Field Validation Of Four Decision Support Systems For The Control Of Late Blight In Potatoes

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SUMMARY

Field experiments were carried out between 2001 and 2003 to determine the efficacy of the NegFry, Simphyt, ProPhy and Plant Plus decision support systems (DSS) in controlling late blight of potatoes compared with routine fungicide treatments. The experiments were also used to determine the potential of the systems to reduce fungicide inputs.

Over the three year period of the experiment the 7-day routine programme received an average of 13.7 fungicide applications while the DSS programmes varied between 5.7 and 12.3 applications. All decision support systems resulted in a reduction in the number of fungicide application (Fig. 2). Compared with the routine control, the NegFry and SimPhyt programmes resulted in a 58-44% reduction in application frequency. The ProPhy and Plant Plus programmes resulted in more modest savings of between 10 and 25% (Tables 1 & 2).

All fungicide treatments significantly delayed the date of disease onset compared with the untreated control. Compared with the routine control treatment, the NegFry and Plant Plus significantly delayed disease onset in King Edward in 2001 as did NegFry and ProPhy in Rooster. In 2002 there were no differences between treatments in terms of delaying disease onset, while in 2003, disease developed significantly earlier the Plant Plus programme compared with the routine control. In general, the date of disease onset was not significantly different between routine programmes and DSS programmes irrespective of the cultivar.

In each of the three years, all fungicide treatments significantly reduced the incidence of foliage blight at the end of the season compared with the untreated control. When compared with the routine control, no decision support system resulted in significantly more foliage blight at the end of the season, irrespective of the cultivar or year. Similar results were achieved when the treatments were compared using the area under the disease progress curve (AUDPC). These results would confirm that none of the DSS's resulted in inferior disease control when compared with the 7-day routine application of fluazinam.

All fungicide treatments resulted in significantly higher marketable yields compared with the untreated control in all years, irrespective of the variety. Within the fungicide treatments the DSS programmes generally out-yielded the routine fungicide treatment. However, these differences were only significant for Plant-Plus in King Edward in 2001. Within the DSS treatments there were no significant differences in marketable yield in any of the years or either of the varieties.

Within the fungicide treatments there were no significant differences between treatments in terms of tuber blight control for the resistant variety Rooster. In the case of the more susceptible variety, King Edward, all the DSS programmes resulted in significantly lower levels of tuber blight than the routine Shirlan control in 2001 except for Simphyt. More importantly, the routine Shilan did not result in significantly better tuber blight control in any of the years when compared with any of the DSS programmes. This confirms that all DSS programmes give equivalent tuber blight control to the routine Shirlan application at 7-day intervals even with a very tuber blight susceptible variety.

INTRODUCTION

Potato late blight, caused by the oomycete fungus *Phytophthora infestans* (Mont.) de Bary is the most destructive disease affecting the potato worldwide. Annual losses in Ireland have been estimated at €10.2 m per annum (Copeland *et al*., 1993). Disease control requires regular application of fungicides at high rates and short intervals throughout the growing season.

There is increasing consumer demand to improve the health status of our foods and to reduce any pollution effects on our environment. This has resulted in a growing international demand to reduce the use of pesticides in food production. Some countries have already introduced legislation to reduce the use of pesticides in crop production while in others, the legislation is still pending. In countries where no such legislation exists, the larger food outlets may insist that their food be produced according to a protocol that includes reduced fungicide inputs. This may involve the scientific justification of each fungicide applied and can only be achieved by the use of a decision support system.

The epidemiology of late blight is very dependent on temperature, relative humidity and rainfall. Due to the large influence of weather on the development and spread of this disease, it is not surprising that forecasting systems have been in use in a number of countries for many years.

One of the first forecasting schemes for potato blight, based on cloudiness, dew, rainfall and temperature was developed in the Netherlands (van Everdingen, 1926). Others were developed in the UK (Beaumont & Staniland, 1933) and the USA (Crosier & Reddick, 1935). Subsequently, Beaumont formulated the Beaumont Period (Beaumont, 1947) which was later superseded by the Smith Period (Smith, 1956). An attempt to refine the system by Sparks (1980) was not successful and the Smith Period continues in use in the UK to the present day.

In the Republic of Ireland, Bourke developed a set of rules for forecasting late blight which were first used in 1952 and are known as the 'Irish Rules'. These rules were based on experimental laboratory work carried out by Crosier in the USA (Bourke, 1955). The rules were used for the development of a late blight warning service that is run by Met. Éireann (the Irish Meteorological Service).

Recent developments in information technology have made it possible to log weather data continuously for individual sites and to use this information in computer-based decision support systems (DSS) to predict the date of disease outbreak and to determine the most suitable intervals between sprays. The objective of any DSS programme is to achieve the most effective timing of each fungicide application while optimising disease control and minimising pesticide use. As part of an EU Concerted Action Programme, four DSS programmes were compared with routine fungicide application at 7-day intervals and an untreated control. The trials were conducted at Oak Park Research Centre, Carlow, Ireland over a three year period between 2001 and 2003. The four DSS programmes were NegFry, SimPhyt, ProPhy and Plant Plus.

The ProPhy and Plant Plus models are restricted to fee paying customers only while NegFry and SimPhyt are both available free of charge. All models require accurate local weather data, especially rainfall, temperature and relative humidity. Other requirements include irradiation, wind speed, cultivar susceptibility, crop growth and future weather prediction for the area. NegFry was developed in Denmark (Hansen *et al*., 1995) and SimPhyt in Germany (Gutsche & Kluge, 1995). Both ProPhy (Nugtern, 1997) and Plant Plus (Hadders, 1997) were developed in The Netherlands.

The objective of this project was to establish if differences existed between these decision support systems in terms of fungicide use, disease control or yield.

METHODS

Weather data recording

The Oak Park weather station was used to record humidity, temperature, rainfall, radiation, wind speed, soil temperature and soil moisture. The data was recorded every 10 minutes and the average of 3 readings was transferred to a computer where it was stored for final analysis using the different decision support software.

Field experiments

Trials were conducted at Oak Park Research Centre, Carlow, from 2001 to 2003, using certified seed of the maincrop potato cultivars Rooster and King Edward. Both cultivars have similar ratings (4) for foliage blight resistance but differ considerably in terms of tuber blight resistance with Rooster (7) being much more resistant than King Edward (3). The preceding crop was winter barley and the soil was a free draining medium loam with a low clay and organic matter content and a pH of 6.6 (+/- 0.2). The trials were planted into destoned beds using a Randsom two-row automatic planter. The drill width was 84.66 cm and the distance between tuber centres was 29.21 cm. Paraquat (600 g. a.i. ha^{1}) and simazine (600 g. a.i. ha^{1}) was applied as pre emergence herbicides.

The trial design was a randomised complete block (RCB) with 4 replications per treatment. Each plot consisted of 6 drills 7.69 m long. The total plot size was 37.5 m^2, from which 12.5 m^2 were harvested across the centre 2 drills. A 3 m divider strip was left between plots to facilitate mechanical harvesting. An unsprayed inoculator plot was planted at each end of the trial. A mancozeb treated non-experimental buffer-plot was planted between the unsprayed plot and the experimental area. Artificial inoculum of *P. infestans* (5,000 sporangia/ml) was applied to the under-surface of 5 leaflets/plant in the inoculator strips at either end of the trial area if no disease was apparent within 10 days after disease onset was predicted by the NegFry DSS.

Spraying was carried out with an ATV drawn Hardi sprayer mounted on a Logic chassis with an independent power source. Machinery access was by rotovated spray paths to prevent crop damage. Spraying commenced when the plants were beginning to meet along the drill or as determined by the decision support systems. The spray volume was equivalent to 250 l ha^{-1} and the spray pressure was 3 bars using Hardi flat spray nozzle number 370694/4110-20 delivering 1.59 l min^{-1} at 7.6 km h^{-1} (4.72 mph). During the growing season, disease levels were assessed at weekly intervals up to desiccation using the B.M.S. foliage blight assessment key (Cox & Large, 1960).

The experiments were desiccated with full rate diquat in September and harvesting took place in September-November using a Randsom two-row elevator digger. The produce was stored at a temperature above 10^{0}C for at least two weeks to allow tuber blight symptoms to develop. The tubers were then graded into the following grades:- < 45 mm, 45-65 mm, 65-85 mm, > 85 mm, blighted tubers and other diseases. After grading the produce was weighed and the yield expressed in tonnes ha^{-1}.

Fungicide Treatments

Routine fungicide application at 7-day intervals was compared with fungicide applications as dictated by the four DSS programmes and an untreated control. The different fungicides applied and their dates of application are given in Appendix 1.

RESULTS

Variation in disease severity between years

The accumulated risk value as measured by the NegFry decision support system is a good measure of the conditions suitable for the spread of foliage blight during the course of each season. It also provides a consistent and scientific comparison between years. High values indicate a year where conditions were most suitable for the spread of foliage blight.

The accumulated risk values for the years 2001 to 2003 are given in Fig. 1. The highest accumulated risk value was recorded for 2003 and the lowest was recorded for 2001. The accumulated risk value for 2002 was normal while 2001 was below normal and 2003 above normal.

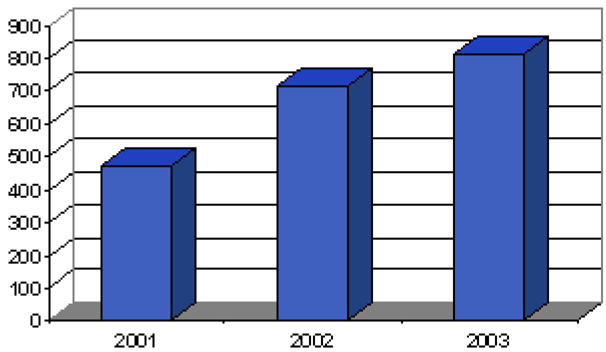

Fig. 1**: Variation in the accumulated risk value 2001-2003 (Blight units from June 1 to September 30)**

Number of fungicide applications

Routine fungicide application started in mid-June and continued at 7-day intervals up to the date of desiccation. The number of routine fungicide applications was dictated mainly by the date of desiccation. The number of fungicide applications for the decision support systems was determined by either the NegFry, SimPhyt, ProPhy or Plant Plus programmes. The number of fungicide applications for each programme in each of the three years is given in Tables 1 & 2.

Table 1: The number of fungicide applications following different application programmes 2001-2003 (cv. King Edward).

Programme	2001	2002	2003	Mean	% Reduction on routine control
7-day routine control	14	14	13	13.7	
NegFry	6	6	7	6.3	54.0
SimPhyt	5	9	9	7.7	43.8
Plant Plus	9	12	10	10.3	24.8
ProPhy	12	15	10	12.3	10.2

Table 2: The number of fungicide applications following different application programmes 2001-2003 (cv. Rooster).

Programme	2001	2002	2003	Mean	% Reduction on routine control
7-day routine control	14	14	13	13.7	
NegFry	6	6	5	5.7	58.4
SimPhyt	5	9	8	7.3	46.7
Plant Plus	-	13	11	12.0	12.4
ProPhy	12	15	10	12.3	10.2

Over the three year period of the experiment, the 7-day routine programme received an average of 13.7 fungicide applications while the DSS programmes varied between 5.7 and 12.3 applications. All decision support systems resulted in a reduction in the number of fungicide applications. Compared with the routine control the NegFry and SimPhyt programmes resulted in a 58-44% reduction in application frequency. The ProPhy and Plant Plus programmes resulted in more modest savings of between 10 and 25% (Tables 1 & 2). All decision support systems represent a considerable saving in fungicide use (Fig. 2) but an acceptable level of disease control must accompany the reduced fungicide inputs.

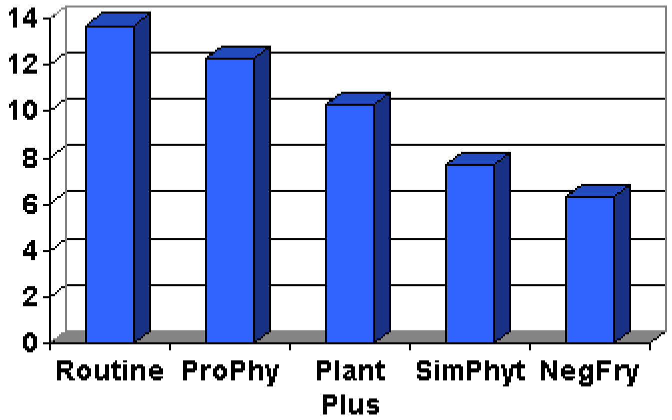

Fig. 2: Effect of spray programme on the mean number of fungicide applications 2001-2003 (cv. King Edward)

Effect on foliage blight

The effect of different fungicide programmes on the incidence of foliage blight can be compared by using the delay in disease onset, the level of foliage blight at the end of the season or by using the area under the disease progress curve (AUDPC) which measures the rate of disease development during the course of the whole epidemic.

Delay in disease onset

The delay in disease onset is the length in days between the first record of disease in the untreated control and the first record in the experimental treatment. The delay in disease onset for the different treatments is given in Tables 3 and 4. All fungicide treatments significantly delayed the date of disease onset compared with the untreated control. Compared with the routine control treatment, the NegFry and Plant Plus significantly delayed disease onset in King Edward in 2001, as did NegFry and ProPhy in Rooster. In 2002 there were no significant differences between treatments in terms of delaying disease onset, while in 2003, disease developed significantly earlier in King Edward following the Plant Plus programme compared with the routine control. In general, the date of disease onset was not significantly different between routine programmes and DSS programmes irrespective of the cultivar (Tables 3 & 4).

Table 3**: Effect of different decision support based fungicide programmes and routine fungicide application on the delay in disease onset (in days) compared with an untreated control (cv. K. Edward)**

Programme	2001	2002	2003	Mean
Shirlan Routine 7-day Control	6.50	20.25	28.00	18.25
NegFry	11.25	20.25	21.00	17.50
ProPhy	9.50	14.50	23.33	15.77

SimPhyt	8.00	25.00	25.67	19.55
Plant Plus	11.00	20.00	14.00	15.00
LSD (5%)	4.25	14.75	11.71	

Table 4**: Effect of different decision support based fungicide programmes and routine fungicide application on the delay in disease onset (in days) compared with an untreated control (cv. Rooster)**

Programme	2001	2002	2003	Mean
Shirlan Routine 7-day Control	8.00	23.00	10.50	13.83
NegFry	14.75	16.25	15.75	15.58
ProPhy	14.50	28.25	26.25	23.00
SimPhyt	6.50	19.75	21.00	15.75
Plant Plus		24.75	12.25	18.50
LSD (5%)	5.95	10.03	21.55	

Foliage blight at end of season

The % foliage blight for the different treatments at the end of the growing season is given in Tables 5 and 6. In each of the three years, all fungicide treatments significantly reduced the incidence of foliage blight at the end of the season compared with the untreated control. When compared with the routine control, no decision support system resulted in significantly more foliage blight at the end of the season, irrespective of the cultivar or year. In the case of King Edward in 2001, the NegFry, ProPhy and Plant Plus DSS resulted in significantly less foliage blight that the routine control. These results would confirm that none of the DSS's resulted in inferior disease control when compared with the 7-day routine application of fluazinam.

Table 5**: Effect of different decision support based fungicide programmes on the % foliage blight at the end of the season compared with routine fungicide application and an untreated control (cv. King Edward)**

Programme	2001	2002	2003
Untreated control	100.00	80.00	100.00
Shirlan Routine 7-day Control	50.00	0.78	3.67
NegFry	15.00	0.78	3.67
ProPhy	10.00	0.10	5.00

SimPhyt	31.25	0.55	5.00
Plant Plus	15.00	0.10	5.00
LSD (5%)	19.36	6.15	2.02
LSD (5% excl. untreated control)	21.86	0.58	2.45

Table 6: **Effect of different decision support based fungicide programmes on the % foliage blight at the end of the season compared with routine fungicide application and an untreated control (cv. Rooster)**

Programme	2001	2002	2003
Untreated control	100.00	100.00	100.00
Shirlan Routine 7-day Control	10.00	8.78	1.00
NegFry	10.00	3.00	1.00
ProPhy	15.00	1.78	1.00
SimPhyt	27.50	2.00	1.00
Plant Plus		1.00	1.00
LSD (5%)	26.66	7.32	1.12
LSD (5% excl. untreated control)	31.25	8.06	1.22

Area under the disease progress curve

The area under the disease progress curve (AUDPC) measures the development of disease over the whole season and is a more accurate assessment of differences between treatments over the course of the epidemic. All fungicide treatments significantly reduced the area under the disease progress curve compared with the untreated control (Tables 7 & 8).

When the programmes applied as per the decision support systems are compared with the fluazinam 7-day routine programme, it can be seen that there was no significant difference between the programmes in any of the years or in either of the cultivars. This again would confirm that the decision support systems resulted in the same level of blight control as the routine application of fluazinam at 7-day intervals.

Table 7: **Effect of different decision support based fungicide programmes on the Area Under the Disease Progress Curve (AUDPC) compared with routine fungicide application and an untreated control (cv. K. Edward)**

	2001	2002	2003
Untreated Control	2,327	1,427	2,346
Shirlan Routine 7-day Control	442	11	35
NegFry	95	14	26
ProPhy	67	2	33
SimPhyt	211	5	32
Plant Plus	94	5	29
LSD (5%)	245	129	74
LSD (5%) excl. untreated control	235	9	17

Table 8**: Effect of different decision support based fungicide programmes on the Area Under the Disease Progress Curve (AUDPC) compared with routine fungicide application and an untreated control (cv. Rooster)**

	2001	2002	2003
Untreated Control	2,212	2,363	2,470
Shirlan Routine 7-day Control	78	39	9
NegFry	67	22	17
ProPhy	85	10	7
SimPhyt	246	27	26
Plant Plus		11	12
LSD (5%)	191	145	170
LSD (5%) excl. untreated control	214	33	13

Effect on yield

The marketable yields for the different treatments in the two varieties in each year are given in Tables 9 and 10. The yield varied considerably between years, with the highest yields recorded in 2001 and the lowest in 2002. All fungicide treatments resulted in significantly higher marketable yields compared with the untreated control in all years irrespective of the variety. Within the fungicide treatments, the DSS programmes generally out-yielded the routine fungicide treatment. However, these differences were only significant for Plant-Plus in King Edward in 2001. Within the DSS treatments there were no significant differences in marketable yield in any of the years or either of the varieties.

Table 9: **Effect of different decision support based fungicide programmes on the marketable yield (t ha^{-1}) compared with routine fungicide application and an untreated control (cv. K. Edward)**

	2001	**2002**	**2003**	**Mean**
Untreated Control	30.90	28.16	14.59	24.55
Shirlan Routine 7-day Control	38.92	34.36	26.40	33.23
NegFry	40.20	35.26	26.11	33.86
ProPhy	40.92	35.00	29.17	35.03
SimPhyt	38.98	40.12	24.35	34.48
Plant Plus	48.08	35.12	28.00	37.06
LSD (5%)	11.74	6.16	8.02	
LSD (5%) excl. untreated control	10.01	6.38	8.94	

Table 10: **Effect of different decision support based fungicide programmes on the marketable yield (t ha^{-1}) compared with routine fungicide application and an untreated control (cv. Rooster)**

	2001	**2002**	**2003**	**Mean**
Untreated Control	39.28	28.34	28.77	32.13
Shirlan Routine 7-day Control	47.74	39.80	41.00	42.76
NegFry	50.02	41.20	43.44	44.89
ProPhy	51.10	41.64	43.00	45.25
SimPhyt	51.60	40.36	42.06	44.67
Plant Plus		43.28	44.46	43.87
LSD (5%)	9.24	8.30	4.57	
LSD (5%) excl. untreated control	10.25	8.84	4.25	

The total yields for the different treatments in the two varieties in each year are given in Tables 11 and 12. All fungicide treatments resulted in higher total yields compared with the untreated control in all years, irrespective of the variety. In most cases this difference was significant. Within the fungicide treatments the DSS programmes generally out-yielded the routine fungicide treatment. However, these differences were only significant for Plant-Plus in Rooster in 2003. Within the DSS treatments, there were no significant differences in total yield in any of the years or either of the varieties.

Table 11**: Effect of different decision support based fungicide programmes on the total yield (t ha^{-1}) compared with routine fungicide application and an untreated control (cv. K. Edward)**

	2001	**2002**	**2003**	**Mean**
Untreated Control	40.62	35.84	21.92	32.79
Shirlan Routine 7-day Control	49.74	42.96	35.71	42.80
NegFry	49.74	43.16	35.23	42.71
ProPhy	52.02	43.36	37.84	44.41
SimPhyt	48.90	48.96	33.71	43.86
Plant Plus	57.92	43.70	36.96	46.19
LSD (5%)	10.08	6.84	9.01	
LSD (5%) excl. untreated control	8.84	7.41	9.74	

Table 12**: Effect of different decision support based fungicide programmes on the total yield (t ha^{-1}) compared with routine fungicide application and an untreated control (cv. Rooster)**

	2001	**2002**	**2003**	**Mean**
Untreated Control	46.53	39.54	39.07	41.71
Shirlan Routine 7-day Control	54.16	48.56	50.08	50.93
NegFry	56.72	50.60	51.87	53.06
ProPhy	57.38	51.18	51.28	53.28
SimPhyt	57.57	49.78	52.88	53.40
Plant Plus	-	51.96	54.38	53.17
LSD (5%)	8.28	8.27	3.73	
LSD (5%) excl. untreated control	9.42	8.67	3.78	

Effect on tuber blight

Despite the existence of good conditions for tuber infection in some years, the overall level of disease during the course of this experiment was low. As expected, there were higher levels of tuber blight in the susceptible variety King Edward compared with the resistant variety Rooster. The incidence of tuber blight in both varieties following the different fungicide programmes is given in Tables 13 and 14. In the case of the susceptible variety King Edward, all fungicide treatments significantly reduced the incidence of tuber blight compared with the untreated control except in the case of the routine Shirlan control in 2001 (Table 14). In the more tuber resistant variety Rooster, fungicide application significantly reduced tuber blight only in 50% of cases (Table 13).

Within the fungicide treatments there were no significant differences between treatments for the resistant variety Rooster. In the case of the more susceptible variety King Edward all the DSS programmes resulted in significantly lower levels of tuber blight than the routine Shirlan control in 2001 except for Simphyt. More importantly, the routine Shilan did not result in significantly better tuber blight control in any of the years or for any of the DSS programmes. This confirms that all DSS programmes give equivalent tuber blight control to the routine Shirlan application at 7-day intervals, even with a very tuber blight susceptible variety.

Table 13**: Effect of different decision support based fungicide programmes on the yield of blighted tubers (t ha^{-1}) compared with routine fungicide application and an untreated control (cv. K. Edward)**

	2001	**2002**	**2003**	**Mean**
Untreated Control	0.20	0.26	0.40	0.29
Shirlan Routine 7-day Control	0.12	0.00	0.00	0.04
NegFry	0.04	0.02	0.08	0.05
ProPhy	0.02	0.00	0.00	0.01
SimPhyt	0.06	0.04	0.01	0.04
Plant Plus	0.02	0.00	0.03	0.02
LSD (5%)	0.14	0.14	0.21	
LSD (5%) excl. untreated control	0.08	0.05	0.04	

Table 14**: Effect of different decision support based fungicide programmes on the yield of blighted tubers (t ha^{-1}) compared with routine fungicide application and an untreated control (cv. Rooster)**

	2001	**2002**	**2003**	**Mean**

Untreated Control	0.13	0.16	0.00	0.10
Shirlan Routine 7-day Control	0.02	0.04	0.00	0.02
NegFry	0.04	0.08	0.00	0.04
ProPhy	0.00	0.02	0.00	0.07
SimPhyt	0.00	0.06	0.00	0.02
Plant Plus		0.10	0.00	0.05
LSD (5%)	0.08	0.11	0.00	
LSD (5%) excl. untreated control	0.05	0.11	0.00	

DISCUSSION

With reduced fungicide use it would be important to use the most effective fungicide and this could be particularly important in relation to tuber blight control. Shirlan has been shown to be an effective and robust fungicide for the control of both foliage and tuber blight in potatoes when used at 7-day intervals (Dowley & O'Sullivan, 1995). Any fungicide application programme, which resulted in equivalent disease control to a 7-day Shirlan routine programme, could be considered to be robust and reliable. During the course of this experiment, the foliage blight control achieved with the different DSS programmes showed no significant difference from the routine application of Shirlan at 7-day intervals. This would confirm that there was no loss in foliage blight control following the use of decision support systems.

Earlier experiments at Oak Park confirmed that the NegFry decision support system gave excellent control of both foliage and tuber blight in the tuber blight resistant variety, Rooster (Leonard *et al*., 2002). This raised the question of the ability of decision support systems to give adequate control of tuber blight in tuber blight susceptible varieties. The current experiments confirmed that all DSS programmes examined gave equivalent tuber blight control to the routine Shirlan application at 7-day intervals even with a very tuber blight susceptible variety.

During the three years of this experiment, the decision support systems reduced fungicide use by between 10% and 58%. The NegFry and Simphyt DSS resulted in much greater fungicide savings compared with ProPhy and Plant-Plus. As a result the most appropriate DSS for Irish growers and consumers would be either NegFry or Simphyt. However, the cost of fungicide application in potatoes is relatively inexpensive and therefore growers will need another incentive to introduce a DSS system into their production programmes. This could come in the form of consumer demand, a statutory order to reduce fungicide input or more likely as a requirement to justify fungicide use by the large food retailers. Whatever the driving force, decision support systems will play a significant part in future potato production.

Potato production in Ireland tends to be carried out on rented land which may be located far from the growers base. This would give rise to problems of information transfer from in-crop weather stations. It may also require a number of weather stations to cover different fields for the same grower. This problem would be eliminated if we had a national or regional weather station grid that would be centrally controlled and could be assessed through the Internet.

CONCLUSIONS

- No significant loss in foliage blight control was recorded following the use of the DSS programmes.
- No significant loss in tuber blight control was recorded following the use of the DSS programmes, even in a tuber blight susceptible variety.
- The DSS programmes resulted in a 10 to 58% saving in fungicide use when compared with a 7-day routine Shirlan treatment.
- The greatest savings were recorded following the NegFry and Simphyt programmes.

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APPENDIX 1

Table 14: Fungicides used and the dates of application for the King Edward trial 2001

Programme	Fungicide	Rate of Product ha^{-1}	Dates of application
Untreated	None	None	None
Routine	Fluazinam	0.40 l	13/6, 20/6, 27/6, 3/7, 11/7, 19/7, 25/7, 1/8, 8/8, 15/8, 22/8, 29/8, 5/9, 12/9
NegFry	Fluazinam	0.40 l	25/6, 3/7, 13/7, 12/8, 20/8, 3/9
SimPhyt	Fluazinam	0.40 l	25/6
	Metalaxyl/	2.50 kg	4/7, 19/7
	Mancozeb	0.20 l	20/6, 15/8
	Fluazinam + Mancozeb/ Cymoxanil	1.88 kg	
ProPhy	Fluazinam	0.40 l	29/5, 7/6, 27/6, 3/7, 3/8, 9/8, 15/8, 22/8, 5/9
	Propamocarb/ Mancozeb	4.00 l	19/6
	Mancozeb/Cymoxanil	2.50 kg	12/7, 30/8
Plant Plus	Fluazinam Mancozeb/ Cymoxanil	0.40 l 2.50 kg	27/6, 3/7, 1/8, 8/8, 13/8, 20/8, 31/8 9/7, 6/9

Table 15: Fungicides used and the dates of application for the Rooster trial 2001

Program	Fungicid	Rate of	Dates of application

me	e	Product ha^{-1}	
Untreated	None	None	None
Routine	Fluazinam	0.40 l	13/6, 20/6, 27/6, 3/7, 11/7, 19/7, 25/7, 1/8, 8/8, 15/8, 22/8, 29/8, 5/9, 12/9
NegFry	Fluazinam	0.40 l	27/6, 9/7, 27/7, 13/8, 22/8, 3/9
SimPhyt	Fluazinam	0.40 l	25/6
	Metalaxyl/ Mancozeb	2.50 kg	4/7, 19/7
	Fluazinam +	0.20 l	20/6, 15/8
	Mancozeb/ Cymoxanil	1.88 kg	
ProPhy	Fluazinam	0.40 l	29/5, 7/6, 27/6, 3/7, 3/8, 9/8, 15/8,
	Propamocarb/ Mancozeb	4.00 l	19/6, 22/8, 5/9
	Mancozeb/Cymoxanil	2.50 kg	12/7, 30/8

Table 16: Fungicides used and the dates of application for the King Edward trial 2002

Programme	Fungicide	Rate of Product ha^{-1}	Dates of application
Untreated	None	None	None
Routine	Fluazinam	0.40 l	12/6, 19/6, 26/6, 3/7, 10/7, 19/7, 24/7, 31/7, 7/8, 14/8, 21/8, 28/8, 4/9, 11/9
NegFry	Fluazinam	0.40 l	14/6, 9/7, 24/7, 7/8, 19/8, 29/8
SimPhyt	Fluazinam	0.40 l	14/6, 12/7, 4/9
	Metalaxyl/Mancozeb	2.50 kg	1/7
	Fluazinam +	0.20 l	19/7, 23/7
	Mancozeb/Cymoxanil	1.88 kg	
	Propamocarb/ Mancozeb		21/8
	Mancozeb/Cymoxanil		7/8, 14/8
ProPhy	Fluazinam	0.40 l	29/5, 10/6, 17/6, 4/7, 11/7, 23/7, 29/7, 29/8, 4/9, 10/9
	Propamocarb/ Mancozeb	4.00 l	15/7, 7/8

	Mancozeb/Cymoxanil	2.50 kg	1/7, 14/8, 22/8
Plant Plus	Dimethomorph/Mancozeb	2.40 kg	10/6
	Fluazinam	0.40 l	13/6, 21/6, 1/7, 9/7, 17/7, 29/7, 14/8, 21/8, 29/8, 10/9
	Propamocarb/Mancozeb	2.50 kg	7/8

Table 17: Fungicides used and the dates of application for the Rooster trial 2002

Programme	Fungicide	Rate of Product ha^{-1}	Dates of application
Untreated	None	None	None
Routine	Fluazinam	0.40 l	12/6, 19/6, 26/6, 3/7, 10/7, 19/7, 24/7, 31/7, 7/8, 14/8, 21/8, 28/8, 4/9, 11/9
NegFry	Fluazinam	0.40 l	1/7, 17/7, 30/7, 7/8, 19/8, 29/8
SimPhyt	Fluazinam	0.40 l	14/6, 12/7, 4/9
	Metalaxyl/Mancozeb	2.50 kg	1/7
	Fluazinam +	0.20 l	19/7, 23/7
	Mancozeb/Cymoxanil	1.88 kg	
	Propamocarb/Mancozeb		21/8
	Mancozeb/Cymoxanil		7/8, 14/8
Programme	**Fungicide**	**Rate of Product ha^{-1}**	**Dates of application**
ProPhy	Fluazinam	0.40 l	29/5, 10/6, 4/7, 11/7, 23/7, 30/7, 19/8, 9/9
	Propamocarb/Mancozeb	4.00 l	17/6, 1/7, 7/8, 14/8, 27/8
	Mancozeb/Cymoxanil	2.50 kg	15/7, 4/9
Plant Plus	Propamocarb/Mancozeb	2.40 kg	10/6
	Fluazinam	0.40 l	13/6, 21/6, 1/7, 9/7, 17/7, 29/7, 14/8, 19/8, 21/8, 27/8, 10/9
	Propamocarb/Mancozeb	4.00 l	7/8

Table 18: Fungicides used and the dates of application for the King Edward trial 2003

Programme	Fungicide	Rate of Product ha^{-1}	Dates of application
Untreated	None	None	None
Routine	Fluazinam	0.40 l	11/6, 17/6, 25/6, 2/7, 9/7, 16/7, 23/7, 30/7, 6/8, 13/8, 20/8, 27/8, 3/9
NegFry	Fluazinam	0.40 l	13/6, 1/7, 11/7, 21/7, 30/7, 18/8, 28/8
SimPhyt	Metalaxyl/Mancozeb	2.50 kg	13/6,
	Dimethomorph /Mancozeb +	1.80 kg	23/6, 27/6,
	Fluazinam	0.20 l	
	Fluazinam	0.40 l	8/7, 21/7, 28/8
	Propamocarb/ Mancozeb	4.00 l	30/7, 7/8, 18/8,
ProPhy	Fluazinam	0.40 l	10/6, 8/7,
	Mancozeb/Cymoxanil	2.50 kg	20/6, 16/7
	Propamocarb/ Mancozeb	4.0 l	1/7, 21/7, 25/7, 5/8, 11/8, 1/9
Plant Plus	Fluazinam	0.40 l	10/6, 18/6, 1/7, 8/7, 16/7, 21/7, 25/7, 5/8, 11/8
	Mancozeb/Cymoxanil	2.40 kg	30/7,

Table 19: Fungicides used and the dates of application for the Rooster trial 2003

Programme	Fungicide	Rate of Product ha^{-1}	Dates of application
Untreated	None	None	None
Routine	Fluazinam	0.40 l	11/6, 17/6, 25/6, 2/7, 9/7, 16/7, 23/7, 30/7, 6/8, 13/8, 20/8, 27/8, 3/9
NegFry	Fluazinam	0.40 l	13/6, 1/7, 16/7, 25/7, 27/8
SimPhyt	Metalaxyl/Mancozeb	2.50 kg	13/6, 21/7,
	Fluazinam	0.40 l	24/6, 8/7, 18/8, 30/8
	Mancozeb/Cymoxanil	2.50 kg	30/7,
	Propamocarb/ Mancozeb	4.00l	8/8,

ProPhy	Fluazinam	0.40 l	10/6, 20/6, 8/7, 21/7,
	Propamocarb/ Mancozeb	4.00 l	1/7, 5/8, 11/8, 1/9
	Mancozeb/Cy moxanil	2.50 kg	16/7, 30/7,
Plant Plus	Fluazinam	0.40 l	11/6,18/6, 1/7, 8/7, 16/7, 21/7, 25/7, 5/8, 11/8, 1/9
	Mancozeb/Cy moxanil	2.50 kg	30/7,