# Research Report

# Exploring the potential for cost savings through matching blight fungicide inputs to cultivar resistance

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# 1 Summary

In 2007 the control of foliar and tuber blight was investigated using combinations of cultivar resistance, fungicide product, spray interval and dose in two trials: one at Llanilar, near Aberystwyth, Ceredigion and one at SAC, Auchincruive Estate, Ayrshire. The primary objective of this study was to evaluate if integrated control of blight, using cultivar resistance to replace some of the fungicide input, was feasible under GB conditions.

At each site, three cultivars were treated with three fungicides at full UK label rate, three-quarter rate and half-rate at 7-day intervals, and full and half-rate at 10-day intervals. Cultivars with different foliar and tuber blight resistances were used (National List foliar blight rating/tuber blight rating): Shepody (2/3), Maris Piper (4/5) and Lady Balfour (8/7). The fungicide active ingredients tested were mancozeb (in Dithane NT DG), fluazinam (in Shirlan 500 SC) and fluopicolide + propamocarb HCl (in Infinito SC) and these were evaluated as components of season-long spray programmes. They were applied from the canopy stable growth stage through to haulm desiccation.

When interpreting the results from these trials the following points must be remembered: the extreme blight pressure in 2007, the presence of 13_A2 at both sites and the fact that the 7-day programmes at the Welsh site were adversely affected by 45 mm of rain shortly after the first 7-day treatment was applied.

The results from both trials demonstrate that cultivar resistance could be utilized in Britain to reduce fungicide inputs even where blight pressure is extremely high and the more aggressive 13_A2 genotype is present.

The relative efficacies of the integrated control treatments, i.e. the combination of a cultivar with a higher resistance rating with less of the same fungicide, in controlling foliar blight was most often significantly better than the combination of the more susceptible variety treated with the maximum fungicide input. In 26 out of 48 comparisons the integrated control treatments gave significantly better control, in 21 there was no significant difference and in only one was foliar blight control significantly worse.

The relative efficacies of the integrated control treatments compared with the benchmark combination of susceptible cultivar and maximum fungicide input was influenced by the trial, fungicide product and the interaction between these two factors. At both trial sites integrated control treatments using Dithane NT almost always gave significantly better control of foliar blight than the benchmark. However, for the two other fungicide products, Shirlan and Infinito, the results were different at the two sites.

At the Ayrshire site all eight integrated control treatments using Shirlan gave significantly better control whereas at the Welsh site only one integrated treatment did. For Infinito two integrated treatments at the Ayrshire site resulted in significantly better control but for one integrated control treatment in the Llanilar trial foliar blight

control was significantly worse. In both trials the benefit to foliar blight control from an integrated control system was greater where the input of the same fungicide was reduced rather than substituting a less effective fungicide.

Efficacy against tuber blight was less easy to summarise because of the low incidences of tuber blight in many of the treatments at both sites. However, for Dithane NT, in 14 out of 16 comparisons the integrated control treatments resulted in significantly better control of tuber blight than Shepody treated with the maximum fungicide input. At the SAC site, for seven out of eight comparisons with Shirlan the integrated control treatments gave significantly less tuber blight.

In 32 out of 56 comparisons blight-free yield was significantly higher for the integrated control treatments compared with the benchmark treatment of Shepody treated with 1.6 L of Infinito every 7 days. No yields for integrated control treatments were significantly less.

In integrated control systems is it better to reduce fungicide input by using a lower dose of fungicide more often or a higher dose less often? Over both sites less fungicide more often gave significantly better control of foliar blight in 13 out of 36 comparisons. For only two comparisons did this combination result in significantly worse foliar blight control. There was no consistent effect of these two options on tuber blight control. Yields were generally not significantly affected by which approach was used. However, on four out of 36 comparisons the less fungicide more often approach resulted in a significantly higher yield.

The foliar resistances of 13 varieties with a published rating of 5 or above and grown widely in the UK were evaluated against the 13_A2 genotype in a 2008 field test to determine if the ratings were different when challenged by this genotype of *P. infestans*. The resistances of these 13 varieties were evaluated alongside the six Eucablight standards and four additional susceptible standards. The foliar resistance ratings obtained in 2008 were reduced for many cultivars and the reduction was clearly greater for the cultivars with higher published ratings. For several more-resistant cultivars the drop in rating was between 2 and 5 on the 9-point scale. One possible explanation for some of the apparent changes in ratings is discussed.

# 2 Experimental Section

## *2.1 Introduction*

Growers in GB are facing increasing pressure to reduce production costs and to protect crops from late blight at a time when consumers and retailers want to see a reduction in the environmental impact of fungicides. At the same time, there is increasing evidence that the population of *P. infestans* in GB has changed in recent years, with a shift towards possibly more aggressive strains and the widespread dominance of *P. infestans* genotype 13_A2 over other A2 and A1 genotypes in 2007 (Cooke *et al*., 2008). Using cultivar resistance offers the potential to reduce fungicide inputs, whilst still achieving adequate control of *P. infestans* in the UK and is a viable option for the future.

Research conducted throughout Europe and the US has shown reduced fungicide inputs can successfully reduce foliar blight severity when used on potato cultivars with good foliar blight resistance. In the United States, fungicide dose (fluazinam: 0, 33, 50, 66 or 100% of label dose) and spray interval (5, 7, 10 and 14 days) have been investigated on cultivars with varying degrees of resistance (Kirk *et al.,* 2005). Similarly, research in Norway was conducted using three doses of fluazinam (100%, 50% and 33% of the label dose) applied at three intervals (7, 14 and 21 days) to six cultivars with different levels of foliar and tuber blight resistance (Naerstad *et al.,* 2007). Also, as part of the Dutch Umbrella Plan, the appropriate dose of Shirlan, i.e. 20, 40, 60, 80 or 100% of 0.4 l/ha, for the 30 most commonly grown cultivars was determined (Kessel *et al.,* 2006). The first three fungicide applications on these trials were at fixed 7-day intervals, with Plant Plus used to determine subsequent spray dates. Researchers in Denmark used a weekly spraying model to determine the appropriate doses (25, 50, 75 or 100% of label dose) of seven fungicides, taking into account cultivar resistance as well as blight risk and the presence of blight in the area (Neilsen, 2004).

The work above shows the potential for adjusting fungicide input depending on cultivar resistance, however, there are too few cultivars grown in common between countries, and differences in climatic conditions and blight populations prevent this research being directly applicable to GB. A Potato Council-funded trial in Ayrshire in 2006 demonstrated that cultivar resistance could be substituted for fungicide input in GB, with foliar blight consistently less severe on the more resistant cultivar Saturna than King Edward. However, further trials were required to test whether similar results would be achievable in different years and locations.

The aim of this work was to study the interactions between cultivar resistance, fungicide dose and application intervals for three GB cultivars and determine the scope for utilising existing cultivar resistance to improve the targeting of fungicide spray programmes. Specific project objectives were:-

- To evaluate the control of foliar blight using combinations of cultivar resistance, fungicide spray interval, product and dose.

 

- To evaluate the control of tuber blight using combinations of cultivar resistance, fungicide spray interval, product and dose.

- To determine the effects of the above treatment factors on blight-free yield (> 35 mm).

## *2.2 Material and methods*

### 2.2.1 Integrated control trials

*2.2.1.1 Experimental design and fungicide application*

*Design*

The fungicide treatments were applied to the cultivars Shepody, Maris Piper and Lady Balfour. The experiment was a split plot design with the fungicide programmes as the main plots and cultivars as sub plots in four replicate blocks. The fungicide spray programmes were randomised in each block and the cultivars were randomised within each fungicide main plot.

The plots at both sites were four rows wide, measuring 4.0 m at Llanilar and 3.4 m at Auchincruive. Plot lengths were 9.0 m at Llanilar and 7.5 m at Auchincruive. Each cultivar sub plot was 32 plants (four rows of 2.4m and 1.75 m at Llanilar and Auchincruive respectively) separated by 0.9 m unplanted row length at Llanilar and 1.125 m at Auchincruive. The main plots were separated by 1.5 m unplanted row length. At both sites a single row of King Edward was planted between each of the blocks as an infector row. The infector rows were not sprayed with fungicide and unsprayed spreader rows of King Edward were inoculated.

At Llanilar inoculation took place on 5 July using a mixture of the following *P. infestans* isolates: 2006_4168B (genotype 7_A1), 2006_4008D (genotype 2_A1), 2006_4256B (genotype 8a_A1), 2006_4100A (genotype 6_A1) and 2006_3928A (genotype 13_A2). The experimental plots were surrounded either by 2 rows or a 2.0 m wide headland. The headlands were sprayed with a range of different fungicides at 10-day intervals.

At Auchincruive inoculation took place on 16 July using a mixture of the following *P. infestans* isolates: 2006_4168B (genotype 7_A1) and 2006_4232E (genotype 8a_A1). These isolates were representative of the genotypes prevalent in Scotland in 2006. On 8 August, five samples from the trial field were genotyped and were found to be the more aggressive 13_A2. Fifty-seven isolates from the Potato Council-funded trial were sampled on 13 August and genotyped: 6 were 4232E but 49 were the genotype 13_A2. This strain must have entered the trial field as natural infection. Consequently the trial site contained a mixture of A1 and A2 mating types.

*Fungicide application*

At Llanilar, spray treatments were applied in 250 litres of water per hectare using a hand held Oxford Precision Sprayer operating at 200 kPa through 110° flat fan nozzles. At Auchincruive fungicides were applied in 200 litres of water per ha using a tractor-mounted, modified AZO compressed air sprayer, operating at 3.5 bars to give a medium/fine spray quality. The nozzles were Lurmark F03-110. The details of spray timings for each site are given in Appendix A, Tables A2 and A3.

*2.2.1.2 Spray programmes, active ingredients and rates of use*

TABLE 2.2.1 FUNGICIDE SPRAY PROGRAMMES

| | |
|---|---|
| T1 | Tattoo* (@ 4.0 L/ha) ( x 3 sprays) applied at 10-day intervals followed by untreated |
| T2 | Tattoo* (@ 4.0 L/ha) ( x 3 sprays) applied at 10-day intervals followed by Infinito (@ 1.6 L/ha) applied at 7-day intervals throughout until desiccation |
| T3 | Tattoo* (@ 4.0 L/ha) ( x 3 sprays) applied at 10-day intervals followed by Infinito (@ 1.2 L/ha) applied at 7-day intervals throughout until desiccation |
| T4 | Tattoo* (@ 4.0 L/ha) ( x 3 sprays) applied at 10-day intervals followed by Infinito (@ 0.8 L/ha) applied at 7-day intervals throughout until desiccation |
| T5 | Tattoo* (@ 4.0 L/ha) ( x 3 sprays) applied at 10-day intervals followed by Infinito (@ 1.6 L/ha) applied at 10-day intervals throughout until desiccation |
| T6 | Tattoo* (@ 4.0 L/ha) ( x 3 sprays) applied at 10-day intervals followed by Infinito (@ 1.2 L/ha) applied at 10-day intervals throughout until desiccation |
| T7 | Tattoo* (@ 4.0 L/ha) ( x 3 sprays) applied at 10-day intervals followed by Shirlan (@ 0.4 L/ha) applied at 7-day intervals throughout until desiccation |
| T8 | Tattoo* (@ 4.0 L/ha) ( x 3 sprays) applied at 10-day intervals followed by Shirlan (@ 0.3 L/ha) applied at 7-day intervals throughout until desiccation |
| T9 | Tattoo* (@ 4.0 L/ha) ( x 3 sprays) applied at 10-day intervals followed by Shirlan (@ 0.2 L/ha) applied at 7-day intervals throughout until desiccation |
| T10 | Tattoo* (@ 4.0 L/ha) ( x 3 sprays) applied at 10-day intervals followed by Shirlan (@ 0.4 L/ha) applied at 10-day intervals throughout until desiccation |
| T11 | Tattoo* (@ 4.0 L/ha) ( x 3 sprays) applied at 10-day intervals followed by Shirlan (@ 0.3 L/ha) applied at 10-day intervals throughout until desiccation |
| T12 | Tattoo* (@ 4.0 L/ha) ( x 3 sprays) applied at 10-day intervals followed by Dithane NT (@ 2.0 kg /ha) applied at 7-day intervals throughout until desiccation |
| T13 | Tattoo* (@ 4.0 L/ha) ( x 3 sprays) applied at 10-day intervals followed by Dithane NT (@ 1.5 kg /ha) applied at 7-day intervals throughout until desiccation |
| T14 | Tattoo* (@ 4.0 L/ha) ( x 3 sprays) applied at 10-day intervals followed by Dithane NT (@ 1.0 kg /ha) applied at 7-day intervals throughout until desiccation |
| T15 | Tattoo* (@ 4.0 L/ha) ( x 3 sprays) applied at 10-day intervals followed by Dithane NT (@ 2.0 kg /ha) applied at 10-day intervals throughout until desiccation |
| T16 | Tattoo* (@ 4.0 L/ha) ( x 3 sprays) applied at 10-day intervals followed by Dithane NT (@ 1.5 kg /ha) applied at 10-day intervals throughout until desiccation |

*Spray programmes started at the first blight warning or when haulm met along the rows, whichever was soonest. Unless specified otherwise, the first three spray treatments were applied at **10- day intervals** unless weather conditions were unsuitable and there was a risk of inaccurate spraying. Subsequent treatments were applied at **7 or 10-day intervals** according to the treatment list again unless weather conditions were unsuitable and there was a risk of inaccurate spraying.

At the Auchincruive site there was concern on 22 July that the general severity of foliar blight would be too high to allow a sensible evaluation of the different integrated control treatments that had not yet been applied. Therefore, on 23 July an additional blanket spray of 2.5 litres/ha of Merlin was applied, 5 days after the second application of Tattoo and 8 days before the third application of Tattoo (Appendix A, Table A2).

TABLE 2.2.2 FUNGICIDES AND RATE OF USE

| Fungicide | Active Ingredients (a.i.) | | Rate (kg or L/ha) | | | |
|---|---|---|---|---|---|---|
| | Common name | g/kg (L) product | active ingredient | Product | Fungicide rating: Foliar blight[2] | Fungicide rating: Curative activity[3] |
| Infinito SC[1] | fluopicolide + propamocarb HCl | 62.5 + 625/L | 100 + 1000 | 1.6 (L) | 3.8 | ++ |
| | | | 75 + 750 | 1.2 (L) | | |
| | | | 50 + 500 | 0.8 (L) | | |
| Shirlan SC | fluazinam | 500/L | 200 | 0.4 (L) | 2.6 | 0 |
| | | | 150 | 0.3 (L) | | |
| | | | 100 | 0.2 (L) | | |
| Dithane NT WG | mancozeb | 750 | 1500 | 2.0 | 2.0 | 0 |
| | | | 1125 | 1.5 | | |
| | | | 750 | 1.0 | | |

[1]Formulated mixture
[2] The foliar blight fungicide ratings are calculated from the results of 10 Euroblight trials between 2006 and 2008 using a standard protocol to evaluate leaf blight protection from season-long applications at 7-daty intervals. The scale is 2 (least effective control) to 5 (most effective control).
[3] The curative activity ratings are the subjective consensus view of European blight fungicide researchers. 0 = no control, + = reasonable control, ++ = good control, +++ = very good control
The Euroblight Fungicide Ratings Table can be viewed at **www.euroblight.net/function/FungicideComparison.asp**

*2.2.1.3 Assessments*

*Assessments of foliar blight*
Foliage blight was assessed regularly during the epidemic as a percentage of leaf area destroyed by blight using a modified MAFF key 2.1.1 – Potato Blight on the Haulm (Anon., 1947 & 1976; Large, 1952). A similar key, modified slightly, was used at Auchincruive.

| Blight % | | Description | | | |
|---|---|---|---|---|---|
| 0 | | Not seen | | | |
| 0.1 | 1+ | Lesion per plot | | ) | |
| 0.2 | 25 | Lesions per plot | | ) | |
| 0.3 | 50 | Lesions per plot | | ) | |
| 0.4 | 75 | Lesions per plot | | ) | |
| 0.5 | 100 | Lesions per plot | or | 1 lesion per plant ) | Assuming |
| 0.6 | | | | 2 lesions per plant) | 100 plants |
| 0.7 | | | | 4 lesions per plant) | per plot |
| 0.8 | | | | 6 lesions per plant) | |
| 0.9 | | | | 8 lesions per plant) | |
| 1.0 | | | | 10 lesions per plant) | |
| 5.0 | 1 | Lesion per compound leaf | or | 50 lesions per plant) | |
| 10.0 | 2 | Lesions per compound leaf | or | 100 lesions per plant) | |
| 25.0 | | Nearly every leaflet with blight lesions – plants still retaining their normal form – 75% plot leaf area remaining green | | | |
| 50.0 | | About half of the leaf area destroyed by blight | | | |
| 75.0 | | About three-quarters of the leaf area destroyed by blight | | | |
| 95.0 | | Stems green, only a few leaves remaining | | | |
| 100.0 | | All leaves dead, stems dead or dying | | | |

*Assessment of tuber blight*
At Llanilar, samples of 100 tubers (>35 mm) were taken from each cultivar sub-plot at harvest and assessed for tuber blight. Where there were fewer than 100 tubers this was recorded.

At Auchincruive the same number of tubers was sampled from each plot of the trial. The tuber blight incidences in other trials from the same field were low therefore it was decided to postpone the tuber blight assessment until after a period of storage at ambient (frost-free) temperatures. The assessment was made between 4 and 16 January 2008.

*Assessment of yield*
At both sites, the centre two rows of each cultivar sub-plot were hand lifted. All tubers >35 mm were included in the yield totals excluding split, green and rotted tubers.

*Assessment of growth stage*
Crop growth stage was recorded at Llanilar at each assessment date (Jeffries & Lawson, 1991). Ground cover was recorded at Auchincruive until it reached 100%.

TABLE 2.2.3 CROP DEVELOPMENT AT AUCHINCRUIVE: GROUND COVER OVER TIME

| Date | % ground cover |
|---|---|
| 6 July | 35 |
| 13 July | 61 |
| 19 July | 83 |
| 30 July | 96 |

*2.2.1.4 Statistical Analysis*

Differences between foliar blight means at each assessment date, tuber blight levels and ware yield were subjected to analysis of variance appropriate for a split plot design. The data were transformed before analysis where appropriate. In addition, the Area Under the Disease Progress Curve (AUDPC) was calculated for each sub-plot and this was also subjected to analysis of variance. The untreated control data were not included in the analyses because of the skewed distribution of the data. To aid interpretation of the data, the statistical significance of differences between treatment means was determined using the Least Significant Difference test at $P<0.05$ (5%).

## 2.2.2 Evaluation of cultivar resistance to foliar blight caused by genotype 13_A2

*2.2.2.1 Experimental design*

The 2008 trial was a field test with a design that complied with the appropriate Eucablight protocol. The trial was situated at the SAC blight fungicide trial site on the Auchincruive Estate, Ayrshire.

Twenty three varieties were screened: 13 popular varieties grown in Britain with ratings for foliar blight resistance equal or greater than 5, four susceptible standard varieties (Harmony, King Edward, Maris Piper and Remarka) and the six Eucablight standard cultivars (Alpha, Bintje, Eersteling, Escort, Gloria and Robijn). It was not possible to include differentials in the trial.

The fertiliser applied was 226, 159 and 215 kg/ha of N, $P_2O_5$ and $K_2O$ respectively. The trial was hand planted on 26 May. The herbicide applied was Defy (4 l/ha) plus Shotput (0.5 kg/ha) on 30 May.

There were three replicate plots per cultivar with four plants in each plot. These four plants were in the centre two rows of a four-row plot that was 3.4 m wide. The seed tubers were spaced 0.3 m apart within the row and there was a 1 m gap between plots within the row. The outer two rows were planted with King Edward to act as spreader rows. A King Edward plant opposite each cultivar plot was inoculated with a sporangia suspension of *P. infestans* isolate 07/39 on 8 July. Isolate 07/39 is genotype 13_A2 and has the virulence genes 1,2,3,4,5,6,7,10,11 (Alison Lees, personal communication).

*2.2.2.2 Assessments*

Foliar blight was assessed on 7 occasions between 24 July and 8 August inclusive.

*2.2.2.3 Statistical Analysis*

AUDPC values and 1 to 9 ratings for foliar blight resistance were calculated using the Euroblight website facility.

## 2.3 Results

### 2.3.1 Integrated control trials

**Important note:** It should be noted that because the data were generated in a single season the results should be treated with caution. Also, for Infinito the maximum number of treatments and/or total dose, as specified on the product label, were exceeded so that scientifically valid comparisons could be made.

*2.3.1.1 The foliar blight epidemic at Llanilar, Ceredigion in 2007*
The crop at Llanilar was planted in dry conditions on 2 May and emergence occurred from 26 May onwards, reaching 100% emergence by approximately 1 June. The daily rainfall recorded at the site together with spray timings are given in Fig. 2.3.1. Blight-favourable conditions, as defined by Smith Periods together with 'Near Misses', are also given in Fig. 2.3.1. These are taken from the BlightWatch section of the Potato Council website (www.potato.org.uk) which uses interpolation routines based on data from synoptic meteorological stations. The data for the Llanilar site uses the SY23 postcode cell. Air temperature and relative humidity were measured on site using a Metos weather station (ref: 0000052A) and data can be made available if required.

On 5 July, a blight strike was found on an untreated area of King Edward near to a hedge base at least 50 metres from the trial area. Samples of infected foliage were sent to the Central Science Laboratory on 9 July as part of the Fight against Blight campaign and were subsequently sent to SCRI for genotype testing. The reference number for this outbreak was 5470 and the isolate was found to be genotype 13_A2.

The 2007 potato growing season in GB was noted for a particularly severe blight epidemic due to the persistently wet conditions from mid June through most of July being very favourable to the disease. Infection was first recorded in the untreated plots on 8 July and it developed rapidly thereafter. Perhaps the most striking progress of the foliar epidemic was the increase in foliar infection from 2 % on 19 July to 36 % on 23 July. This is almost certainly as a result of the very heavy rainfall which occurred on 20 July and clearly shows the speed and aggressiveness of the epidemic in this trial in 2007. By early August, foliar blight had completely destroyed the haulm in the untreated plots and there was extensive infection in the treated plots ranging from 10 % to 76 % haulm infected on 8 August. Although there was clear treatment separation in such a severe epidemic, most spray programmes had effectively broken down by the end of August and the trial was desiccated on 22 August.

*2.3.1.2 Evaluation of integrated control treatments – Llanilar, Ceredigion.*

The application dates for the fungicide treatments at Llanilar are given in Fig. 2.3.1 and Appendix A, Table A3. Spray programme comparisons followed three applications of Tattoo applied during the rapid growth phase starting when the haulm was meeting along the rows on all three cultivars.

*Foliar Blight*

The disease pressure was exceptionally high and this should be considered when interpreting the results. A heavy rainfall event coincided with the first 7 day application treatment on 20 July (Fig. 2.3.1).

In order to assess the efficacy of the integrated control treatments they were compared with the benchmark treatment of Shepody treated with the highest rate of fungicide at 7-day intervals. The three benchmark treatments were 1.6 l/ha Infinito, 0.4 l/ha Shirlan and 2.0 kg/ha Dithane NT applied to Shepody every 7 days. Integrated control treatments were the two more resistant cultivars, Maris Piper and Lady Balfour, treated with less fungicide input than the highest rate at the shortest interval.

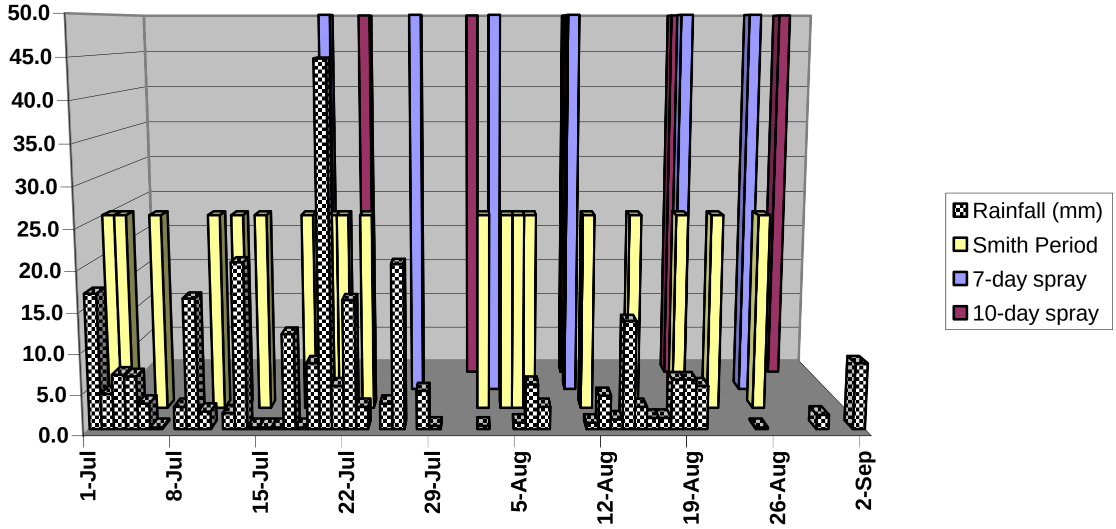


FIG. 2.3.1 THE TIMINGS OF THE 7-DAY AND 10-DAY SPRAYS IN RELATION TO DAILY RAINFALL (MM) AND SMITH PERIODS AT LLANILAR, CEREDIGION IN 2007

Comparison of the AUDPC values with that for 1.6 L of Infinito applied every 7 days on Shepody (benchmark treatment) showed a significant reduction in foliar blight on Maris Piper and Lady Balfour only where 1.6 L of Infinito had been applied at 7 day intervals (Fig. 2.3.2).  At 7 day intervals, the AUDPC where 1.2 L of Infinito was applied to more resistant cultivars Maris Piper and Lady Balfour was similar to 1.6 L Infinito applied to Shepody.  At 10 day intervals, 1.2 L and 1.6 L of Infinito gave similar foliar blight control on Maris Piper and Lady Balfour to the benchmark treatment.

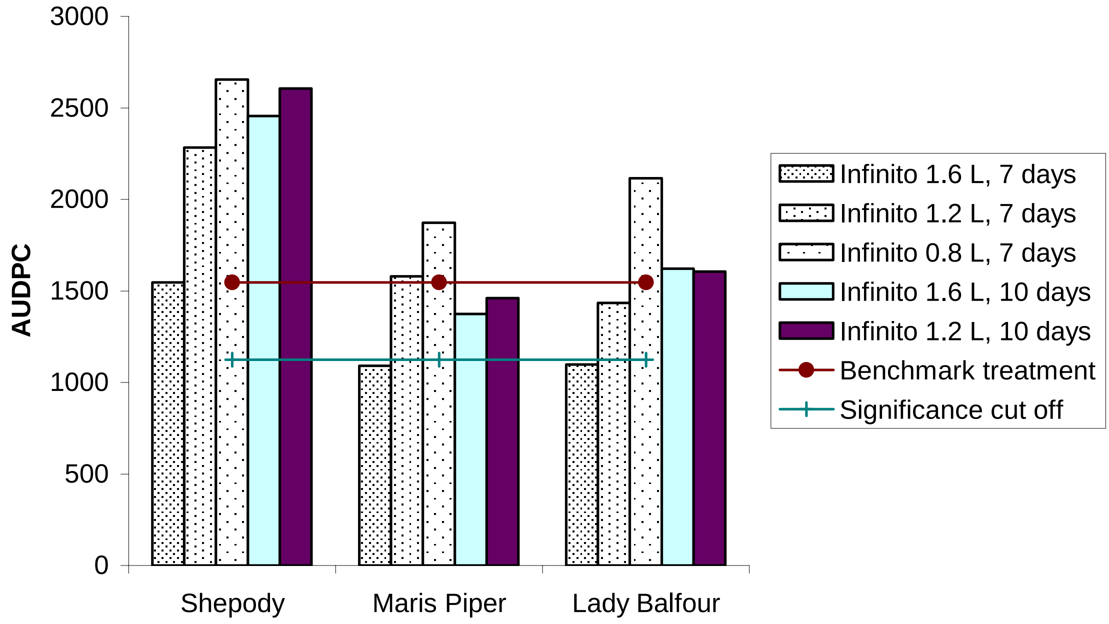


FIG. 2.3.2 FOLIAR BLIGHT SEVERITIES (AUDPC) FOR DIFFERENT COMBINATIONS OF CULTIVAR RESISTANCE AND FUNGICIDE INPUT IN RELATION TO THE BENCHMARK TREATMENT OF 1.6 L OF INFINITO APPLIED EVERY 7 DAYS TO THE CULTIVAR SHEPODY AT LLANILAR, CEREDIGION. AUDPC VALUES BELOW THE SIGNIFICANCE CUT-OFF LINE INDICATE SIGNIFICANTLY BETTER CONTROL THAN THE BENCHMARK TREATMENT.

Shirlan at 0.4 litres applied to Shepody at 7 day intervals (benchmark treatment) compared with the same interval, fungicide and rate applied to Maris Piper and Lady Balfour showed a significant reduction in foliar blight severity on the more resistant cultivars (Fig. 2.3.3).  Shirlan at 0.3 L applied at 7 day intervals to Maris Piper significantly reduced foliar blight severity compared to the benchmark.  The AUDPC for 0.2 L of Shirlan applied at 7 days on Maris Piper and Lady Balfour was similar to that of the benchmark.  Ten day intervals of Shirlan at 0.4 L or 0.3 L did not reduce foliar blight severity on any of the more resistant cultivars.

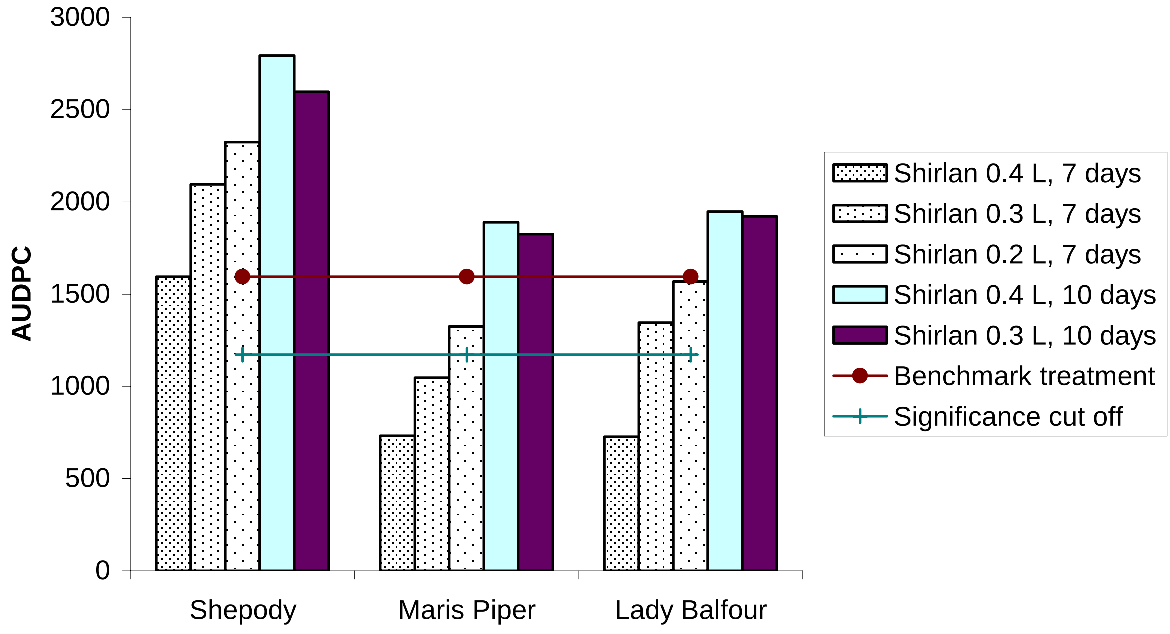


FIG 2.3.3 FOLIAR BLIGHT SEVERITIES (AUDPC) FOR DIFFERENT COMBINATIONS OF CULTIVAR RESISTANCE AND FUNGICIDE INPUT IN RELATION TO THE BENCHMARK TREATMENT OF 0.4 L OF SHIRLAN APPLIED EVERY 7 DAYS TO THE CULTIVAR SHEPODY AT LLANILAR, CEREDIGION. AUDPC VALUES BELOW THE SIGNIFICANCE CUT-OFF LINE INDICATE SIGNIFICANTLY BETTER CONTROL THAN THE BENCHMARK TREATMENT.

Comparison of blight development on Maris Piper and Lady Balfour with the benchmark (Dithane 2.0 kg at 7 days on Shepody) found significantly less disease where more resistant varieties had been used, regardless of rate and interval (Figure 2.3.4).

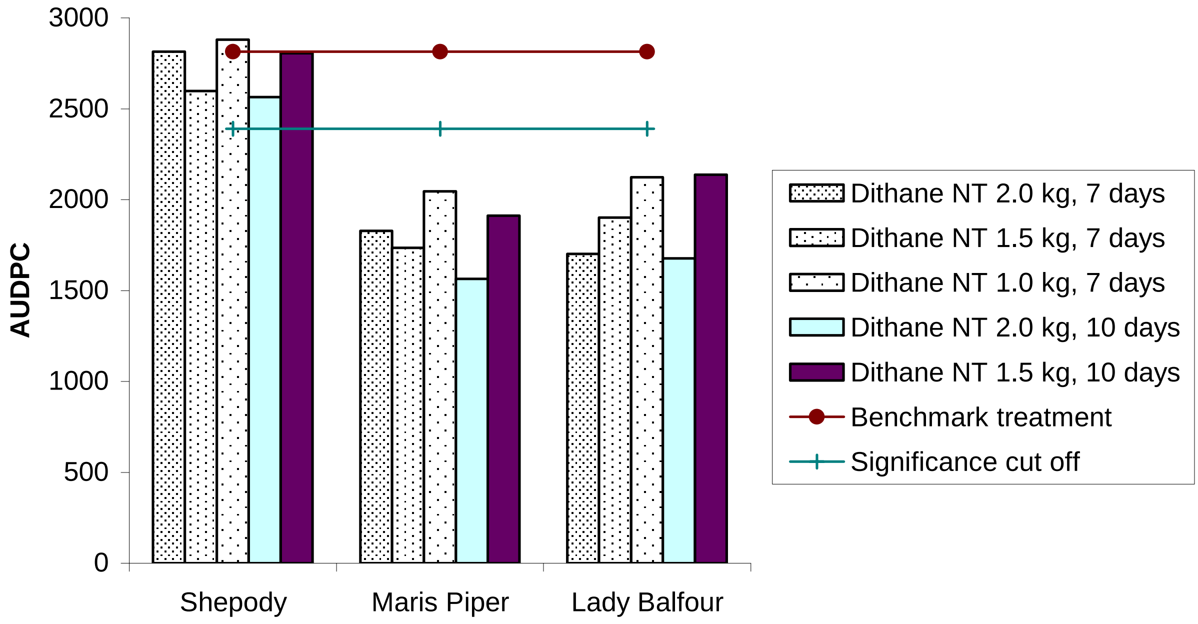


FIG. 2.3.4 FOLIAR BLIGHT SEVERITIES (AUDPC) FOR DIFFERENT COMBINATIONS OF CULTIVAR RESISTANCE AND FUNGICIDE INPUT IN RELATION TO THE BENCHMARK TREATMENT OF 2.0 KG OF DITHANE NT APPLIED EVERY 7 DAYS TO THE CULTIVAR SHEPODY AT LLANILAR, CEREDIGION. AUDPC VALUES BELOW THE SIGNIFICANCE CUT-OFF LINE INDICATE SIGNIFICANTLY BETTER CONTROL THAN THE BENCHMARK TREATMENT.

The results presented in Figs. 2.3.2 to 2.3.4 are summarized in the groups of columns for individual fungicides in Fig. 2.3.5. One Shirlan treatment (0.4 L Shirlan on Lady Balfour at 7 day intervals) and eight Dithane treatments (all those applied to Maris Piper and Lady Balfour regardless of rate and interval) were significantly better than the benchmark. Integrated control is also the combination of a less effective fungicide and greater cultivar resistance. The official ratings for the effectiveness of Infinito, Shirlan and Dithane NT against foliar blight are 3.8, 2.6 and 2.0 on a 2 to 5 scale (Schepers *et al.*, 2008). The fourth group of columns in Fig. 2.3.5 shows the comparative efficacies of all integrated control treatments compared with the Infinito benchmark treatment.

Two possible approaches to reduced fungicide inputs in integrated control are a lower dose at 7-day intervals or a higher dose at 10-day intervals. When these two approaches were compared, a reduced dose applied more frequently was marginally more effective than a higher dose applied every 10 days (Fig. 2.3.6). The 7-day programmes were adversely affected by the timing of a high rainfall event (Fig. 2.3.1). There were 45 mm of rain the day after the first of the 7-day treatments was applied.

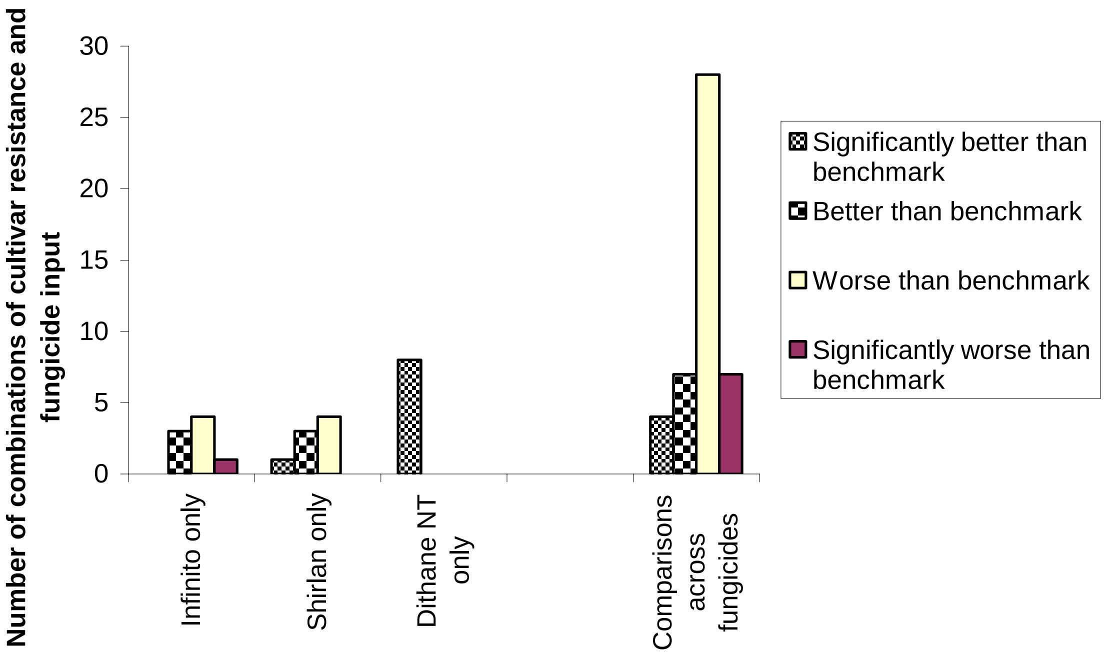


FIG. 2.3.5 COMPARATIVE EFFICACIES OF COMBINATIONS OF A MORE RESISTANT CULTIVAR AND REDUCED FUNGICIDE INPUT AT LLANILAR, CEREDIGION. THE FIRST THREE GROUPS OF COLUMNS COMPARE TREATMENTS WITH THE SAME FUNGICIDE PRODUCT ONLY. THE FOURTH GROUP INCLUDES COMPARISONS OF WEAKER FUNGICIDES ON MORE RESISTANT CULTIVARS COMPARED WITH STRONGER FUNGICIDES ON SHEPODY.

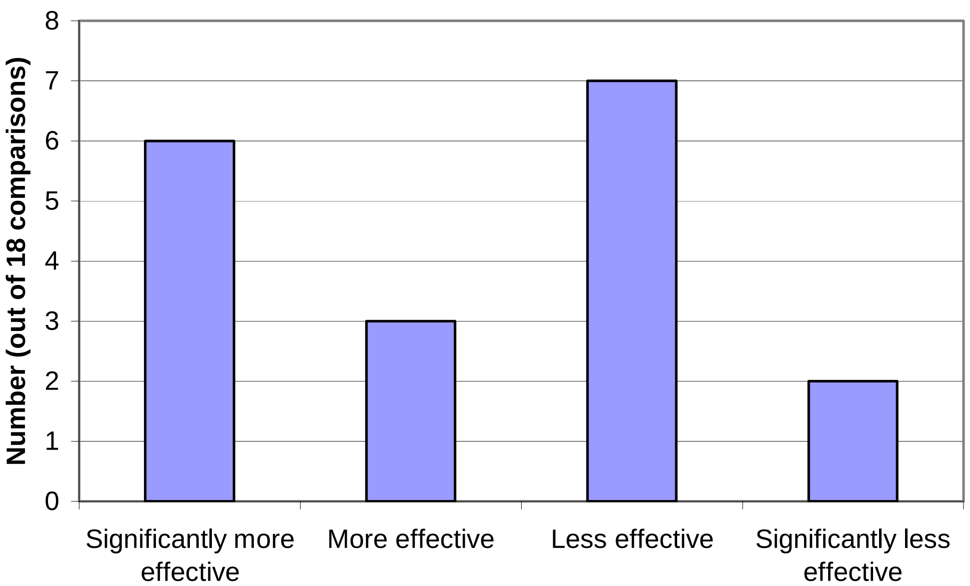


FIG. 2.3.6 NUMBER OF TIMES THAT THE COMBINATION OF REDUCED FUNGICIDE DOSE AT 7-DAY INTERVALS WAS MORE OR LESS EFFECTIVE COMPARED WITH A HIGHER DOSE AT 10-DAY INTERVALS IN CONTROLLING FOLIAR BLIGHT AT LLANILAR, CEREDIGION

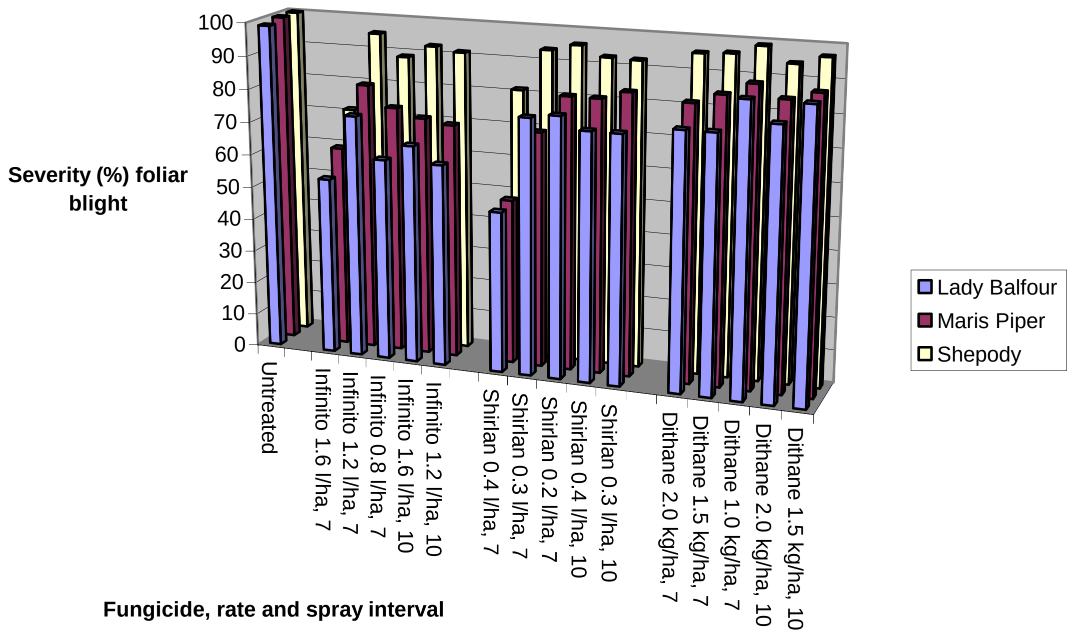


FIGURE 2.3.7 EFFECT OF FUNGICIDE PRODUCT, RATE AND SPRAY INTERVAL ON FINAL FOLIAR BLIGHT SEVERITY ON THREE CULTIVARS AT LLANILAR. LSD 11.0 (P = 0.05). UNTREATED CONTROL NOT INCLUDED IN THE STATISTICAL ANALYSIS.

*Tuber blight*

Shepody, Maris Piper and Lady Balfour have National List tuber blight resistance ratings of 3, 5 and 7 respectively. There were no significant interactions between fungicide product, dose, interval and variety for tuber blight incidence by weight (Table 2.3.1). The incidence of tuber blight ranged from low to moderate, and a comparison of variety means showed no significant differences between Maris Piper and Lady Balfour. Shepody had significantly more tuber blight overall compared with the other two cultivars.

The benchmark treatments of Infinito and Shirlan applied at full label dose every 7 days gave very good control of tuber blight on Shepody therefore there was little scope for significantly improved control by the integrated control treatments comprising greater cultivar resistance and a reduced fungicide input. However, for Infinito reduced inputs on the two more resistant cultivars always resulted in less tuber blight than 1.6 litres every 7 days on Shepody. A similar result was obtained for Shirlan, except for one treatment, i.e. 0.3 litres at 10-day intervals on Maris Piper gave slightly more tuber blight than the Shirlan benchmark treatment on Shepody. The incidence of tuber blight for the Dithane NT benchmark was 4.8%. The majority of the combinations of reduced Dithane input on Maris Piper and Lady Balfour resulted in significantly less tuber blight. However, for two treatments tuber blight was less but not significantly so. These two exceptions were 1.5 kg every 7 days and 2.0 kg every 10 days on Lady Balfour.

Two comparisons for each combination of cultivar and fungicide product, i.e. 1) three-quarter dose every 7 days with full dose every 10 days and 2) half-dose every 7 days with three-quarter dose at the longer interval, were made to determine if a reduced dose applied more often was a better approach than a higher dose sprayed less often. There were only two significant differences between lower doses applied every 7 days and higher doses applied at the longer interval (Table 2.3.1). These were both for Shepody. Shirlan at 0.3 litres applied every 7 days resulted in significantly less tuber blight than 0.4 litres every 10 days. However, the opposite result was obtained with Dithane NT. Dithane at 1.5 kg applied every 7 days resulted in a significantly higher incidence of tuber blight than the full label rate applied at the longer spray interval.

*Total marketable yield*
The main purpose of the trials was to evaluate the efficacy of integrated control measures focused on cultivar resistance. It is therefore valid to make treatment comparisons across cultivars for foliar blight and tuber blight control because two of the cultivars were deliberately chosen to be more resistant to blight. However, it is less certain how robust yield comparisons between treatments on different cultivars are because inevitably the different cultivars have different yield potentials and the two more resistant cultivars are known to have less inherent potential than Shepody. Quoted yield potentials for Shepody, Maris Piper and Lady Balfour are 57.4, 65.0 and 60.3 t/ha (Anon., 2003). Total marketable yields were significantly greater for the most resistant cultivar Lady Balfour than for both Maris Piper and Shepody. Maris Piper had a significantly higher yield than Shepody (Table 2.3.2).

Ten of the integrated control treatments resulted in a significantly higher yield than Shepody treated with the highest input of Infinito. The ten were Infinito: 1.2 L at 7 days (MP and LB), 1.6 L at 10 days (LB), 1.2 L at 10 days (LB), Shirlan: 0.4 L at 7 days (MP and LB), 0.3 L at 7 days (MP and LB), Dithane NT: 2.0 kg at 7 days (MP and LB).

Comparisons within cultivars of the combination of shorter interval plus lower fungicide dose against longer interval plus higher dose in general demonstrated little effect on yield. However, for two of the 18 comparisons the less fungicide, more often approach was significantly better. Both of these were with Shirlan. On both Maris Piper and Lady Balfour 0.3 litres of Shirlan every 7 days significantly out yielded 0.4 litres every 10 days.

TABLE 2.3.1 EVALUATION OF INTEGRATED CONTROL PROGRAMMES – EFFECT ON TUBER BLIGHT INCIDENCE (% WEIGHT) AT LLANILAR, CEREDIGION 2007

| Treatments | Shepody | Maris Piper | Lady Balfour | Fungicide treatment mean |
|---|---|---|---|---|
| Untreated * | 5.77 | 0.31 | 0.34 | 2.14 |
| Infinito 1.6 l/ha at 7-day intervals | 0.55 | 0.33 | 0.14 | 0.34 |
| Infinito 1.2 l/ha at 7-day intervals | 0.83 | 0.00 | 0.00 | 0.28 |
| Infinito 0.8 l/ha at 7-day intervals | 2.52 | 0.40 | 0.43 | 1.12 |
| Infinito 1.6 l/ha at 10-day intervals | 2.17 | 0.43 | 0.00 | 0.87 |
| Infinito 1.2 l/ha at 10-day intervals | 1.81 | 0.53 | 0.00 | 0.78 |
| Shirlan 0.4 l/ha at 7-day intervals | 1.03 | 0.00 | 0.00 | 0.34 |
| Shirlan 0.3 l/ha at 7-day intervals | 0.34 | 0.35 | 0.10 | 0.26 |
| Shirlan 0.2 l/ha at 7-day intervals | 3.74 | 0.00 | 0.40 | 1.38 |
| Shirlan 0.4 l/ha at 10-day intervals | 6.38 | 0.00 | 0.26 | 2.21 |
| Shirlan 0.3 l/ha at 10-day intervals | 2.73 | 1.07 | 0.60 | 1.47 |
| Dithane NT 2.0 kg/ha at 7-day intervals | 4.80 | 0.00 | 1.29 | 2.03 |
| Dithane NT 1.5 kg/ha at 7-day intervals | 5.46 | 0.00 | 1.27 | 2.24 |
| Dithane NT 1.0 kg/ha at 7-day intervals | 4.17 | 0.15 | 0.73 | 1.68 |
| Dithane NT 2.0 kg/ha at 10-day intervals | 1.47 | 0.33 | 1.32 | 1.04 |
| Dithane NT 1.5 kg/ha at 10-day intervals | 0.71 | 0.00 | 1.04 | 0.58 |
| Variety means (excluding untreated) | 2.58 | 0.24 | 0.51 | |
| F pr.(Variety/Fungicide/Rate & Interval)<br>LSD (*P* = 0.05) | 0.461 (NS)<br>3.610 | | | |
| F pr.(Variety means)<br>LSD (*P* = 0.05) | <0.001<br>0.920 | | | |
| F pr.(Fungicide means)<br>LSD (*P* = 0.05) | 0.463 (NS)<br>2.162 | | | |

* Untreated excluded from the analysis of variance

TABLE 2.3.2 EVALUATION OF INTEGRATED CONTROL PROGRAMMES – EFFECT ON TOTAL MARKETABLE YIELD (T/HA), CEREDIGION 2007

| Treatments | Shepody | Maris Piper | Lady Balfour | Fungicide treatment mean |
|---|---|---|---|---|
| Untreated * | 14.00 | 22.54 | 19.70 | 18.75 |
| Infinito 1.6 l/ha at 7-day intervals | 26.65 | 34.61 | 44.47 | 35.24 |
| Infinito 1.2 l/ha at 7-day intervals | 22.46 | 35.52 | 35.91 | 31.30 |
| Infinito 0.8 l/ha at 7-day intervals | 17.28 | 27.33 | 32.11 | 25.58 |
| Infinito 1.6 l/ha at 10-day intervals | 20.52 | 31.42 | 36.24 | 29.39 |
| Infinito 1.2 l/ha at 10-day intervals | 21.53 | 30.58 | 35.27 | 29.13 |
| Shirlan 0.4 l/ha at 7-day intervals | 25.84 | 43.20 | 47.24 | 38.76 |
| Shirlan 0.3 l/ha at 7-day intervals | 23.61 | 34.88 | 44.81 | 34.43 |
| Shirlan 0.2 l/ha at 7-day intervals | 22.74 | 32.91 | 32.63 | 29.43 |
| Shirlan 0.4 l/ha at 10-day intervals | 19.18 | 26.98 | 31.31 | 25.83 |
| Shirlan 0.3 l/ha at 10-day intervals | 19.76 | 30.99 | 30.29 | 27.02 |
| Dithane NT 2.0 kg/ha at 7-day intervals | 18.63 | 35.59 | 38.21 | 30.81 |
| Dithane NT 1.5 kg/ha at 7-day intervals | 20.06 | 27.53 | 31.13 | 26.24 |
| Dithane NT 1.0 kg/ha at 7-day intervals | 17.22 | 27.22 | 27.25 | 23.90 |
| Dithane NT 2.0 kg/ha at 10-day intervals | 19.88 | 32.82 | 33.08 | 28.59 |
| Dithane NT 1.5 kg/ha at 10-day intervals | 16.88 | 27.02 | 26.99 | 23.63 |
| Variety Means (excluding untreated) | 20.82 | 31.91 | 35.13 | |
| F pr.(Variety/Fungicide/Rate & Interval)<br>LSD (*P* = 0.05) | 0.577 (NS)<br>7.872 | | | |
| F pr.(Fungicide treatment means)<br>LSD (*P* = 0.05) | 0.124 (NS)<br>5.47 | | | |
| F pr.(Variety means)<br>LSD (*P* = 0.05) | <0.001<br>1.789 | | | |

* Untreated excluded from the analysis of variance

*2.3.1.3 The foliar blight epidemic at Auchincruive in 2007*

The trial was inoculated on 16 July with the A1 isolates 4168B (genotype 7_A1) and 4232E (genotype 8_2a_A1), which were prevalent in Scotland in 2006. Within a few days of inoculation symptoms of early natural infection were observed in other trials in the same field. It is rare for natural infection to contribute substantially to the epidemic at SAC, Auchincruive. On 8 August, five samples from the trial field were genotyped and were found to be the more aggressive 13_A2. Fifty-seven isolates from the Potato Council-funded trial were sampled on 13 August and also genotyped: six were genotype 8_2a_A1, but 49 were 13_A2. The latter must have entered the trial field as natural infection. Consequently the trial site contained a mixture of A1 and A2 mating types that represented 56% of the GB population in 2006.

The blight pressure at SAC, Auchincruive Estate, in 2007 was the highest at the site in the previous 21 years. Seventeen Smith Periods were recorded at the Met. Office station at Auchincruive, seven in July, six in August and four in September (Fig. 2.3.8). There was early natural infection and by the time the different fungicide treatments started the site was infected by the aggressive genotype 13_A2. Air temperature and relative humidity were also measured in the trial field using a Metos weather station and data can be made available if required.

The combination of a large number of Smith Periods and 13_A2 resulted in a very high disease pressure that provided a very severe test of the integrated treatments. Foliar blight was first observed in the trial on 22 July. In the untreated plots the disease progressed slowly until the third week of August when there was a very large increase in foliar blight severity. By the end of August foliar blight severities in untreated plots were greater than 92.5%.

*2.3.1.4 Evaluation of integrated control treatments – Auchincruive*

*Foliar Blight*

It was anticipated that the different fungicide treatments would commence before foliar blight was observed in the treated plots. However, an additional blanket application, of Merlin, was applied to all plots during rapid haulm growth in order to minimise foliar blight development favoured by the seven Smith Periods in July. In spite of this the severity of foliar blight when the different fungicide treatments started on 8 August was between 0.3 and 0.6% for Lady Balfour, between 0.5 and 1.0% for Maris Piper and between 0.6 and 1.2% for Shepody.

It is reasonable to assume that when Infinito was applied within 2 days of a Smith Period or Near Miss that curative activity occurred. Of the 7-day sprays, numbers 1, 2, 5 and 6 had the opportunity to be curative, as did numbers 1, 2, 3 and 4 of the 10-day sprays. Shirlan and Dithane NT have no curative activity.

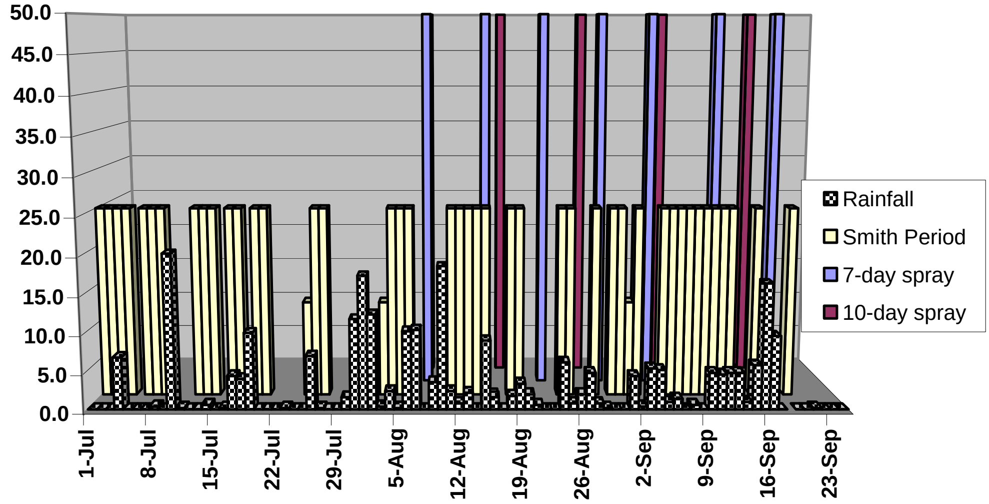


FIG. 2.3.8 THE TIMINGS OF THE 7-DAY AND 10-DAY SPRAYS IN RELATION TO DAILY RAINFALL (MM) AND SMITH PERIODS AT AUCHINCRUIVE IN 2007

The disease pressure was exceptionally high and this should be considered when interpreting the results.

 

In order to assess the efficacy of the integrated control treatments, they were compared with the benchmark treatment of Shepody treated with the highest rate of fungicide at 7-day intervals. The three benchmark treatments were 1.6 l/ha Infinito, 0.4 l/ha Shirlan and 2.0 kg/ha Dithane NT applied to Shepody every 7 days. Integrated control treatments were the two more resistant cultivars, Maris Piper and Lady Balfour, treated with less fungicide input than the highest rate at the shortest interval.

Compared with the benchmark treatment of the highest rate of fungicide applied every 7 days on Shepody, the combination of more resistant cultivar and less of the same fungicide generally resulted in better foliar blight control, i.e. a lower AUDPC, frequently significantly so (Figs 2.3.9, 2.3.10 and 2.3.11). For example, all of the reduced Shirlan input treatments on the more resistant M. Piper and L. Balfour resulted in significantly better control than the benchmark treatment (Fig. 2.3.10). The same was true for Dithane NT, except the three-quarter dose applied at 10-day intervals (Fig. 2.3.11). However, only two of the integrated control treatments using Infinito, i.e. the 1.2 and 0.8 l/ha rates of Infinito applied every 7 days to Lady Balfour, gave significantly better control than the benchmark treatment (Fig. 2.3.9).

Integrated control can also be the combination of a less effective fungicide and greater cultivar resistance. The comparison of integrated control treatments was expanded to include comparisons across different fungicide products, i.e. comparisons of weaker fungicides on more resistant cultivars with stronger fungicides on Shepody. The official ratings for the effectiveness of Infinito, Shirlan and Dithane NT against foliar blight are 3.8, 2.6 and 2.0 on a 2 to 5 scale on which 5 is the most effective (Schepers *et al.*, 2008). The fourth group of columns in Fig. 2.3.12 shows the comparative efficacies of all integrated control treatments with the Infinito benchmark treatment. The benefit from increased cultivar resistance combined with reduced fungicide input was less clear cut than for fungicide products considered individually. However, for 29 out of 46 comparisons the combination of more resistant cultivar and reduced fungicide input was significantly better, or better, than the benchmark.

For an individual fungicide, lower doses applied every 7 days were generally more effective than higher doses at the longer intervals, frequently significantly so (Figs 2.3.13). These data were calculated from two comparisons for each combination of cultivar and fungicide product, i.e. 1) three-quarter dose every 7 days with full dose every 10 days and 2) half-dose every 7 days with three-quarter dose at the longer interval. The individual comparisons can be made in Figs. 2.3.9, 2.3.10 and 2.3.11.

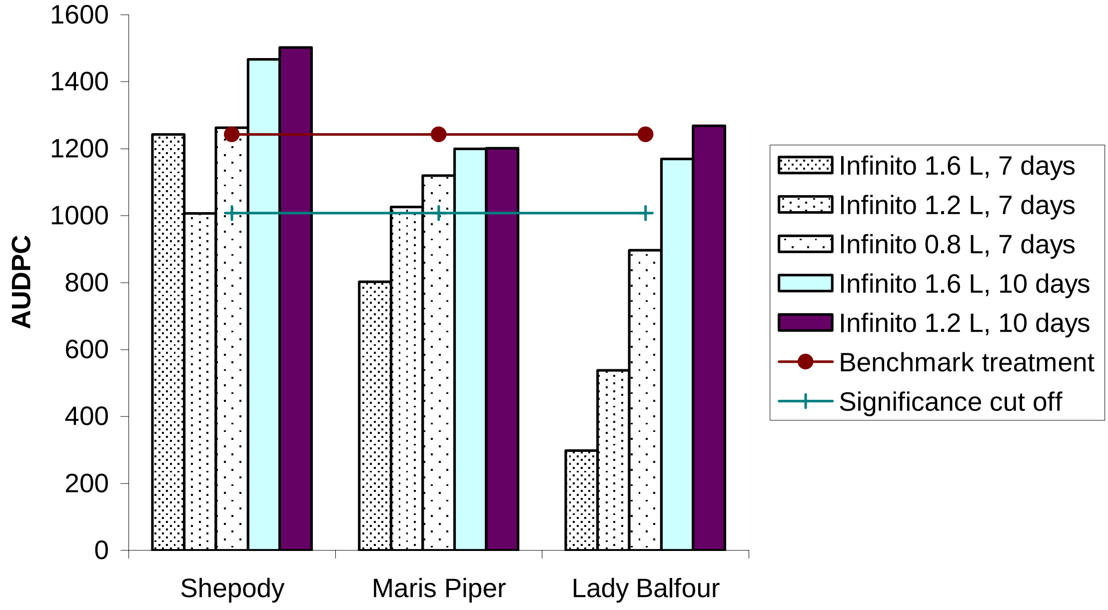


FIG. 2.3.9 FOLIAR BLIGHT SEVERITIES (AUDPC) FOR DIFFERENT COMBINATIONS OF CULTIVAR RESISTANCE AND FUNGICIDE INPUT IN RELATION TO THE BENCHMARK TREATMENT OF 1.6 LITRES OF INFINITO APPLIED EVERY 7 DAYS TO THE CULTIVAR SHEPODY AT AUCHINCRUIVE. AUDPC VALUES BELOW THE SIGNIFICANCE CUT-OFF LINE INDICATE SIGNIFICANTLY BETTER CONTROL THAN THE BENCHMARK TREATMENT.

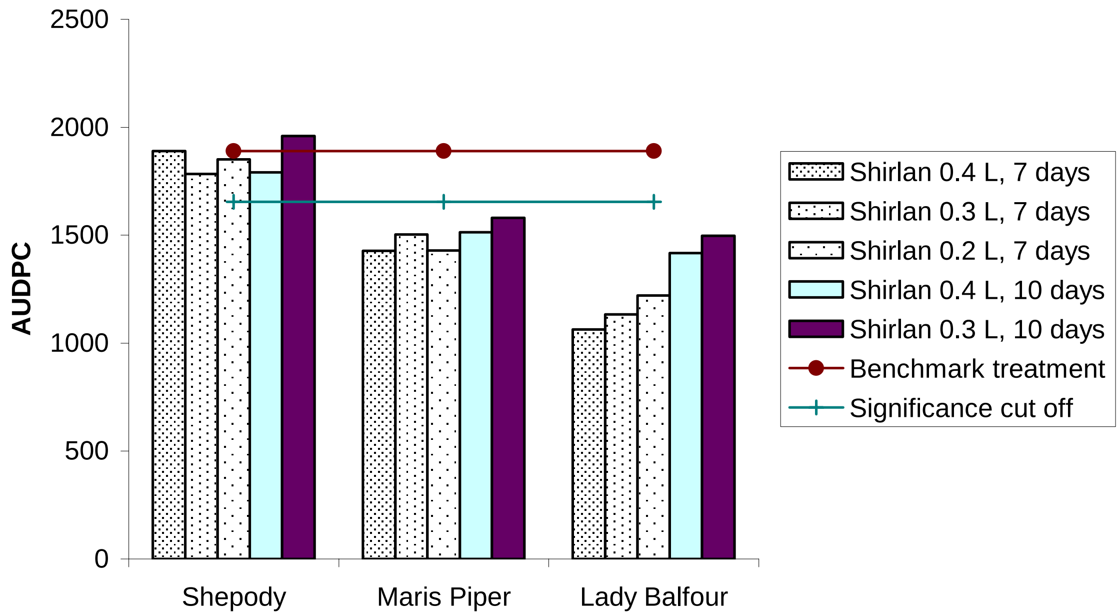


FIG. 2.3.10 FOLIAR BLIGHT SEVERITIES (AUDPC) FOR DIFFERENT COMBINATIONS OF CULTIVAR RESISTANCE AND FUNGICIDE INPUT IN RELATION TO THE BENCHMARK TREATMENT OF 0.4 LITRES OF SHIRLAN APPLIED EVERY 7 DAYS TO THE CULTIVAR SHEPODY AT AUCHINCRUIVE. AUDPC VALUES BELOW THE SIGNIFICANCE CUT-OFF LINE INDICATE SIGNIFICANTLY BETTER CONTROL THAN THE BENCHMARK TREATMENT.

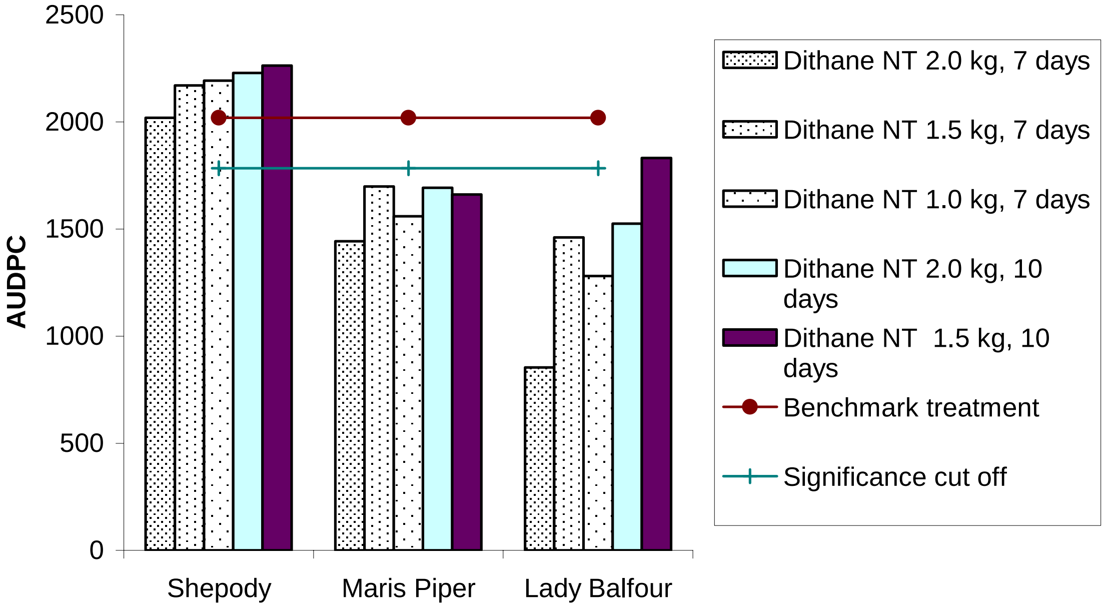


FIG. 2.3.11 FOLIAR BLIGHT SEVERITIES (AUDPC) FOR DIFFERENT COMBINATIONS OF CULTIVAR RESISTANCE AND FUNGICIDE INPUT IN RELATION TO THE BENCHMARK TREATMENT OF 2.0 KG OF DITHANE NT APPLIED EVERY 7 DAYS TO THE CULTIVAR SHEPODY AT AUCHINCRUIVE. AUDPC VALUES BELOW THE SIGNIFICANCE CUT-OFF LINE INDICATE SIGNIFICANTLY BETTER CONTROL THAN THE BENCHMARK TREATMENT.

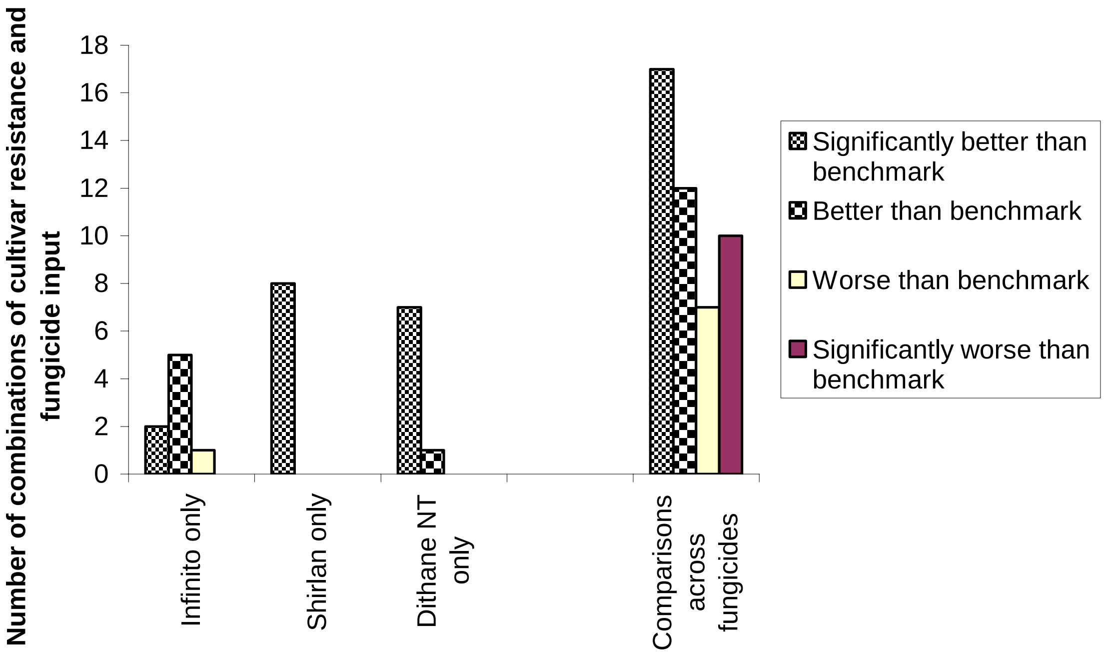


FIG. 2.3.12 COMPARATIVE EFFICACIES OF COMBINATIONS OF A MORE RESISTANT CULTIVAR AND REDUCED FUNGICIDE INPUT AT AUCHINCRUIVE. THE FIRST THREE GROUPS OF COLUMNS COMPARE TREATMENTS WITH THE SAME FUNGICIDE PRODUCT ONLY. THE FOURTH GROUP INCLUDES COMPARISONS OF WEAKER FUNGICIDES ON MORE RESISTANT CULTIVARS COMPARED WITH STRONGER FUNGICIDES ON SHEPODY.

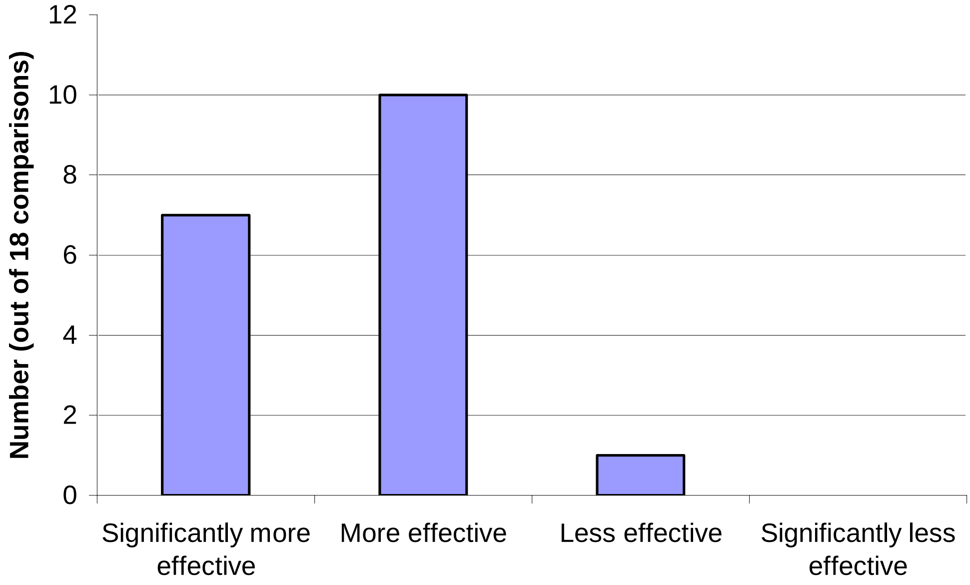


FIG. 2.3.13 NUMBER OF TIMES THAT THE COMBINATION OF REDUCED FUNGICIDE DOSE AT 7-DAY INTERVALS WAS MORE OR LESS EFFECTIVE COMPARED WITH A HIGHER DOSE AT 10-DAY INTERVALS IN CONTROLLING FOLIAR BLIGHT AT AUCHINCRUIVE, AYRSHIRE

The “resistance” of the three cultivars to foliar blight appeared to depend on the degree of fungicide protection. For all three fungicide products, differences between the three cultivars in the severity of foliar blight at the final assessment were greater for higher compared with lower inputs of fungicide (Fig. 2.3.14). In the absence of fungicide the three cultivars developed similar amounts of foliar blight. In addition, the AUDPC values for untreated Shepody, Maris Piper and Lady Balfour were similar, 2425, 2281 and 2628 respectively. The impact of fungicide input on cultivar differences should be borne in mind when considering the implications of the results obtained in the following experiment that compared the published ratings for foliar blight resistance with resistance to 13_A2 in 2008.

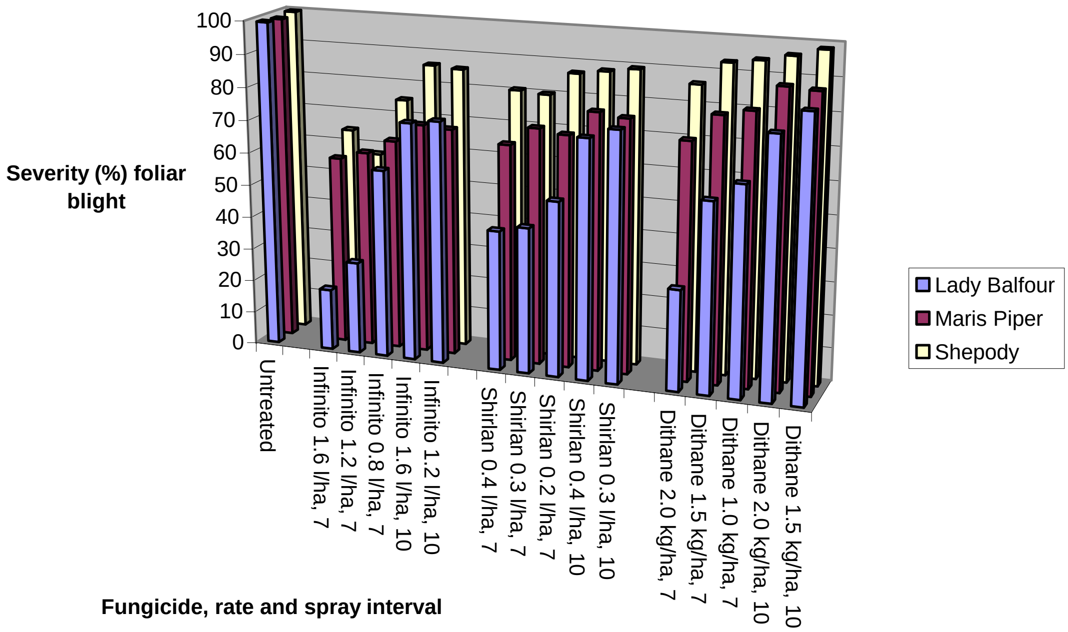


FIGURE 2.3.14 EFFECT OF FUNGICIDE PRODUCT, RATE AND SPRAY INTERVAL ON FINAL FOLIAR BLIGHT SEVERITY ON THREE CULTIVARS AT AUCHINCRUIVE. LSD 11.3 (P = 0.05). UNTREATED CONTROL NOT INCLUDED IN THE STATISTICAL ANALYSIS.

*Tuber blight*

The comments below refer to the incidence of tuber blight by weight. Tuber blight incidence was low in Maris Piper and Lady Balfour but moderate in Shepody.

The greater resistance to foliar and tuber blight of Maris Piper (4, 5) and Lady Balfour (8, 7) allowed reduced fungicide inputs on these varieties and yet for comparisons within fungicide products the incidence of tuber blight was consistently significantly lower than for the Dithane NT benchmark treatment (2.0 kg/ha every 7 days on Shepody) and almost always than for the Shirlan benchmark treatment (0.4 L/ha every 7 days on Shepody) (Table 2.3.3). Clearly cultivar had a very large influence on tuber blight incidence. This is supported by the lack of response to fungicide input for either Shirlan or Dithane NT on Shepody. The benchmark treatment of Infinito applied at full label dose every 7 days gave very good control of tuber blight on Shepody therefore there was no scope for significantly better tuber blight control with the integrated control treatments comprising greater cultivar resistance and a reduced fungicide input.

There were no significant differences between lower doses of the same fungicide applied every 7 days and higher doses applied at the longer interval (Table 2.3.3). These data were calculated from two comparisons for each combination of cultivar and fungicide product, i.e. 1) three-quarter dose every 7 days with full dose every 10 days and 2) half-dose every 7 days with three-quarter dose at the longer interval.

*Total marketable yield*

The main purpose of the trials was to evaluate the efficacy of integrated control measures focused on cultivar resistance. It is therefore valid to make treatment comparisons across cultivars for foliar blight and tuber blight control because two of the cultivars were deliberately chosen to be more resistant to blight. However, the validity of yield comparisons between treatments on different cultivars is uncertain because inevitably the different cultivars had different inherent yield potentials and for the two more resistant cultivars the potentials were greater compared with Shepody. Quoted yield potentials for Shepody, Maris Piper and Lady Balfour are 57.4, 65.0 and 60.3 t/ha (Anon., 2003).

It is therefore not surprising that irrespective of fungicide treatment all of the reduced fungicide input treatments on Maris Piper resulted in a significantly higher yield than the benchmark treatment of Shepody treated with the maximum label rate of Infinito every 7 days (Table 2.3.4). Many of the reduced fungicide input treatments applied to Lady Balfour also out yielded the benchmark treatment, i.e. all four Infinito treatments, 0.3 l/ha Shirlan applied every 10 days and all three Dithane NT treatments applied every 7 days.

Comparisons within cultivars of shorter interval plus lower fungicide dose and longer interval plus higher dose of the same fungicide generally had little effect on yield. However, for two of the 18 comparisons the less fungicide, more often approach was significantly better, both with Lady Balfour, i.e. 1) 1.2 l/ha Infinito every 7 days compared with 1.6 l/ha every 10 days and 2) 1.0 kg/ha Dithane NT applied every 7 days compared with 1.5 kg/ha applied at the longer interval.

TABLE 2.3.3 EVALUATION OF INTEGRATED CONTROL PROGRAMMES – EFFECT ON TUBER BLIGHT INCIDENCE (% WEIGHT) AT AUCHINCRUIVE, 2007

| **Treatments** | **Shepody** | **Maris Piper** | **Lady Balfour** | **Fungicide treatment mean** |
|---|---|---|---|---|
| Untreated * | 3.0 | 0.0 | 0.8 | 1.3 |
| Infinito 1.6 l/ha at 7-day intervals | 0.1 | 0.0 | 0.1 | 0.1 |
| Infinito 1.2 l/ha at 7-day intervals | 0.8 | 0.0 | 0.0 | 0.3 |
| Infinito 0.8 l/ha at 7-day intervals | 1.4 | 0.0 | 0.0 | 0.5 |
| Infinito 1.6 l/ha at 10-day intervals | 0.7 | 0.0 | 0.2 | 0.3 |
| Infinito 1.2 l/ha at 10-day intervals | 2.6 | 0.0 | 0.0 | 0.9 |
| Shirlan 0.4 l/ha at 7-day intervals | 2.8 | 0.0 | 0.5 | 1.1 |
| Shirlan 0.3 l/ha at 7-day intervals | 2.6 | 0.0 | 0.1 | 0.9 |
| Shirlan 0.2 l/ha at 7-day intervals | 2.0 | 0.0 | 0.0 | 0.7 |
| Shirlan 0.4 l/ha at 10-day intervals | 2.4 | 0.0 | 0.6 | 1.0 |
| Shirlan 0.3 l/ha at 10-day intervals | 2.2 | 0.0 | 0.4 | 0.9 |
| Dithane NT 2.0 kg/ha at 7-day intervals | 4.9 | 0.5 | 0.6 | 2.0 |
| Dithane NT 1.5 kg/ha at 7-day intervals | 5.6 | 0.0 | 0.0 | 1.9 |
| Dithane NT 1.0 kg/ha at 7-day intervals | 3.5 | 0.0 | 0.2 | 1.2 |
| Dithane NT 2.0 kg/ha at 10-day intervals | 3.5 | 0.0 | 0.1 | 1.2 |
| Dithane NT 1.5 kg/ha at 10-day intervals | 3.8 | 0.0 | 0.2 | 1.3 |
| | | | | |
| Variety means (excluding untreated) | 2.6 | 0.03 | 0.2 | |

| | |
|---|---|
| F pr.(Variety/Fungicide/Rate & Interval)<br>LSD (*P* = 0.05) | 0.993 (NS)<br>2.287 |
| F pr.(Fungicide treatment means)<br>LSD (*P* = 0.05) | <0.001<br>0.553 |
| F pr.(Variety means)<br>LSD (*P* = 0.05) | <0.001<br>0.616 |

Untreated excluded from the analysis of variance

 

TABLE 2.3.4 EVALUATION OF INTEGRATED CONTROL PROGRAMMES – EFFECT ON TOTAL MARKETABLE YIELD, (T/HA) AUCHINCRUIVE, 2007

| **Treatments** | **Shepody** | **Maris Piper** | **Lady Balfour** | **Fungicide treatment mean** |
|---|---|---|---|---|
| Untreated * | 13.91 | 41.36 | 20.60 | 25.29 |
| Infinito 1.6 l/ha at 7-day intervals | 33.08 | 61.88 | 62.35 | 52.44 |
| Infinito 1.2 l/ha at 7-day intervals | 32.70 | 65.68 | 64.20 | 54.19 |
| Infinito 0.8 l/ha at 7-day intervals | 32.17 | 62.63 | 55.15 | 49.98 |
| Infinito 1.6 l/ha at 10-day intervals | 25.64 | 66.71 | 46.09 | 46.15 |
| Infinito 1.2 l/ha at 10-day intervals | 27.62 | 56.35 | 48.28 | 44.08 |
| Shirlan 0.4 l/ha at 7-day intervals | 19.93 | 61.08 | 40.77 | 40.59 |
| Shirlan 0.3 l/ha at 7-day intervals | 23.10 | 53.33 | 36.96 | 37.80 |
| Shirlan 0.2 l/ha at 7-day intervals | 18.98 | 60.62 | 38.36 | 39.32 |
| Shirlan 0.4 l/ha at 10-day intervals | 23.85 | 53.25 | 38.26 | 38.45 |
| Shirlan 0.3 l/ha at 10-day intervals | 20.29 | 56.19 | 45.66 | 40.71 |
| Dithane NT 2.0 kg/ha at 7-day intervals | 20.36 | 54.14 | 48.21 | 40.90 |
| Dithane NT 1.5 kg/ha at 7-day intervals | 15.72 | 47.31 | 42.45 | 35.16 |
| Dithane NT 1.0 kg/ha at 7-day intervals | 16.70 | 52.89 | 46.18 | 38.59 |
| Dithane NT 2.0 kg/ha at 10-day intervals | 16.90 | 49.94 | 38.84 | 35.23 |
| Dithane NT 1.5 kg/ha at 10-day intervals | 18.83 | 51.04 | 34.71 | 34.86 |
| Variety Means (excluding untreated) | 22.49 | 55.90 | 44.19 | |
| F pr.(Variety/Fungicide/Rate & interval)<br>LSD (*P* = 0.05: DF = 116 ) | 0.019<br>8.828 | | | |
| F pr.(Fungicide treatment means)<br>LSD (*P* = 0.05: DF = 42 ) | <0.001<br>2.784 | | | |
| F pr.(Variety means)<br>LSD (*P* = 0.05: DF = 85) | <0.001<br>2.022 | | | |

* Untreated excluded from the analysis of variance

### *2.3.2 Evaluation of cultivar resistance to foliar blight caused by genotype 13_A2*

Fewer Smith Periods were recorded in 2008 compared with 2007. In 2008 full Smith Periods were recorded on 17-18 July, 26-27 July, 6-7 August and 27-28 August (Table 2.3.5). Near Miss Periods were recorded on 1-2 and 4-5 August. Between the times the trial was inoculated and the final assessment of foliar blight on 8 August there were two Smith Periods and one Near Miss. The effect of the Near Miss and Smith Period on 4-5 and 6-7 August respectively would not be visible on 8 August.

Foliar blight was obvious in the cultivar plots on 24 July, 16 days after the King Edward spreader rows were inoculated (Table 2.3.6). The severity of foliar blight increased very rapidly. The timing of this rapid increase depended on cultivar. It was necessary to assess the trial every 2 days in August instead of twice a week as planned.

TABLE 2.3.5 BLIGHT HIGH-RISK CONDITIONS 2008 (SAC, AUCHINCRUIVE, DIAMOND FIELD, MET. OFFICE DATA)

| July | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|
| | | | **P** | | | | | | |
| | **I** | | | | | | | | |

| | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **P** | **P** | **P** | | | | **N** | | | **P** | **P** | | | | |
| | | | | | | | | **A** | | | | **A** | | | **A** |

| August | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| | **N** | **P** | | **P** | **N** | **P** | **P** | |
| | | **A** | | **A** | | **A** | | **A** |

P Smith criteria (temperature and relative humidity) met on the day
N Smith criteria almost met on the day but RH short by 1 hour
PP Full Smith Period.
I Trial inoculated
A Foliar blight assessment

Table 2.3.7 lists the published foliar blight resistance ratings (valid when the trial was planned). Where a cultivar had no published rating an average rating was calculated using all of the available data from the Euroblight host database. Table 2.3.7 also lists the ratings based on the results for the 23 cultivars in the 2008 SAC trial and the results from the 2008 trial expressed as AUDPC values.

The 2008 ratings for cultivars with a published rating of 5 or less were generally similar to the published ones (Table 2.3.7 and Fig. 2.3.15). Of the 10 cultivars with a published rating of 5 or less, only two cultivars had ratings changes greater than 1 on the 1 to 9 scale (Table 2.3.7). Harmony increased from 3 to 5.5 and Claret decreased from 5 to 3.6. In contrast the 2008 ratings for cultivars with a published rating greater than 5 were generally considerably reduced compared with their published ratings. Of the 13 cultivars with a published rating of 6 or above, nine had the rating reduced by at least one point. Sarpo Mira increased its rating from 7 to 8.9. For many cultivars the size of the difference between 2008 ratings and published ratings was generally proportional to the original rating value ($r^2$=-0.947; P<0.001) (Table 2.3.7 and Fig. 2.3.16).

TABLE 2.3.6 FIELD EVALUATION OF CULTIVAR RESISTANCE TO FOLIAR BLIGHT (GENOTYPE 13_A2), AUCHINCRUIVE, 2008: % FOLIAR BLIGHT

| | % foliar blight | | | | | | |
|---|---|---|---|---|---|---|---|
| | 24 Jul | 28 Jul | 31 Jul | 2 Aug | 4 Aug | 6 Aug | 8 Aug |
| Harmony | 0.3 | 1.1 | 4.7 | 55.0 | 66.7 | 73.3 | 80.0 |
| K Edward | 0.5 | 4.3 | 70.0 | 75.0 | 85.0 | 91.7 | 98.3 |
| M Piper | 0.4 | 1.4 | 48.3 | 71.7 | 80.0 | 88.3 | 95.0 |
| Claret | 0.3 | 2.5 | 51.7 | 73.3 | 78.3 | 80.0 | 83.3 |
| Slaney | 0.4 | 1.8 | 17.7 | 58.3 | 63.3 | 63.3 | 66.7 |
| Picasso | 0.2 | 0.8 | 19.2 | 58.3 | 71.7 | 76.7 | 83.3 |
| Markies | 0.3 | 1.2 | 23.8 | 56.7 | 61.7 | 66.7 | 71.7 |
| Nadine | 0.3 | 1.0 | 6.2 | 61.7 | 68.3 | 76.7 | 85.0 |
| Ambo | 0.3 | 0.9 | 6.7 | 56.7 | 61.7 | 68.3 | 73.3 |
| Cara | 0.1 | 0.7 | 19.8 | 51.7 | 55.0 | 56.7 | 61.7 |
| P Dell | 0.4 | 1.3 | 25.0 | 66.7 | 76.7 | 86.7 | 91.7 |
| L Balfour | 0.1 | 1.2 | 51.7 | 75.0 | 85.0 | 90.0 | 95.0 |
| Romano | 0.4 | 2.0 | 18.2 | 65.0 | 76.7 | 83.3 | 91.7 |
| Sante | 0.3 | 2.5 | 28.3 | 76.7 | 81.7 | 86.7 | 91.7 |
| Robinta | 0.3 | 1.0 | 32.7 | 71.7 | 78.3 | 81.7 | 86.7 |
| S Mira | 0.3 | 0.4 | 0.6 | 0.8 | 0.8 | 0.8 | 0.9 |
| Remarka | 0.3 | 0.9 | 21.0 | 63.3 | 75.0 | 81.7 | 86.7 |
| Alpha | 0.5 | 1.1 | 31.0 | 75.0 | 85.0 | 91.7 | 98.3 |
| Bintje | 0.4 | 3.2 | 51.7 | 76.7 | 85.0 | 91.7 | 100.0 |
| Eersteling | 0.4 | 4.7 | 70.0 | 83.3 | 93.3 | 100.0 | 100.0 |
| Escort | 0.4 | 1.2 | 7.3 | 61.7 | 76.7 | 80.0 | 86.7 |
| Gloria | 0.5 | 2.5 | 58.3 | 80.0 | 86.7 | 93.3 | 100.0 |
| Robijn | 0.1 | 0.9 | 2.6 | 48.3 | 58.3 | 63.3 | 68.3 |
| F pr. | 0.002 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| LSD (P=0.05) | 0.21 | 1.43 | 22.39 | 8.90 | 9.15 | 8.67 | 8.15 |

Eucablight standards: Robijn, Escort, Alpha, Bintje, Gloria, Eersteling

TABLE 2.3.7. FIELD EVALUATION OF CULTIVAR RESISTANCE TO FOLIAR BLIGHT (GENOTYPE 13_A2), AUCHINCRUIVE, 2008: FOLIAR RESISTANCE RATINGS AND AUDPC VALUES

| Cultivar/Genotype | Published foliar resistance rating | Foliar resistance rating from the 2008 trial | Difference between published and 2008 rating[1] | AUDPC mean | AUDPC SE |
|---|---|---|---|---|---|
| Eersteling | (2) | 1.9 | -0.1 | 843.5 | 15.4 |
| Bintje | (2.4) | 2.9 | 0.5 | 746.8 | 19.7 |
| Gloria (1972) | (2.6) | 2.6 | 0.0 | 775.7 | 13.6 |
| Harmony | 3 | 5.5 | **2.5** | 486.0 | 40.0 |
| King Edward | 3 | 2.4 | -0.6 | 792.1 | 9.9 |
| Remarka | 4 | 4.6 | 0.6 | 582.9 | 54.5 |
| Maris Piper | 4 | 3.4 | -0.6 | 701.4 | 52.2 |
| Picasso | 5 | 5.0 | 0.0 | 547.7 | 50.8 |
| Claret | 5 | 3.6 | **-1.4** | 685.1 | 12.9 |
| Escort | (5.2) | 5.0 | -0.2 | 546.5 | 37.8 |
| Cara | 6 | 5.9 | -0.1 | 440.5 | 47.0 |
| Ambo | 6 | 5.7 | -0.3 | 467.0 | 43.2 |
| Nadine | 6 | 5.2 | -0.8 | 517.7 | 37.2 |
| Pentland Dell | 6 | 4.3 | **-1.7** | 619.3 | 23.1 |
| Alpha | (6) | 3.6 | **-2.4** | 683.5 | 45.9 |
| Sarpo Mira | 7 | 8.9 | **1.9** | 9.2 | 0.6 |
| Slaney | 7 | 5.5 | **-1.5** | 487.8 | 32.7 |
| Markies | 7 | 5.3 | **-1.7** | 505.9 | 65.5 |
| Romano | 7 | 4.5 | **-2.5** | 595.0 | 20.7 |
| Santé | 7 | 3.8 | **-3.2** | 661.9 | 20.9 |
| Robijn | (8) | 6.1 | **-1.9** | 418.3 | 33.7 |
| Robinta | 8 | 4.1 | **-3.9** | 635.8 | 77.1 |
| Lady Balfour | 8 | 3.1 | **-4.9** | 728.8 | 53.0 |

[1] Values in bold indicate a change greater than 1 on the 1 to 9 scale

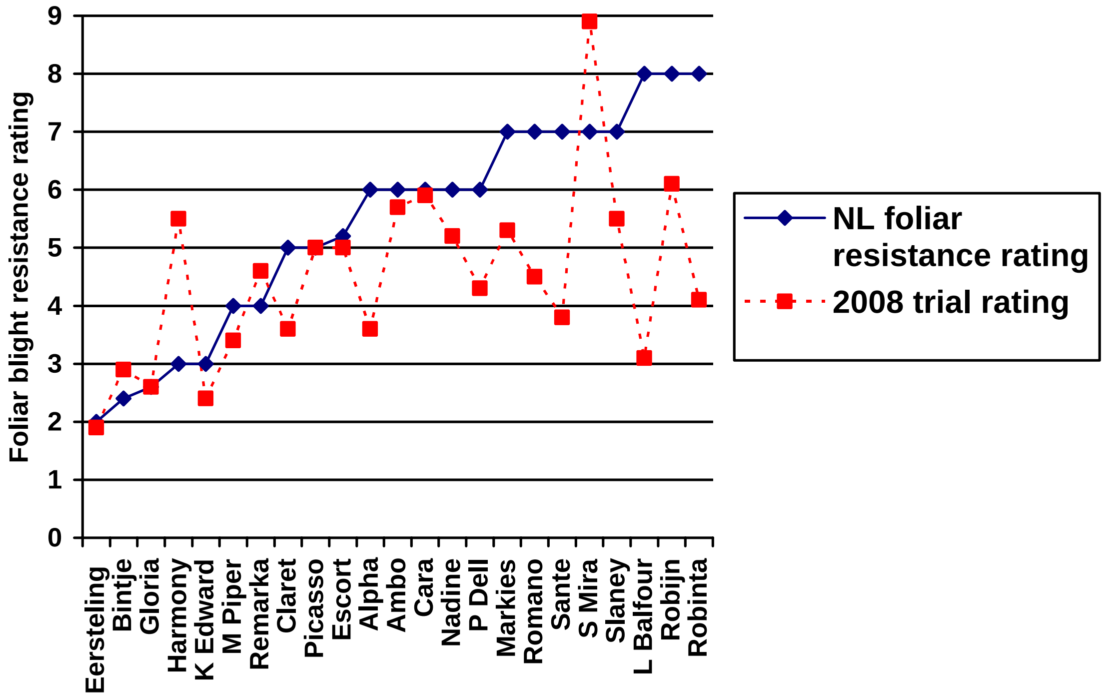


FIG. 2.3.15 FOLIAR BLIGHT RESISTANCE RATINGS FROM THE 2008 SCREEN USING GENOTYPE 13_A2 COMPARED WITH PUBLISHED RATINGS

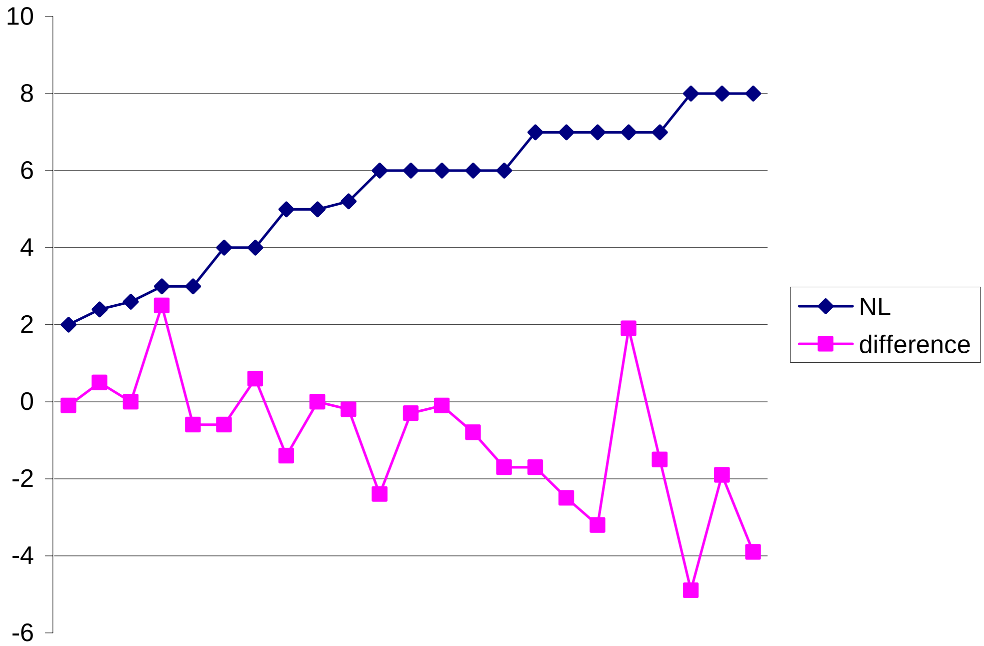


FIG. 2.3.16 DIFFERENCE (BETWEEN PUBLISHED AND 2008 RATINGS) IN RELATION TO PUBLISHED RATINGS FOR 23 CULTIVARS. CULTIVARS LISTED IN THE SAME ORDER AS IN FIG. 2.3.15.

## *2.4 Discussion*

The principle of reducing fungicide inputs on potato cultivars with good resistance to foliar blight has been established for many years (Fry, 1978; Gans *et al*., 1995; Clayton & Shattock, 1995; Kirk, 2005). But only recently have attempts been made to provide sufficient data to allow agronomists to recommend fewer fungicide inputs on cultivars with a higher disease rating. Most of the research has been in countries where there is considerable pressure to reduce the use, or environmental impact, of blight fungicides (Kessel *et al*., 2006; Neilsen, 2004; Naerstad *et al*., 2007). The work carried out in these other countries shows that there is potential for adjusting fungicide input depending on cultivar resistance. However, results using UK cultivars and fungicides under UK conditions are necessary to give agronomists confidence in integrated control. The 2007 study has confirmed the findings of the earlier Potato Council-funded work in 2006 (Bradshaw & Bain, 2007) that cultivar resistance could be used in Britain to reduce fungicide inputs as part of an integrated control strategy to protect potato crops from foliar and tuber blight.

Some previous research found that lower fungicide application rates were less effective on moderately susceptible varieties where disease pressure was high, but successful control of foliar blight could be achieved with lower rates where conditions were moderately conducive for foliar blight development (Kirk *et al*., 2001). The 2007 results demonstrate that even under very high disease pressure integrated control can contribute substantially to blight control.

Robust information on cultivar resistance is a pre-requisite for successful integrated control. The published foliar resistance ratings for the most popular cultivars were checked in 2008 in the field using genotype 13_A2. The foliar resistance ratings of many cultivars were reduced compared with published ratings. The reduction was clearly greater for the cultivars with higher published ratings. For several more resistant cultivars the drop in rating was between 2 and 5 on the 9-point scale.

It was not unexpected that the ratings of some cultivars changed and clearly interactions between *P. infestans* genotype and cultivar partly explain some of the results obtained. However, the very clear relationship between published rating and size of the rating fall was unexpected. The divergence of the lines for published ratings and ratings obtained from the 2008 field trial at SAC using 23 cultivars (Figs. 2.3.14 & 2.3.15) was also obtained for 47 cultivars when the results of similar trials carried out using genotype 13_A2 in Ayrshire in 2008 by SASA and SCRI were combined with the SAC results (results not shown).

We need to be certain that the disproportionate fall in the ratings of cultivars with higher ratings in the published system was not an artefact of the testing procedure when it was used under extremely favourable conditions for foliar blight development and using a *P. infestans* genotype that sporulates very quickly and profusely. It is possible that the results obtained in these trials are at least in part due to the cultivar plots being challenged by an extremely high number of sporangia.

In the 2008 trial at Auchincruive several key factors favoured the production of a very large number of sporangia. The trial was not treated with fungicide to dampen the foliar epidemic. There were eight susceptible King Edward spreader plants for every cultivar plot. The trial was inoculated with *P. infestans* genotype 13_A2, which sporulates quickly and therefore produces a very large number of sporangia. Weather conditions from the day of inoculation were favourable for sporulation.

Foliar blight developed very rapidly in the trial. The intention had been to assess foliar blight twice a week but the rate of disease development was so fast that assessments every 2 days needed to be made. The speed of the epidemic in a similar SCRI trial at Balgreen, Ayrshire, was also very fast and only three assessments were possible (John Bradshaw, personal communication). Also, in 2008 foliar blight symptoms in fungicide-treated plots at the Auchincruive trial site occurred as very many small infections on leaflets. Such symptoms are unusual for this trial site and they suggest a challenge by a very high concentration of spores.

The results from the 2007 integrated control trials support the idea that cultivar differences in foliar blight resistance can be obscured where the inoculum challenge is very large. In the trial at Auchincruive (Fig. 2.3.14) cultivar differences in foliar blight severity were small where the three varieties were not treated with fungicide. For each of the three fungicides cultivar differences were greater where full label doses were applied every 7 days compared with half-rate fungicide applied at the longer spray interval. The data from the ADAS trial (Fig. 2.3.7) were not as consistent but the same trend was clear for Shirlan and Dithane NT.

Exactly how the very high inoculum challenge led to the ratings obtained requires further investigation. As a first step it would be useful to collate the results from all available cultivar screens using 13_A2. Results from tests in which the inoculum challenge was much less than in the 2008 field trials would be particularly useful. If such data are too limited then consideration should be given to the evaluation of cultivar resistance to 13_A2 with at least two levels of inoculum. There are different methods of achieving this but one would be to test cultivars with and without a fungicide programme. The purpose of the fungicide programme is to make the inoculum challenge more typical of that experienced by conventionally grown crops.

*Apparent changes in varietal resistance to potato late blight*

At the Potato Council's Blight Forum 2008, delegates discussed anecdotal evidence that performance of some varieties appeared to be poorer than expected. In response, researchers have drawn together experiences from various trials (including Potato Council's Independent Variety Trials and Integrated Crop Management Trials) that support the idea of reduced variety resistance. These were presented to support discussions at the 2009 Blight Forum, held in February 2009. At this stage it is unclear whether the changes are a consequence of more aggressive blight, more conducive conditions in the test period (2007 and 2008 seasons) or a combination of the two.

The table below summarises apparent estimates of changes in resistance rating. Only varieties tested in two or more trials have been included and the portfolio of varieties reflects the nature of the trials rather than significance of a variety in GB. Furthermore, additional statistical analyses need to be carried out. As such Potato Council accepts no liability relating to inclusion, error or omission. Any formal changes to resistance ratings, if required, will be actioned after further research and analysis. Readers are encouraged to reflect on this information as one component in blight management strategies.

Table 2.4.1 Varieties where resistance ratings appear to have changed based on two or more trials in 2007 & 2008

| Increased or stayed the same | Decreased by **less than 1** resistance point | Decreased by **1-3** resistance points | Decreased by **more than 3** resistance points |
|---|---|---|---|
| Duke of York<br>Hermes<br>King Edward | Lady Rosetta<br>Maris Piper<br>Valor | Alpha<br>Estima<br>Escort<br>Markies<br>Pentland Dell<br>Robijn<br>Romano<br>Slaney | Lady Balfour<br>Orla<br>Robinta<br>Sante<br>Setanta<br>Stirling |

## 2.5 Conclusions

1. The results presented here, in combination with the data from the preliminary trials on integrated control funded by the Potato Council in 2006, show that there is the potential to utilise cultivar resistance as part of an integrated strategy for the control of blight on potatoes.

2. The results from both trials in 2007 show that cultivar resistance could be utilized to reduce fungicide inputs even where blight pressure is extremely high and the more aggressive 13_A2 genotype is dominant.

3. The relative efficacies of the integrated control treatments, i.e. the combination of a cultivar with a higher resistance rating with less of the same fungicide, in controlling foliar blight was most often significantly better than the combination of the more susceptible variety treated with the maximum fungicide input.

4. The relative efficacies of the integrated control treatments, compared with the benchmark combination of susceptible cultivar and maximum fungicide input, was influenced by the trial, fungicide product and the interaction between these two factors.

5. In both trials the benefit to foliar blight control from an integrated control system was greater where the input of the same fungicide was reduced rather than substituting a less effective fungicide.

6. Only limited comparisons for tuber blight control were possible. However, most the integrated control treatments resulted in significantly better control of tuber blight than Shepody treated with the maximum fungicide input.

7. Blight-free yield was frequently significantly higher for the integrated control treatments, compared with the benchmark treatment of Shepody treated with 1.6 L of Infinito every 7 days. No yields for integrated control treatments were significantly less.

8. The results suggest that in an integrated control system, better control of foliar blight is achieved where fungicide reductions are obtained by using a lower dose of fungicide more often rather than a higher dose less often. There was no consistent effect of these two options on tuber blight control. Yields were generally not significantly affected by which approach was used.

9. Further research is required to develop the potential contribution of integrated control identified in this research into a reliable control system that the GB potato industry can use with confidence. This is the aim of the current Sustainable LINK proposal.

10. The foliar resistance ratings of the popular varieties tested using 13_A2 in the field in 2008 were reduced for many cultivars compared with published ratings. The reduction was clearly greater for the cultivars with higher published ratings. For several more resistant cultivars the drop in rating was between 2 and 5 on the 9-point scale.

11. Research is required to understand the cause of the strong relationship for cultivars between published rating and the size of the apparent decline in resistance when challenged by 13_A2.

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# 4  Acknowledgements

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# 5  Knowledge transfer activities

Bain RA (2007) “Integrated control of blight : making the most of cultivar resistance.” Presentation at Potatoes in Practice, August 2007.

Bain RA (2007) An explanation of the project was given and the trial plots demonstrated at the SAC Blight Day at Auchincruive Estate on 5 Sep 2007.

Bain RA, Ritchie F & Bradshaw NJ (2008) “Potential cost savings through matching blight fungicide inputs to cultivar resistance.”  Presentation at the Potato Council Blight Forum, February 2008, Grantham.

The following is suggested for the Blight Forum in 2009. Authors not yet decided. “Cultivar resistance to *P. infestans* genotype 13_A2.” Potato Council Blight Forum, 10 February 2009, Peterborough.

# Appendix A

## *Site and application details*

TABLE A1. DETAILS OF SOIL TYPE, NUTRIENT STATUS, CULTIVATIONS AND AGRONOMY

| | **Llanilar, Ceredigion** | **SAC, Auchincruive 2007** | **SAC,Auchincruive 2008** |
|---|---|---|---|
| Soil Series: | Denbigh Series | - | - |
| Soil Texture: | Clay Loan | Silty sandy loam | Silty sandy loam |
| Soil Analysis: | | | |
| P index | 2 | Moderate | Moderate |
| K index | 3 | High | Moderate |
| Mg index | 3 | Moderate | Moderate |
| PH | 6.5 | 5.9 | 5.8 |
| Previous Cropping: | | | |
| 2005 | Spring barley | Grass | Grass |
| 2004 | Spring barley | Grass | Grass |
| 2003 | Spring barley | Grass | Grass |
| Cultivations: | Plough<br>Ridge Tilled | Plough<br>Disked then rotovated | Plough<br>Disked then rotovated |
| Cultivars & seed health status: | Shepody – SE2 | Shepody – SE2 | 23 cultivars |
| | Maris Piper – SE2 | Maris Piper – SE2 | |
| | Lady Balfour – SE2 | Lady Balfour – SE2 | |
| Planting date: | 2 May | 4 June | 26 May |
| Harvesting date: | 27 Sept | 13 October | Foliar blight only |
| Fertiliser (kg/ha): | | | |
| N | 230 | 214 | 226 |
| P | 130 | 187 | 159 |
| K | 130 | 187 | 215 |
| FYM (t/ha) | | - | - |
| Herbicides: | Citation @ 1.25 kg/ha | Linuron @ 2.9 l/ha + | Defy @ 4 l/ha + |
| | Gramoxone 100 @ 2.0l/ha | PDQ @ 1.0 l/ha | Shotput @ 0.5 kg/ha |
| | 1 June 2007 | 11 June 2007 | 30 May 2008 |
| Insecticides: | None | None | None |

| | | | |
|---|---|---|---|
| Desiccant: | Standon Diquat @ 4.0 L/ha on 22 Aug | Reglone @ 4 l/ha on 18 September | Foliar blight only |
| Trace elements | None | None | None |

TABLE A2. SPRAY TREATMENT DATES AND FUNGICIDE PRODUCTS AND RATES (KG OR L/HA) USED AT AUCHINCRUIVE, 2007

| | 7-Jul | 18-Jul | 23 Jul | 31-Jul | 8-Aug | 15 Aug | 17-Aug | 22-Aug |
|---|---|---|---|---|---|---|---|---|
| **Interval (7 days)** | **-** | **-** | **-** | **-** | **8** | **7** | **-** | **7** |
| **Interval (10 days)** | **-** | **11** | **5** | **8** | **8** | **-** | **9** | **-** |
| **Treatment No.** | | | | | | | | |
| 1 | Tattoo | Tattoo | Merlin | Tattoo | | | | |
| 2 | Tattoo | Tattoo | Merlin | Tattoo | Infinito 1.6 | Infinito 1.6 | | Infinito 1.6 |
| 3 | Tattoo | Tattoo | Merlin | Tattoo | Infinito 1.2 | Infinito 1.2 | | Infinito 1.2 |
| 4 | Tattoo | Tattoo | Merlin | Tattoo | Infinito 0.8 | Infinito 0.8 | | Infinito 0.8 |
| 5 | Tattoo | Tattoo | Merlin | Tattoo | Infinito 1.6 | | Infinito 1.6 | |
| 6 | Tattoo | Tattoo | Merlin | Tattoo | Infinito 1.2 | | Infinito 1.2 | |
| 7 | Tattoo | Tattoo | Merlin | Tattoo | Shirlan 0.4 | Shirlan 0.4 | | Shirlan 0.4 |
| 8 | Tattoo | Tattoo | Merlin | Tattoo | Shirlan 0.3 | Shirlan 0.3 | | Shirlan 0.3 |
| 9 | Tattoo | Tattoo | Merlin | Tattoo | Shirlan 0.2 | Shirlan 0.2 | | Shirlan 0.2 |
| 10 | Tattoo | Tattoo | Merlin | Tattoo | Shirlan 0.4 | | Shirlan 0.4 | |
| 11 | Tattoo | Tattoo | Merlin | Tattoo | Shirlan 0.3 | | Shirlan 0.3 | |
| 12 | Tattoo | Tattoo | Merlin | Tattoo | Dithane NT 2.0 | Dithane NT 2.0 | | Dithane NT 2.0 |
| 13 | Tattoo | Tattoo | Merlin | Tattoo | Dithane NT 1.5 | Dithane NT 1.5 | | Dithane NT 1.5 |
| 14 | Tattoo | Tattoo | Merlin | Tattoo | Dithane NT 1.0 | Dithane NT 1.0 | | Dithane NT 1.0 |
| 15 | Tattoo | Tattoo | Merlin | Tattoo | Dithane NT 2.0 | | Dithane NT 2.0 | |
| 16 | Tattoo | Tattoo | Merlin | Tattoo | Dithane NT 1.5 | | Dithane NT 1.5 | |

TABLE A2. SPRAY TREATMENT DATES AND FUNGICIDE PRODUCTS AND RATES (KG OR L/HA) USED AT AUCHINCRUIVE, 2007 (CONT'D)

| | **27-Aug** | **29-Aug** | **4_Sep** | **6 Sep** | **12 Sep** | **17-Sep** | **19 Sep** |
|---|---|---|---|---|---|---|---|
| **Interval (7 days)** | **-** | **7** | **6** | **-** | **8** | **-** | **7** |
| **Interval (10 days)** | **10** | **-** | **-** | **10** | **-** | **11** | **-** |
| **Treatment No.** | | | | | | | |
| 1 | | | | | | | |
| 2 | | Infinito 1.6 | Infinito 1.6 | | Infinito 1.6 | | Infinito 1.6 |
| 3 | | Infinito 1.2 | Infinito 1.2 | | Infinito 1.2 | | Infinito 1.2 |
| 4 | | Infinito 0.8 | Infinito 0.8 | | Infinito 0.8 | | Infinito 0.8 |
| 5 | Infinito1.6 | | | Infinito 1.6 | | Infinito 1.6 | |
| 6 | Infinito1.2 | | | Infinito 1.2 | | Infinito 1.2 | |
| 7 | | Shirlan 0.4 | Shirlan 0.4 | | Shirlan 0.4 | | Shirlan 0.4 |
| 8 | | Shirlan 0.3 | Shirlan 0.3 | | Shirlan 0.3 | | Shirlan 0.3 |
| 9 | | Shirlan 0.2 | Shirlan 0.2 | | Shirlan 0.2 | | Shirlan 0.2 |
| 10 | Shirlan 0.4 | | | Shirlan 0.4 | | Shirlan 0.4 | |
| 11 | Shirlan 0.3 | | | Shirlan 0.3 | | Shirlan 0.3 | |
| 12 | | Dithane NT 2.0 | Dithane NT 2.0 | | Dithane NT 2.0 | | Dithane NT 2.0 |
| 13 | | Dithane NT 1.5 | Dithane NT 1.5 | | Dithane NT 1.5 | | Dithane NT 1.5 |
| 14 | | Dithane NT 1.0 | Dithane NT 1.0 | | Dithane NT 1.0 | | Dithane NT 1.0 |
| 15 | Dithane NT 2.0 | | | Dithane NT 2.0 | | Dithane NT 2.0 | |
| 16 | Dithane NT 1.5 | | | Dithane NT 1.5 | | Dithane NT 1.5 | |

TABLE A3. SPRAY TREATMENT DATES AND FUNGICIDE PRODUCTS AND RATES (KG OR L/HA) USED AT LLANILAR, CEREDIGION 2007

| | **21-Jun** | **05-Jul** | **12-Jul** | **19-Jul** | **22-Jul** | **27-Jul** | **01-Aug** | **03-Aug** |
|---|---|---|---|---|---|---|---|---|
| **Interval (7 days)** | **-** | **-** | **-** | **7** | **-** | **8** | **-** | **7** |
| **Interval (10 days)** | **-** | **14** | **7** | **-** | **10** | **-** | **10** | **-** |
| **Treatment No.** | | | | | | | | |
| 1 | Tattoo | Tattoo | Tattoo | | | | | |
| 2 | Tattoo | Tattoo | Tattoo | Infinito 1.6 | | Infinito 1.6 | | Infinito 1.6 |
| 3 | Tattoo | Tattoo | Tattoo | Infinito 1.2 | | Infinito 1.2 | | Infinito 1.2 |
| 4 | Tattoo | Tattoo | Tattoo | Infinito 0.8 | | Infinito 0.8 | | Infinito 0.8 |
| 5 | Tattoo | Tattoo | Tattoo | | Infinito 1.6 | | Infinito 1.6 | |
| 6 | Tattoo | Tattoo | Tattoo | | Infinito 1.2 | | Infinito 1.2 | |
| 7 | Tattoo | Tattoo | Tattoo | Shirlan 0.4 | | Shirlan 0.4 | | Shirlan 0.4 |
| 8 | Tattoo | Tattoo | Tattoo | Shirlan 0.3 | | Shirlan 0.3 | | Shirlan 0.3 |
| 9 | Tattoo | Tattoo | Tattoo | Shirlan 0.2 | | Shirlan 0.2 | | Shirlan 0.2 |
| 10 | Tattoo | Tattoo | Tattoo | | Shirlan 0.4 | | Shirlan 0.4 | |
| 11 | Tattoo | Tattoo | Tattoo | | Shirlan 0.3 | | Shirlan 0.3 | |
| 12 | Tattoo | Tattoo | Tattoo | Dithane NT 2.0 | | Dithane NT 2.0 | | Dithane NT 2.0 |
| 13 | Tattoo | Tattoo | Tattoo | Dithane NT 1.5 | | Dithane NT 1.5 | | Dithane NT 1.5 |
| 14 | Tattoo | Tattoo | Tattoo | Dithane NT 1.0 | | Dithane NT 1.0 | | Dithane NT 1.0 |
| 15 | Tattoo | Tattoo | Tattoo | | Dithane NT 2.0 | | Dithane NT 2.0 | |
| 16 | Tattoo | Tattoo | Tattoo | | Dithane NT 1.5 | | Dithane NT 1.5 | |

TABLE A3. SPRAY TREATMENT DATES AND FUNGICIDE PRODUCTS AND RATES (KG OR L/HA) USED AT LLANILAR, CEREDIGION 2007 (CONT'D)

| | **10-Aug** | **10-Aug** | **20-Aug** | **20-Aug** | **26-Aug** | **30-Aug** |
|---|---|---|---|---|---|---|
| **Interval (7 days)** | **7** | **-** | **10** | **-** | **6** | **-** |
| **Interval (10 days)** | **-** | **9** | **-** | **10** | **-** | **10** |
| **Treatment No.** | | | | | | |
| 1 | | | | | | |
| 2 | Infinito 1.6 | | Infinito 1.6 | | Infinito 1.6 | |
| 3 | Infinito 1.2 | | Infinito 1.2 | | Infinito 1.2 | |
| 4 | Infinito 0.8 | | Infinito 0.8 | | Infinito 0.8 | |
| 5 | | Infinito 1.6 | | Infinito 1.6 | | Infinito 1.6 |
| 6 | | Infinito 1.2 | | Infinito 1.2 | | Infinito 1.2 |
| 7 | Shirlan 0.4 | | Shirlan 0.4 | | Shirlan 0.4 | |
| 8 | Shirlan 0.3 | | Shirlan 0.3 | | Shirlan 0.3 | |
| 9 | Shirlan 0.2 | | Shirlan 0.2 | | Shirlan 0.2 | |
| 10 | | Shirlan 0.4 | | Shirlan 0.4 | | Shirlan 0.4 |
| 11 | | Shirlan 0.3 | | Shirlan 0.3 | | Shirlan 0.3 |
| 12 | Dithane NT 2.0 | | Dithane NT 2.0 | | Dithane NT 2.0 | |
| 13 | Dithane NT 1.5 | | Dithane NT 1.5 | | Dithane NT 1.5 | |
| 14 | Dithane NT 1.0 | | Dithane NT 1.0 | | Dithane NT 1.0 | |
| 15 | | Dithane NT 2.0 | | Dithane NT 2.0 | | Dithane NT 2.0 |
| 16 | | Dithane NT 1.5 | | Dithane NT 1.5 | | Dithane NT 1.5 |

# Appendix B

## *Area under the disease progress curve (AUDPC) tables*

TABLE B1 SUMMARY OF THE EFFECT OF CULTIVAR, FUNGICIDE, APPLICATION RATE AND INTERVAL ON THE AREA UNDER THE DISEASE PROGRESS CURVE (AUDPC) AT AUCHINCRUIVE IN 2007

| **Treatments** | **Shepody** | **Maris Piper** | **Lady Balfour** | **Fungicide treatment mean** |
|---|---|---|---|---|
| Untreated * | 2425 | 2281 | 2628 | 2445 |
| Infinito 1.6 l/ha at 7-day intervals | 1243 | 802 | 298 | 781 |
| Infinito 1.2 l/ha at 7-day intervals | 1007 | 1026 | 538 | 857 |
| Infinito 0.8 l/ha at 7-day intervals | 1263 | 1120 | 897 | 1093 |
| Infinito 1.6 l/ha at 10-day intervals | 1467 | 1200 | 1169 | 1279 |
| Infinito 1.2 l/ha at 10-day intervals | 1503 | 1202 | 1269 | 1324 |
| Shirlan 0.4 l/ha at 7-day intervals | 1890 | 1427 | 1063 | 1460 |
| Shirlan 0.3 l/ha at 7-day intervals | 1783 | 1503 | 1133 | 1473 |
| Shirlan 0.2 l/ha at 7-day intervals | 1852 | 1429 | 1221 | 1501 |
| Shirlan 0.4 l/ha at 10-day intervals | 1790 | 1513 | 1417 | 1573 |
| Shirlan 0.3 l/ha at 10-day intervals | 1960 | 1581 | 1498 | 1680 |
| Dithane NT 2.0 kg/ha at 7-day intervals | 2019 | 1443 | 854 | 1439 |
| Dithane NT 1.5 kg/ha at 7-day intervals | 2170 | 1699 | 1461 | 1777 |
| Dithane NT 1.0 kg/ha at 7-day intervals | 2192 | 1559 | 1280 | 1677 |
| Dithane NT 2.0 kg/ha at 10-day intervals | 2229 | 1693 | 1526 | 1816 |
| Dithane NT 1.5 kg/ha at 10-day intervals | 2262 | 1661 | 1832 | 1919 |
| Variety means (excluding untreated) | 1775 | 1390 | 1164 | 1443 |
| F pr.(Variety/Fungicide/Rate & Interval)<br>LSD (*P* = 0.05) | 0.560 (NS)<br>235.4 | | | |
| F pr.(Fungicide treatment means)<br>LSD (*P* = 0.05) | <0.001<br>82.5 | | | |
| F pr.(Variety means)<br>LSD (*P* = 0.05) | <0.001<br>47.0 | | | |

*Untreated excluded from the analysis of variance.

TABLE B2 THE INTERACTION BETWEEN VARIETY AND FUNGICIDE ON THE AREA UNDER THE DISEASE PROGRESS CURVE (AUDPC) AT AUCHINCRUIVE IN 2007

| **Treatments** | **Shepody** | **Maris Piper** | **Lady Balfour** |
|---|---|---|---|
| Untreated * | 2425 | 2281 | 2628 |
| Infinito | 1297 | 1070 | 834 |
| Shirlan | 1855 | 1490 | 1266 |
| Dithane | 2175 | 1611 | 1391 |
| F pr. | <0.001 | | |
| LSD (*P*=0.05) | 156.0 | | |
| Means with the same level of fungicide<br>LSD (*P=0.05*) | 121.5 | | |

*Untreated excluded from the analysis of variance.

TABLE B3 THE INTERACTION BETWEEN FUNGICIDE, DOSE AND SPRAY INTERVALS ON THE AREA UNDER THE DISEASE PROGRESS CURVE (AUDPC) AT AUCHINCRUIVE IN 2007

| Treatments | 7 days | 10 days |
|---|---|---|
| Infinito 1.6 l/ha | 781 | 1279 |
| Infinito 1.2 l/ha | 857 | 1324 |
| Infinito 0.8 l/ha | 1093 | - |
| Shirlan 0.4 l/ha | 1460 | 1573 |
| Shirlan 0.3 l/ha | 1473 | 1680 |
| Shirlan 0.2 l/ha | 1501 | - |
| Dithane NT 2.0 kg/ha | 1439 | 1816 |
| Dithane NT 1.5 kg/ha | 1777 | 1919 |
| Dithane NT 1.0 kg/ha | 1677 | - |
| | | |
| F pr. | 0.093 (NS) | |
| LSD (*P*=0.05) | 237.7 | |

*Untreated excluded from the analysis of variance.

TABLE B4 SUMMARY OF THE EFFECT OF CULTIVAR, FUNGICIDE, APPLICATION RATE AND INTERVAL ON THE AREA UNDER THE DISEASE PROGRESS CURVE (AUDPC) AT LLANILAR, CEREDIGION IN 2007

| Treatments | Shepody | Maris Piper | Lady Balfour | Fungicide treatment mean |
|---|---|---|---|---|
| Untreated * | 3135 | 2568 | 2648 | 2784 |
| Infinito 1.6 l/ha at 7-day intervals | 1546 | 1090 | 1098 | 1245 |
| Infinito 1.2 l/ha at 7-day intervals | 2283 | 1580 | 1435 | 1766 |
| Infinito 0.8 l/ha at 7-day intervals | 2655 | 1872 | 2116 | 2214 |
| Infinito 1.6 l/ha at 10-day intervals | 2455 | 1373 | 1621 | 1816 |
| Infinito 1.2 l/ha at 10-day intervals | 2605 | 1460 | 1605 | 1890 |
| Shirlan 0.4 l/ha at 7-day intervals | 1594 | 733 | 727 | 1018 |
| Shirlan 0.3 l/ha at 7-day intervals | 2094 | 1047 | 1345 | 1495 |
| Shirlan 0.2 l/ha at 7-day intervals | 2324 | 1324 | 1568 | 1739 |
| Shirlan 0.4 l/ha at 10-day intervals | 2792 | 1888 | 1947 | 2209 |
| Shirlan 0.3 l/ha at 10-day intervals | 2596 | 1825 | 1922 | 2114 |
| Dithane NT 2.0 kg/ha at 7-day intervals | 2813 | 1828 | 1702 | 2114 |
| Dithane NT 1.5 kg/ha at 7-day intervals | 2598 | 1734 | 1902 | 2079 |
| Dithane NT 1.0 kg/ha at 7-day intervals | 2880 | 2045 | 2123 | 2349 |
| Dithane NT 2.0 kg/ha at 10-day intervals | 2565 | 1565 | 1676 | 1935 |
| Dithane NT 1.5 kg/ha at 10-day intervals | 2805 | 1912 | 2137 | 2285 |
| Variety means | 2440 | 1552 | 1662 | 1885 |
| F pr.(Variety/Fungicide/Rate & Interval)<br>LSD (*P* = 0.05) | 0.073 (NS)<br>422.3 | | | |
| F pr.(Fungicide treatment means)<br>LSD (*P* = 0.05) | <0.001<br>351.3 | | | |
| F pr.(Variety means)<br>LSD (*P* = 0.05) | <0.001<br>74.1 | | | |

*Untreated excluded from the analysis of variance.

 

TABLE B5 THE INTERACTION BETWEEN FUNGICIDE, DOSE AND SPRAY INTERVALS ON THE AREA UNDER THE DISEASE PROGRESS CURVE (AUDPC) AT LLANILAR, CEREDIGION IN 2007

| **Treatments** | **7 days** | **10 days** |
|---|---|---|
| Infinito 1.6 l/ha | 1245 | 1816 |
| Infinito 1.2 l/ha | 1766 | 1890 |
| Infinito 0.8 l/ha | 2214 | - |
| Shirlan 0.4 l/ha | 1018 | 2209 |
| Shirlan 0.3 l/ha | 1495 | 2115 |
| Shirlan 0.2 l/ha | 1739 | - |
| Dithane NT 2.0 kg/ha | 2114 | 1935 |
| Dithane NT 1.5 kg/ha | 2079 | 2285 |
| F pr. | 0.020 | |
| LSD (*P*=0.05) | 366.7 | |

*Untreated excluded from the analysis of variance.

TABLE B6 THE INTERACTION BETWEEN VARIETY AND FUNGICIDE ON THE AREA UNDER THE DISEASE PROGRESS CURVE (AUDPC) AT LLANILAR, CEREDIGION IN 2007

| **Treatments** | **Shepody** | **Maris Piper** | **Lady Balfour** |
|---|---|---|---|
| Untreated * | 3135 | 2568 | 2648 |
| Infinito | 2161 | 1514 | 1550 |
| Shirlan | 2004 | 1035 | 1213 |
| Dithane | 2763 | 1869 | 1910 |
| F pr. | 0.042 | | |
| LSD (*P*=0.05) | 247.1 | | |

*Untreated excluded from the analysis of variance.