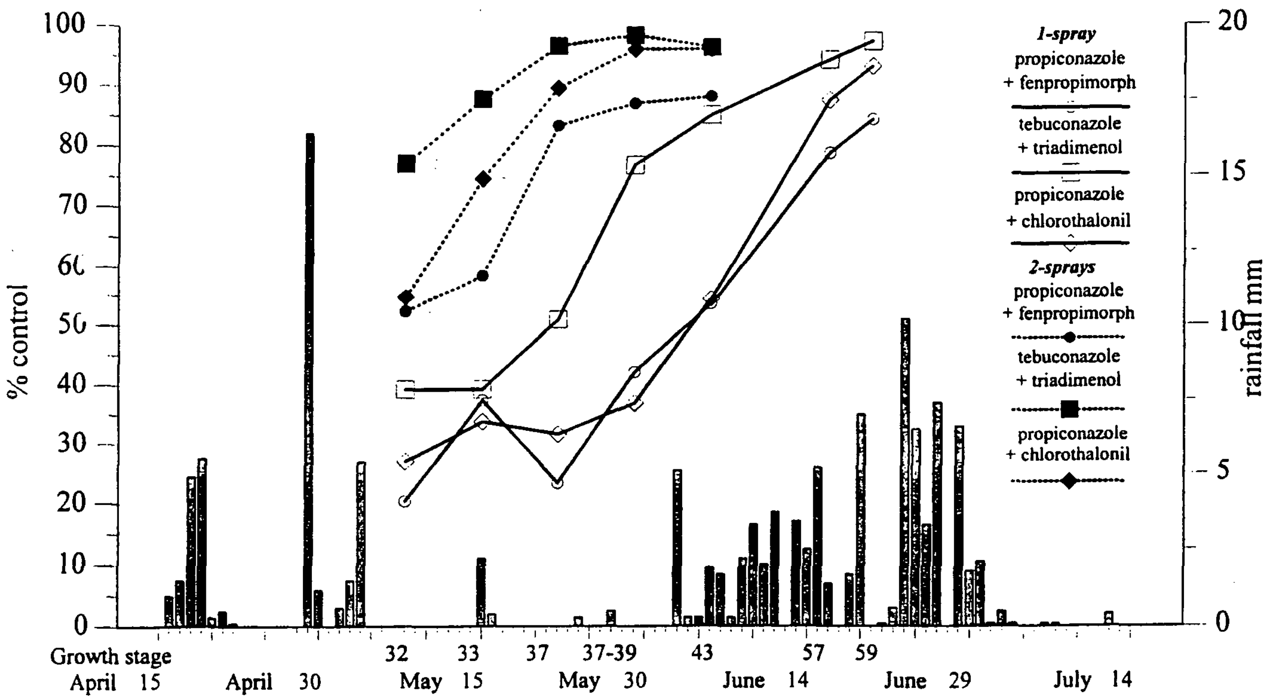
Morley Research 1991: ***Septoria tritici***

Disease progress on the final four leaves in relation to the temporal distribution of rainfall, date & growth stage



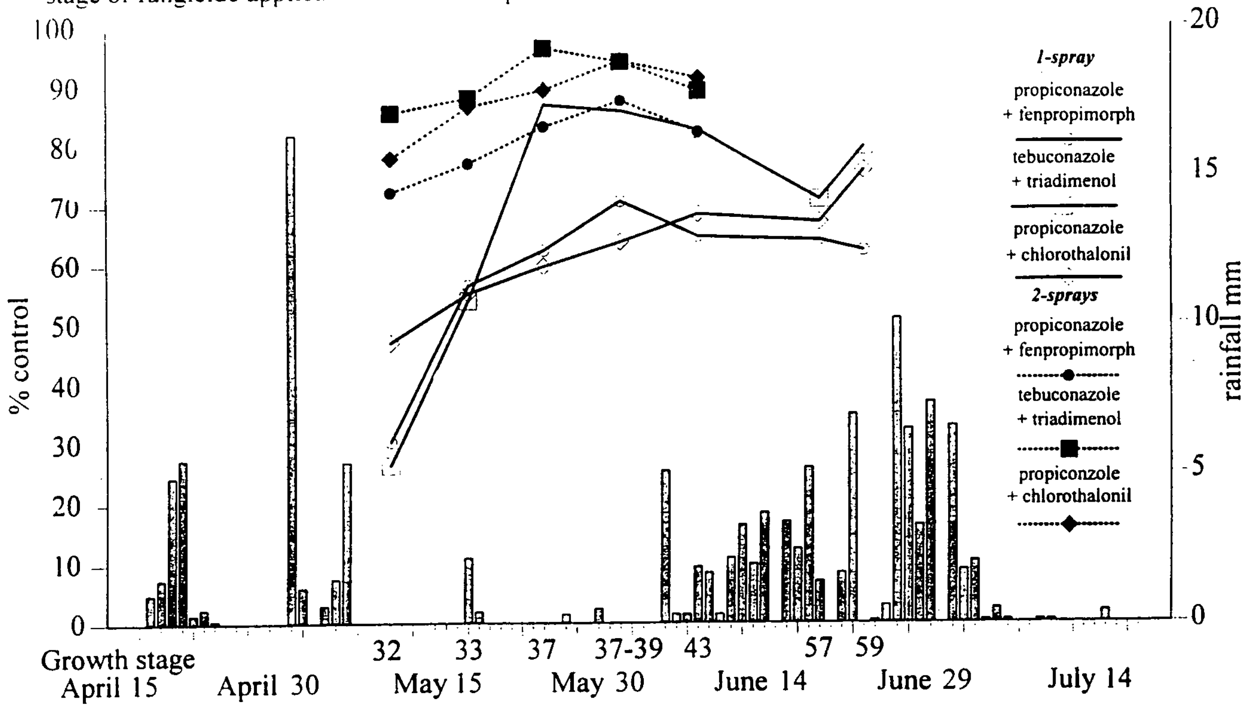
Morley Research 1991: ***Septoria tritici*** **- leaf 1**

% reduction (= control of disease) of accumulated disease at GS77-81 - 25 July in relation to date and growth stage of fungicide application and the temporal distribution of rainfall



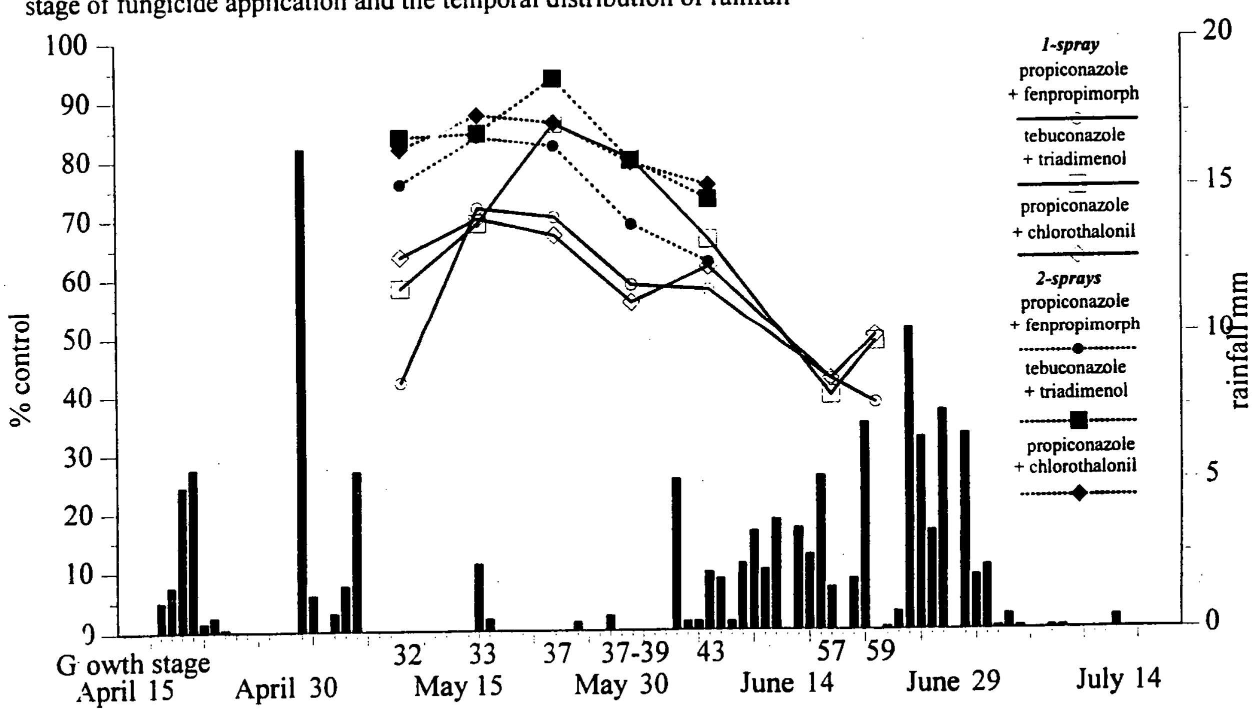
Morley Research 1991: *Septoria tritici* - leaf 2

% reduction (= control of disease) of accumulated disease at GS77-81 - 25 July in relation to date and growth stage of fungicide application and the temporal distribution of rainfall



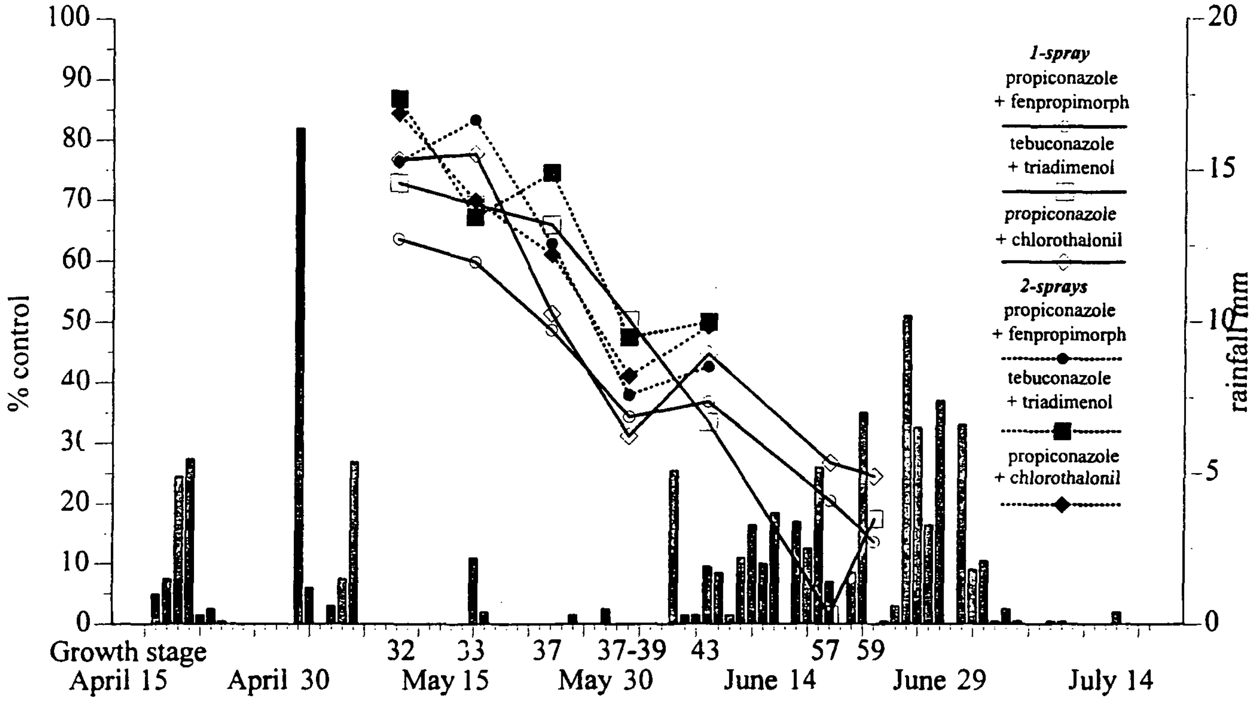
Morley Research 1991: *Septoria tritici* - leaf 3

% reduction (= control of disease) of accumulated disease at GS77-81 - 25 July in relation to date and growth stage of fungicide application and the temporal distribution of rainfall



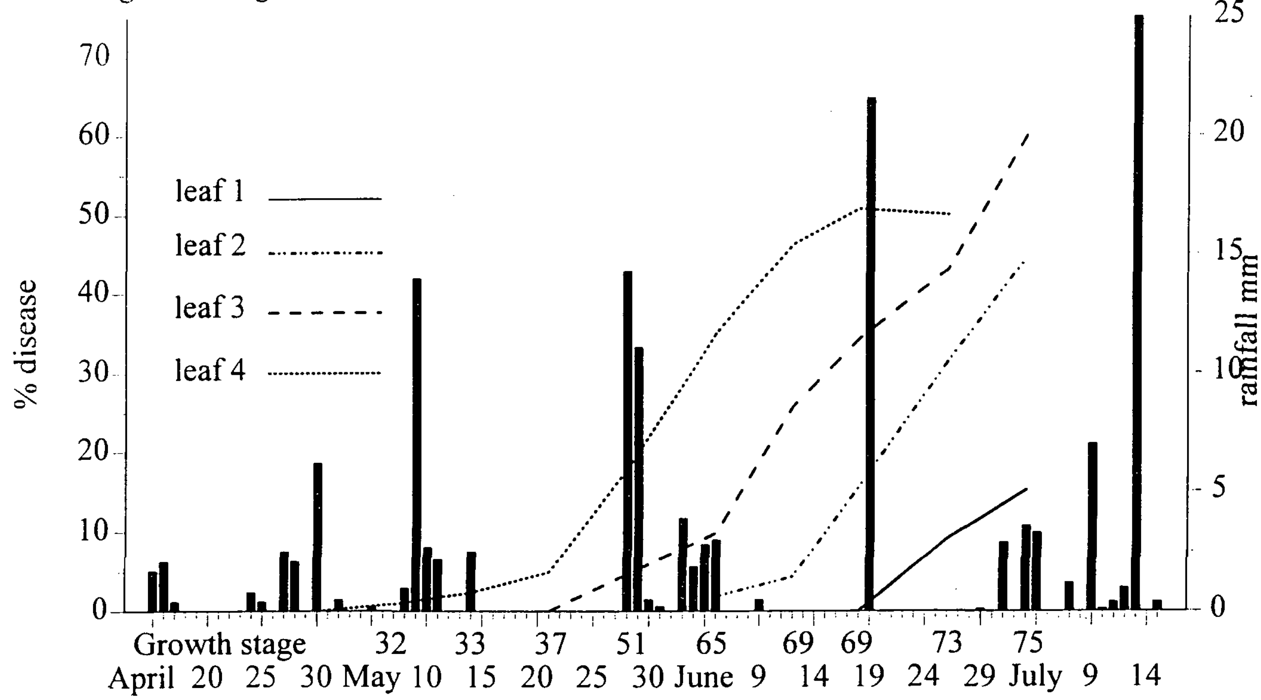
Morley Research 1991: *Septoria tritici* - leaf 4

% reduction (= control of disease) of accumulated disease at GS77-81 - 25 July in relation to date and growth stage of fungicide application and the temporal distribution of rainfall



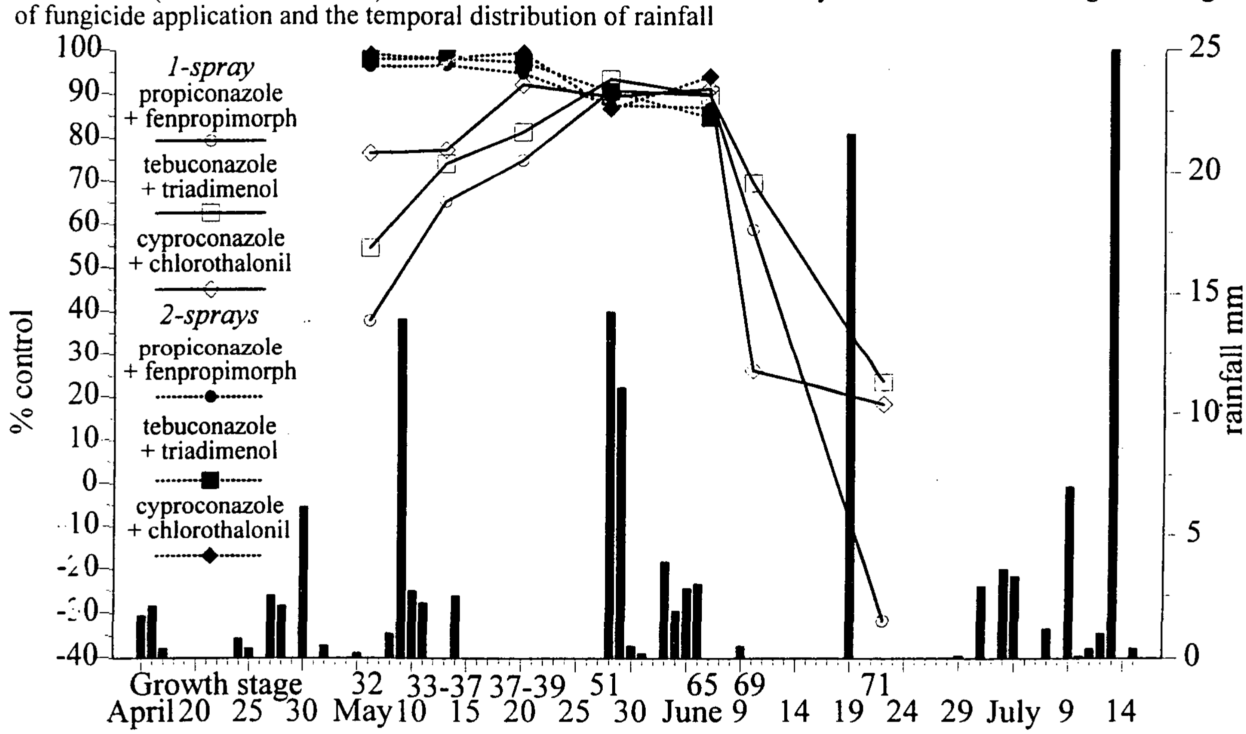
Morley Research 1992: ***Septoria tritici***

Disease progress on the final four leaves in relation to the temporal distribution of rainfall, date & growth stage



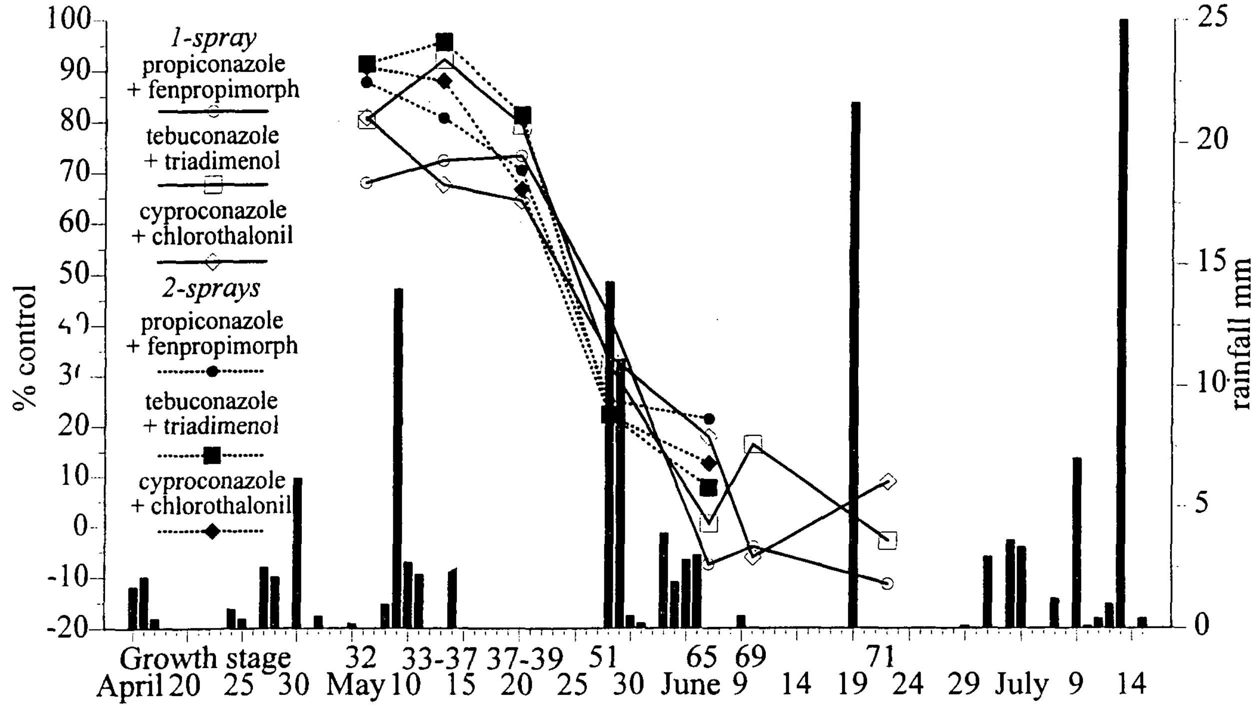
Morley Research 1992: ***Septoria tritici*** **- leaf 1**

% reduction (= control of disease) of accumulated disease at GS75 - 3 July in relation to date and growth stage of fungicide application and the temporal distribution of rainfall



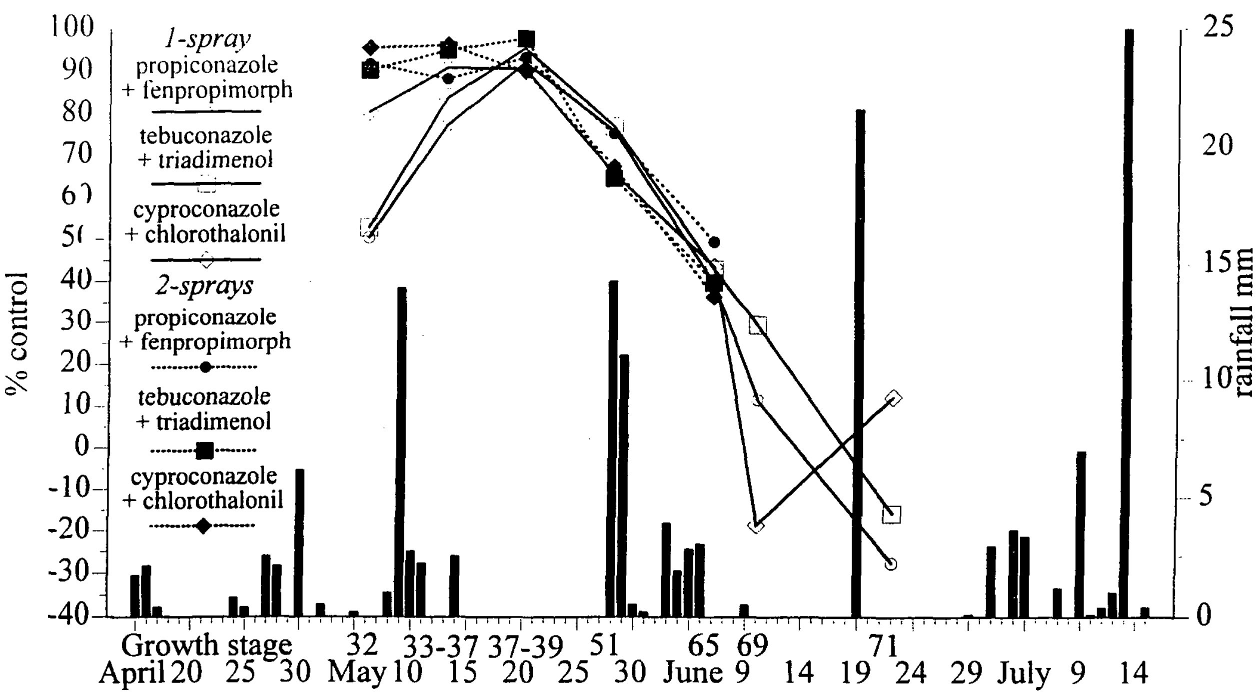
Morley Research 1992: ***Septoria tritici*** **- leaf 3**

% reduction (= control of disease) of accumulated disease at GS75 - 3 July in relation to date and growth stage of fungicide application and the temporal distribution of rainfall



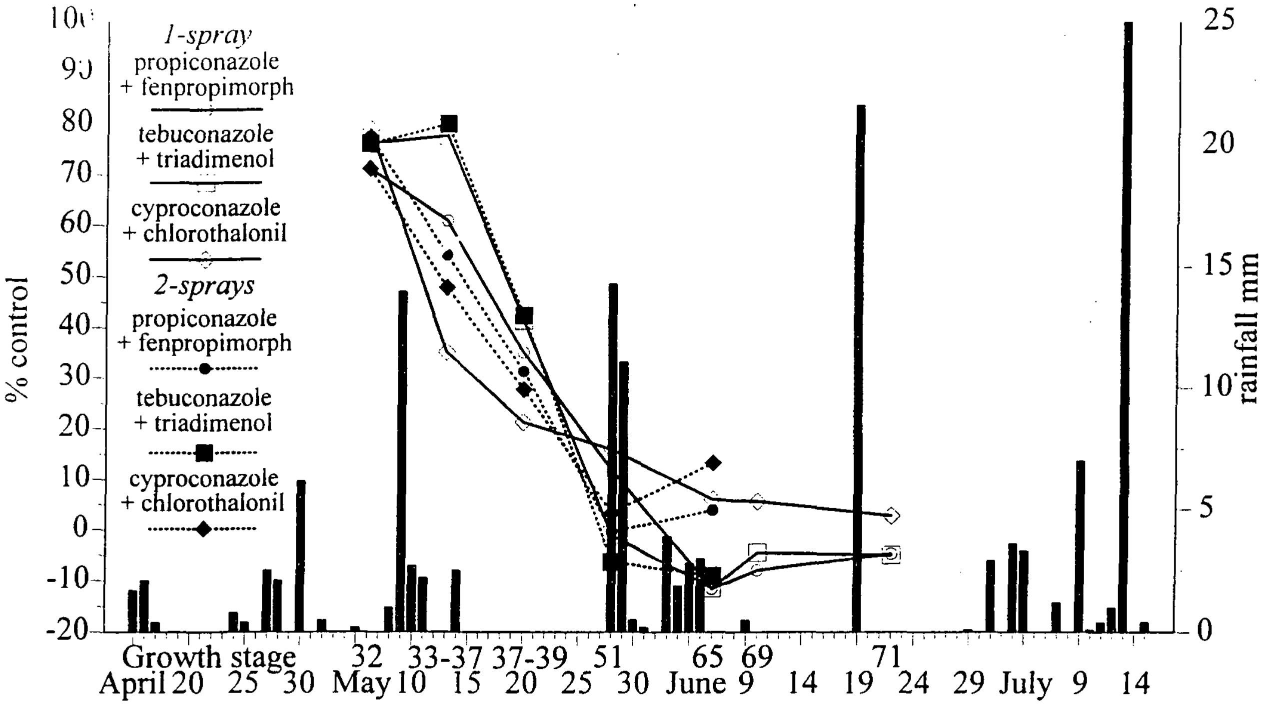
Morley Research 1992: ***Septoria tritici*** **- leaf 2**

% reduction (= control of disease) of accumulated disease at GS75 - 3 July in relation to date and growth stage of fungicide application and the temporal distribution of rainfall



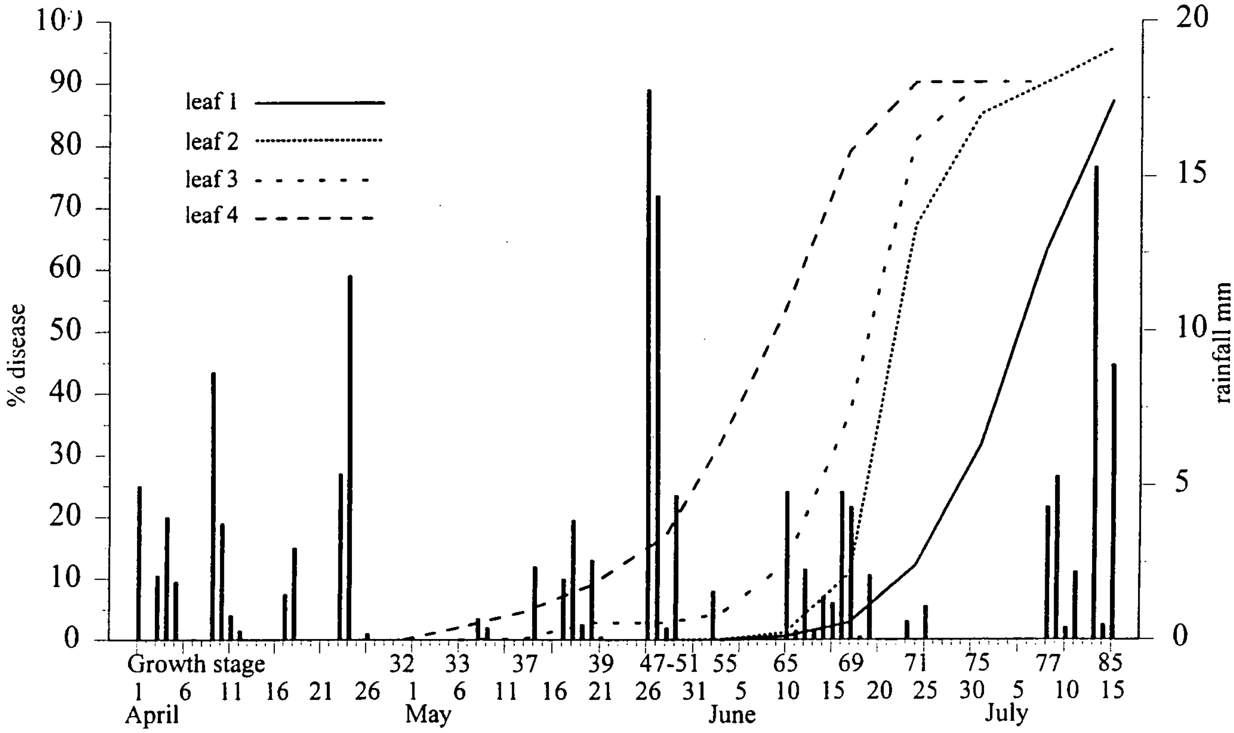
Morley Research 1992: *Septoria tritici* - leaf 4

% reduction (= control of disease) of accumulated disease at GS75 - 3 July in relation to date and growth stage of fungicide application and the temporal distribution of rainfall



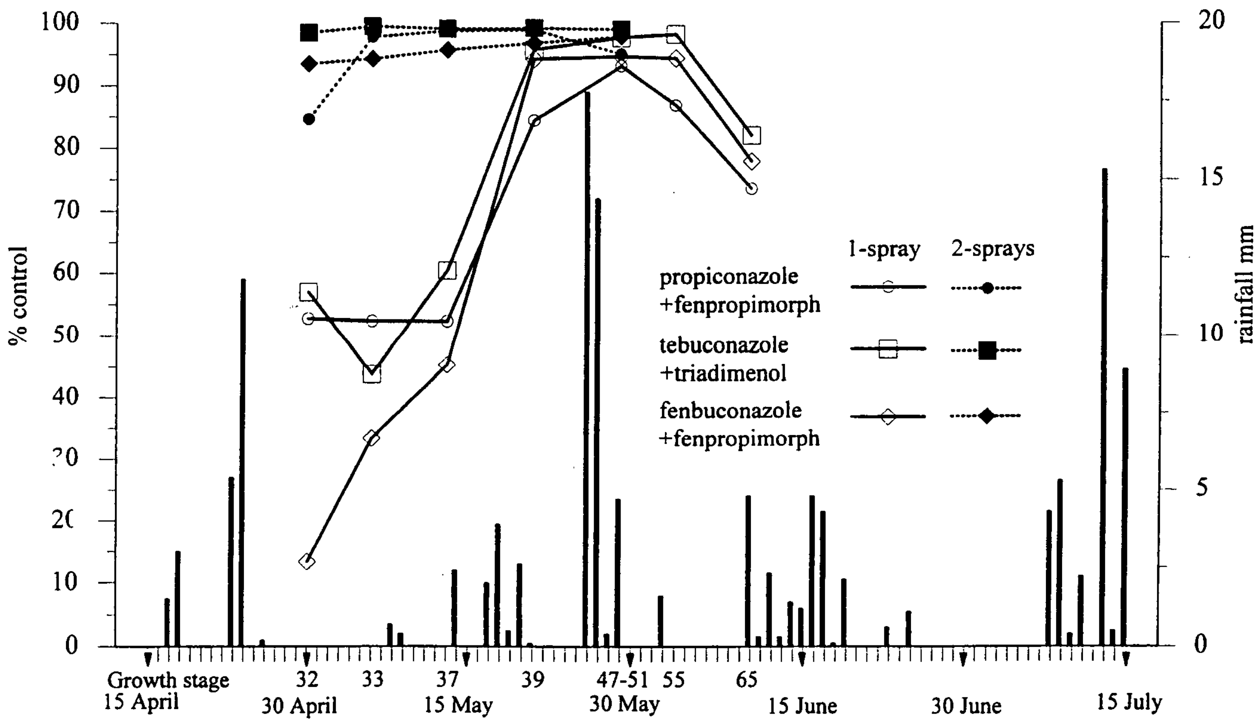
Morley Research 1993: *Septoria tritici*

Disease progress on the final four leaves in relation to the temporal distribution of rainfall, date & growth stage



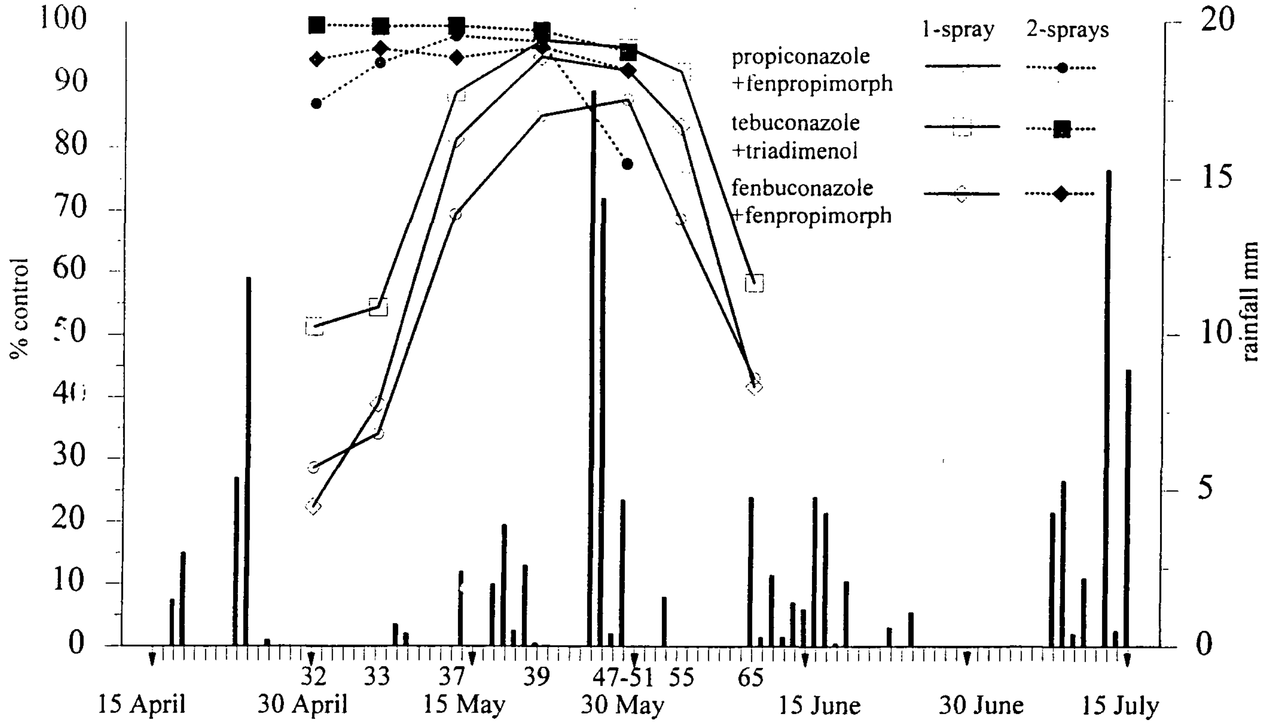
Morley Research 1993: *Septoria tritici* - leaf 1

% reduction (= control of disease) of accumulated disease at GS85 - 15 July in relation to the temporal distribution of rainfall, date &growth stage of fungicide application



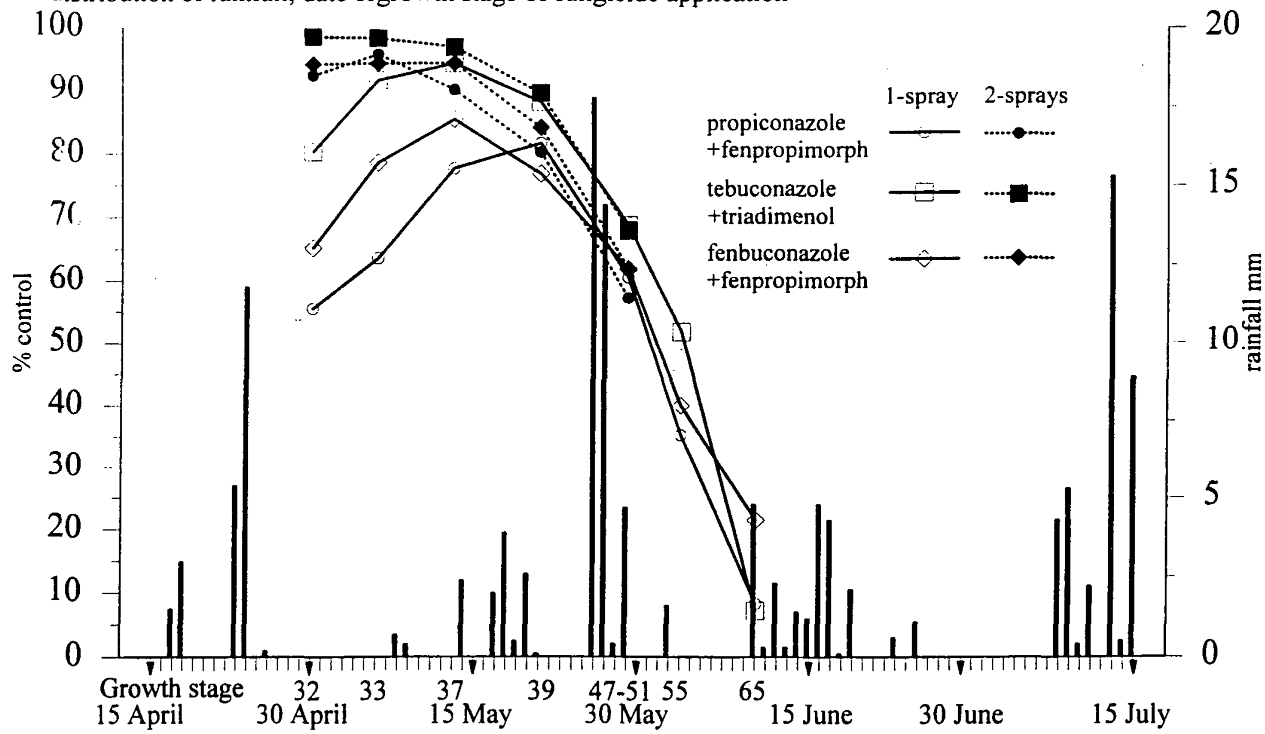
Morley Research 1993: *Septoria tritici* - leaf 2

% reduction (= control of disease) of accumulated disease at GS85 - 15 July in relation to the temporal distribution of rainfall, date &growth stage of fungicide application



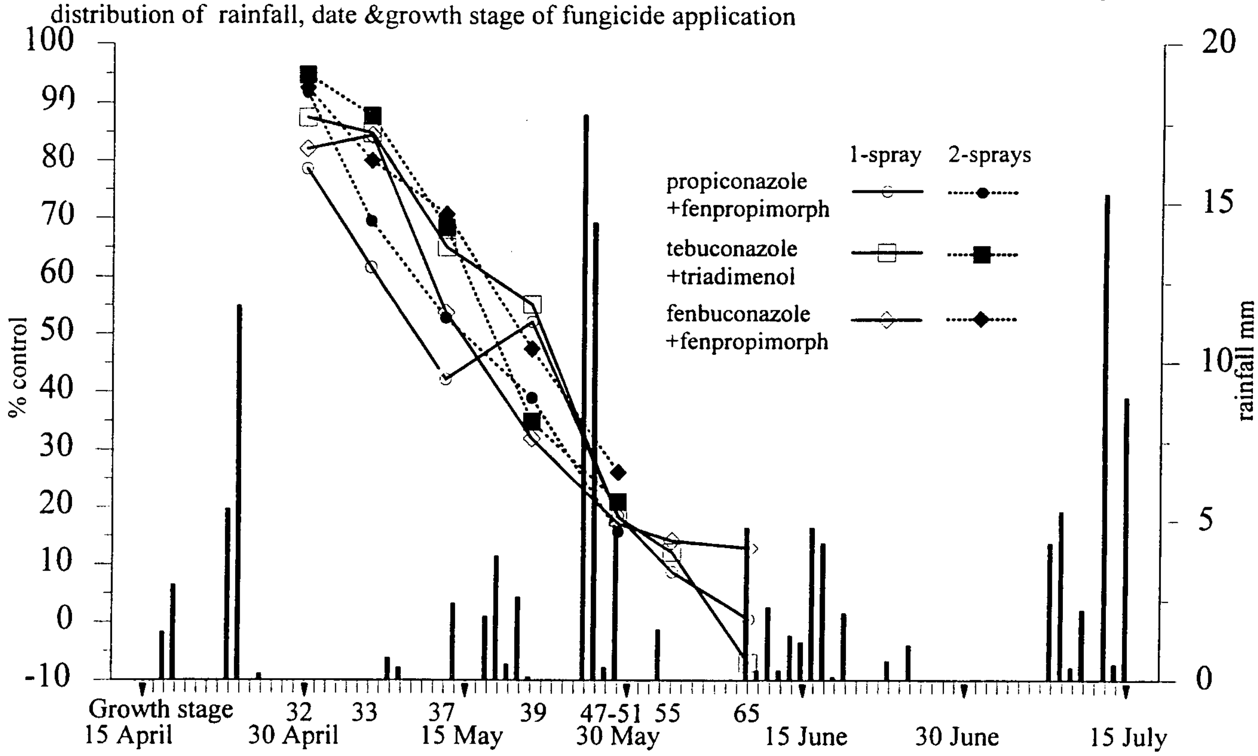
Morley Research 1993: *Septoria tritici* - leaf 3

% reduction (= control of disease) of accumulated disease at GS77 - 8 July in relation to the temporal distribution of rainfall, date &growth stage of fungicide application



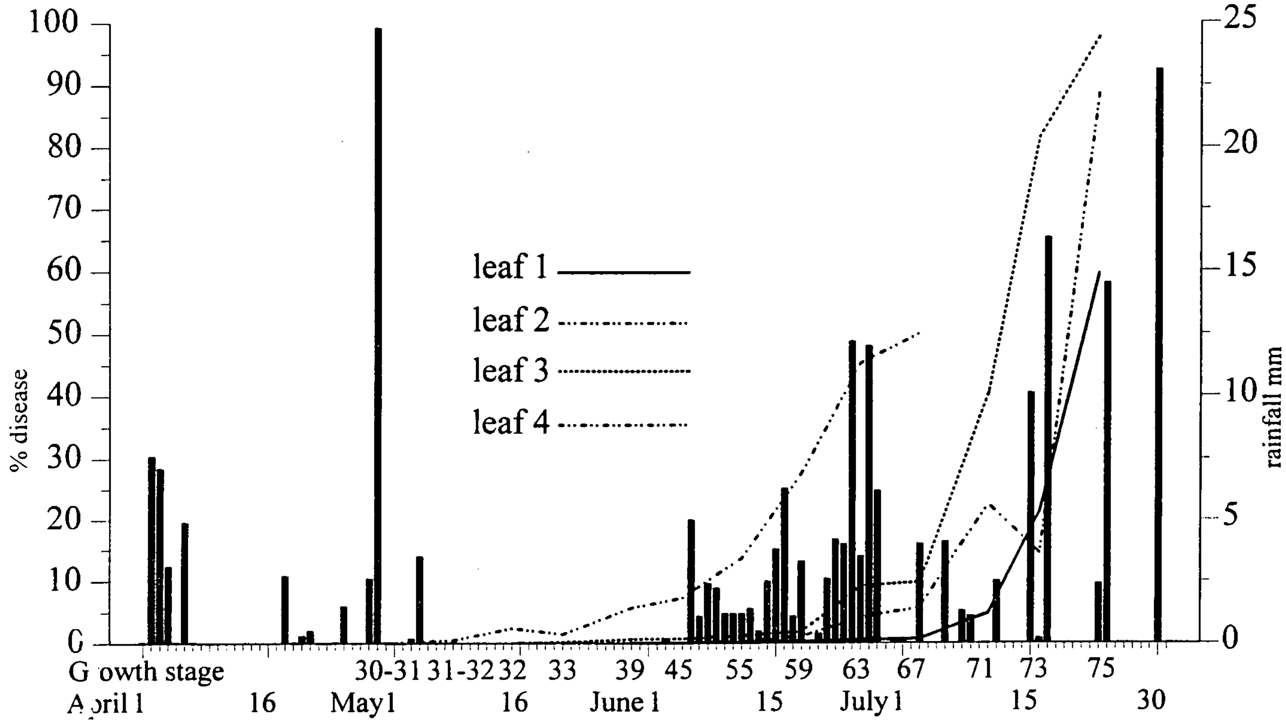
Morley Research 1993: *Septoria tritici* - leaf 4

% reduction (= control of disease) of accumulated disease at GS75 - 1 July in relation to the temporal distribution of rainfall, date &growth stage of fungicide application



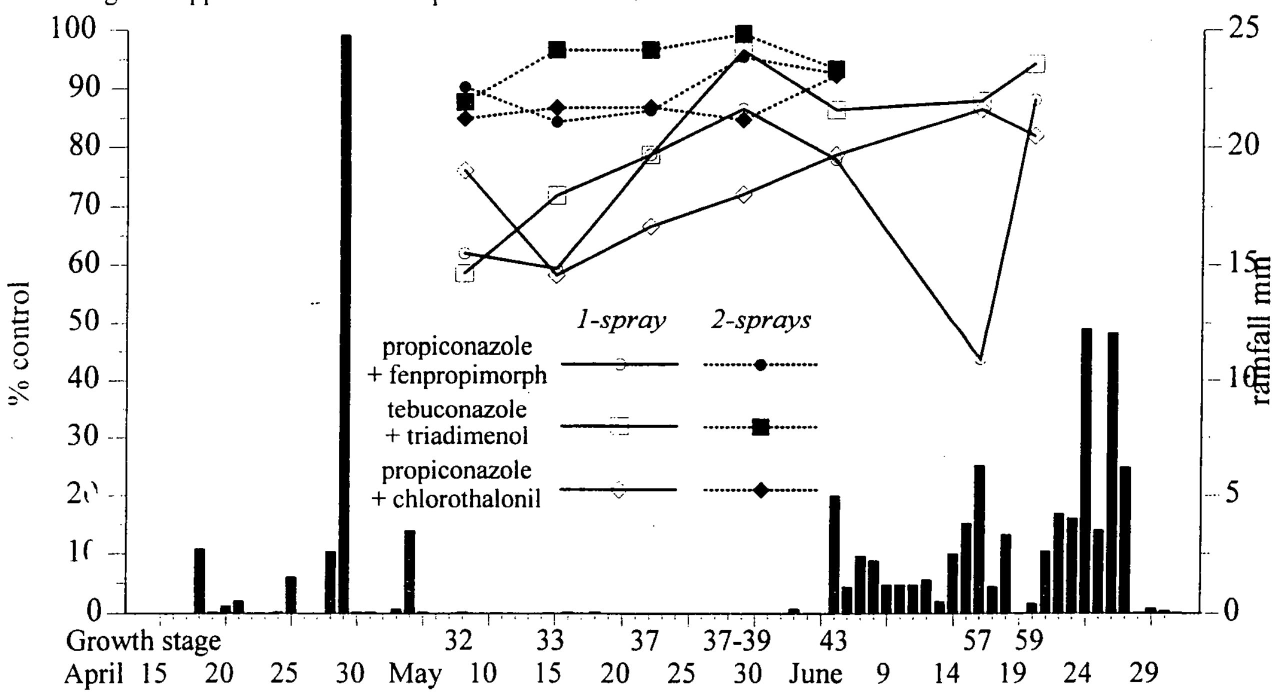
ADAS Rosemaund 1991: *Septoria tritici*

Disease progress on the final four leaves in relation to the temporal distribution of rainfall, date and growth stage



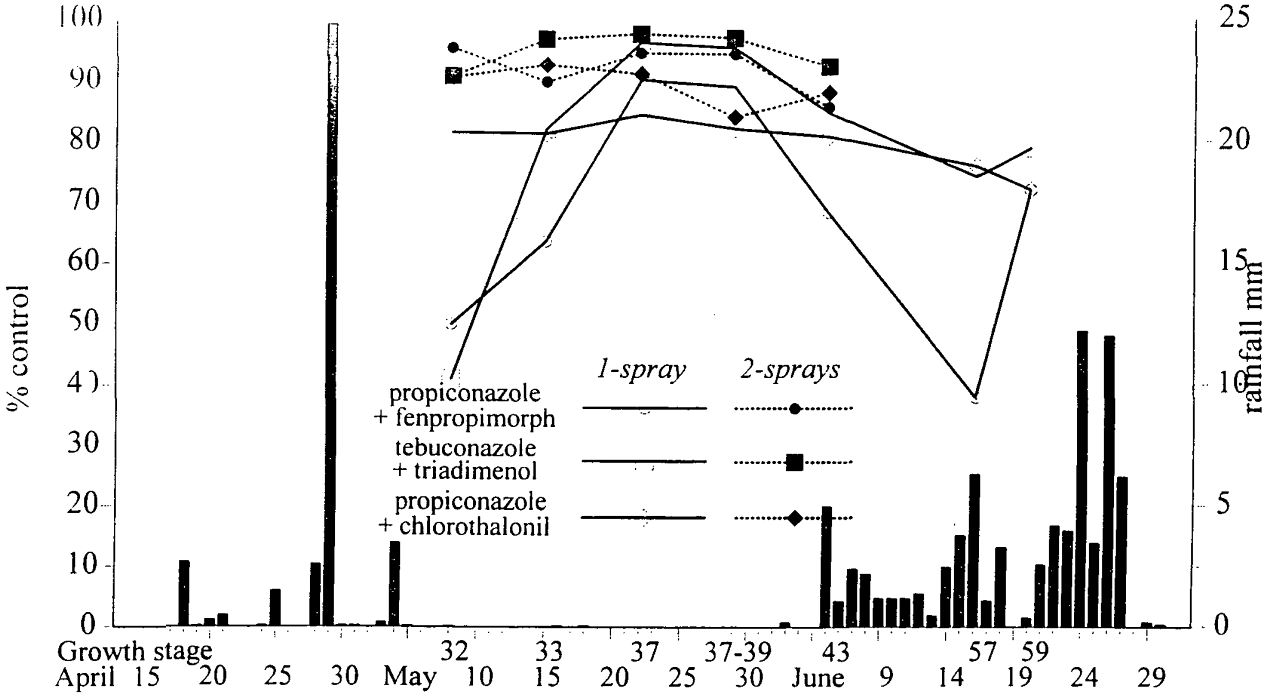
ADAS Rosemaund 1991: *Septoria tritici* - leaf 1

% reduction (= control of disease) of accumulated disease at GS75 - 23 July in relation to date and growth stage of fungicide application and the temporal distribution of rainfall



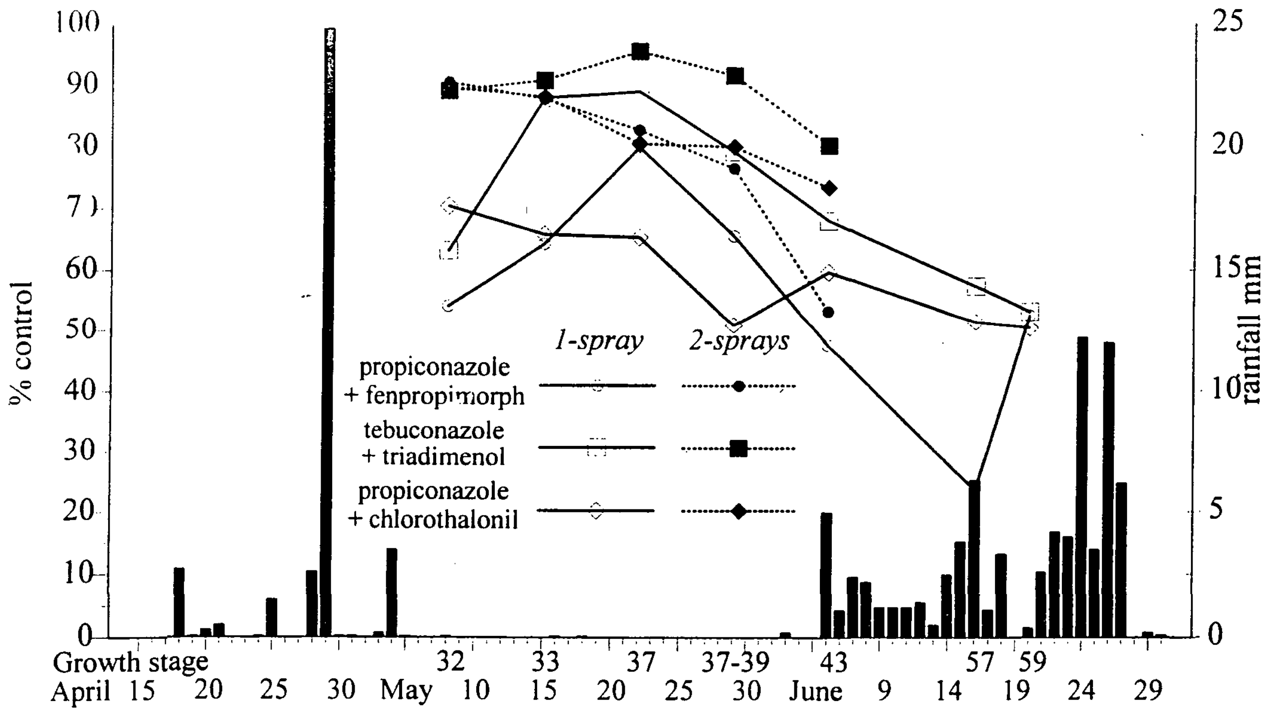
ADAS Rosemaund 1991: ***Septoria tritici*** **- leaf 2**

% reduction (= control of disease) of accumulated disease at GS75 - 23 July in relation to date and growth stage of fungicide application and the temporal distribution of rainfall



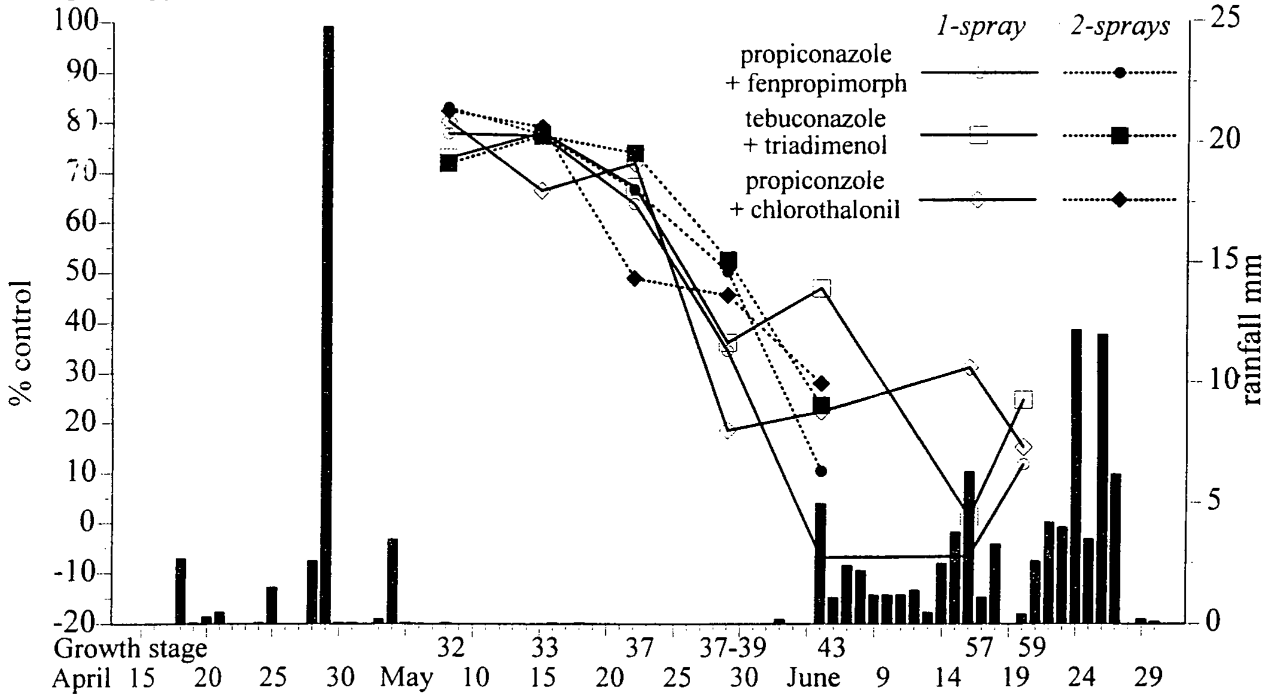
ADAS Rosemaund 1991: ***Septoria tritici*** **- leaf 3**

% reduction (= control of disease) of accumulated disease at GS75 - 23 July in relation to date and growth stage of fungicide application and the temporal distribution of rainfall



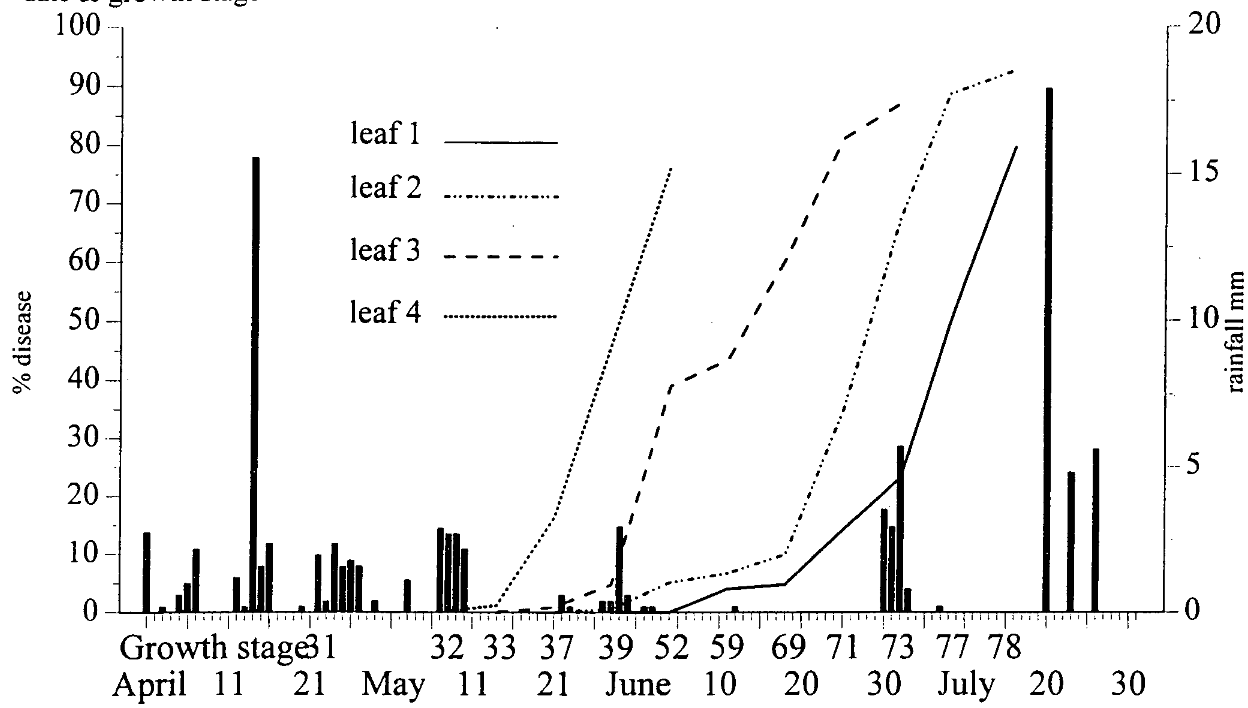
ADAS Rosemaund 1991: *Septoria tritici* - leaf 4

% reduction (= control of disease) of accumulated disease at GS67 - 2 July in relation to date and growth stage of fungicide application and the temporal distribution of rainfall



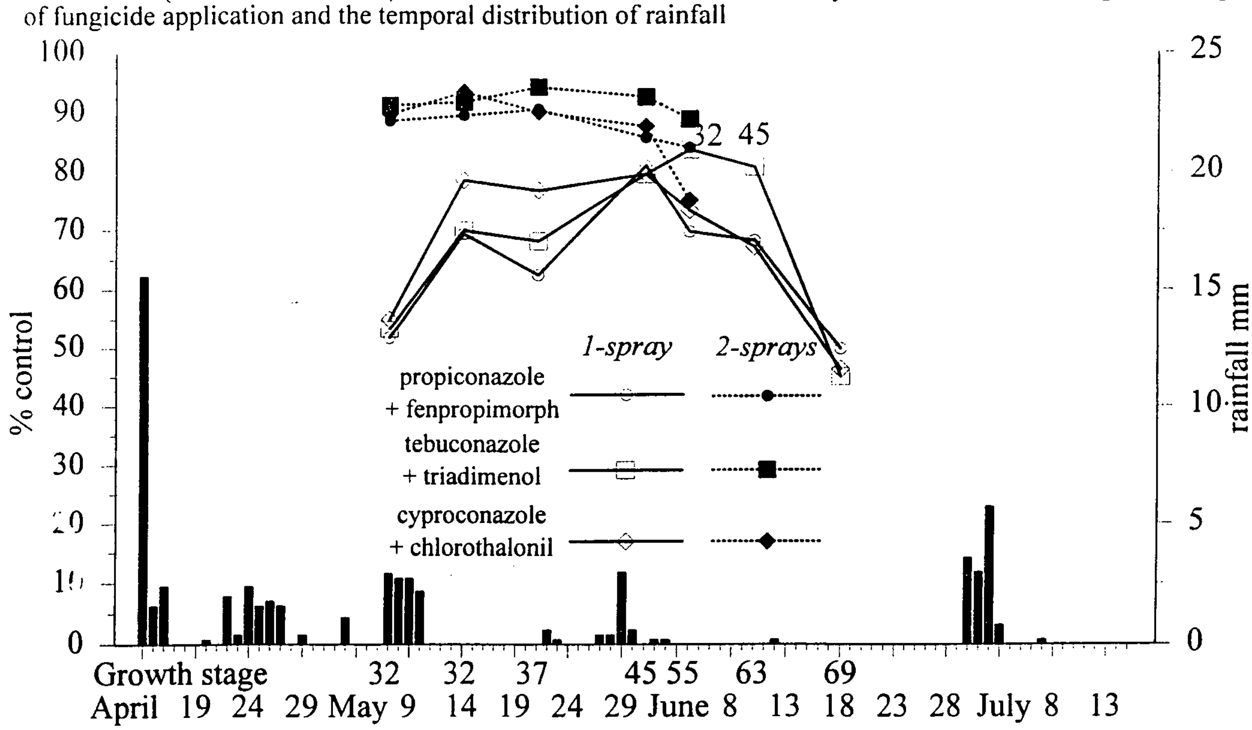
ADAS Rosemaund 1992: *Septoria tritici*

Dise; se progress on the final four leaves in relation to the temporal distribution of rainfall, date & growth stage



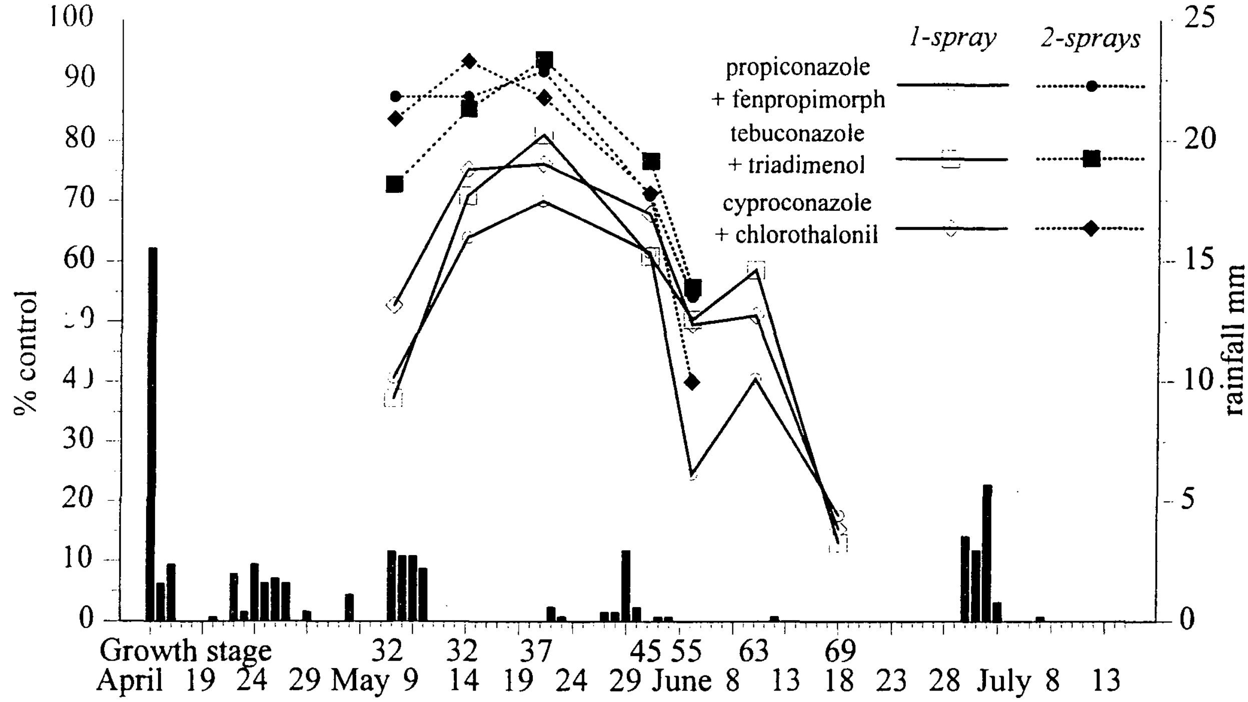
ADAS Rosemaund 1992: *Septoria tritici* - leaf 1

% reduction (= control of disease) of accumulated disease at GS75 - 3 July in relation to date and growth stage of fungicide application and the temporal distribution of rainfall



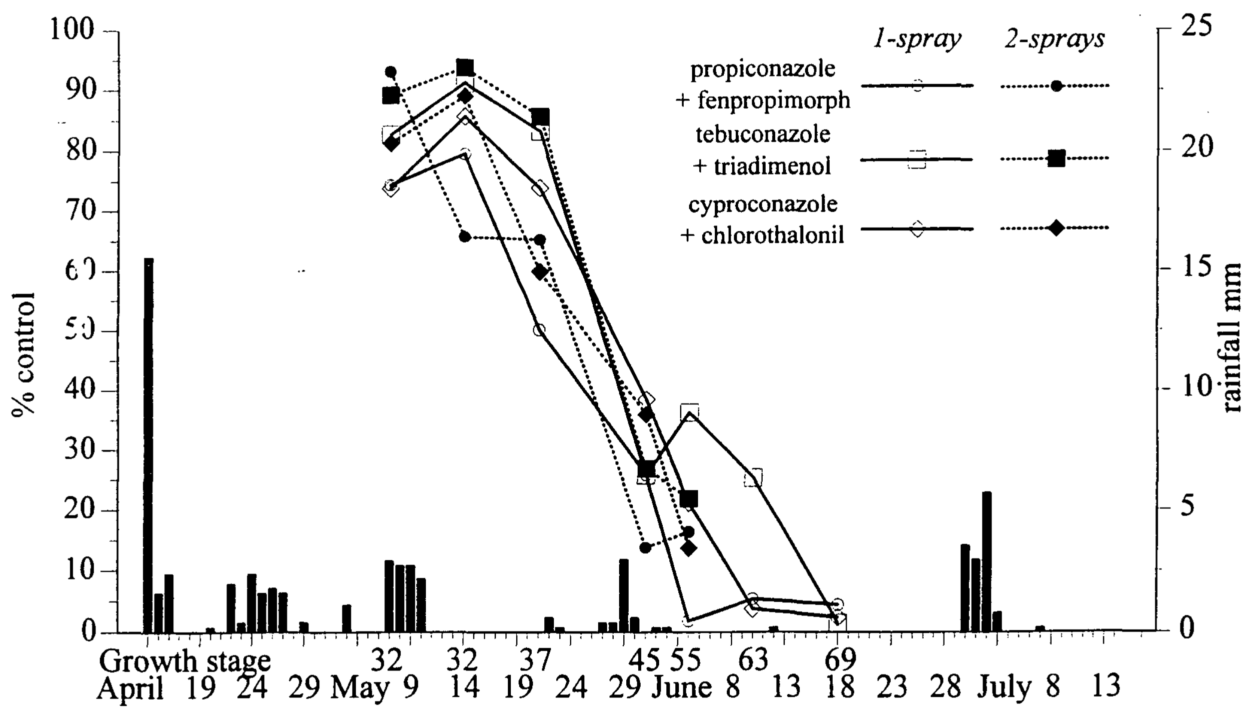
ADAS Rosemaund 1992: ***Septoria tritici*** **- leaf 2**

% reduction (= control of disease) of accumulated disease at GS78 - 16 July in relation to date and growth stage of fungicide application and the temporal distribution of rainfall



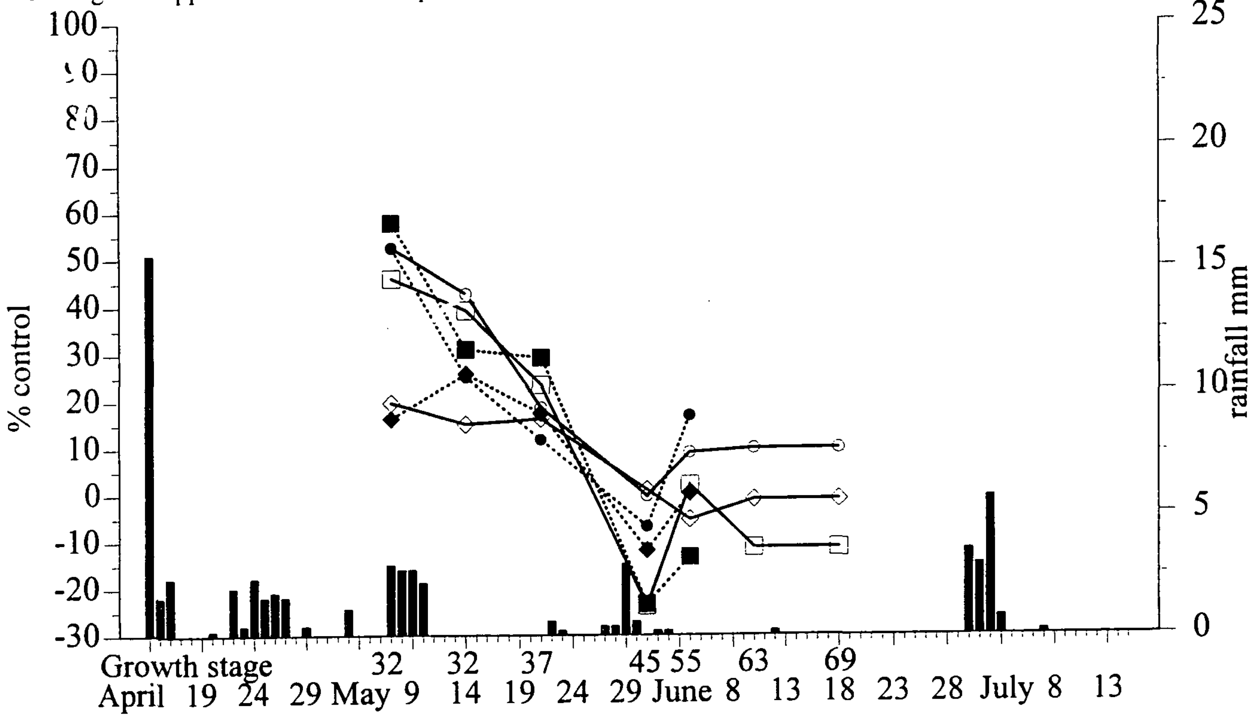
ADAS Rosemaund 1992: ***Septoria tritici*** **- leaf 3**

% reduction (= control of disease) of accumulated disease at GS73 - 2 July in relation to date and growth stage of fungicide application and the temporal distribution of rainfall



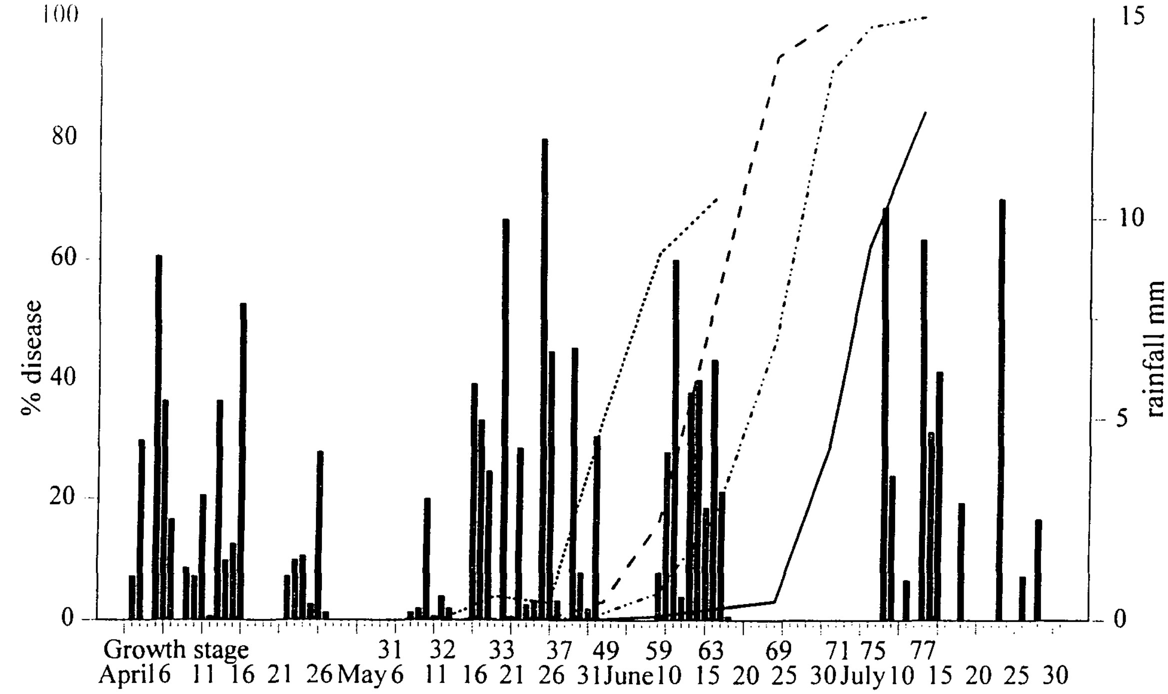
ADAS Rosemaund 1992: *Septoria tritici* - leaf 4

% reduction (= control of disease) of accumulated disease at GS71 - 25 June in relation to date and growth stage of fungicide application and the temporal distribution of rainfall



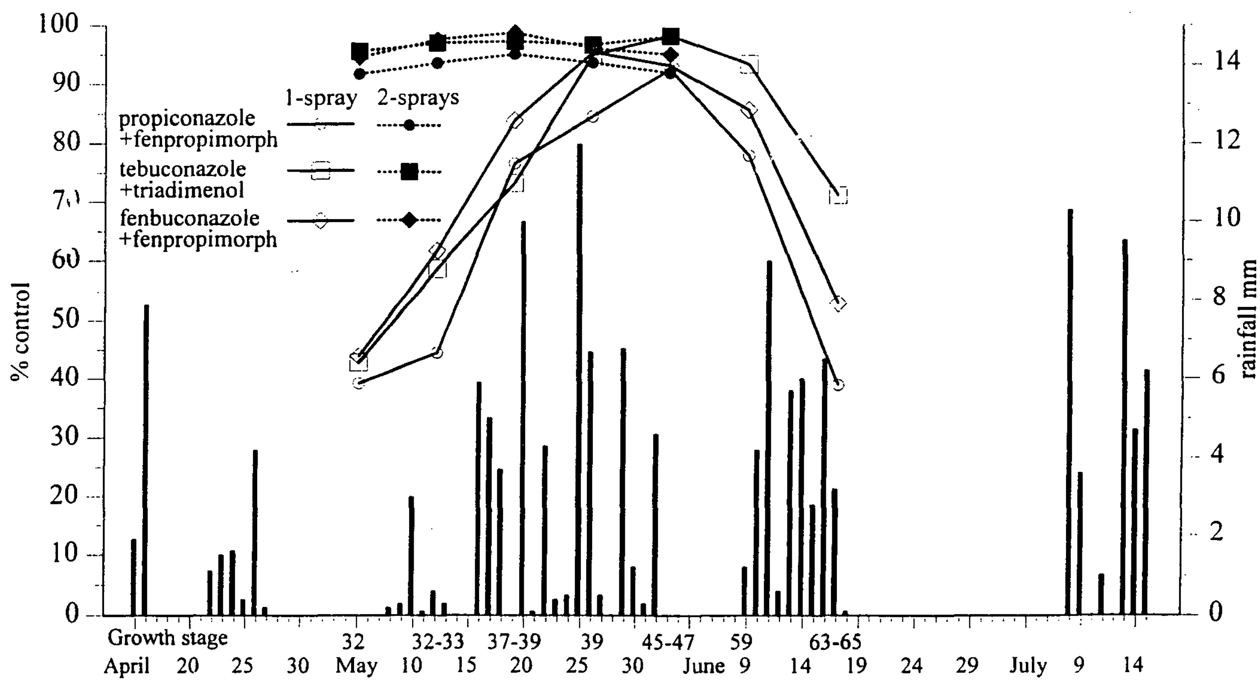
ADAS Rosemaund 1993: *Septoria tritici*

Disease progress on the final four leaves in relation to the temporal distribution of rainfall, date & growth stage



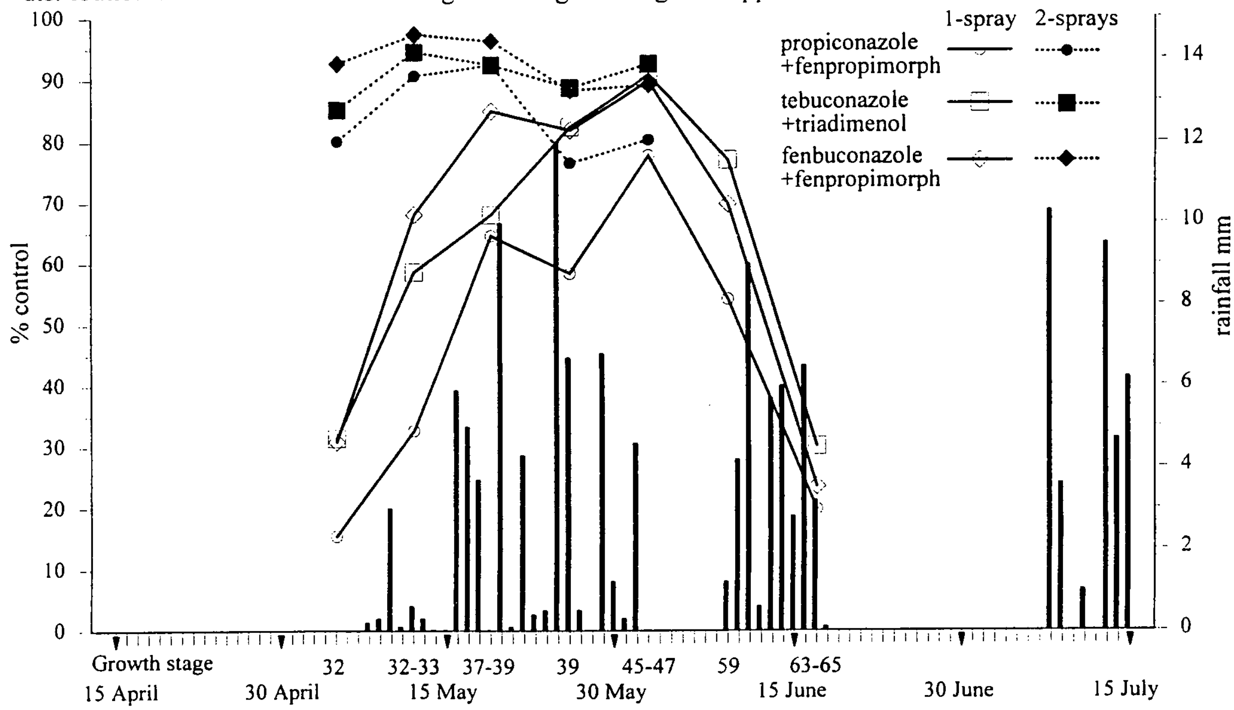
ADAS Rosemaund 1993: *Septoria tritici* - leaf 1

% reduction (= control of disease) of accumulated disease at GS77 - 13 July in relation to the temporal distribution of rainfall, date & growth stage



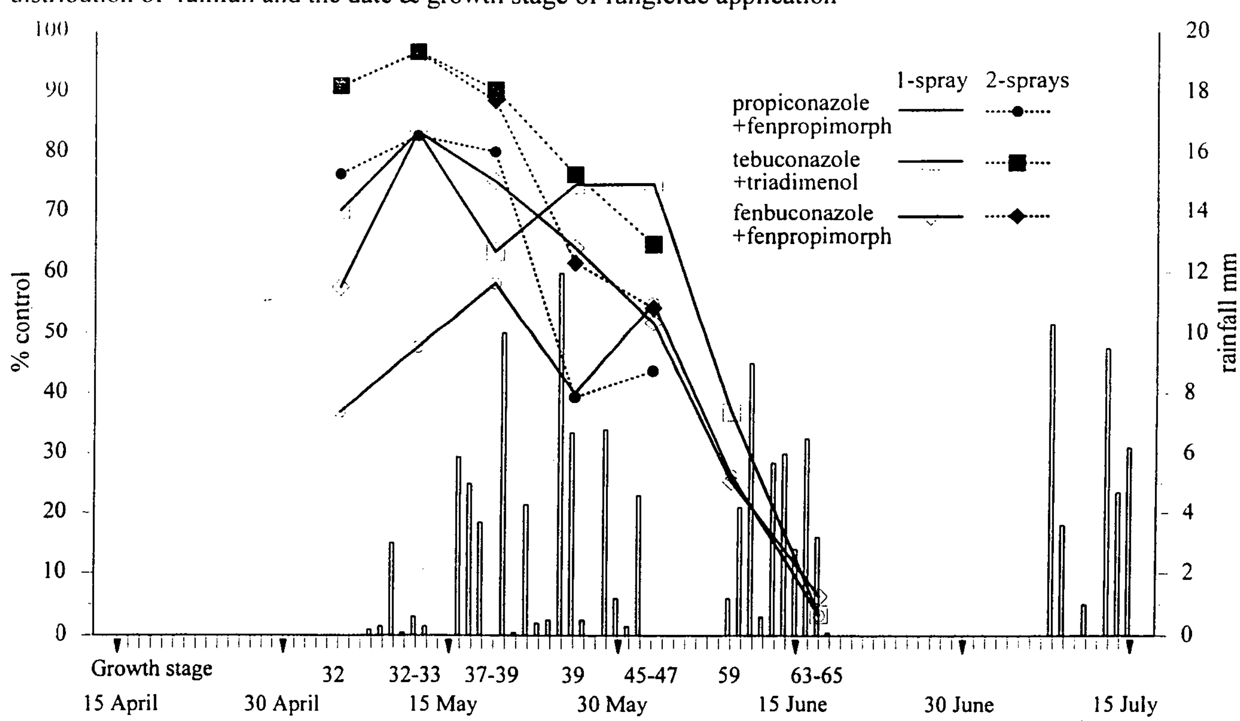
ADAS Rosemaund 1993: *Septoria tritici* - leaf 2

% reduction (= control of disease) of accumulated disease at GS77 - 13 July in relation to the temporal distribution of rainfall and the date & growth stage of fungicide application



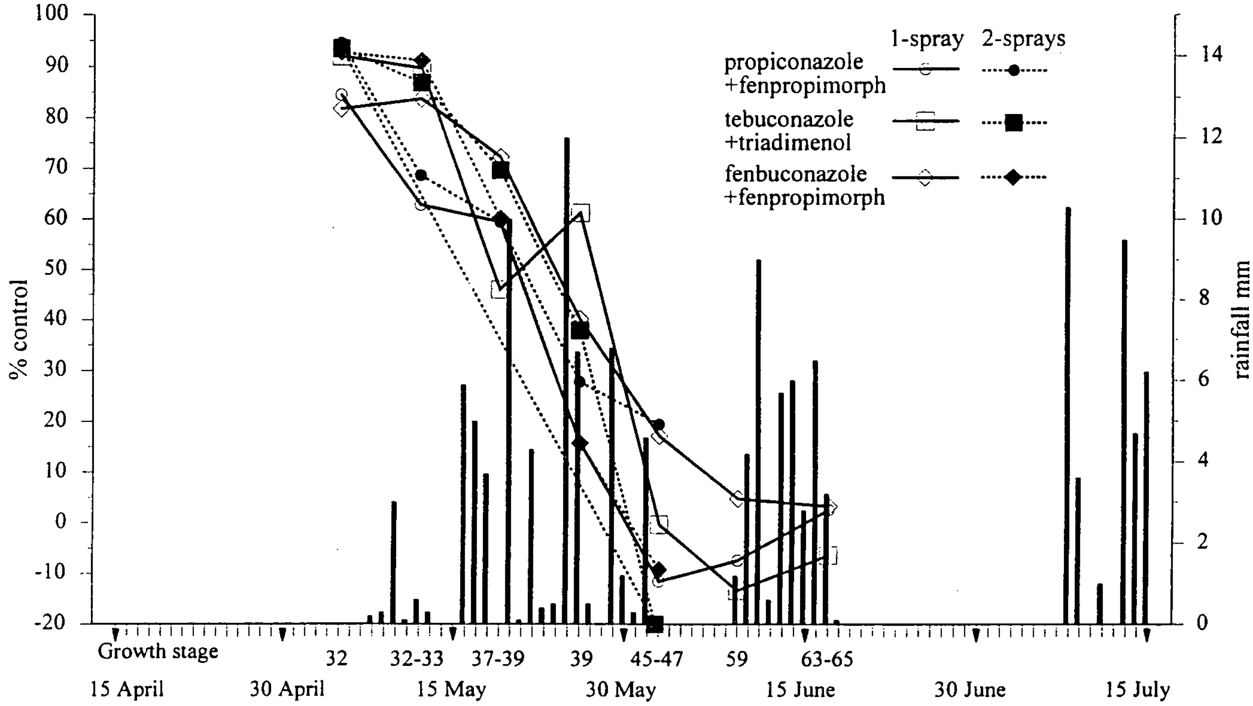
ADAS Rosemaund 1993: *Septoria tritici* - leaf 3

% reduction (= control of disease) of accumulated disease at GS71 - 7 July in relation to the temporal distribution of rainfall and the date & growth stage of fungicide application



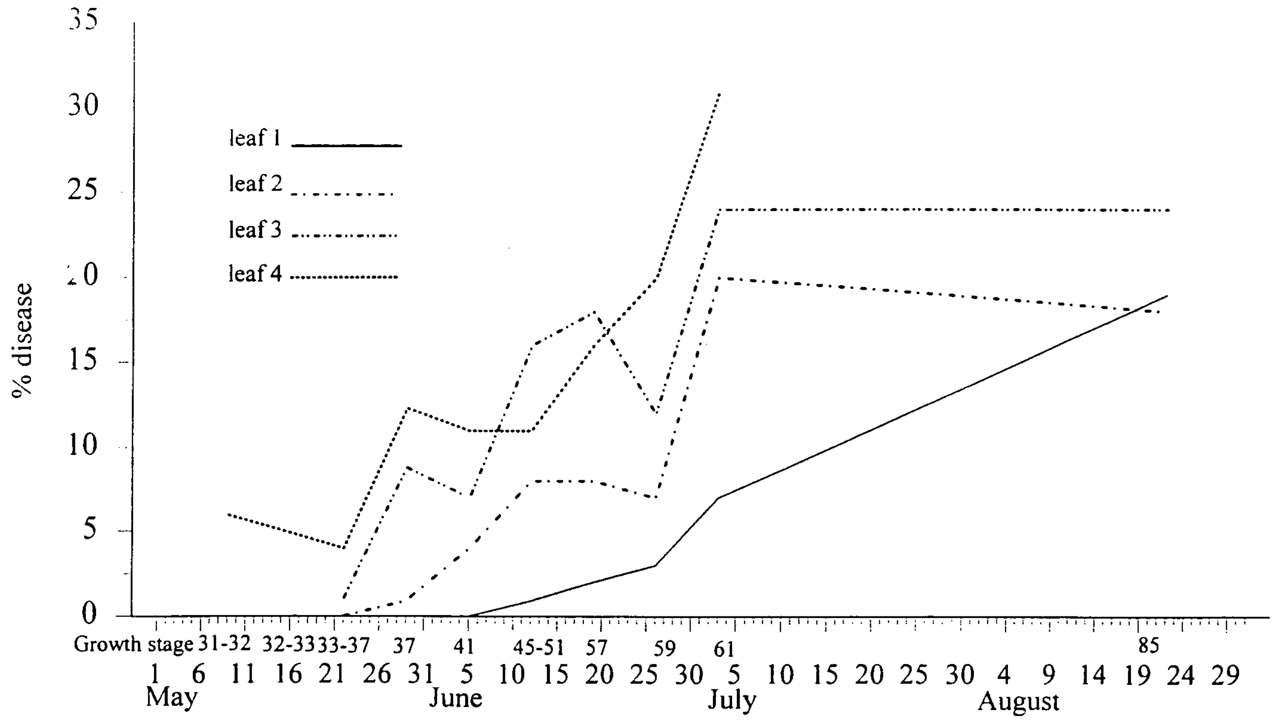
ADAS Rosemaund 1993: *Septoria tritici* - leaf 4

% reduction (= control of disease) of accumulated disease at GS63-65 - 17 June in relation to the temporal distribution of rainfall and the date & growth stage of fungicide application



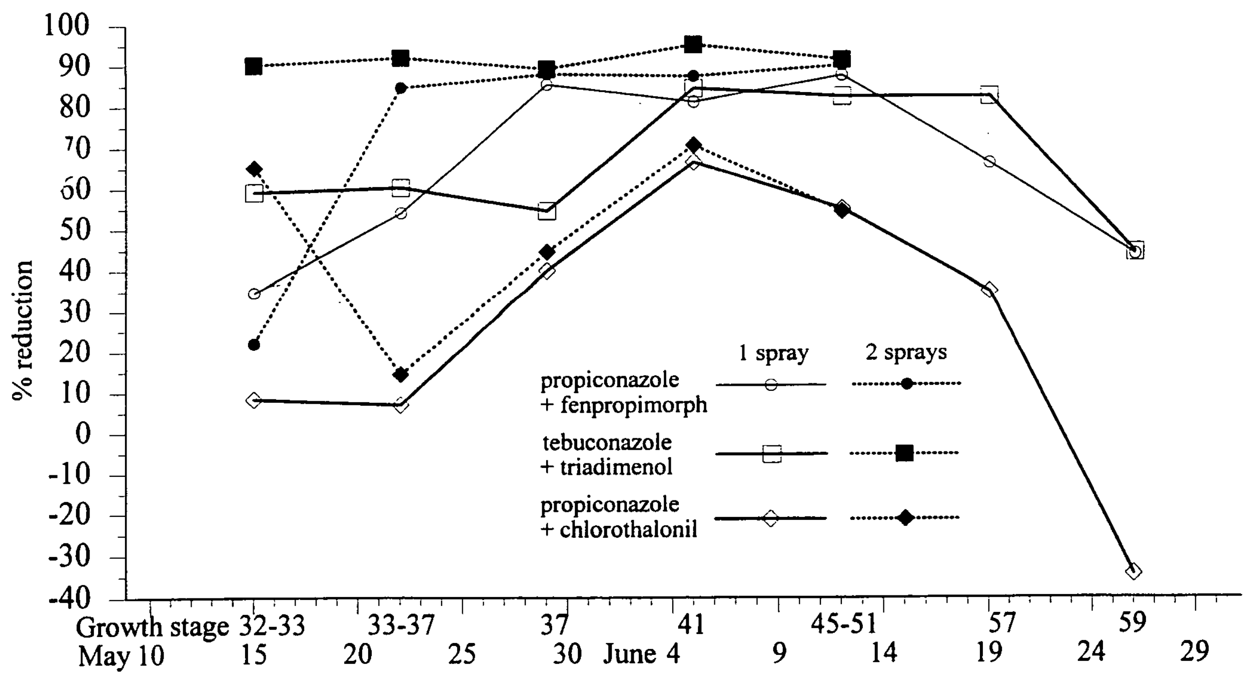
SAC Edinburgh 1991: Mildew

Disease progress on the final four leaves in relation to date and growth stage



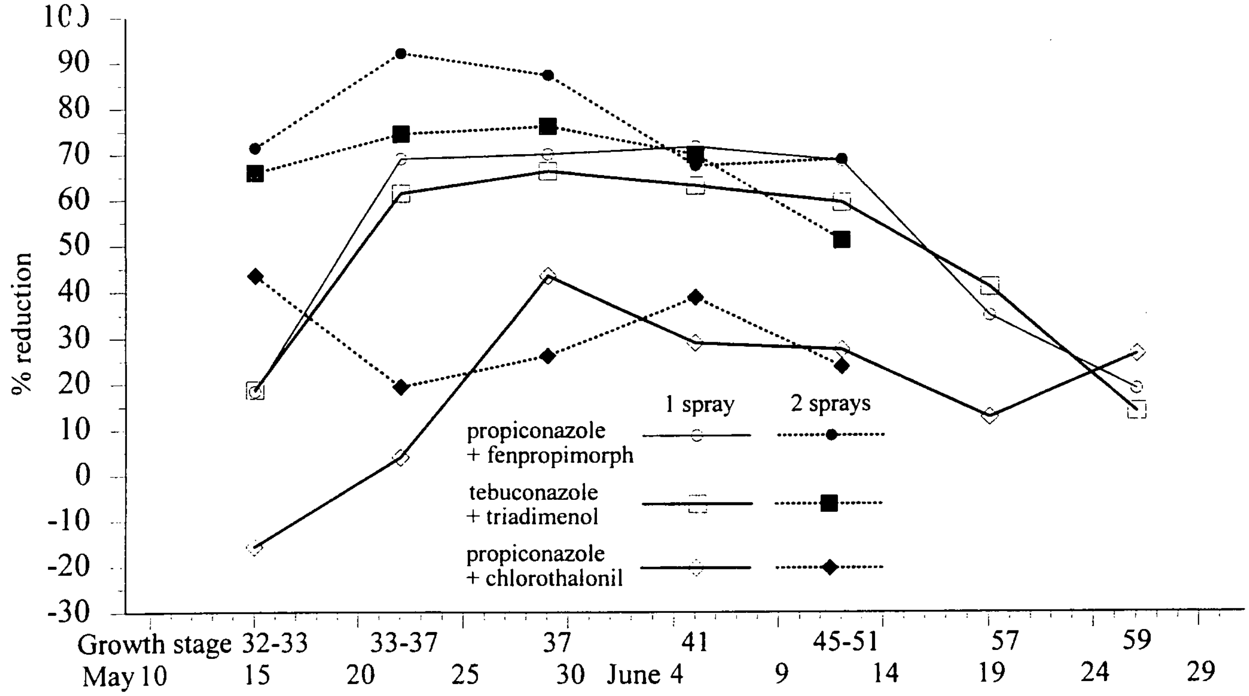
SAC Edinburgh 1991: Mildew - leaf 1

% reduction (= control of disease) of accumulated disease at GS85 - 22 August in relation to the date and growth stage of fungicide application



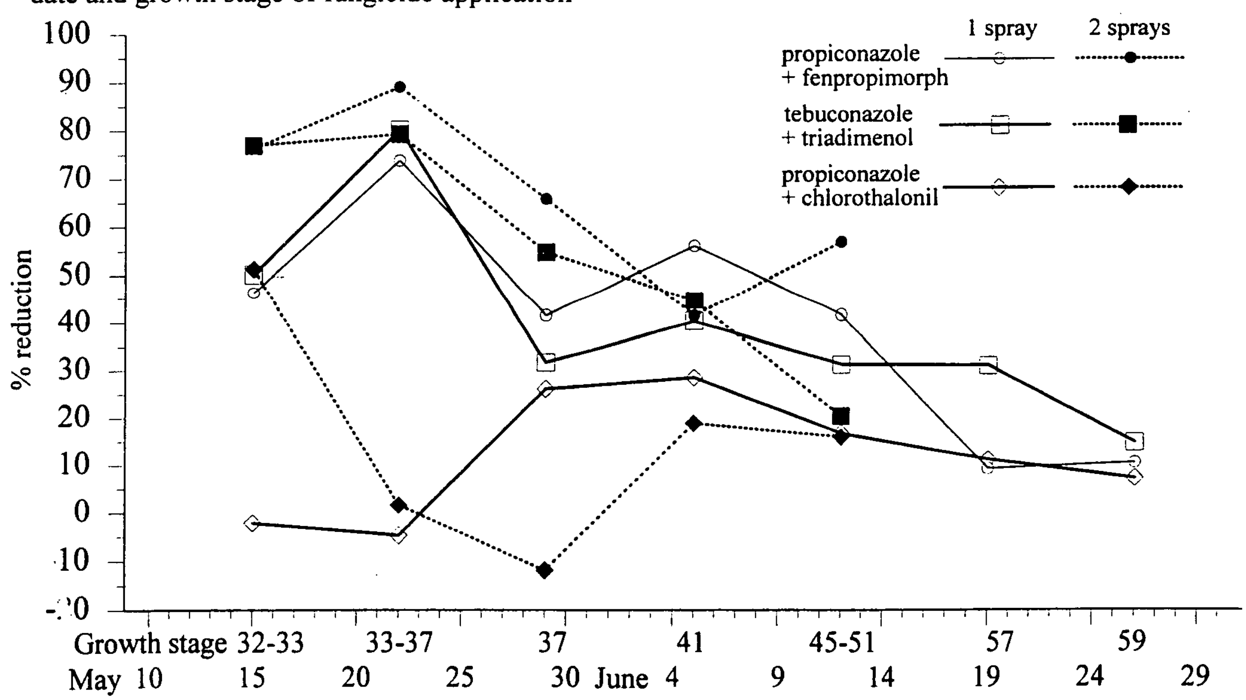
SAC Edinburgh 1991: Mildew - leaf 2

% reduction (= control of disease) of accumulated disease at GS85 - 22 August in relation to the date and growth stage of fungicide application



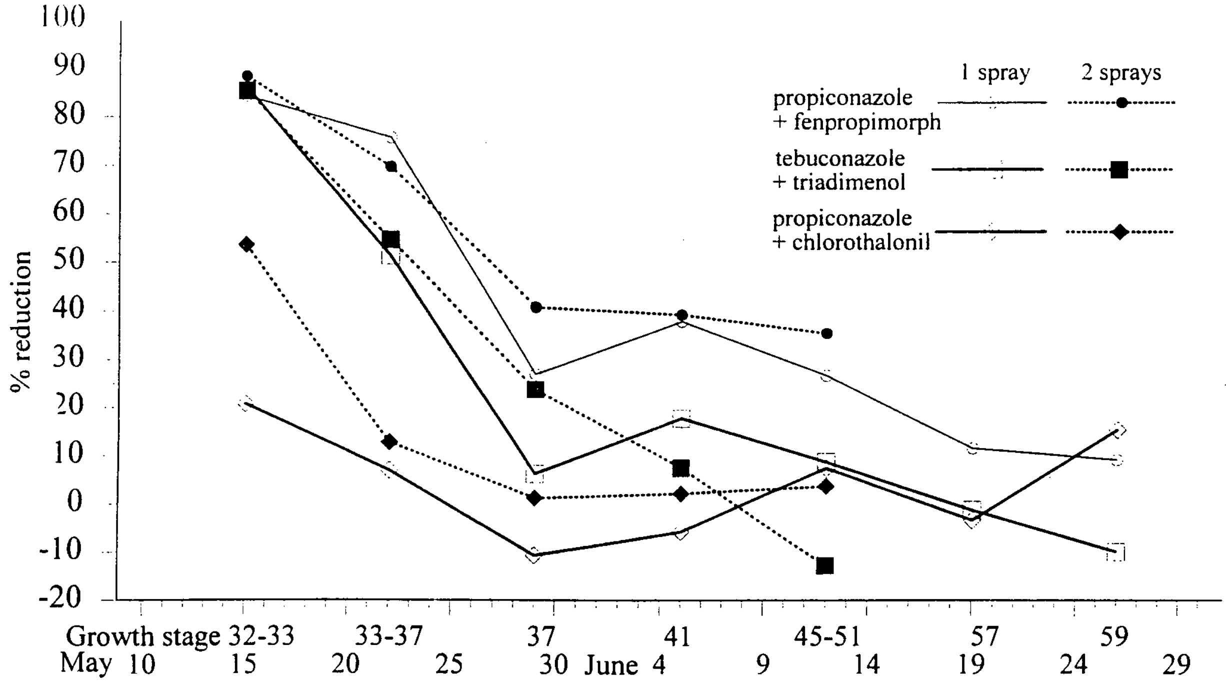
SAC Edinburgh 1991: Mildew - leaf 3

% reduction (= control of disease) of accumulated disease at GS85 - 22 August in relation to the date and growth stage of fungicide application



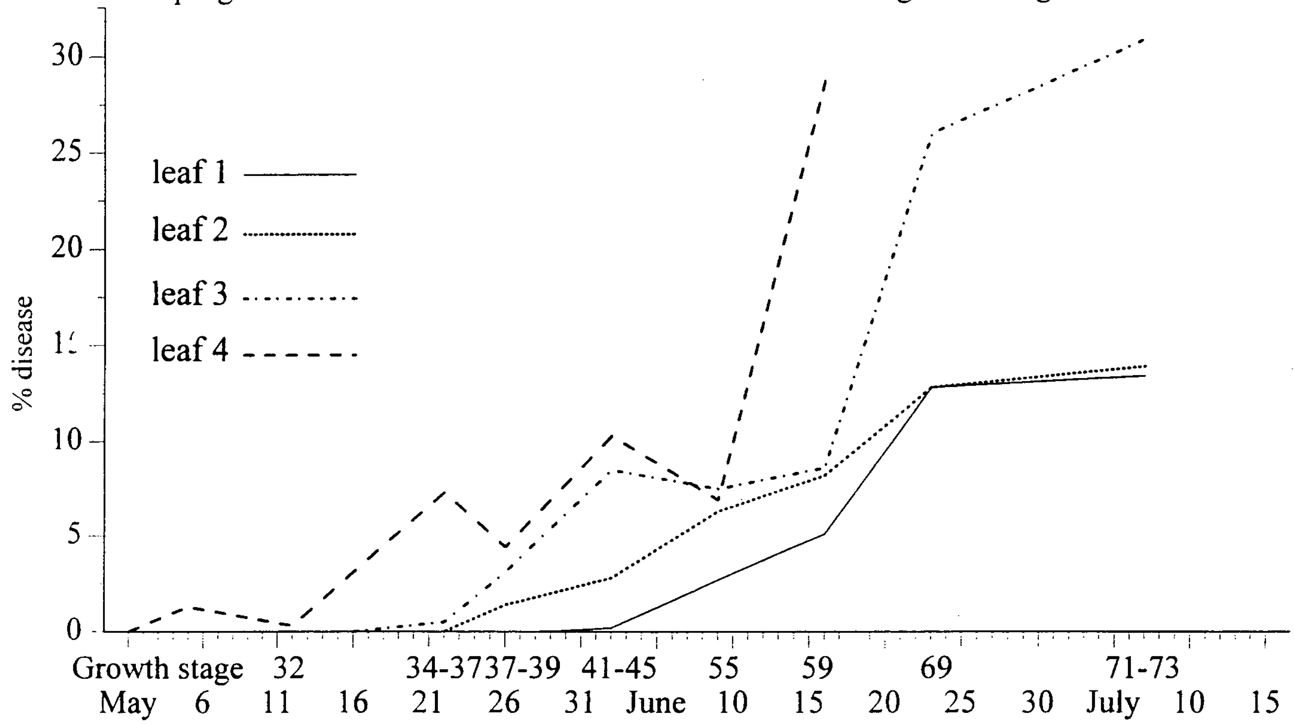
SAC Edinburgh 1991: Mildew - leaf 4

% reduction (= control of disease) of accumulated disease at GS85 - 22 August in relation to the date and growth stage of fungicide application



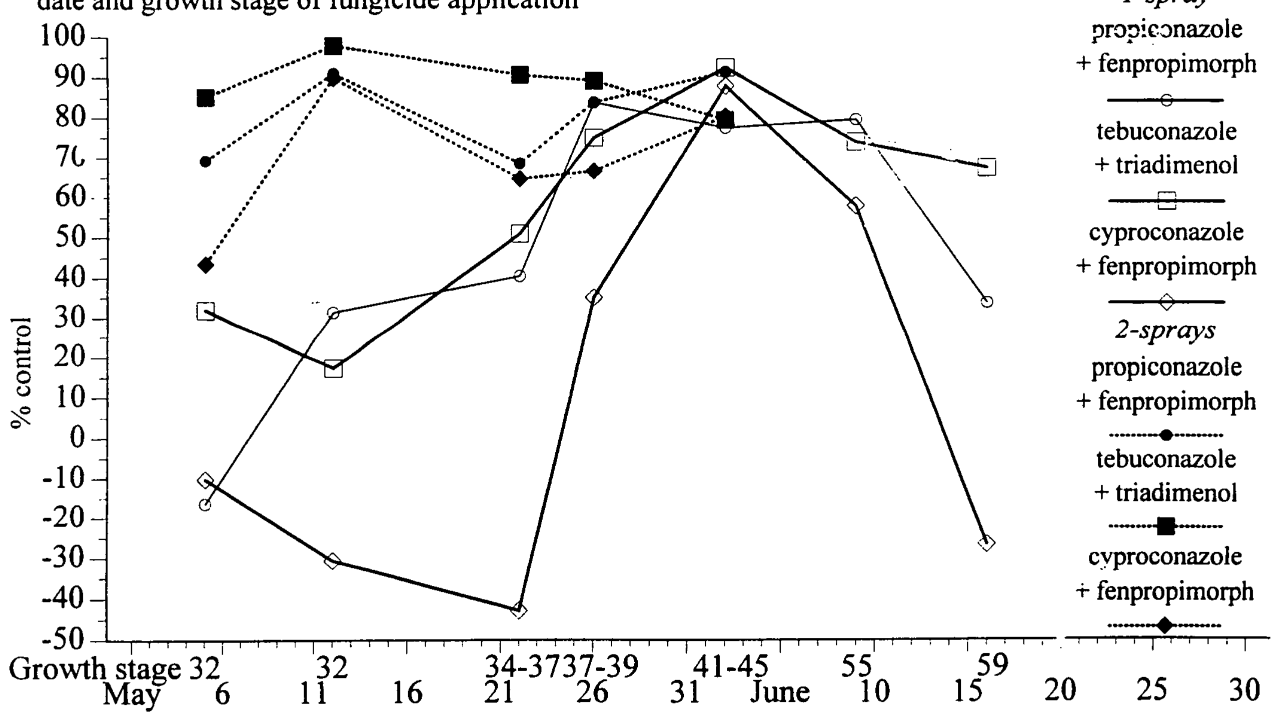
SAC Edinburgh 1992: Mildew

Disease progress on the final four leaves in relation to date and growth stage



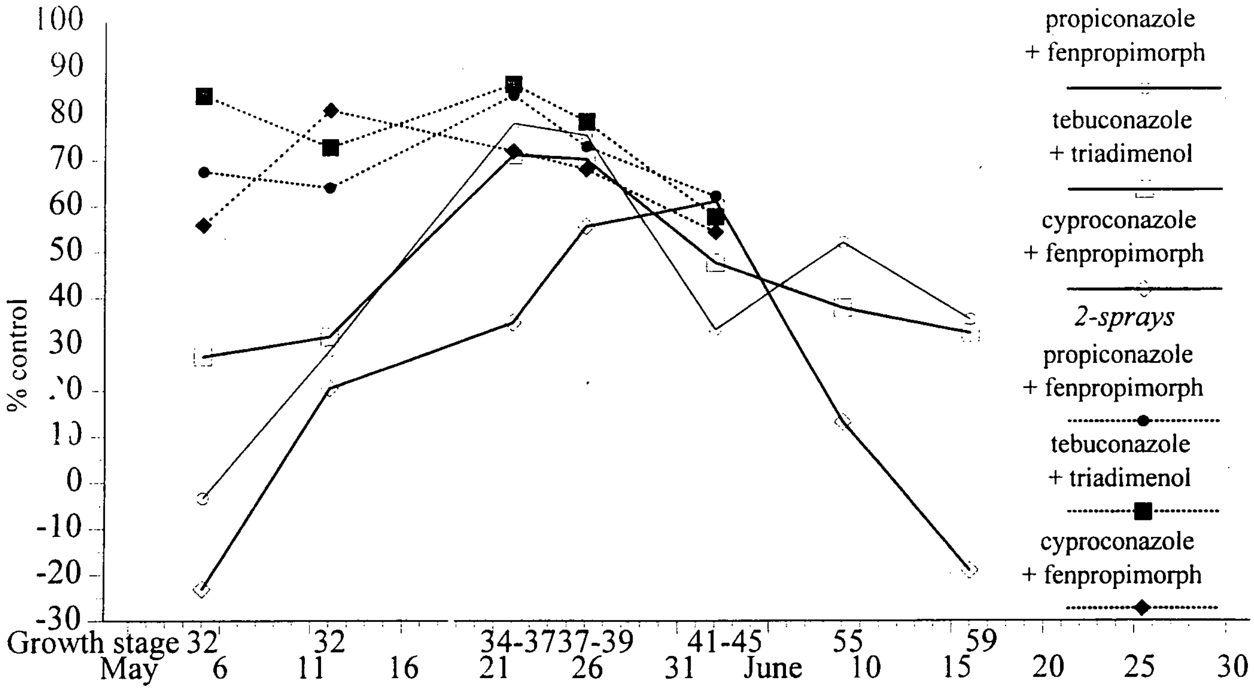
SAC Edinburgh 1992: Mildew - leaf 1

% reduction (= control of disease) of accumulated disease at GS71-73 - 7 July in relation to the date and growth stage of fungicide application



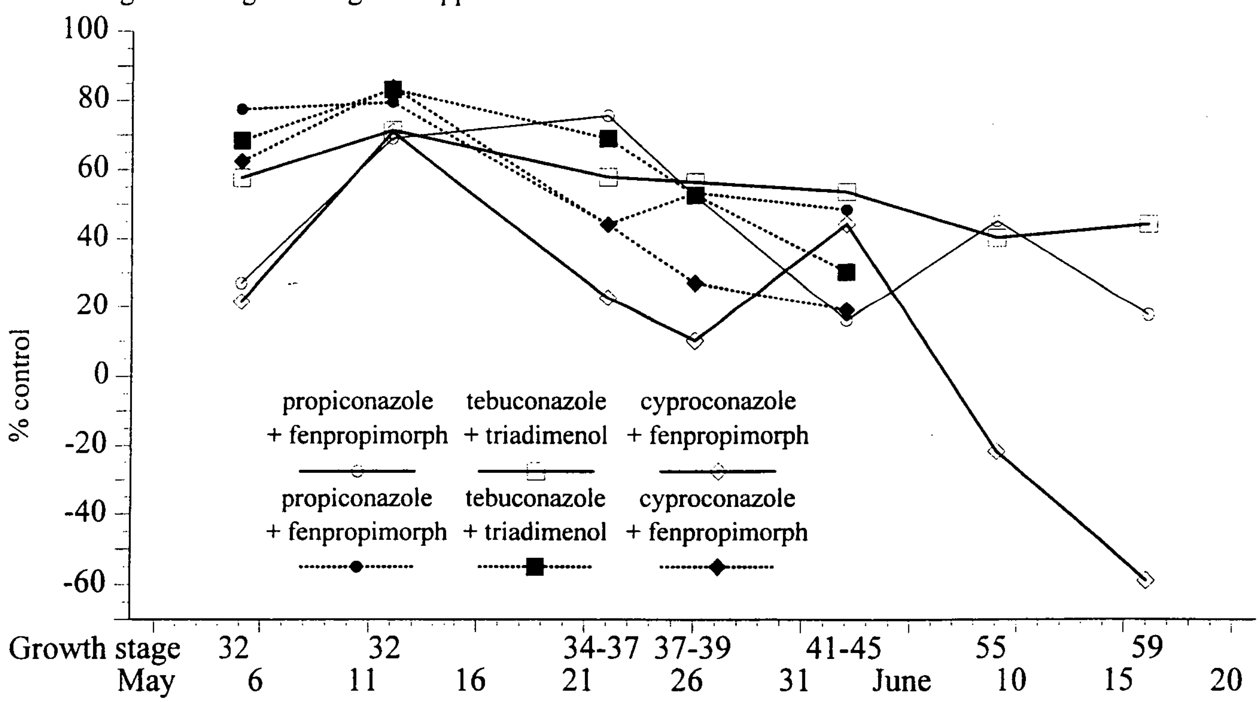
SAC Edinburgh 1992: Mildew - leaf 2

% reduction (= control of disease) of accumulated disease at GS71-73 - 7 July in relation to the date and growth stage of fungicide application



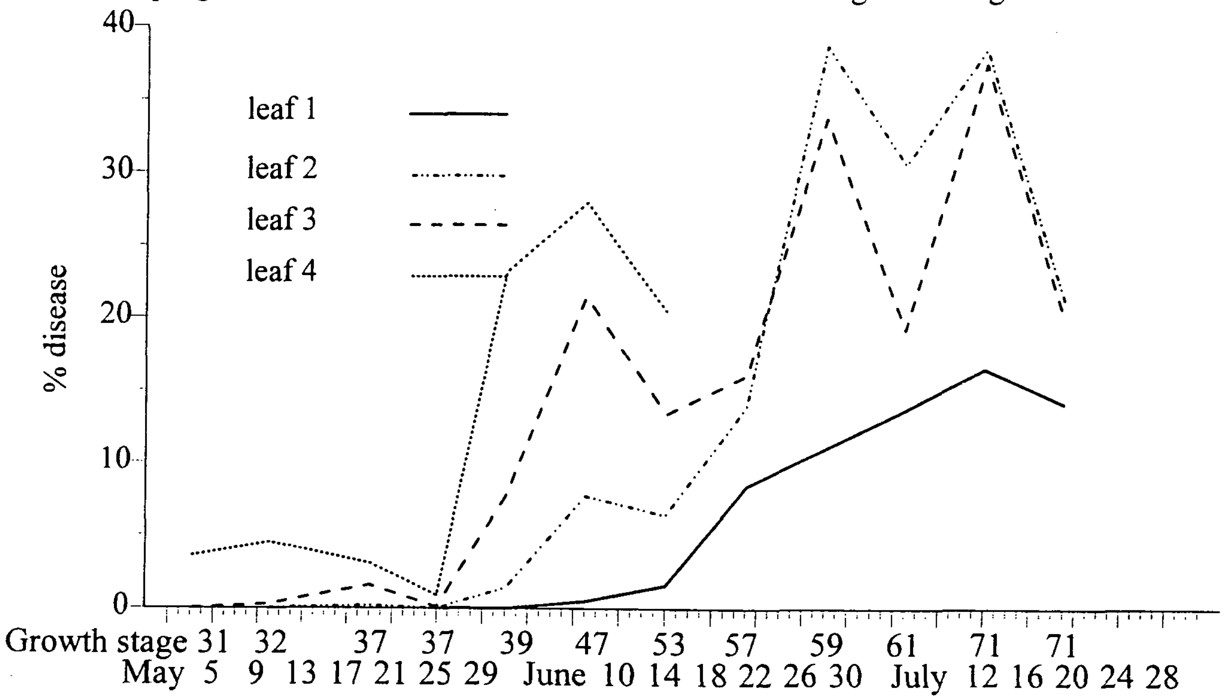
SAC Edinburgh 1992: Mildew - leaf 3

% reduction (= control of disease) of accumulated disease at GS71-73 - 7 July in relation to the date and growth stage of fungicide application



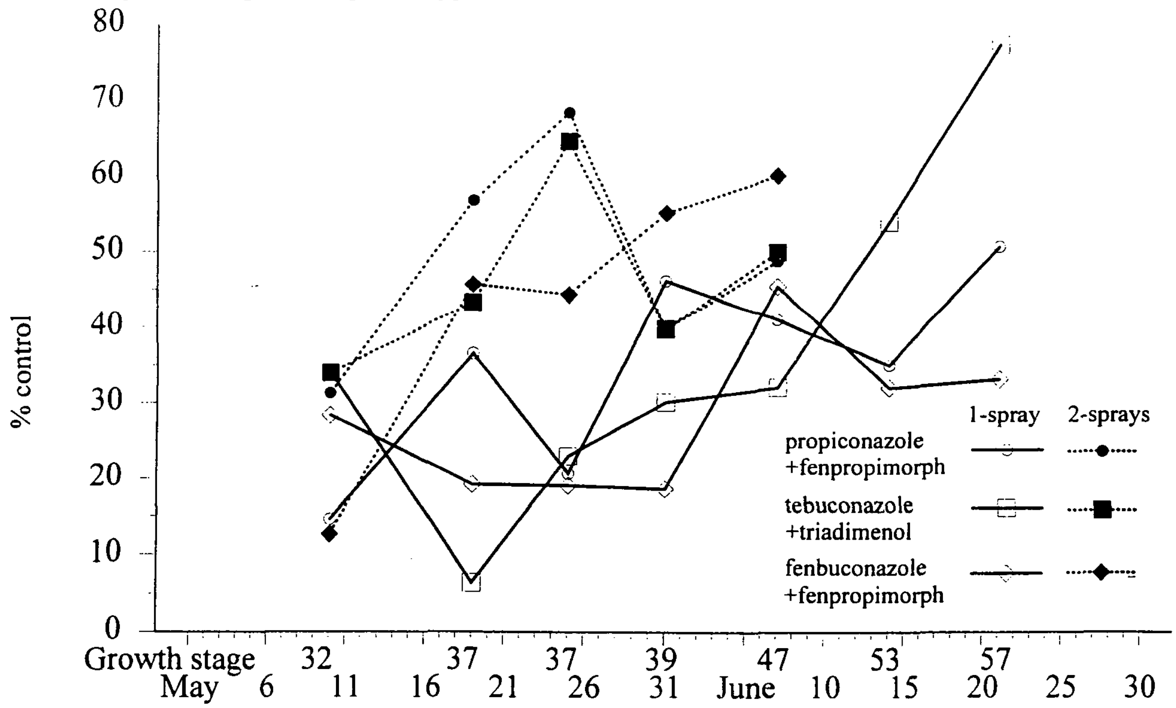
SAC Edinburgh1993: Mildew

Disease progress on the final four leaves in relation to date & growth stage



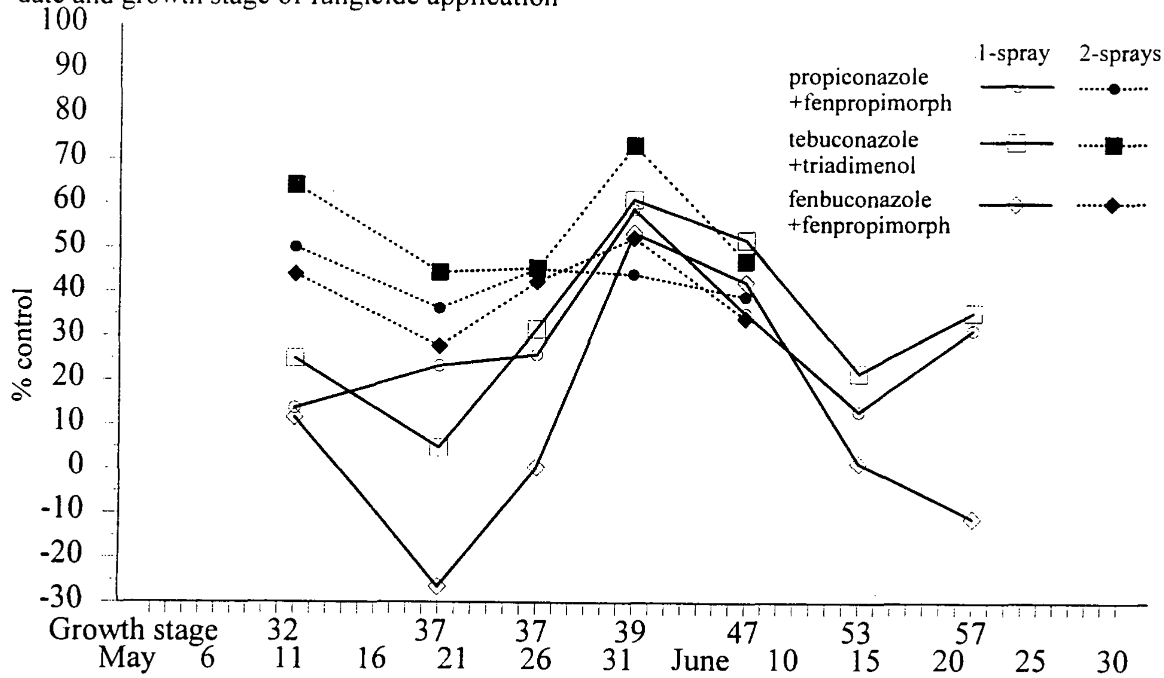
SAC Edinburgh 1993: Mildew - leaf 1

% reduction (= control of disease) of accumulated disease at GS71 - 19 July in relation to the date and growth stage of fungicide application



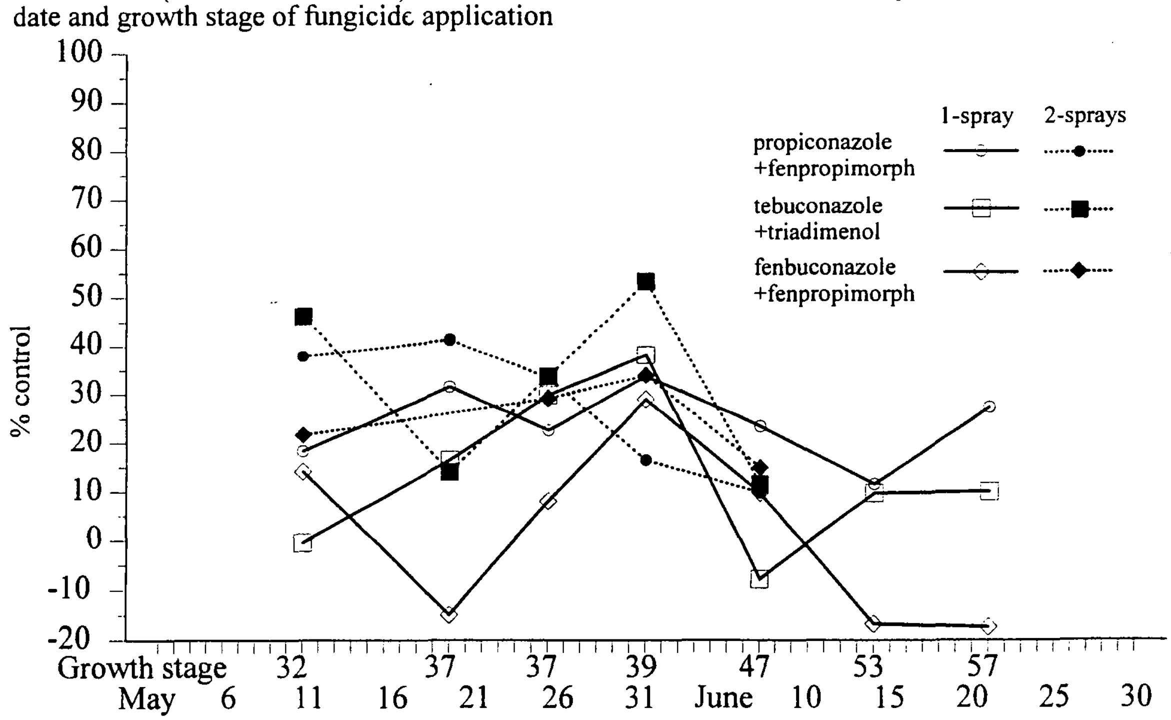
SAC Edinburgh 1993: Mildew - leaf 2

% reduction (= control of disease) of accumulated disease at GS71 - 19 July in relation to the date and growth stage of fungicide application



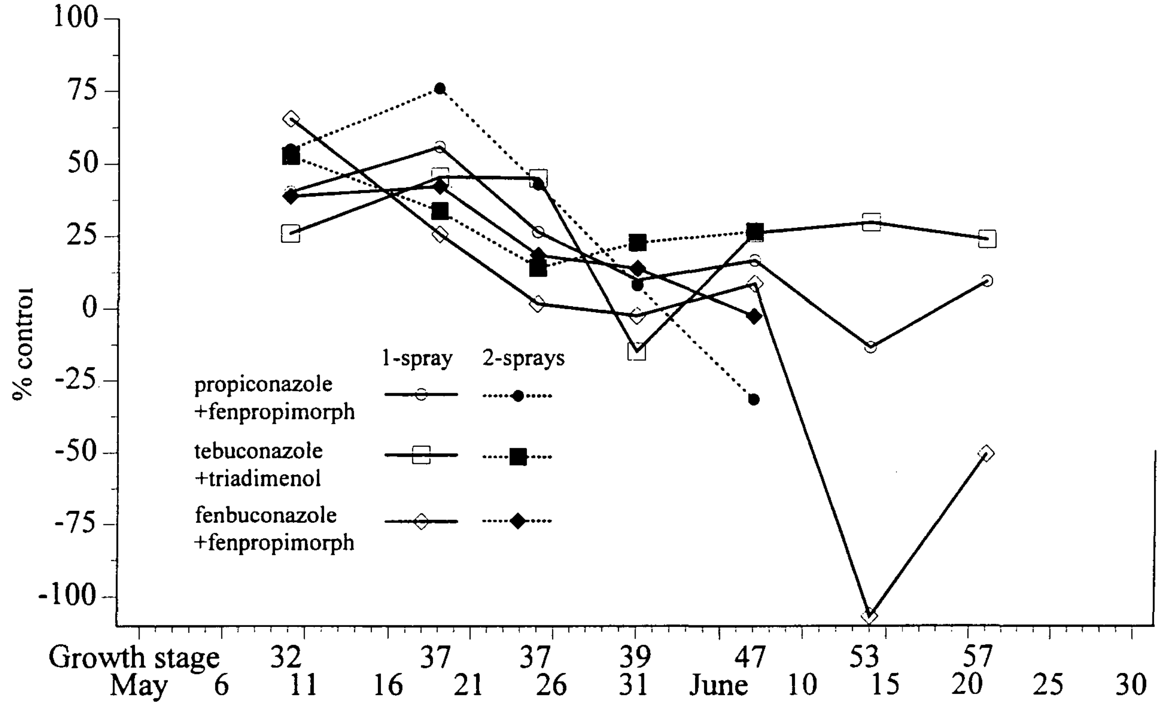
SAC Edinburgh 1993: Mildew - leaf 3

% reduction (= control of disease) of accumulated disease at GS71 - 19 July in relation to the date and growth stage of fungicide application



SAC Edinburgh 1993: Mildew - leaf 4

% reduction (= control of disease) of accumulated disease at GS71 - 19 July in relation to the date and growth stage of fungicide application



Annex II

Cultivar resistance and disease control

Annex II

Table A	Site location and crop details
Table B	Fungicides used in Managed Disease Control treatments
Table C	Fungicide regimens used for evaluation of Managed Disease Control
Table D	Individual site yields, 1991
Table E	Individual site yields, 1992
Table F	Individual site yields, 1993

Individual site and crop details for wheat cultivar fungicide interactions (Experiment II)

	Site					
	Boxworth	Bridgets	Cirencester	Treaton	Stowmarket	Rosemaund
1991						
Soil texture	CL	ZyL	ZC	-	CL	ZyL
Soil series	Hanslope	Andover	Sherborne	Darvel	Beccles	Bromyard
PH	7.3	7.9	8.0	6.3	7.1	7.0
Previous crop						
1990	Rape	Grass	W.barley	S.barley	Rape	Beans
1989	Wheat	Grass	Wheat	-	Wheat	Wheat
1988	Wheat	W.barley	Wheat	-	-	Wheat
Total N (kg/ha)	120	200	200	200	220	136
Sowing date	15:10:90	26:09:90	04:10:90	22:10:90	07:10:90	8:10:90
Harvest date	14:08:91	29:08:91	17:08:91	04:09:91	28:08:91	19:08:91
1992						
Soil texture	C	ZyL	ZC	SCL	SCL	ZyCL
Soil series	Hanslope	Andover	Sherborne	Balrownie	Beccles	Bromyard
pH	7.9	7.5	7.5	6.4	7.2	6.8
Previous crop						
1991	Beans	Grass	Rape	Rape	W.beans	W.beans
1990	Wheat	Grass	W.barley	W.barley	Wheat	Maize
1989	Wheat	W.barley	Wheat	Wheat	Wheat	Hops
Total N (kg/h)	180	120	200	180	220	83
Sowing date	31:10:91	14:10:91	11:10:91	09:10:91	09:10:91	15:10:91
Harvest date	06:08:92	07:08:92	06:08:92	-	28:08:91	-

	Boxworth	Bridgets	Cirencester	Forfar	Stowmarket	Rosemaund
1993						
Soil texture	C	ZyCL		SL	SCL	ZyCL
Soil series	Hanslope	Andover		Balrownie	Beccles	Bromyard
pH	7.7	8.0		6.3	7.2	5.9
Previous crop						
1990	W.beans	Wheat		Rape	Peas	Grass
1989	Wheat	Linseed		W.barley	Wheat	Potatoes
1988	Wheat	Wheat		S.barley	Wheat	-
Total N (kg/h)	145	200		175	220	122
Sowing date	09:10:92	01:10:92		12:10:92	06:10:92	31:10:92
Harvest date	17:08:93	08:08:93		-	19:08:93	27:08:93

Fungicides used in Managed Disease Control treatments

Product	active ingredient (g ai/l)
Up to GS33:	
Sportak 45	prochloraz (450)
Bayfidan or Spinnaker	triadimenol (125)
Corbel, Mistral or Patrol	fenpropimorph or fenpropidin (750)
GS33-55:	
Bravo 500	chlorothalonil (500)
Dorin	triadimenol + tridemorph (125 + 375)
Tilt Turbo	propiconazole + tridemorph (125 + 350)
Impact Excel	chlorothalonil + flutriafol (300 + 47)
Corbel, Mistral or Patrol	fenpropimorph or fenpropidin
Tilt or Radar	propiconazole (400)
Sanction	flusilazole (400)
GS55-69:	
Tilt or Radar	propiconazole
Tilt Turbo	propiconazole + tridemorph
Corbel, Mistral or Patrol	fenpropimorph or fenpropidin
Delsene M	carbendazim + maneb (50 + 320); or
equivalent product	
Sanction	flusilazole

Individual site yields for winter wheat cultivar fungicide interactions, 1991 (t/ha 85% dm)

Treatment*	Cirencester	Boxworth	Rosemaund	Bridgets	Morley	SAC	Mean
Riband							
1	7.82	9.03	8.18	6.44	8.71	7.19	7.90
2	7.90	9.53	9.65	7.59	9.48	8.05	8.70
3	8.04	9.68	9.52	8.57	9.80	7.83	8.91
4	9.42	10.15	10.12	9.30	10.50	8.25	9.62
5	9.17	10.05	10.17	9.45	10.16	8.83	9.64
6	8.26	9.91	9.73	8.47	9.83	7.63	8.97
7	8.31	9.60	9.82	8.40	9.63	8.05	8.97
Apollo							
1	6.45	7.55	7.93	7.43	9.33	7.55	7.71
2	6.32	8.32	8.29	8.71	9.55	7.97	8.19
3	6.99	8.51	8.53	9.14	9.65	8.05	8.48
4	7.41	8.63	8.46	9.00	9.76	7.94	8.53
5	7.16	9.02	8.76	9.33	9.83	8.13	8.71
6	7.52	8.77	8.74	8.91	9.78	7.79	8.59
7	6.70	8.67	8.54	9.07	9.43	8.24	8.44
Hereward							
1	6.90	8.35	7.53	7.13	8.67	7.07	7.61
2	7.57	8.57	8.07	7.80	9.17	7.81	8.17
3	7.57	8.63	8.14	7.95	9.25	7.52	8.18
4	7.58	8.93	8.03	8.12	9.43	7.39	8.25
5	7.87	8.91	8.07	8.32	9.50	7.78	8.41
6	7.42	9.01	8.25	7.94	9.31	7.19	8.19
7	6.96	8.53	7.84	7.65	9.13	7.78	7.98
Beaver							
1	6.15	9.45	9.01	6.87	9.75	7.72	8.16
2	7.49	9.64	9.60	7.73	10.27	8.79	8.92
3	7.00	10.12	9.44	7.79	10.33	8.39	8.85
4	9.10	9.77	9.48	8.45	10.62	8.69	9.35
5	8.64	9.86	9.70	8.62	10.79	8.42	9.34
6	8.49	10.35	9.52	8.14	10.54	8.20	9.21
7	7.81	9.59	9.69	8.08	10.16	8.70	8.99
SED	0.195	0.379	0.214	0.147	0.124	0.536	

*see Table 9, page 29 for treatment details

Individual site yields for winter wheat cultivar fungicide interactions, 1992 (t/ha 85% dm)

Treatment*	Cirencester	Boxworth	Rosemaund	Bridgets	Morley	SAC	Mean
Riband							
1	7.96	7.06	4.55	7.63	7.47	8.19	7.14
2	8.79	7.65	5.59	8.49	8.92	9.16	8.10
3	9.19	8.07	6.69	9.16	8.85	9.49	8.57
4	9.55	7.85	7.51	9.38	9.64	9.80	8.96
5	9.79	8.27	7.58	9.68	9.77	9.71	9.13
6	8.89	7.94	6.89	9.23	9.17	9.48	8.60
7	9.21	7.90	6.88	9.08	9.44	9.73	8.71
Apollo							
1	8.39	6.97	7.15	7.26	9.20	8.36	7.89
2	8.92	7.90	7.32	8.09	9.85	8.65	8.46
3	8.74	7.71	7.83	8.32	10.10	9.14	8.64
4	9.27	8.06	8.40	8.35	10.41	9.14	8.94
5	9.20	8.46	8.08	8.78	10.60	9.27	9.07
6	8.99	8.13	8.04	8.60	10.40	9.23	8.90
7	10.01	7.84	8.34	8.22	10.43	8.98	8.97
Hereward							
1	8.66	7.87	5.87	8.02	9.26	8.06	7.96
2	8.94	8.29	7.32	9.06	9.87	8.29	8.63
3	9.59	8.30	7.70	8.89	10.00	8.43	8.82
4	10.03	8.55	8.11	9.39	10.52	8.40	9.17
5	10.00	8.62	8.18	9.41	10.55	8.51	9.21
6	8.84	8.04	7.61	9.25	10.16	8.50	8.73
7	9.58	7.93	7.27	8.57	10.07	8.42	8.64
Beaver							
1	8.71	6.88	5.64	8.53	9.44	8.68	7.98
2	8.98	8.40	6.22	9.11	9.79	9.01	8.59
3	9.44	8.20	6.99	9.31	10.34	9.19	8.91
4	9.98	8.91	7.32	9.80	10.84	9.23	9.35
5	9.90	8.68	7.09	9.75	11.07	9.23	9.29
6	9.32	8.74	7.68	9.33	10.67	9.23	9.16
7	9.17	7.64	6.72	8.64	10.22	9.14	8.59
SED	0.390	0.293	0.377	0.254	0.180	0.236	

*see Table 9, page 29 for treatment details

Individual site yields for winter wheat cultivar fungicide interactions (Experiment II), 1993 (t/ha, 85% dm)

Treatment*	Cirencester	Boxworth	Rosemaund	Bridgets	Morley	SAC	Mean
Riband							
1	4.46	4.90	5.99	6.50	7.97	7.41	6.21
2	5.61	7.89	7.17	7.28	9.38	8.72	7.68
3	7.60	8.06	7.22	7.93	10.15	9.62	8.43
4	8.17	8.55	7.76	8.40	10.29	9.87	8.84
5	7.46	8.87	7.81	8.56	10.53	10.23	8.91
6	7.24	8.22	7.26	8.02	9.99	9.55	8.38
7	7.83	8.89	8.04	8.27	10.53	9.48	8.84
Apollo							
1	4.62	4.80	6.51	5.52	7.73	7.19	6.06
2	6.00	6.40	7.19	6.02	8.58	7.92	7.02
3	6.52	6.61	7.07	6.03	8.56	8.12	7.15
4	6.58	6.49	7.53	6.94	8.70	8.52	7.46
5	6.50	6.72	7.76	6.93	9.09	8.47	7.58
6	6.39	6.87	7.59	6.75	8.68	8.29	7.43
7	6.58	6.19	7.10	6.29	9.03	7.67	7.14
Hereward							
1	6.60	7.43	6.58	6.91	9.67	6.61	7.30
2	7.39	7.95	7.17	7.40	10.03	6.82	7.79
3	7.60	8.04	7.59	7.45	10.35	7.40	8.07
4	7.67	8.42	7.66	7.97	10.28	7.25	8.21
5	8.10	8.31	7.94	7.96	10.52	7.50	8.39
6	7.97	6.32	7.50	7.70	10.41	7.17	7.85
7	7.57	7.92	7.56	7.45	10.15	6.75	7.90
Beaver							
1	6.20	5.80	6.72	7.30	9.29	7.30	7.10
2	7.20	8.05	7.85	7.88	10.46	7.80	8.21
3	7.70	8.42	8.22	8.26	10.62	8.26	8.58
4	8.01	8.81	9.07	8.63	10.94	8.23	8.95
5	8.50	8.86	8.76	8.88	10.83	8.66	9.08
6	8.19	8.74	8.57	8.72	10.53	8.43	8.86
7	8.03	8.82	7.87	8.36	10.87	8.25	8.70
SED							

*see Table 9, page 29 for treatment details

Annex III

Fungicide comparison

Annex III

Table A	Site location, collaborating partner and cultivar
Table B	Site details 1991
Table C	Site details 1992
Table D	Site details 1993
Table E	Fungicide active ingredients used in treatments
Table F	Mean mildew infection on Apollo (% leaf 2 at GS 75)
Table G	Green leaf area on Apollo (% leaf 2 at GS 75)
Table H	Grain yield, Apollo (t/ha at 85% dm)
Table I	Specific weight,Apollo (kg/hl at 85% dm)
Table J	1000 grain weight,Apollo (g at 85% dm)
Table K	Mean infection with *Septoria tritici* on Riband (% leaf 2 at GS 75)
Table L	Green leaf area on Riband (% leaf 2 at GS 75)
Table M	Grain yield, Riband (t/ha at 85% dm)
Table N	Specific weight, Riband (kg/hl at 85% dm)
Table O	1000 grain weight, Riband (g at 85% dm)

Table A. *Site location, collaborating partner and cultivar used in winter wheat fungicide comparison experiment*

Site	Cultivar	Organisation
Codford	Apollo	Chalkland Cereal Centre, Wiltshire
Mepal	Apollo	ADAS Arthur Rickwood, Cambridge
Wetherby	Apollo*	Yorkshire Arable Centre, ADAS
Louth, Lincolnshire	Apollo	Arable Research Centres
Newcastle	Apollo	North of England Arable Centre, Cockle Park, Northumberland
Terrington	Riband	ADAS Terrington, Norfolk
Romney Marsh	Riband	ADAS Crop Centre, Kent
Charminster	Riband	ADAS Crop Centre, Dorset
Cirencester	Riband	Arable Research Centres
Udney	Riband	SAC, Aberdeen
Morley	Riband	Morley Research Centre
Dunmow	Riband	Arable Research Centres, Essex

*Mercia in 1992 and 1993

Table B. *Site details for winter wheat fungicide comparisons, 1991*

Sowing date	Previous crop	Soil type	Soil series	Treatment dates GS32	GS39	GS59-69	Total nitrogen (kg/ha)
Codford							
4 October	W Oats	ZyCL	Andover	23:04	31:05	26:06	200
Mepal							
17 October	Peas	OSL	Adventurer's	08:05	30:05	28:06	60
Wetherby							
24 September	OSR	SCL	Escrick 2	22:04	29:05	20:06	185
Louth							
2 October	Wheat	Zyl	Carstens	10:05	29:05	28:06	150
Cockle Park, Newcastle							
5 October	OSR	CL	Hallsworth	24:04	08:05	28:06	154
Terrington							
28 September	Peas	ZyCL	Agney	23:04	29:05	20:06	100
Romney Marsh							
1 October	OSR	CL	Romney	24:04	29:05	28:06	150
Charminster							
26 September	OSR	ZyCL	Andover	02:05	30:05	26:06	191
Cirencester							
4 October	W Barley	ZyCL	Sherborne	10:05	08:06	01:07	200
Udny							
18 October	OSR	SL	Tarves	24:05	06:06	04:07	175
Morley							
8 October	W Beans	SL	Ashley	08:05	31:05	28:06	205
Dunmow							
8 October	OSR	CL	Hanslope	23:04	22:05	04:06	200

Table C. *Site details for winter wheat fungicide comparisons, 1992*

Sowing date	Previous crop	Soil type	Soil series	Treatment dates GS32	GS39	GS59-69	Total nitrogen (kg/ha)
Codford							
31 October	W Oats	ZyCL	Andover	01:05	3:06	19:06	226
Mepal							
21 October	Potatoes	OSL	Prickwillow	21:04	21:05	12:06	60
Wetherby							
23 October	Potatoes	SZyL	Foggathorpe	28:04	01:06	15:06	200
Louth							
8 October	Wheat	Zyl	Carstens	07:05	23:05	12:06	210
Cockle Park, Newcastle							
2 October	OSR	CL	Hallsworth	06:05	28:05	16:06	150
Terrington							
9 October	Peas	ZyCL	Agney	29:04	01:06	15:06	135
Romney Marsh							
3 October	OSR	ZyCL	Newchurch	29:04	28:05	10:06	120
Charminster							
30 September	OSR	ZyCL	Andover	01:05	21:05	09:06	181
Cirencester							
11 October	OSR	ZyCL	Sherborne	14:05	02:06	22:06	200
Udny							
15 October	OSR	SL	Pitmeddon	19:05	12:06	6:07	178
Morley							
4 October	Linseed	SL	Ashley	06:05	22:06	22:06	220
Dunmow							
2 October	Peas	CL	Hanslope	29:04	20:05	18:06	185

Table D. *Site details for winter wheat fungicide comparisons, 1993*

Sowing date	Previous crop	Soil type	Soil series	Treatment dates GS32	GS39	GS59-69	Total nitrogen (kg/ha)
Codford							
7 October	Wheat	ZyL	Upton 1	22:04	28:05	25:06	227
Mepal							
14 October	Potatoes	OSL	Prickwillow	06:05	21:05	07:06	60
Wetherby							
5 October	Sugar beet	SL	Escrick	04:05	03:06	22:06	204
Louth							
9 October	Peas	Zyl	Carstens	04:05	28:05	16:06	169
Cockle Park, Newcastle							
17 September	OSR	SCL	Dunkeswick	27:04	01:06	24:06	160
Terrington							
5-6 November	Beans	ZyCL	Agney	30:04	29:05	21:06	140
Romney Marsh							
8 October	OSR	ZyCL	Newchurch	28:04	27:05	09:06	150
Charminster							
3 October	OSR	ZyCL	Andover	27:04	25:05	25:06	177
Cirencester							
1 October	W.barley	ZyCL	Sherborne	29:04	27:05	22:06	200
Udny							
5 November	OSR	SCL	Tarves	26:05	16:06	13:07	150
Morley							
October	Sugar beet	SL	Ashley	30:04	22:05	15:06	220
Dunmow							
1 October	Peas	CL	Hanslope	20:04	22:05	15:06	210

Table E. *Fungicide active ingredients used in the core treatments for fungicide comparisons (Experiment III)*

Fungicides product	Active ingredient (g ai/l)
Bravo 500	chlorothalonil
Corbel or Mistral	fenpropimorph (750)
Dorin	triadimenol + tridemorph (125+375)
Patrol	fenpropidin (750)
Radar or Tilt	propiconazole (125)
Sportak 45	prochloraz (450)
HGCA 6 (Silvacur)	tebuconazole + tridimenol (250+125)
HGCA 7	tebuconazole (250)
HGCA 8	varied from year to year
HGCA 9* (Alto Elite)	chlorothalonil + cyproconazole (375+40)
HGCA 10 (Alto 100)	cyproconazole (100)
Cyclone	flutriafol + iprodione (94+300)
Indar	fenbuconazole + propiconazole (50+125)

*0.75 l fenpropimorph added in 1993 only for Apollo sites

Table F. *Mean mildew infection on Apollo (% leaf 2 at GS 75)*

Treatment	Codford	Mepal	Site Wetherby**	Louth	Newcastle
1991					
1	41.0	7.3	17.8	6.0	13.2
2	19.9	5.6	5.8	1.8	7.8
3	5.1	2.0	3.3	0.0	3.2
4	13.8	4.5	4.1	0.0	3.3
5	3.9	1.2	2.6	1.3	1.6
6	5.7	2.5	3.6	0.0	2.0
7	7.8	3.0	5.2	0.8	2.9
8	25.8	6.9	14.0	2.0	11.4
9	34.0	7.3	9.9	7.8	13.3
10	15.8	5.1	7.2	0.3	9.7
s.e.d.	2.87	1.06	2.20	1.16	1.36
1992					
1	45.0	7.0	1.5	25.0	22.1
2	17.6	4.8	-	1.8	3.3
3	11.0	4.2	0.2	0.0	1.6
4	18.9	3.8	0.5	0.0	4.0
5	9.1	3.0	0.6	0.0	0.6
6	13.1	3.4	0.6	0.0	0.5
7	18.0	2.4	0.5	0.0	3.3
8	38.3	8.0	0.7	0.0	14.4
9	31.6	8.1	0.	7.5	9.0
10	17.8	4.1	0.9	5.0	2.9
s.e.d.	3.80	1.36	0.9	1.52	ϕ
1993					
1	19.2	0.0	3.1	46.8☼	8.3
2	13.9	2.9	1.1	16.0	5.4
3	11.0	0.0	1.0	2.1	3.9
4	14.1	0.1	1.9	12.3	7.7
5	9.9	0.0	0.7	1.4	3.5
6	9.0	0.3	0.9	10.8	4.1
7	11.3	0.2	1.1	31.0	5.7
8*	15.0	0.1	2.1	15.2	9.5
9*	11.6	0.0	0.9	13.2	4.7
10	13.3	0.7	1.4	27.2	5.2
s.e.d.	1.27	ϕ	ϕ	ϕ	0.84

* Fenpropimorph added in 1993

** This site was Mercia in 1992 and 1993

ϕ Analysis performed on transformed data. Details of the statistical analysis can be obtained from the Experiment Leader.

☼ Leaf 1

Table G. *Green leaf area on leaf 2 at GS 75 on Apollo (%)*

Treatment	Codford	Mepal	Site Wetherby**	Louth	Newcastle
1991					
1	40.0	70.0	67.4	-	76.9
2	68.8	86.3	86.1	-	86.3
3	83.8	89.8	89.8	-	91.7
4	76.3	90.8	90.3	-	92.2
5	85.8	91.5	91.6	-	94.6
6	82.3	88.0	90.3	-	92.5
7	80.8	87.0	86.6	-	92.6
8	60.5	74.8	76.0	-	79.2
9	53.3	81.8	81.5	-	81.6
10	71.3	85.3	85.0	-	86.9
1992					
1	44.7	66.2	83.0	-	81.4
2	73.4	76.9	74.2	-	93.5
3	82.5	75.7	87.4	-	90.7
4	73.9	72.0	79.2	-	93.2
5	83.9	75.7	87.4	-	94.8
6	78.4	77.2	93.2	-	93.1
7	74.7	71.7	81.3	-	94.6
8	51.3	58.7	77.6	-	86.0
9	61.3	62.5	81.0	-	91.6
10	75.1	67.2	82.3	-	93.2
1993					
1	4.2	0.0	20.7	-	64.2
2	59.0	69.6	40.8	-	75.0
3	64.3	79.9	60.4	-	86.0
4	70.2	75.1	32.0	-	78.8
5	74.1	91.5	52.2	-	87.1
6	74.7	85.0	50.1	-	83.7
7	68.4	90.8	44.7	-	81.1
8*	59.1	84.0	32.9	-	74.3
9*	71.2	85.5	31.5	-	85.7
10	55.3	77.8	37.6	-	77.3

* Fenpropimorph added in 1993
** This site was Mercia in 1992 and 1993

Note At some sites data were transformed for analysis and back transformed values are presented in the Table. For this reason some data may differ slightly from individual site reports.

Table H. *Grain yield for Apollo sites t/ha at 85% dm*

Treatment	Codford	Mepal	Site Wetherby**	Louth	Newcastle	Mean
1991						
1	7.74	7.90	7.29	9.12	8.03	8.02
2	8.20	8.06	7.90	9.51	8.32	8.40
3	8.20	8.17	7.94	9.40	8.29	8.40
4	8.24	8.37	8.01	9.68	8.56	8.57
5	8.62	8.52	7.76	9.58	9.52	8.60
6	8.30	8.39	7.95	9.36	8.35	8.47
7	8.13	8.43	7.73	9.55	8.32	8.43
8	8.02	8.21	7.60	9.32	8.19	8.27
9	8.00	8.26	7.85	9.41	8.19	8.34
10	8.04	8.31	7.65	9.52	8.38	8.38
s.e.d for treatment means						0.073
1992						
1	*	6.25	5.87	8.80	10.09	8.38
2	*	6.75	6.39	9.26	10.50	8.84
3	*	6.93	6.82	9.39	10.55	8.96
4	*	6.64	6.38	9.54	11.18	9.12
5	*	7.06	6.96	10.14	11.15	9.45
6	*	7.05	6.53	9.11	10.76	8.97
7	*	6.62	6.17	8.92	10.73	8.76
8	*	6.14	6.01	8.99	10.13	8.42
9	*	6.38	6.25	9.25	10.43	8.69
10	*	6.78	5.81	8.79	10.52	8.70
s.e.d for treatment means						0.098
1993						
1	5.16	5.97	3.98	6.65	6.83	6.16
2	6.34	6.70	4.81	8.56	7.24	7.21
3	6.66	7.16	5.48	8.82	7.24	7.47
4	7.02	6.86	5.00	8.93	7.58	7.60
5	7.07	7.48	5.47	9.19	7.81	7.89
6	6.50	6.85	4.86	8.72	7.42	7.37
7	6.56	6.73	4.83	8.49	7.12	7.22
8	6.62	6.88	4.59	8.06	7.16	7.18
9ϕ	6.72	7.08	4.73	8.62	7.18	7.40
10ϕ	6.50	6.73	4.81	8.05	7.14	7.10
s.e.d for treatment means						0.082

ϕ Fenpropimorph added in 1993
* Lodging prevented harvest
** Excluded from mean in 1992 and 1993 as this site was Mercia

Table I. *Specific weight for Apollo sites (kg/hl at 85% dm)*

Treatment	Codford	Mepal	Site Wetherby*	Louth	Newcastle	Mean
1991						
1	81.4	81.9	76.6	-	80.1	80.0
2	82.1	81.8	76.1	-	80.3	80.1
3	82.5	82.1	77.9	-	80.2	80.7
4	82.2	81.8	76.6	-	80.5	80.3
5	82.6	82.1	76.1	-	80.1	80.2
6	82.2	82.2	76.8	-	80.6	80.4
7	82.3	82.1	76.4	-	80.0	80.2
8	82.2	80.6	77.0	-	80.1	79.6
9	82.2	81.7	77.3	-	79.8	80.3
10	82.4	82.1	77.0	-	79.8	80.3
s.e.d. for treatment means						0.9
1992						
1	*	76.3	67.9	72.2	80.2	76.2
2	*	77.7	70.8	72.8	80.2	76.9
3	*	78.4	73.4	73.6	80.2	77.4
4	*	78.2	70.9	73.8	80.4	77.4
5	*	78.1	74.0	74.5	80.2	77.6
6	*	77.9	71.5	73.2	79.8	77.0
7	*	77.9	69.7	73.1	80.1	77.0
8	*	77.6	69.6	72.5	80.1	76.7
9	*	77.9	69.7	72.9	80.4	77.1
10	*	78.4	68.9	73.4	80.3	77.3
s.e.d for treatment means						0.21
1993						
1	76.1	83.5	67.1	77.3	80.4	79.3
2	77.0	84.0	70.2	79.0	80.9	80.2
3	77.3	84.4	72.1	79.6	81.5	80.7
4	77.6	84.1	70.1	79.5	81.1	80.5
5	77.6	84.5	71.4	79.9	81.6	80.9
6	77.6	84.2	69.0	79.1	81.5	80.6
7	77.5	84.2	70.1	78.8	80.6	80.3
8	77.6	84.3	69.3	78.7	81.5	80.5
9ϕ	77.3	84.2	69.6	79.0	81.2	80.4
10ϕ	77.1	84.4	67.9	78.6	81.8	80.3
s.e.d. for treatment means						0.24

*Lodging prevented harvested

** Excluded from mean in 1992 and 1993 as this site was Mercia

ϕFenpropimorph added in 1993

Table J. *1000 grain weight for Apollo sites (g at 85% dm)*

Treatment	Codford	Mepal	Site Wetherby**	Louth	Newcastle	Mean
1991						
1	52.7	-	55.3	-	59.4	55.8
2	55.4	-	56.7	-	60.5	57.5
3	55.4	-	58.1	-	61.2	58.2
4	55.0	-	57.7	-	61.6	58.1
5	56.8	-	58.3	-	60.9	58.7
6	55.4	-	57.5	-	61.3	58.0
7	54.9	-	56.7	-	61.7	57.8
8	55.6	-	56.4	-	58.9	57.0
9	55.5	-	56.6	-	60.6	57.6
10	54.8	-	57.1	-	60.6	57.5
s.e.d for treatment means						0.4
1992						
1	*	36.4	30.2	36.1	52.7	41.7
2	*	39.8	33.2	37.8	54.9	44.2
3	*	38.5	36.4	38.5	57.1	44.7
4	*	39.9	34.0	39.4	55.5	44.9
5	*	39.1	35.2	39.9	56.5	45.2
6	*	38.8	33.9	37.9	55.6	44.1
7	*	39.8	33.9	36.9	54.8	43.8
8	*	38.4	32.7	36.7	53.7	42.9
9	*	39.0	30.9	37.6	55.3	44.0
10	*	40.0	30.2	37.1	55.0	44.0
s.e.d for treatment means						0.45
1993						
1	43.3	42.6	26.2	33.8	44.5	41.0
2	50.7	46.4	28.7	37.6	48.3	45.8
3	51.0	47.9	30.7	37.6	49.0	46.4
4	51.9	46.1	28.3	38.6	49.9	46.6
5	53.8	48.0	31.4	39.6	52.4	48.5
6	52.1	46.5	27.3	37.8	48.0	46.1
7	51.8	44.6	27.8	38.1	47.4	45.5
8	51.3	46.3	28.1	36.5	47.6	45.4
9ϕ	51.6	46.3	28.4	38.2	48.8	46.2
10ϕ	51.3	47.7	26.3	36.5	47.1	45.7
s.e.d for treatment means						0.64

* Lodging prevented harvest

**Excluded from mean in 1992 and 1993 as this site was Mercia

\- Data incomplete

ϕFenpropimorph added in 1993

Table K. *Mean infection with* Septoria tritici, *on Riband (% leaf 2 at GS 75)*

Treatment	Site 1	2	3	4	5	6	7
1991							
1	**	42.0	26.4	68	7.2	56.5	6.8
2		14.1	0.9	24	2.7	35.0	2.3
3		8.8	0.4	20	0.7	20.4	2.3
4		5.5	0.9	17	0.6	26.8	2.5
5		5.5	0.1	10	0.2	18.3	2.3
6		10.2	4.0	22	4.9	20.0	2.3
7		10.0	1.8	16	0.8	22.9	2.8
8		15.4	13.2	50	9.1	36.9	3.5
9		12.1	1.6	27	4.2	26.5	2.5
10		9.4	4.1	38	5.3	25.1	3.8
s.e.d.		3.44	2.92	**	1.36	3.03	0.65
1992							
1	**	34.8	85.3	**	34.0	51.4	**
2		31.9	15.0		17.1	22.4	
3		27.4	9.6		10.5	14.1	
4		24.8	11.4		9.6	18.9	
5		17.4	4.6		7.8	13.1	
6		32.6	17.5		9.6	17.5	
7		36.4	26.9		12.5	17.9	
8		37.8	11.9		18.0	32.0	
9		27.4	6.5		17.3	23.8	
10		32.5	23.2		22.4	25.9	
s.e.d.		4.75	2.74		6.95	4.10	
1993							
1	0.1	25.0	91.6	**	51.4	83.6	18.3
2	0.4	10.4	80.4		22.4	8.2	6.9
3	0.5	7.0	70.6		14.1	3.6	5.8
4	0.3	8.4	75.0		18.9	5.3	1.2
5	0.4	6.2	63.6		13.1	1.2	0.9
6	0.1	12.8	61.0		17.5	0.4	2.1
7	0.3	9.3	66.5		17.9	1.9	2.3
8	0.4	7.5	64.5		32.0	6.6	1.5
9	0.5	10.5	76.1		23.8	4.4	4.3
10	0.6	7.0	74.9		25.9	8.3	5.5
s.e.d.	*	*	3.20		2.90	*	*

Site numbers

1 Terrington
2 Romney Marsh, Kent
3 Charminster, Dorset
4 Cirencester
5 Udny, Aberdeen
6 Morley
7 Dunmow

* Data transformed for statistical analysis, back transformed figures presented. Anyone requiring statistical information should contact the author.

** Records not available.

Table L. *Green leaf area on leaf 2 at GS 75 on Riband (%)*

Treatment	Site 1	2	3	4	5	6	7
1991							
1	-	39.0	49.7	-	0.6	2.7	-
2	-	72.4	93.0	-	77.9	20.8	-
3	-	77.1	96.2	-	93.4	49.4	-
4	-	81.9	93.3	-	90.8	37.0	-
5	-	81.9	97.5	-	96.9	47.8	-
6	-	74.0	85.0	-	46.0	48.3	-
7	-	74.9	92.4	-	77.3	44.2	-
8	-	67.9	76.2	-	8.7	23.4	-
9	-	75.3	87.3	-	48.1	40.5	-
10	-	78.0	82.6	-	17.9	39.4	-
1992							
1	-	12.9	1.0	-	32.3	46.4	-
2	-	23.9	45.4	-	67.7	79.1	-
3	-	35.4	63.5	-	83.2	79.5	-
4	-	33.7	56.2	-	75.8	87.7	-
5	-	53.0	75.5	-	84.0	87.5	-
6	-	16.4	36.4	-	77.9	82.8	-
7	-	22.3	26.9	-	76.6	85.4	-
8	-	17.6	49.7	-	62.6	83.3	-
9	-	27.9	65.7	-	64.3	82.9	-
10	-	22.8	29.9	-	56.8	80.7	-
1993							
1	40.2	0.0	0.0	-	37.9	1.0	19.7
2	91.0	47.0	0.9	-	71.0	67.2	81.8
3	89.8	56.7	2.8	-	81.7	83.8	80.5
4	92.0	53.9	4.7	-	76.2	61.0	90.0
5	86.5	63.8	6.8	-	82.9	80.8	90.0
6	92.3	56.7	17.7	-	74.8	88.0	92.2
7	90.5	63.8	15.2	-	77.6	81.5	91.5
8	87.0	49.0	16.2	-	54.5	69.9	88.6
9	91.5	49.6	2.6	-	70.2	80.5	88.3
10	87.3	59.6	5.8	-	64.9	69.1	85.1

Site numbers
1 Terrington
2 Romney Marsh, Kent
3 Charminster, Dorset
4 Cirencester
5 Udny, Aberdeen
6 Morley
7 Dunmow

Table M. *Grain yield for Riband sites (t/ha at 85% dm)*

Treatment	Site 1	2	3	4	5*	6	7	Mean
1991								
1	7.84	6.35	5.89	5.68	6.14	8.44	11.16	7.36
2	8.79	7.34	6.71	7.69	8.08	9.28	11.78	8.52
3	9.73	8.30	7.60	8.04	9.43	9.80	12.25	9.31
4	9.18	7.56	7.18	8.10	8.54	9.72	12.35	8.95
5	10.11	8.47	7.86	9.14	10.25	10.11	12.90	9.83
6	9.52	7.50	6.77	8.15	7.73	9.78	12.37	8.83
7	9.44	7.35	6.65	8.27	8.18	9.65	12.34	8.84
8	8.96	7.14	6.39	6.84	6.93	9.36	11.92	8.22
9	9.50	7.66	6.55	7.33	7.13	9.58	12.49	8.61
10	9.37	7.40	6.60	6.77	7.06	9.33	12.34	8.41
s.e.d for treatment means								0.089
1992								
1	7.71	7.12	7.03	7.90	5.79	7.12	9.21	7.41
2	8.82	7.97	7.82	8.29	7.00	8.29	11.31	8.50
3	8.90	8.28	8.18	9.36	8.21	8.60	11.44	9.00
4	9.11	7.98	8.46	9.07	8.55	8.47	12.00	9.09
5	9.43	8.54	8.41	8.48	9.10	8.74	12.18	9.27
6	9.15	7.79	8.10	10.03	8.88	8.48	11.73	9.17
7	9.14	7.63	8.00	8.13	8.14	8.40	12.01	8.78
8	8.58	7.86	8.07	8.54	7.76	8.39	11.79	8.71
9	9.01	7.96	8.17	8.73	7.67	8.40	12.03	8.85
10	8.66	7.73	8.04	8.64	8.29	8.10	11.53	8.71
s.e.d. for treatment means								0.098
1993								
1	5.47	5.63	5.12	5.19	4.59	7.69	7.90	6.17
2	7.19	7.54	5.87	7.20	6.05	8.98	9.03	7.64
3	8.21	8.68	6.33	7.89	6.47	9.77	9.26	8.35
4	7.95	7.93	7.03	8.29	6.68	9.58	9.76	8.42
5	8.61	8.44	7.29	8.92	6.74	10.32	9.81	8.90
6	8.53	8.38	7.10	8.34	6.18	10.05	9.52	8.65
7	8.73	8.34	7.29	7.79	6.04	9.85	9.51	8.58
8	7.78	7.61	7.04	7.58	5.35	9.34	9.47	8.14
9	8.45	8.07	6.38	7.59	6.05	9.66	9.14	8.21
10	7.90	8.22	6.89	7.15	5.66	9.67	9.10	8.15
s.e.d. for treatment means								0.098

Site numbers

1	Terrington	5	Udny, Aberdeen
2	Romney Marsh, Kent	6	Morley
3	Charminster, Dorset	7	Dunmow
4	Cirencester		

*1993 data excluded from the mean

Table N. *Specific weight for Riband sites (kg/hl at 85% dm)*

Treatment	Site 1	2	3	4	5	6	7	Mean
1991								
1	68.5	63.3	66.8	63.7	63.5	74.1	80.6	68.7
2	71.2	67.5	68.4	69.7	69.6	76.1	80.6	71.9
3	72.8	68.8	68.8	71.4	74.0	77.3	80.7	73.4
4	72.2	66.9	68.1	71.9	71.5	76.3	81.0	72.6
5	73.3	71.3	68.1	71.9	69.1	77.6	80.2	73.1
6	72.2	67.4	68.8	71.5	69.3	76.7	81.6	72.5
7	72.3	65.8	68.7	70.7	69.9	76.8	80.8	72.1
8	71.3	66.7	68.4	67.9	67.6	76.2	81.4	71.4
9	72.2	67.4	67.3	68.5	69.9	76.5	80.4	71.4
10	72.9	66.9	68.7	67.9	66.8	76.7	80.5	71.5
s.e.d for treatment means								0.37
1992								
1	63.7	69.5	66.9	67.4	64.3	68.0	70.1	67.1
2	66.1	70.9	67.0	68.0	66.9	70.0	69.9	68.4
3	66.1	71.3	66.4	68.7	71.6	71.2	70.5	69.4
4	65.8	71.0	68.0	68.0	70.0	70.3	71.2	69.2
5	67.6	71.4	67.4	67.5	73.6	71.0	70.9	69.9
6	67.4	70.7	67.1	68.8	71.9	70.9	70.8	69.7
7	67.5	70.3	67.7	67.6	71.4	71.0	71.5	69.6
8	65.7	70.9	66.9	68.2	69.1	69.9	71.2	68.8
9	67.1	70.8	66.8	68.2	69.6	69.5	71.3	69.0
10	66.7	70.7	66.9	68.6	71.4	69.5	70.6	68.2
s.e.d. for treatment means								0.40
1993								
1	68.3	75.9	70.1	69.0	61.3*	74.9	75.0	72.2
2	70.0	78.8	71.5	71.8	65.4	76.4	75.2	73.9
3	72.3	79.6	72.8	72.9	66.8	77.2	75.0	75.0
4	70.6	79.0	72.8	72.9	66.5	76.8	74.9	74.5
5	72.3	79.9	73.4	73.1	67.2	77.3	75.5	75.3
6	72.4	79.9	73.2	73.5	65.4	77.3	75.5	75.3
7	73.0	79.3	73.5	72.6	65.9	77.1	74.8	75.0
8	71.6	78.5	73.0	72.1	64.5	76.4	75.4	74.5
9	72.0	78.9	72.5	73.0	66.0	77.0	75.4	74.8
10	71.1	79.3	73.1	72.4	65.1	77.1	75.0	74.7
s.e.d. for treatment means								0.23

*These results analysed separately and excluded from mean

Site numbers

1	Terrington	5	Udny, Aberdeen
2	Romney Marsh, Kent	6	Morley
3	Charminster, Dorset	7	Dunmow
4	Cirencester		

Table O. *1000 grain weight for Riband sites (g at 85% dm)*

Treatment	Site 1	2	3	4	5	6	7	Mean
1991								
1	43.3	34.7	40.7	38.0	32.5	43.3	-	38.7
2	47.5	39.7	45.8	45.5	39.4	47.1	-	44.2
3	51.3	40.7	49.5	47.0	45.8	50.1	-	47.4
4	47.6	39.0	46.1	48.1	43.7	47.7	-	45.4
5	51.3	43.8	49.6	47.7	44.7	51.5	-	48.1
6	48.4	39.3	44.9	47.8	38.6	50.0	-	44.8
7	48.8	38.0	44.6	45.4	37.4	49.0	-	43.9
8	47.7	35.9	44.1	42.7	35.9	48.5	-	42.5
9	49.2	39.1	43.0	43.7	38.9	48.1	-	43.7
10	49.9	38.7	44.1	42.8	36.0	48.8	-	43.4
s.e.d. for treatment means								0.537
1992								
1	37.5	39.4	48.7	46.3	36.3	39.5	35.0	40.4
2	41.3	42.6	52.9	47.5	36.9	42.8	38.5	43.2
3	41.0	43.3	53.7	48.7	44.5	43.8	40.1	45.0
4	41.1	43.0	53.9	49.8	43.9	42.8	42.5	45.3
5	42.8	43.3	55.7	49.4	47.6	44.8	41.9	46.5
6	42.6	42.4	53.3	48.0	45.7	43.3	41.3	45.2
7	42.9	42.4	53.2	48.5	45.5	42.3	41.5	45.2
8	40.0	42.2	52.7	47.5	41.2	42.1	42.5	44.0
9	42.7	42.6	53.8	48.8	38.8	44.0	42.1	44.7
10	40.7	42.2	51.8	48.2	44.7	42.6	40.4	44.4
s.e.d. for treatment means								0.53
1993								
1	-	39.8	41.1	40.2	35.4*	47.0	54.8	44.6
2	-	45.3	43.7	43.4	41.7	51.2	57.7	48.3
3	-	49.8	46.6	45.3	45.7	54.1	57.2	50.6
4	-	48.8	45.9	46.3	44.4	52.0	57.4	50.1
5	-	50.9	49.9	48.1	46.3	57.5	55.9	52.5
6	-	49.9	49.1	46.7	42.3	55.3	56.8	51.5
7	-	49.3	50.8	45.3	43.1	54.4.	58.1	51.6
8	-	47.3	49.1	45.1	40.1	53.2	59.4	50.8
9	-	49.2	47.5	45.8	42.2	54.9	55.8	50.6
10	-	48.4	48.2	45.7	40.3	53.8	55.0	50.2
s.e.d. for treatment means								0.58

* These results analysed separately and excluded from the mean

Site numbers

1	Terrington	5	Udny, Aberdeen
2	Romney Marsh, Kent	6	Morley
3	Charminster, Dorset	7	Dunmow
4	Cirencester		