PPO – SPECIAL REPORT NO 16 – 2014, 65-74

Impact of fungicide input on leaf blight (*Phytophthora infestans*) development on different potato cultivars

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SUMMARY

A shift towards more aggressive and virulent late blight (*Phytophthora infestans)* genotypes in GB, including 13_A2 and 6_A1, has resulted in the resistance ratings of previously resistant cultivars being downgraded in 2011. The use of 13_A2, the dominant A2 strain in GB, in untreated cultivar screening trials has increased the disease pressure and discrimination between varieties is now less clear. Integrated control of late blight using cultivar resistance and reduced fungicide inputs requires robust information on the resistance ratings of varieties and downgrading of resistance ratings may be considered a set back to its implementation. The results of thirteen experiments conducted from 2009 to 2011, however, provide evidence that the contribution of cultivar resistance differs substantially for different levels of fungicide input. The contribution of moderately resistant varieties (resistance ratings of 5 to 7) is considerably greater when plants are fungicide treated than left unprotected, with fungicide application of 0.5 dose (as a proportion of the full recommended label rate) sufficient to demonstrate cultivar differences in small plot screening trials. Previous experiments have demonstrated that the rank order of varieties is similar regardless of whether fungicide is applied or plants are left untreated. The inclusion of fungicide treatment in resistance screening trials could be used to slow the epidemic. Fungicide treatment would therefore allow the contribution of cultivar resistance to season long late blight control to be determined and also offer clearer discrimination between varieties.

KEYWORDS

Late blight, *Phytophthora infestans*, foliar blight, cultivar resistance, fungicides, integrated control

INTRODUCTION

EU legislation requires member states to promote lower pesticide inputs and encourage incorporation of non-chemical control measures into crop disease management practices. This includes the control of late blight (*Phytophthora infestans*) on potato. Cultivar resistance, in combination with reduced fungicide input, has been shown to successfully reduce foliar blight severity in previous experiments (Fry 1978; Neilsen 2004; Kirk *et al.,* 2001 & 2005; Kessel *et al.,* 2006; Naerstad *et al.,* 2007; Bain *et al.,* 2011). A shift in the late blight population in GB towards more aggressive and virulent *P. infestans* genotypes, including 13_A2 and 6_A1, resulted in the foliar resistance ratings of several cultivars being downgraded from resistant (e.g. Cara with a rating of 7 in 2010) to moderately resistant (Cara with rating of 5 in 2012) (Lees *et al.,* 2012). Sufficiently large differences in foliar resistance between varieties are a key part of integrated control; however 99% of the potato hectarage in GB is of cultivars with a resistance rating of 5 or below. Cultivar resistance ratings are based on disease progress on test varieties (as determined by the area under the disease progress curve) relative to disease progress on two standard (anchor) varieties (one susceptible and one resistant). Recent trials in GB have shown that, in the presence of the more aggressive genotypes, differences between varieties tended to be smaller in untreated compared with fungicide-treated plots and gave a preliminary indication that the inclusion of fungicide would allow better discrimination between varieties (Bain *et al.,* 2008, Bain *et al.,* 2011). The inclusion of fungicide treatment in variety screening trials could therefore offer more robust information on varieties for use in an integrated control strategy.

This work was carried out as part of a government and industry funded Sustainable Arable LINK project which aims to deliver robust information on the use of integrated late blight control to the GB industry. The first objective was to test whether the use of fungicides improves discrimination between cultivars when disease pressure is high. The second objective was to test whether the downgrading of cultivar resistance ratings due to the presence of more virulent and aggressive genotypes will affect the use of cultivar resistance as part of an integrated control strategy during both rapid haulm growth and stable canopy.

MATERIALS AND METHODS

Discrimination between varieties: cultivar resistance ratings in relation to fungicide dose

In 2012, an experiment with five varieties with resistance ratings ranging from 3 (least resistant) to 8 (most resistant) was conducted at the SRUC site at Auchincruive Estate, Ayrshire, Scotland (Table 1). The trial was laid out in a randomised split plot design with six replicates. Plots consisted of four plants of each cultivar (two in each row, 30cm apart) in the centre two rows, with an outer row of King Edward on each side of the plot. These rows of King Edward acted as spreader rows but were treated with the same fungicide input as the four test plants in each plot. Three treatments were included: two fungicide programmes of Shirlan (0.4 or 0.2 L/ha) alternating at 7 day intervals with Quell Flo (1.65 or 3.3 L/ha)) applied season long plus an untreated control (Table 2). Fungicides were applied as main plot treatments with cultivars included as sub-plots.

In 2010, a similar experiment consisting of 19 varieties with resistance ratings from 2 (least resistant) to 8 (most resistant) was conducted at the ADAS site near Cilcennin, near Aberystwyth, Ceredigion, Wales. Results from five varieties with similar cultivar resistance ratings to the SRUC trial in 2012 were selected and presented in this paper (Table 1). The trial was laid out in a randomised split plot design with three replicates, with plots arranged as described previously for the SRUC site. In this experiment and in contrast to the SRUC site in 2012, the single spreader rows of King Edward were left untreated. Three treatments: two fungicide programmes of Shirlan (0.4 or 0.2 L/ha) applied season long plus an untreated control were included as main plot treatments with the cultivars included as sub-plots (Table 2).

The cultivar x fungicide experiment was inoculated on 12 July 2010 at Cilcennin using a *P. infestans* isolate of 13_A2 representative of the GB population. The trial at Auchincruive was not inoculated directly but became infected from a neighbouring trial that had been inoculated with 13_A2.

Table 1. *The six cultivars included in the cultivar x fungicide dose trials and their foliar resistance ratings at SRUC Aucincruive in 2012 and ADAS Cilcennin in 2010*

Cultivar resistance rating	Varietal resistance rating (from the British Potato Variety Database, 2012)
3 (least resistant)	King Edward
4	Maris Piper
5	Cara
6	Axonaa
7	Ambob
8 (most resistant)	Sarpo Mira

[a]Included in ADAS Cilcennin experiment in 2010 only; [b]Included in SRUC Auchincruive experiment in 2012 only.

Table 2. *Fungicides, rates and intervals in the cultivar x fungicide dose trials at SRUC Auchincruive in 2012 and ADAS Cilcennin in 2010*

Treatment	Product	Active ingredient(s)	g/kg or L product	Concentration (g a.i./ha)	Rate/ha	Interval (days)
1	Untreated	-	-	-	-	-
2	Shirlan SCa	fluazinam	500g/L	200	0.4 (L)	7 days
3	Shirlan SCb	fluazinam	500g/L	100	0.2 (L)	7 days

[a]alternated with 1.65 L/ha Quell Flo (455 g/L mancozeb; 750g a.i./ha) for SRUC Auchincruive experiment in 2012.

[b]alternated with 3.30 L/ha Quell Flo (455 g/L mancozeb; 1500g a.i./ha) for SRUC Auchincruive experiment in 2012.

Integrated control trials: cultivar resistance ratings in relation to fungicide dose across two sites and three years

IN 2009, 2010 and 2011 a total of twelve experiments were conducted to determine the effectiveness of integrated control treatments incorporating reduced fungicide inputs and cultivar resistance to control foliar late blight during rapid canopy growth and stable canopy. Six experiments, 3 investigating integrated control strategies during rapid haulm growth and 3 during stable canopy were conducted at the SRUC site near Auchincruive, with a similar 6 trials conducted in parallel at the ADAS site near Cilcennin. Experiments were laid out in a randomised split plot design with 4 replicates. Each sub-plot consisted of either King Edward (resistance rating 3) or Cara (resistance rating 5) and was 4 rows wide by c. 3m long, with seed spacing determined by tuber size. All foliar assessments were done on the centre 2 rows of each sub-plot. In the rapid haulm growth trials, treatment fungicide applications were started as soon as plants started to meet within the rows or earlier if late blight risk was high. In the stable canopy trials, all plots including the untreated were oversprayed with Merlin 2.5 L/ha (propamocarb-HCL + chlorothalonil) during rapid canopy growth at 7 or 10-day intervals depending on early season risk or as soon as plants started to meet within the rows. One fungicide was tested in the rapid haulm growth trial (Revus; 250g/L mandipropamid: full label rate 0.6 L/ha). Three fungicides were tested in the stable canopy trial (Infinito: 62.5g/L fluopicolide + 625g/L propamocarb-hydrochloride, full label rate 1.6 L/ha; Revus and Shirlan). Fungicides were applied at 7-day or 10-day intervals in both rapid haulm and stable canopy trials at 0, 25, 50, 75 and 100% of the recommended label rate. Dithane NT (mancozeb 75% w/w) at 1.7 kg/ha or an alternative mancozeb product at an equivalent rate (1275g a.i./ha) was applied to the stable canopy trial for the remainder of the season once test treatment applications were completed. Dithane NT at 2.0 Kg/ha was applied to the rapid haulm trials once treatment applications were completed. Data were averaged across application interval and fungicide product for the stable canopy trial results presented in this paper.

Experimental sites were inoculated on 12, 12 and 3 July (Cilcennin) and 7, 12 and 8 July (Auchincruive) in 2009, 2010 and 2011 respectively. At Cilcennin, fungicides 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 (350 kPa) to give a medium/fine spray quality using Lurmark F03-110 nozzles.

The percentage leaf area destroyed by foliar blight was assessed at regular intervals during the epidemic using a modified version of the keys Large (1952) and Anon (1976). Data are presented as the percentage of leaf area affected by foliar late blight or used to calculate the Area Under the Disease Progress Curve (AUDPC) as appropriate. AUDPCs were subjected to ANOVA to test whether there was an interaction between fungicide treatment and cultivar resistance rating, with the least significant difference (LSD) for specific comparisons included.

RESULTS AND DISCUSSION

Discrimination between varieties in untreated and fungicide treated situations

In untreated plots at the SRUC experiment site in 2012, there was little or no separation in the progress of foliar late blight on varieties with a resistance rating of 3 (King Edward) or 4 (Maris Piper) (Figure 1A to C). Cara, with a resistance rating of 5, appeared to be more resistant than Ambo which has a resistance rating of 6 and little foliar blight developed on Sarpo Mira (Figure 1A). Following application of Shirlan at 0.2 L/ha (half the recommended label rate), separation between the varieties became more distinct, with progress of foliar blight clearly slower on Maris Piper than King Edward (Figure 1B). Foliar blight development was still slower on Cara than Ambo where Shirlan at 0.4 L/ha (the full recommended label rate) was applied. Application of fungicide moved the progress of foliar late blight on moderately resistant varieties away from the susceptible anchor variety, King Edward, and closer to the more resistant anchor variety, Sarpo

Mira. Where Shirlan at 0.4 L/ha (the full recommended label rate) was applied, moderately resistant varieties were giving control closer to Sarpo Mira than King Edward (Figure 1C).

At the ADAS experiment site in 2010, differences between varieties in untreated plots were less distinct (Figure 1D to F). Progress of foliar late blight on varieties in untreated plots with resistance ratings of 3, 4 and 5 (King Edward, Maris Piper and Cara) was similar, with disease development on Axona and Sarpo Mira also similar (Figure 1D). With application of Shirlan at 0.2 L/ha and 0.4 L/ha, progress of foliar late blight on moderately resistant varieties (Cara and Axona) was closer to the resistant anchor variety Sarpo Mira than the susceptible anchor variety King Edward (Figure 1E and 1F).

Comparison of the AUDPCs in the ADAS Cilcennin trial in 2010 showed no statistically significant differences between varieties with resistance ratings of 3 to 5, King Edward, Maris Piper and Cara respectively, where varieties were left untreated (Table 3). Where Shirlan at 0.4 L/ha was applied, however, control of foliar late blight on Cara was not statistically different from that on Axona and Sarpo Mira.

Table 3. *Effect of fungicide input (Shirlan at 7 day intervals) on AUDPC values for five varieties with resistance ratings from 3 to 8 grown at the ADAS Cilcennin site in 2010*

Fungicide rate applied	**Variety (resistance rating)**				
	King Edward (3)	**Maris Piper (4)**	**Cara (5)**	**Axona (6)**	**Sarpo Mira (8)**
Untreated	3561	3545a	3484 a	2284b	2024
0.2 L/ha	1971	1308	956	502 b	340
0.4 L/ha	1152	536	387 b	136 b	159
F pr. treatment x variety	<0.001				
LSD (P=0.05) (for same level of fungicide)	335.9				

[a]AUDPC not significantly different from King Edward for the same level of treatment; [b]AUDPC not significantly different from Sarpo Mira for the same level of treatment.

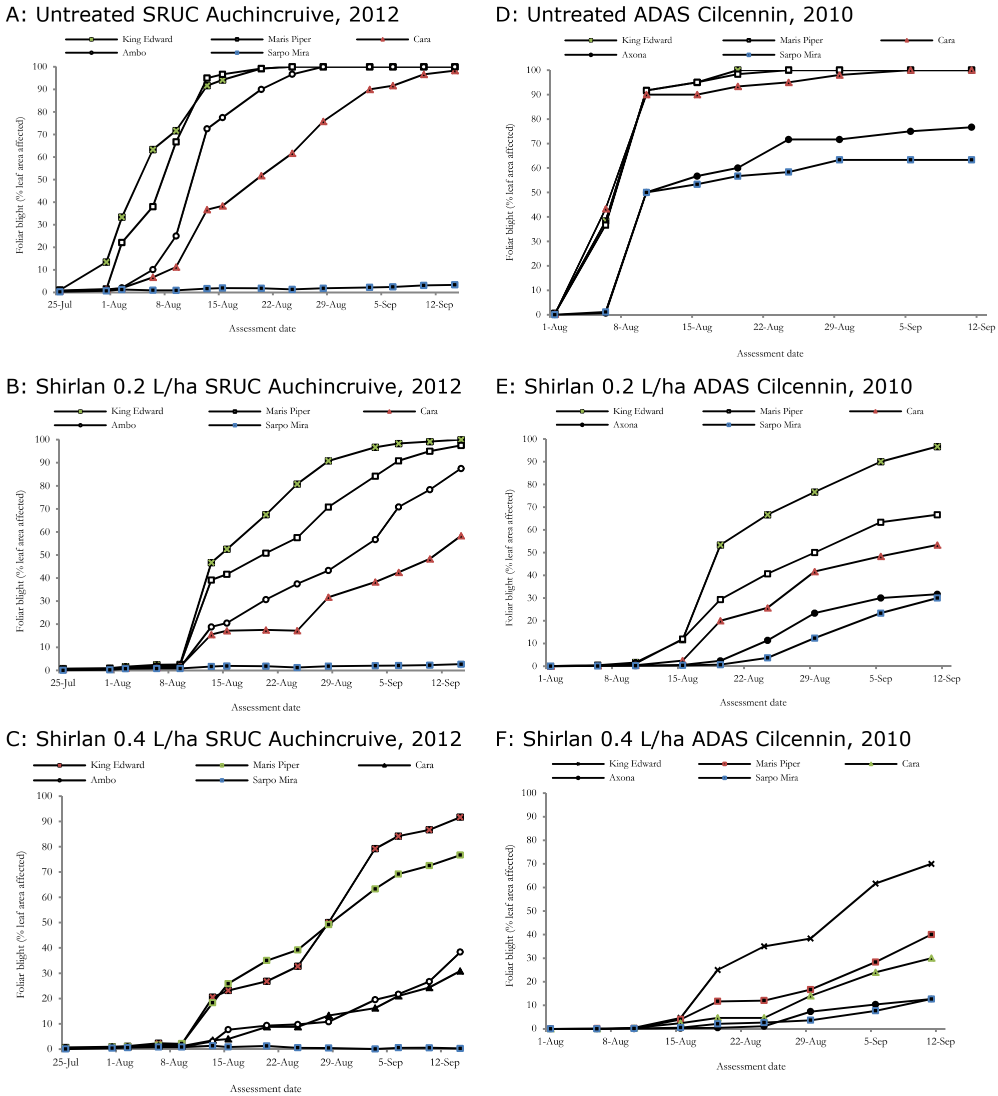

Figure 1. *Progress of foliar late blight (as the percentage leaf area affected) in untreated and fungicide treated plots on varieties with resistance ratings ranging from 3 to 8 in two trials; one at SRUC Auchincruive in 2012 and one at ADAS Cilcennin in 2010. Shirlan at the rate specified was applied season long in the ADAS Cilcennin trial in 2010 but alternated with half of full rate Quell Flo as appropriate in the SRUC Auchincruive trial in 2012*

Comparison of integrated control strategies for control of foliar late blight

During rapid canopy growth discrimination between King Edward and the more resistant Cara was greater where fungicides had been applied compared with completely untreated plots (Figure 2A and 2B). In all but one trial the difference between the two cultivars progressively increased with increasing fungicide dose. The exception was the rapid canopy trial in 2010 at the SRUC Auchincruive site, where low disease pressure meant discrimination between varieties was little affected by fungicide dose (Figure 2A). Application of fungicide doses above 0.5 (as the proportion of the full recommended label rate) offered diminishing discrimination between the two varieties. For treatments applied during stable canopy, disease progress was also closer on varieties left untreated than when fungicides were applied (Figure 2B). With these trials also differences between varieties increased as fungicide dose increased but there was a greater response to fungicide dose during stable canopy. This could either be due to the growth stage at the time of treatment application or the different fungicides used. One fungicide (Revus) was used in the rapid canopy trial but three fungicides (Revus, Infinito and Dithane NT) were applied in the stable canopy trial.

A: Rapid Canopy B: Stable canopy

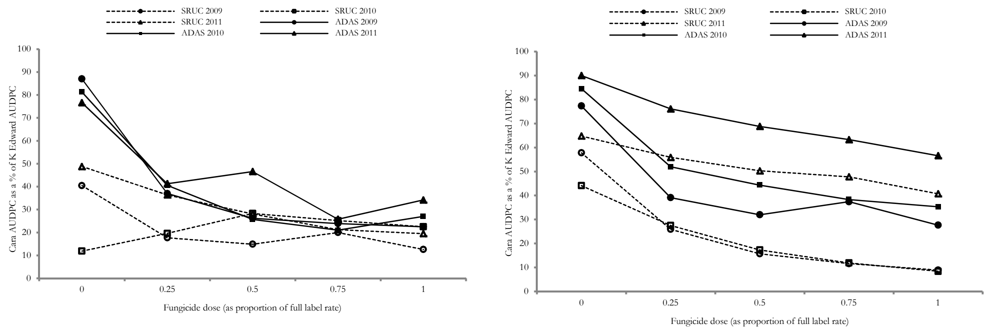

Figure 2. *Change in AUDPC between the more resistant variety (Cara) and the more susceptible variety (King Edward) expressed as a percentage of AUDPC with increasing fungicide dose across twelve field experiments at SRUC and ADAS. Data presented are average of six trials conducted at two sites (SRUC Auchincruive and ADAS Cilcennin) over three years (2009 to 2011) during rapid canopy growth (A) and stable canopy (B). Where the percentage is higher there was a greater degree of similarity in disease progress on the two varieties*

The results of thirteen out of fourteen experiments presented here provide clear evidence that relative AUDPCs for varieties differ substantially for different levels of fungicide input. The contribution of moderately resistant varieties (resistance ratings of 5 to 7) to foliar late blight control is considerably greater where plants are fungicide treated than left unprotected. In these experiments, applying 0.5 dose (as a proportion of the full label rate) was sufficient to pull apart varietal differences in small plot variety screening trials. Fungicide use slows the epidemic by indirectly or directly limiting sporulation and allows the assessment of cultivar resistance over a wider range of growth stages and leaf ages. There is evidence to suggest that leaf position/age has an impact on cultivar resistance to late blight, with no significant differences in the growth of late blight on basal leaves on varieties with resistance ratings from 2 to 8. Discrimination between the growth rates of late blight on susceptible and resistant varieties occurred to a much greater extent on the apical leaves (Visker *et al.*, 2003). The impact this would have on implementation of integrated control strategies is unknown and warrants further investigation, however, the inclusion of fungicide treatment in resistance screening trials would be beneficial to determine how varieties would perform as part of a season long integrated control strategy and also their contribution to the control of late blight in standard commercial practice.

It has been demonstrated previously in experiments comparing the performance of varieties in untreated and fungicide protected conditions that the rank order of varieties is similar in untreated and treated situations (Bain *et al.*, 2011). Although the downgrading of resistance ratings due to the dominance of more virulent and aggressive genotypes could be regarded as problematic to the use of integrated control in GB, it has been demonstrated that substantial differences between varieties do exist that can be exploited in combination with reduced fungicide inputs for the successful control of late blight.

ACKNOWLEDGEMENTS
The trials were part of Sustainable Arable LINK project 533, funded by Bayer, Branston, DEFRA, Greenvale, Higgins, Potato Council, Scottish Government and Syngenta. The funding is gratefully acknowledged. An Undergraduate Vacation Bursary Award by The British Society for Plant Pathology is also gratefully acknowledged because this part funded the 2012 trial at Auchincruive. The isolates of genotype 13_A2 used to inoculate the trials were kindly provided by The James Hutton Institute.

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