DECISION SUPPORT SYSTEMS FOR DISEASE CONTROL IN WINTER WHEAT

Authors

E. O'Sullivan, B. Dunne, and J.J. Burke

Crops Research Centre
Oak Park, Carlow

ISBN 1 84170 243 9

August 2001

NATIONAL DEVELOPMENT PLAN

Agriculture and Food Development Authority

EUROPEAN UNION
European Agricultural Guidance and Guarant

CONTENTS

SUMMARY

A leaf diagnostic test and a computer-based decision support system were evaluated for the control of diseases of winter wheat caused by *Septoria* spp. Fungicide programmes, as dictated by both methods, were compared with a standard routine programme, a reduced-rate programme and an unsprayed control from 1998 to 2000.

In some instances fungicide programmes, dictated by leaf diagnostic tests, resulted in lower disease and higher yields than routine programmes but these were not consistent.

Fungicide programmes, based on the computer-based decision support system, offered no advantages over routine programmes in terms of lower levels of disease, reduced numbers of fungicide applications or increased yields.

Reduced-rate programmes, based on more frequent applications of low rates of fungicides, resulted in substantial savings of fungicides and in 1999 and 2000 better disease control and higher yields than routine programmes.

INTRODUCTION

In 1997 some 19 million hectares of wheat were grown in Western Europe, where yields averaged 7.4 t/ha. This is approximately twice that achieved in the USA. The high yields in Western Europe are achieved through the use of high levels of inputs, including fungicides, with an annual cost of £1.4 billion of which approximately £17 million is spent in Ireland. There is a need to maximise profits to cereal growers in a climate of falling cereal prices and increasing environmental constraints. Currently fungicides are applied in a prophylactic manner with application dictated by crop development stage but with little reference to factors affecting disease epidemiology. There is a wealth of data and information regarding fungicide efficacy and disease epidemiology available. This information can be used to predict the occurrence of crop diseases and so use effective crop protection products only when required. In attempting to achieve this several decision support systems (DSSs) have been developed over recent decades. These invariably were either expert or rule based systems and after an initial period of use, have largely fallen into disuse. The advent and widespread use of PCs made possible the use of DSSs based on mathematical models (Secher & Bouma 1996; Brooks, 1998; Verreet *et al.*, 2000). These models can simulate the development of crops and their associated pests and diseases, accounting for the impact of weather, disease pressure and other factors and predict both the need for and timing of application of crop protection products. Leaf diagnostic tests have also been developed to detect pre-symptomatic infections so that fungicides need only be applied if disease is present (Lockley *et al*., 1996). If a DSS is to become widely accepted it must offer economic benefits through savings in inputs, increased outputs or enhance the monetary value of the crop. The objectives of this work were to evaluate a leaf diagnostic test and a computer-based DSS for the control of diseases of winter wheat caused by *Septoria* spp.

METHODS

Field investigations were conducted from 1998 to 2000 on techniques and methods that allow timing of fungicide applications in winter wheat in relation to disease development. The target diseases were those caused by *Septoria* spp. Two methods were used to identify the time of spraying (1) a leaf diagnostic test (LDT) for the presence of *Septoria* spp. and (2) a computer-based Decision Support System (DSS). These were compared with a standard routine fungicide programme, a reduced-rate programme and an unsprayed control. The field trials were laid down as randomised blocks with six-fold replication. Two winter wheat cultivars were used in 1998, Brigadier and Ritmo, with rating of 4 and 6 respectively for susceptibility to *Septoria* spp. In 1999 only Brigadier was used. In 2000 two cultivars, Madrigal (rating 4) and Claire (rating 7), were used. Brigadier and Madrigal were classed as susceptible and Ritmo and Claire as moderately resistant for the purpose of the DSS.

Leaves for LDT were sampled at regular intervals. In 1998 and 1999 they were sent to Cryptotechnology Ltd. UK where serological tests were carried out to detect pre-symptomatic *Septoria nodorum* and *Septoria tritici*. In 2000 the serological tests were carried out at Oak Park using test kits supplied by Adgen Ltd. UK. Flag leaf fungicide sprays were applied when pre-symptomatic infection was detected on the third leaf and head sprays applied when pre-symptomatic infection was detected on the second leaf. The DSS used was the Risk Index Programme from the Danish Institute of Agricultural Science and was supplied courtesy of Hardi International, AG Denmark. The weather data was recorded by a weather station (Hardi Metpole) located at Oak Park. The data was transmitted by radio signal to a receiver and transferred to a computer where it was stored for final analysis using the Risk Index Programme. In the light of the results obtained in each of the previous years some modifications of the DSS were used in subsequent years so that there were three DSS-based programmes in 1999 and four in 2000. The DSS programmes used are summarised in Table 1.

Table 1: DSS programmes used on winter wheat 1998-2000

Year	Programme	Index for spraying	Start of data recording for DSS-based sprays	
			First spray	Subsequent sprays
1998	DSS 1	Standard (8)[a]	Crop GS 32	Immediately on application of previous spray
1999	DSS 1	Standard (8)[a]	Crop GS 32	Immediately on application of previous spray
1999	DSS 2	Standard (8)[a]	Crop GS 32	One week after application of previous spray
1999	DSS 3	Standard (8)[a]	Crop GS 32	Two weeks after application of previous spray
2000	DSS 1	Low (7)[b]	Crop GS 32	Immediately on application of previous spray
2000	DSS 2	Low (7)[b]	Crop GS 32	One week after application of previous spray
2000	DSS 3	Standard (8)[a]	Crop GS 32	Immediately on application of previous spray
2000	DSS 4	Standard (8)[a]	Crop GS 32	One week after application of previous spray

[a] (9) for moderately resistant cultivar; [b] (8) for moderately resistant cultivar

LDT and DSS were used in conjunction with three-spray and two-spray programmes each year. In the three-spray programmes the first sprays were applied routinely at GS 31 and the subsequent sprays were applied in response to LDT or DSS recommendations. In the two-spray programmes the routine GS 31 sprays were omitted, all sprays being those in response to LDT or DSS. Some different products were applied at GS 31 in conjunction with LDT to determine if there were differences between products in impeding the upward movement of *Septoria* spp. In the standard routine programmers the fungicides were applied in response to the growth stage of the crop.

RESULTS AND DISCUSSION

1998

There was one DSS programme used in 1998, the Risk Index Programme. In this DSS an accumulated index of 8 triggered spraying of the susceptible cultivar Brigadier and an index of 9 triggered spraying of the moderately resistant cultivar Ritmo. The LDT was also used as an indicator of spraying for both cultivars. Two different fungicide products, Allegro and Sportak, were applied at GS 31 in conjunction with the LDT. Opus, or a tank mix of Opus/Amistar were used as second sprays in conjunction with the DSS. Sportak at GS 31 followed by Opus/Amistar (GS 37) followed by Amistar (GS 59) was used as the standard routine treatment. The reduced-rate programme consisted of Amistar at a quarter of the recommended rate applied on emergence of third, second, flag leaves and head. This was used with and without Sportak at GS 31. The details of the spray programmes and dates of application are given in Table 2.

The main foliar disease present in the trial was caused by *S. tritici* and levels were moderate to high. The trial site was infested with take-all (*Gaeumannomyces graminis*). This occurred more severely in patches particularly in cv. Brigadier, causing premature senescence of leaves and making diagnosis of the foliar disease more difficult.

In the three-spray programmes, the DSS-based second sprays were applied earlier and the LDT-based sprays later than the routine sprays (Table 2). Routine DSS- and LDT-based third sprays were all applied on 11 June except where Allegro was applied at GS 31 when this LDT spray was delayed until 19 June.

For both cultivars all spray programmes yielded significantly higher and had significantly lower levels of disease when compared with the unsprayed controls

($p \leq 0.05$) (Table 3). The highest yielding treatments were those that received Allegro at GS 31. All three-spray programmes yielded higher than their corresponding two-spray programmes. These differences were significant for some treatments in cv. Ritmo but not for cv. Brigadier. In the Brigadier trial there were severe patches of take-all. The high LSD value is probably a reflection of this unevenness in the crop and may explain the non-significance of yield differences among treatments. Treatments receiving Opus/Amistar second sprays yielded higher than those receiving Opus alone. There were no significant yield benefits from applying fungicides in response to LDT when compared with routine treatments. However it was only in the timing of the second sprays in the three-spray programmes that these differed. Sprays applied in response to DSS compared favourably with routine sprays in the case of cv. Brigadier. However this could be expected since the number of sprays were the same with only a few days difference in the timing of the second sprays. In cv. Ritmo, spraying in response to DSS reduced by one the number of applications but yields were significantly lower when compared with routine applications. This suggests that the decision to regard Ritmo as a moderately resistant cultivar for the purpose of the DSS was not correct. Amistar applied at reduced rates (resulting in considerable savings in fungicides) performed well in both cultivars following a GS 31 spray but poorly in the absence of this early spray.

All spray programmes significantly ($p \leq 0.05$) reduced levels of disease caused by *Septoria* spp. when compared with untreated controls (Table 3). Generally the three-spray programmes resulted in lower levels of disease than their corresponding two-spray programmes and some of these differences were significant. Applying fungicides in response to LDT did not result in significantly lower levels of disease when compared with the standard treatments. The highest level of disease followed the DSS-based programme on Ritmo.

Table 2: Fungicide treatments and times of application, winter wheat, Oak Park, 1998

Treatment No.	Products	Rate (l/ha)	Timing	Application date
1	Allegro Opus/Amistar Amistar	1.0 0.3/0.7 1.0	GS 31 LDT, 3rd leaf LDT, 2nd leaf	15 April 28 May 19 June
2	Sportak Opus/Amistar Amistar	1.0 0.3/0.7 1.0	GS 31 LDT, 3rd leaf LDT, 2nd leaf	15 April 28 May 11 June
3	Sportak Opus/Amistar Amistar	1.0 0.3/0.7 1.0	GS 31 GS 37 GS 59	15 April 18 May 11 June
4	Sportak Amistar x 4	1.0 0.25 x 4	GS 31 On unfolding of 3rd , 2nd and flag leaf and on emergence of head	15 April 30 April, 13 and 25 May, 11 June
5	Sportak Opus/Amistar Amistar	1.0 0.3/0.7 1.0	GS 31 As per DSS As per DSS [2]	15 April 13 May [1] 11 June
6	Sportak Opus Amistar	1.0 1.0 1.0	GS 31 LDT, 3rd leaf LDT, 2nd leaf	15 April 28 May 11 June
7	Opus/Amistar Amistar	0.3/0.7 1.0	LDT, 3rd leaf LDT, 2nd leaf	18 May 11 June
8	Opus/Amistar Amistar	0.3/0.7 1.0	GS 37 GS 59	18 May 11 June
9	Amistar x 4	0.25 x 4	On unfolding of 3rd , 2nd and flag leaf and on emergence of head	30 April, 13 and 25 May, 11 June
10	Opus/Amistar Amistar	0.3/0.7 1.0	As per DSS As per DSS [2]	13 May [1] 11 June
11	Opus Amistar	1.0 1.0	LDT, 3rd leaf LDT, 2nd leaf	18 May 11 June
12	Opus/Amistar Amistar	0.3/0.7 1.0	LDT, 3rd leaf GS 59	18 May 11 June
13	Unsprayed			

[1] 4 June for cv. Ritmo; [2] DSS did not recommend second spray for cv. Ritmo

These results show that in 1998, when compared with routine treatments, there was no significant benefit in terms of reduced numbers of spray applications, increased disease control or increased yields from applying fungicides to winter wheat in response to LDT. Neither was there a significant benefit from the DSS-based programme in cv. Brigadier. In cv. Ritmo the DSS-based programme reduced the number of sprays but at the expense of a significant reduction in yield.

Table 3: Effect of fungicide programmes on disease and yield of winter wheat 1998

Treatment No.	Cultivar			
	Brigadier		Ritmo	
	% Necrosis 2nd leaf	Yield (t/ha) @ 85% D M	% Necrosis 2nd leaf	Yield (t/ha) @ 85% D M
1	40.6	7.81	20.0	9.28
2	40.5	7.37	22.1	9.09
3	37.7	7.46	31.8	9.19
4	65.7	7.37	50.0	8.92
5	53.3	7.42	61.6	7.94
6	47.4	7.29	35.2	8.43
7	59.5	6.98	43.8	8.55
8	59.1	7.04	41.8	8.53
9	64.2	6.68	56.4	8.13
10	59.6	7.26	72.7	7.62
11	56.8	6.45	38.2	8.31
12	62.3	7.23	40.5	8.67
13	100	4.59	99.1	6.29
LSD (0.05)	14.6	1.02	14.2	0.64

1999

In 1999 only one cultivar, Brigadier, was sown, which is susceptible to diseases caused by *Septoria* spp. Since there was no advantage from using the DSS in 1998 some modifications were evaluated in 1999. There were three DSS-based programmes where data recording for the first DSS-based sprays started at GS 32 and recording for the second DSS-based sprays started either immediately (standard used in 1998), one week or two weeks later (Table 1). There were also LDT-based, reduced rate and routine programmes. Allegro and Sportak were used at GS 31 in conjunction with LDT. In the reduced-rate programme Allegro at a quarter of the recommended rate was used for the first three sprays followed by Amistar (¼ rate) for the final spray. The routine programme was the same as that used in 1998. The details of the spray programmes and dates of application are given in Table 4.

Table 4: Fungicide treatments and times of application, winter wheat, Oak Park, 1999

Treatment No.	Products	Rate (l/ha)	Timing	Application date
1	Allegro	1.0	GS 31	19 April
	Opus/Amistar	0.3/0.7	LDT, 3rd leaf	17 May
	Amistar	1.0	LDT, 2nd leaf	8 June
2	Allegro	1.0	GS 31	19 April
	Opus/Amistar	0.3/0.7	GS 37	20 May
	Amistar	1.0	GS 59	15 June
3	Sportak	1.0	GS 31	19 April
	Opus/Amistar	0.3/0.7	LDT, 3rd leaf	17 May
	Amistar	1.0	LDT, 2nd leaf	8 June
4	Sportak	1.0	GS 31	19 April
	Opus/Amistar	0.3/0.7	GS 37	20 May
	Amistar	1.0	GS 59	15 June
5	Sportak	1.0	GS 31	19 April
	Opus/Amistar	0.3/0.7	As per DSS 1	17 May
	Amistar	1.0	As per DSS 1	22 June
6	Sportak	1.0	GS 31	19 April
	Opus/Amistar	0.3/0.7	As per DSS 2	17 May
	Amistar	1.0	As per DSS 2	22 July
7	Sportak	1.0	GS 31	19 April
	Opus/Amistar	0.3/0.7	As per DSS 3	17 May
	Amistar	1.0	As per DSS 3	No head spray
8	Sportak	1.0	GS 31	19 April
	Allegro x 3	0.25 x 3	On unfolding of 3rd, 2nd and flag leaves	28 April, 14 and 25 May
	Amistar	0.25	Head emergence	15 June
9	Opus/Amistar	0.3/0.7	LDT, 3rd leaf	17 May
	Amistar	1.0	LDT, 2nd leaf	8 June
10	Opus/Amistar	0.3/0.7	GS 37	20 May
	Amistar	1.0	GS 59	15 June
11	Opus/Amistar	0.3/0.7	As per DSS 1	17 May
	Amistar	1.0	As per DSS 1	22 June
12	Opus/Amistar	0.3/0.7	As per DSS 2	17 May
	Amistar	1.0	As per DSS 2	22 July
13	Opus/Amistar	0.3/0.7	As per DSS 3	17 May
	Amistar	1.0	As per DSS 3	No head spray
14	Allegro x 3	0.25 x 3	On unfolding of 3rd, 2nd and flag leaves	28 April, 14 and 25 May
	Amistar	0.25	Head emergence	15 June
15	Unsprayed			

The LDT and DSS-based second sprays (or first sprays in the case of two-spray programmes) were applied three days earlier than the standard routine sprays. The LDT-based third sprays were applied one week earlier and DSS-based (DSS 1) third sprays one week later than the routine sprays. Where data recording for the second sprays started one or two weeks after the application of the first spray (DSS 2 and DSS 3) the third sprays did not become due until 22 July. Only one of the treatments (DSS 2) was sprayed, the data was then compared with that of the other to see if there was a benefit from a final spray at this late stage.

Table 5: Effect of fungicide programmes on disease and yield of winter wheat, 1999

Treatment No.	% Necrosis, 2nd leaf	% Necrosis, flag leaf	Yield (t/ha) @ 85% D M
1	17.1	0.8	10.31
2	19.3	0.6	10.40
3	25.7	0.9	10.34
4	37.8	1.3	9.66
5	31.0	2.9	9.85
6	55.9	14.4	9.06
7	54.7	21.9	8.68
8	10.2	0.4	10.28
9	42.6	1.8	9.57
10	53.1	1.8	9.56
11	50.9	7.7	9.09
12	67.3	22.0	8.66
13	63.6	17.9	8.75
14	16.5	0.5	10.40
15	100.0	99.7	5.55
LSD (0.05)	11.1	5.0	0.6

All spray programmes yielded significantly higher and had levels of disease that were significantly lower ($p \leq 0.05$) than the unsprayed control (Table 5). The highest yielding programmes were those that included Allegro at GS 31 (Treatments 1 and 2), the reduced-rate programmes (Treatments 8 and 14) and the programme that included Sportak at GS 31 with the following two sprays applied in response to LDT (Treatment 3). All these programmes yielded over 10 t/ha and there was no significant difference between them. The programme that included Sportak at GS 31 with the two subsequent sprays applied routinely (standard programme) yielded significantly lower and had significantly higher levels of disease than the corresponding treatment where the two latter sprays were applied in response to LDT. All three-spray programmes yielded higher than the corresponding two-spray programmes and these differences were significant in the case of the higher yielding programmes. All three-spray programmes had significantly lower levels of disease than the corresponding two-spray programmes but these were not always reflected in significantly higher yields. The DSS-based programme where recording recommenced on the application of the first spray was higher yielding than where recording recommenced a week later in both three-spray and two-spray programmes. There was a benefit from applying the late July spray associated with the latter as part of a three-spray programme but not as part of a two-spray programme.

Where Allegro was applied at GS 31 there was no benefit from applying the subsequent sprays in response to LDT when compared with routine applications, despite differences in the timing of the fungicide applications. Where Sportak was applied at GS 31 there was a substantial yield benefit from the LDT-based treatments but not from DSS-based treatments. In the two-spray programmes there were no differences in yield between routine and LDT-based programmes and DSS-based programmes yielded slightly lower than either. The major difference between programmes was in the timing of the final sprays. The LDT-based sprays were applied a week earlier and the DSS-based sprays a week later than the routine sprays. It appears that in 1999 the DSS recommended final sprays too late to maximise grain yields. The reduced-rate programmes, which resulted in considerable savings of fungicides, performed well irrespective of whether or not a GS 31 spray was included.

2000

Two cultivars, Madrigal, which is susceptible to diseases caused by *Septoria* spp. and Claire, which is moderately resistant to these diseases, were used. In 1999 the treatments sprayed in accordance with the DSS had higher levels of disease and yielded lower than those sprayed routinely or in response to LDT. The DSS-based sprays were applied later and this may have accounted for the higher levels of disease. In 2000 modifications of the Risk Index Programme were used in an attempt to overcome the apparent problems encountered in 1999. The standard

Risk Index Programme was used together with a modification in which the index for spraying was reduced by one unit. In standard and reduced index programmes data recording for the timing of the second DSS-based sprays started either immediately or one week after the application of the first sprays resulting altogether in four DSS-based programmes as shown in Table 1. There were also LDT-based, reduced-rate and routine programmes. Three different products Allegro, Sportak and a tank mix of Unix/Opus were used at GS 31 in conjunction with the leaf diagnostic test to see if there were differences between products in impeding the upward movement of *Septoria* spp. In all other three-spray programmes GS 31 sprays were Unix/Opus. The details of the programmes and dates of application of sprays are shown in Table 6.

Generally sprays applied in response to LDT were applied later than routine sprays except where there was no GS 31 spray. All DSS-based second sprays were applied later and DSS-based third sprays earlier than the routine second and third sprays. The main disease occurring in the crop was caused by *S. tritici*. The weather was very wet and favourable for this disease during May and June and some DSS-based programmes received a fourth spray application.

Of the three products applied at GS 31 Allegro had the greatest effect on delaying the upward movement of *Septoria* spp. as can be seen from the timings of the sprays applied in response to LDT (Table 7). In cv. Madrigal all treatments yielded significantly higher ($p \leq 0.01$) and had significantly lower ($p \leq 0.01$) levels of disease when compared with the unsprayed control (Table 7). The highest yielding programmes were those that included Allegro at GS 31 and the reduced-rate programmes.

Table 6: Fungicide treatments and times of application, winter wheat, Oak Park 2000

Treatment No.	Products	Rate (l/ha)	Timing	Application date	
				Madrigal	Claire
1	Allegro	1.0	GS 31	14 April	14 April
	Opus/Amistar	0.3/0.7	LDT, 3rd leaf	31 May	31 May
	Amistar	1.0	LDT, 2nd leaf	20 June	20 June
2	Allegro	1.0	GS 31	14 April	14 April
	Opus/Amistar	0.3/0.7	GS37	15 May	15 May
	Amistar	1.0	GS59	12 June	12 June
3	Sportak	1.0	GS 31	14 April	14 April
	Opus/Amistar	0.3/0.7	LDT, 3rd leaf	18 May	18 May
	Amistar	1.0	LDT, 2nd leaf	16 June	20 June
4	Sportak	1.0	GS 31	14 April	14 April
	Opus/Amistar	0.3/0.7	GS37	15 May	15 May
	Amistar	1.0	GS59	12 June	12 June
5	Unix/Opus	0.5/0.5	GS 31	14 April	14 April
	Opus/Amistar	0.3/0.7	LDT, 3rd leaf	18 May	18 May
	Amistar	1.0	LDT, 2nd leaf	16 June	16 June
6	Unix/Opus	0.5/0.5	GS 31	14 April	14 April
	Opus/Amistar	0.3/0.7	GS37	15 May	15 May
	Amistar	1.0	GS59	12 June	12 June
7	Unix/Opus	0.5/0.5	GS 31	14 April	14 April
	Opus/Amistar	0.3/0.7	As per DSS1	19 May	22 May
	Amistar	1.0	As per DSS1	31 May	06 June
	Amistar	1.0	As per DSS1	23 June	23 June
8	Unix/Opus	0.5/0.5	GS 31	14 April	14 April
	Opus/Amistar	0.3/0.7	As per DSS2	19 May	22 May
	Amistar	1.0	As per DSS2	09 June	23 June
9	Unix/Opus	1.0	GS 31	14 April	14 April
	Opus/Amistar	0.3/0.7	As per DSS3	22 May	26 May
	Amistar	1.0	As per DSS3	06 June	16 June
	Amistar	1.0	As per DSS3	23 June	
10	Unix/Opus	0.5/0.5	GS 31	14 April	14 April
	Opus/Amistar	0.3/0.7	As per DSS4	22 May	26 May
	Amistar	1.0	AS per DSS4	23 June	03 July
11	Unix/Opus	0.5/0.5	GS 31	14 April	14 April
	Allegro x 3	0.25 x 3	On unfolding of 3rd, 2nd and flag leaves	02, 11, 25 May	02, 11, 25 May
	Amistar	0.25	Head emergence	16 June	16 June

Table 6: Continued

Treatment No.	Products	Rate (l/ha)	Timing	Application date	
				Madrigal	Claire
12	Opus/Amistar	0.3/0.7	LDT, 3rd leaf	11 May	18 May
	Amistar	1.0	LDT, 2nd leaf	16 June	20 June
13	Opus/Amistar	0.3/0.7	GS 37	15 May	15 May
	Amistar	1.0	GS 59	12 June	12 June
14	Opus/Amistar	0.3/0.7	AS per DSS1	19 May	22 May
	Amistar	1.0	As per DSS1	31 May	06 June
	Amistar	1.0	As per DSS1	23 June	23 June
15	Opus/Amistar	0.3/0.7	As per DSS2	19 May	22 May
	Amistar	1.0	As per DSS2	09 June	23 June
16	Opus/Amistar	0.3/0.7	As per DSS3	22 May	26 May
	Amistar	1.0	As per DSS3	06 June	16 June
	Amistar	1.0	As per DSS3	23 June	
17	Opus/Amistar	0.3/0.7	As per DSS4	22 May	Not included for cv. Claire
	Amistar	1.0	As per DSS4	23 June	
18	Allegro x 3	0.25 x 3	On unfolding of 3rd, 2nd and flag leaves	02, 11 and 25 May	02, 11 and 25 May
	Amistar	0.25	Head emergence	16 June	16 June
19	Unsprayed				

Treatments receiving Allegro at GS 31 yielded significantly higher ($p \leq 0.01$) than those receiving either Sportak or Unix/Opus. All three-spray programmes yielded significantly higher ($p \leq 0.01$) than their corresponding two-spray programmes. Where Allegro was applied at GS 31 there were no differences in yield between routine and LDT-based second and third sprays. Where Sportak and Unix/Opus were applied at GS 31 the LDT-based sprays yielded higher but the differences were not significant. Where the GS 31 sprays were omitted (i.e. two-spray programmes) the LDT-based sprays yielded significantly higher than the routine sprays. Following a GS 31 spray there were no significant differences in yields between routine and DSS-based programmes, even where DSS recommended a fourth spray. Where the GS 31 spray had been omitted treatments that received an extra DSS-based spray (third in this case) yielded significantly higher than those that received two sprays but all yielded significantly lower than the standard routine three-spray programme that received a spray at GS 31.

In cv. Claire the level of disease was much lower than in cv. Madrigal. The yields were also lower but the crop was infected by take-all (*Gaeumannomyces graminis*) and this may have contributed to the lower yields. All treatments had significantly lower levels of disease ($p \leq 0.01$) and yielded significantly higher ($p \leq 0.05$) than the untreated control (Table 8). There were no significant differences in yield between two- and three-spray programmes and none of the LDT or DSS-based programmes yielded higher than the standard routine three-spray programme.

Table 7: Effect of fungicide programmes on disease and yield of winter wheat cv. Madrigal, 2000

Treatment No.	% Necrosis 2nd leaf	% Necrosis Flag leaf	Yield (t/ha) @ 85% DM
1	54.0	16.2	12.3
2	59.8	18.8	12.3
3	86.4	42.1	10.8
4	95.6	58.5	10.6
5	78.3	33.8	11.6
6	90.2	52.8	11.4
7	53.5	14.1	11.8
8	70.5	31.1	11.5
9	61.0	16.7	11.7
10	92.9	51.6	11.0
11	22.9	9.6	12.4
12	85.1	56.0	10.6
13	96.9	68.6	10.2
14	65.2	23.1	11.1
15	86.4	45.5	10.4
16	71.8	19.9	11.1
17	95.4	66.0	9.9
18	27.1	13.3	11.6
19	100	99.0	7.6
LSD (0.5)	10.59	6.33	0.38
LSD (0.01)	13.14	10.76	0.47

Table 8: Effect of fungicide programmes on disease and yield of winter wheat cv. Claire, 2000

Treatment No.	% Necrosis 2nd leaf	Yield (t/ha) @ 85% DM
1	1.2	9.4
2	1.3	9.5
3	1.3	9.0
4	2.3	9.5
5	1.1	9.4
6	2.2	9.8
7	0.7	9.7
8	1.8	9.6
9	1.1	9.3
10	1.8	9.4
11	0.8	9.0
12	2.2	9.0
13	2.4	9.1
14	1.9	9.0
15	4.1	9.0
16	3.5	9.0
17	0.4	9.6
18	47.3	8.4
LSD (0.05)	5.8	0.62

CONCLUSIONS

- Three-spray fungicide programmes yield higher than two-spray programmes irrespective of whether the spray applications are in response to crop growth stage, leaf diagnostic tests or computer-based DSS.

- In some instances fungicides applied in response to leaf diagnostic tests result in lower disease and higher yields than those applied routinely in response to crop growth stage.

- The Risk Index Programme does not result in lower disease, reduced numbers of fungicide applications or increased yields when compared with routine programmes. In seasons of high rainfall it may recommend increased numbers of sprays but without compensatory yield benefits.

- Reduced-rate fungicide programmes based on frequent applications of low rates of fungicides result in substantial savings of fungicides and compare favourably with routine three-spray programmes in terms of disease control and yield. However, the increased number of applications may be a disadvantage in these programmes.

- Notwithstanding that the version of the Risk Index Programme used offers no advantage over routine programmes, work on developing improved Decision Support Systems for disease control in winter wheat in Ireland is warranted. This system has since been updated to account for newer types of fungicides and there are other Decision Support Systems available which should be evaluated in trials in future.

REFERENCES

Brooks, D. H., 1998. Decision Support Systems for arable crops (DESSAC): an integrated approach to decision support. *Proceedings of the 1998 Brighton Conference: Pests and Diseases* 239-246.

Lockley, K. D., Paveley, N. D., Leadbeater, A. J., Smith, J. A. & Booth, G. M., 1996. The value of ELISA diagnostics as tools to optimise fungicide use for the control of *Septoria tritici* in winter wheat. *1996 BCPC Symposium Proceedings No. 65: Diagnostics in Crop Production.*

Secher, E. J. M. & Bouma, E., 1996. Survey of European Decision Support Systems. *Danish Institute of Plant and Soil Science. SP Report No. 16*, 95 pages.

Verreet, J. A., Klink H. & Hoffmann, G.M., 2000. Regional monitoring for disease prediction and optimisation of plant protection measures: The IPM Wheat Model. *Plant Disease* 8 816-826.

Appendix

Fungicides used

Product	ISO-name	Concentration
Allegro	Kresoxim-methyl + Epoxiconazole	125 g/l + 125 g/l
Amistar	Azoxystrobin	250 g/l
Opus	Epoxiconazole	125 g/l
Sportak	Prochloraz	450 g/l
Unix	Cyprodinil	750 g/l