Development of foliar late blight (*Phytophthora infestans*) in relation to cultivar resistance and fungicide dose on potato

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SUMMARY

In Britain the shift in the late blight population towards more aggressive and virulent *Phytophthora infestans* genotypes, including 13_A2 and 6_A1, is well documented. Genotype 13_A2 is now used to screen varieties for resistance to late blight and, consequently, disease pressure is considerably greater than before as the protocol remains the same. There is an optimum inoculum density range below or above which discrimination between varieties is diminished, therefore, there is an argument for managing the inoculum density in trials testing cultivar resistance to 13_A2. Of the many ways in which inoculum density could be managed, e.g. isolation of the cultivar screen from other trials that are a potent source of inoculum or a reduced ratio of susceptible infectors to test cultivars or larger plots of test cultivars, this paper examined the impact of a fungicide programme.

Experiments consistently showed that cultivar differences, between AUDPCs, were greater for fungicide treated plots compared with untreated plots. In the integrated control trials carried out in 2009, 2010 and 2011 at 2 sites, the difference between the more resistant Cara and the susceptible King Edward decreased progressively with decreasing fungicide dose. In 2010, two experiments with 19 cultivars showed discrimination between cultivars to be improved where a full- or half-rate fungicide programme was applied to the plots and the resistance ranking orders obtained for untreated and fungicide-treated plots were not significantly different. Additional experiments are required to confirm these findings.

The reduced resistance of some cultivars, associated with the change in *P. infestans* population, is a setback to implementing integrated control, but there remain substantial differences between cultivars and these are large enough to be exploited.

KEYWORDS

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

INTRODUCTION

There is increasing pressure from EU legislation for member states to promote lower pesticide inputs and incorporate non- chemical approaches into crop disease management practices including for the control of late blight (*Phytophthora infestans*) on potato. Cultivar resistance offers the potential to reduce fungicide inputs, whilst still achieving adequate disease control. Reduced fungicide inputs have been shown in previous studies to successfully reduce foliar blight severity when used on potato cultivars with good foliar blight resistance (Fry, 1978; Nielsen 2004; Kirk *et al.* 2001 & 2005; Kessel *et al.* 2006; Naerstad *et al.* 2007). In GB, there has been a shift in the late blight population towards more aggressive and virulent *P. infestans* genotypes including 13_A2 and 6_A1. As a result, the resistance ratings of several cultivars have been downgraded, for example Lady Balfour, a cultivar with a resistance rating of 7 and originally developed for the organic market, was downgraded to a resistance rating of 4 (BVDB, 2012). A key part of integrated control based on cultivar resistance is sufficiently large differences in foliar resistance between varieties. Previous trials in GB have shown that cultivar differences tended to be smaller in untreated compared with fungicide-treated plots, suggesting that cultivar resistance in conjunction with reduced fungicide inputs could give greater separation of cultivars (Bain *et al.*, 2008). At present, 99% of the potato cultivars grown in GB have a cultivar resistance rating of 5 or below.

This work was carried out as part of a government and industry funded Sustainable Arable LINK project which aims to deliver robust information to the GB industry on the use of integrated late blight control. One of the objectives was to test whether the downgrading of cultivar resistance ratings will affect the use of cultivar resistance for integrated control and whether the use of fungicides improves discrimination between cultivars in high disease pressure situations.

MATERIALS AND METHODS

Integrated control trials
In 2009, 2010 and 2011 at SAC, Auchincruive Estate, Ayrshire, Scotland and Cilcennin, near Aberystwyth, Ceredigion, Wales, six trials were conducted to determine the effectiveness of 24 integrated control treatments incorporating fungicide dose and cultivar resistance to control foliar late blight during the stable canopy phase. The trials were laid out in a randomised split plot design with 4 replicates. Each sub-plot 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. All plots were over sprayed with propamocarb-HCL + chlorothalonil (as Merlin; 2.5 L/ha) during rapid canopy growth at 7 or 10 day intervals depending on early season risk as soon as plants started to meet within the rows. Three fungicides were tested (Infinito, Revus and Shirlan) at 7-day intervals and also 10-day intervals during stable canopy at 0, 25, 50, 75 and 100% of recommended dose on each of 4 application dates to cvs King Edward (foliar resistance rating 3) and Cara (5). Dithane NT (1.7 Kg/ha) or an alternative mancozeb product at an equivalent rate was applied for the remainder of the season once test treatment applications were completed.

Discrimination between 19 cultivars
In 2010, a separate experiment was included at both the above sites, with three fungicide treatments applied to 19 cultivars with cultivar resistance ratings from 2 to 8 (Table 1). The trial was laid out in a randomised split plot design with three replicates. Three treatments: two fungicide programmes, Shirlan (0.4 or 0.2 L/ha) plus an untreated control were included and applied as main plot treatments, with the cultivars included as sub-plots (Table 2). Plots at both sites 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 single rows of King Edward acted as spreader rows and were left untreated at Cilcennin but were fungicide treated at Auchincruive.

Table 1. The 19 cultivars included in the cultivar x fungicide dose trial and their foliar resistance ratings in 2010 and 2011

Resistance rating	Varietal resistance ratings in 2010	Varietal resistance ratings in 2011
2	Harmony	
3	Hermes, King Edward, Russet Burbank	Hermes, King Edward, Russet Burbank
4	Maris Piper, Rooster, Saturna	Cosmos, Lady Balfour, Maris Piper, Orla, Pentland Dell, Rooster, Sante, Saturna
5	Claret, Navan, Valor	Cara, Claret, Druid, Harmony, Navan, Slaney, Valor,
6	Cosmos, Pentland Dell, Axona	Axona
7	Cara, Sante, Slaney	
8	Druid, Lady Balfour, Orla	

Table 2. Fungicides, rates and intervals applied to all 19 cultivars in the cultivar x fungicide dose trial

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

The sites were inoculated on 12, 12 and 3 July (Cilcennin) and 7, 12 and 8 July (Auchincruive) in 2009, 2010 and 2011 respectively using an appropriate *P. infestans* isolate of 13_A2, representative of the GB population. 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.

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 were used to calculate the Area under the Disease Progress Curve (AUDPC) and converted to the relative AUDPC (rAUDPC) prior to an analysis of variance (ANOVA) where appropriate. To test whether there was an interaction between fungicide application and cultivar resistance rating, the rAUDPCs from both sites were subjected to an over trials ANOVA following log transformation.

RESULTS AND DISCUSSION

Integrated control trials
The 13_A2 genotype of *P. infestans* dominated at both sites, with the exception of Cilcennin in 2011 where only 6_A1 was identified in the trial area. To determine whether there were differences in foliar blight development between fungicide treated and untreated plots, the AUDPCs for the different fungicide products were averaged to give a single figure for fungicide dose at each site/year. The AUDPCs were then used to compare whether these were similar for Cara (5) and King Edward (3) when untreated and following fungicide treatment. This was done by expressing the AUDPC for Cara as a percentage of that of King Edward for each fungicide dose (Fig. 1). At Cilcennin in 2009, 2010 and 2011 disease progress on untreated King Edward and Cara was similar, with the AUDPC for Cara between 77.3% and 90% that of King Edward across the 3 years. There was greater distinction between the two cultivars when left untreated at Auchincruive over the 3 years, however, this was still high with the AUDPC for Cara between 44.1% and 64.8% of King Edward. Following fungicide application and regardless of dose, the AUDPC of the more resistant cultivar Cara was proportionally much lower than on the more susceptible King Edward than the two varieties left untreated. For example, where full rate fungicides had been applied, the AUDPC for

Cara was between 27.6% and 56.6% of the AUDPC for King Edward at Cilcennin. This was more pronounced at Auchincruive, where the AUDPC for Cara was between 8.4% and 40.7% of the more susceptible variety. In all six trials, the AUDPC for Cara as a percentage of K Edward decreased progressively with increasing fungicide dose (Fig. 1).
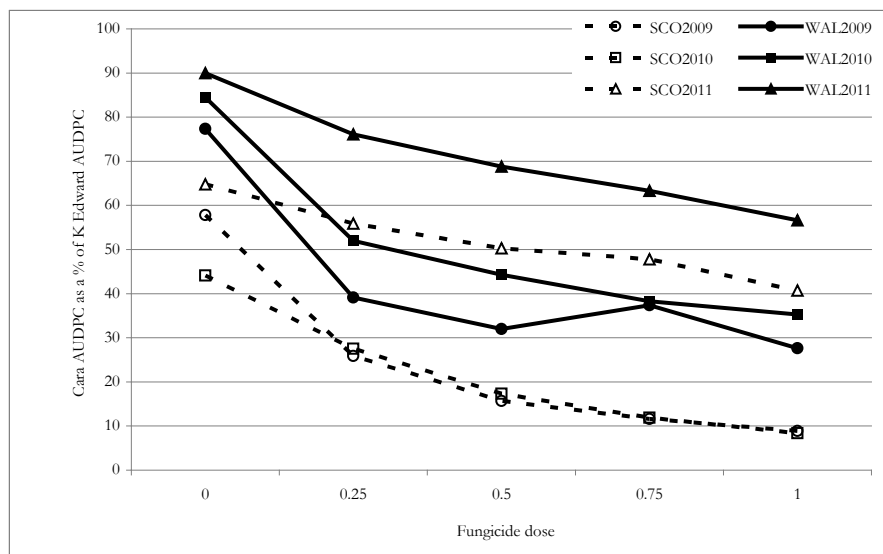
Figure 1. Change in AUDPC of the more resistant Cara expressed as a percentage of AUDPC of the susceptible King Edward with increasing fungicide dose in six field experiments at Cilcennin (WAL) and Auchincruive (SCO). Fungicide dose is the proportion of the recommended UK label rate, applied four times

Discrimination between 19 cultivars

A similar effect of fungicide treatment was also seen in the 2010 trials with 19 varieties at Cilcennin and Auchincruive (Fig. 2). The Mean Squares and F-statistics, following log transformation of rAUDPCs, from the over-trial ANOVAs are shown in Table 3. Varietal discrimination (F-statistic for variety) was significant for the half- and full-rate treatments only. However, further experiments are required to confirm this finding. It is clear that the variety mean squares (a measure of between variety variability) were much larger for the half- and full-rate treatments. This is not reflected in the F-statistics; the extent of this difference is reduced because the residual is smaller for untreated varieties and may well represent greater consistency. At both sites the disease pressure was very high and this should be taken into consideration when interpreting the results.

Table 3. ANOVAs for each level of fungicide (log transform of rAUDPC)

Source	df	No fungicide		Half-rate		Full-rate	
		MS	F-stat	MS	F-stat	MS	F-stat
Trial	1	0.964	50.2	0.003	0.1	0.000	0.0
Variety	18	0.081	4.2	0.371	8.1*	0.596	6.7*
Residual	18	0.019		0.046		0.089	

*significant at the 5% level

There is no evidence of a treatment-by-variety interaction over the two trials (F-stat 0.41), implying that the broad ranking of varieties is similar regardless of whether left untreated or fungicide treated.

Genotypes of the new population of *P. infestans* in GB, such as 13_A2, are both more virulent (Lees *et al.*, 2011) and more aggressive. When 13_A2 is used in cultivar resistance screening trials the decline in resistance of cultivars is a combination of resistance genes being overcome and the greater aggressiveness of new genotypes compressing differences between cultivars. It is not straightforward to quantify the relative contribution of these two effects to a general decline in cultivar resistance.
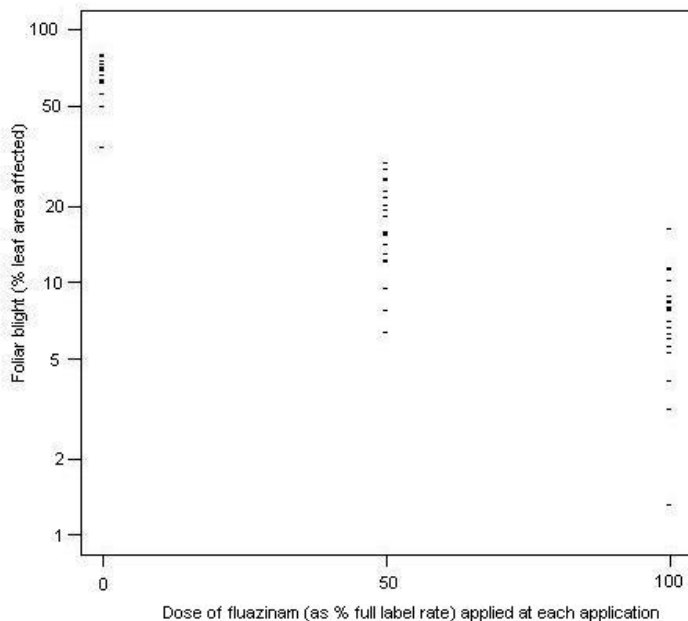
Figure 2. Variation in foliar blight between 19 cultivars left untreated (0), or treated with 50% or 100% of the recommended rate of fluazinam (as Shirlan) in 2010

Results from any trial evaluating cultivar resistance to 13_A2 clearly need to provide an accurate assessment of the current relative resistances of different cultivars. However, data presented in this paper suggest that the contribution of more resistant cultivars to disease control is consistently relatively lower where plants are unprotected. As a consequence of the EU Sustainable Use Directive 2009/128/EC there is increased interest in exploiting cultivar resistance in integrated control. Results presented here suggest that the contribution of cultivar resistance in commercial potato growing, in which a very high percentage of the national crop is protected by fungicide, may be underestimated by resistance ratings obtained in screening trials using the more aggressive genotypes without managing (in most cases reducing) inoculum density. Currently, plots in cultivar screening trials are untreated. Further studies are required to allow resistance ratings obtained from trials using genotypes from the new population to accurately inform the true contribution of foliar resistance for control of *P. infestans* in commercial crops.

It is reassuring that the resistance ranking orders obtained for untreated and fungicide-treated plots were not significantly different. However, additional experiments are again required to confirm this result. Although reduced resistance in some cultivars, associated with the change in *P. infestans* population, is a setback to implementing integrated control, there remain substantial differences between cultivars and these can be exploited.

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