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Optimizing the Use of Curative Late Blight Fungicides

KYRAN MALONEY[1], NEIL HAVIS[1], DAVID COOKE[2], GARY LOAKE[3] AND RUAIRIDH BAIN[4]

[1] Crop and Soil Systems Group, SRUC, West Mains Road, Edinburgh EH9 3JG, UK
[2] Cell and Molecular Sciences, The James Hutton Institute, Invergowrie, Dundee DD2 5DA, UK
[3] Institute of Molecular Plant Sciences, University of Edinburgh, Edinburgh EH9 3BF, UK
[4] Crop and Soil Systems Group, SRUC, Auchincruive Estate, Ayr KA6 5HW, UK

SUMMARY

Fungicides that can act curatively (within the incubation period of pathogen development) are an increasingly important component of late blight (*Phytophthora infestans*) control strategies. This study aims to produce a simple decision aid for the use of products with curative activity by growers and agronomists. Interim results, which form the basis of the decision aid, are presented here. Data from glasshouse bioassays with a representative curative fungicide (fluopicolide + propamocarb), a susceptible variety (King Edward), and an isolate belonging to an aggressive genotype suggest that curative control declines 24 hours after infection, with little benefit gained from curative treatments applied 40 hours or more post infection. However, results from field trials suggest that varietal resistance is a significant modifying factor: curative treatments sprayed 43 hours after infection significantly reduced lesion number for the varieties Cara and Sarpo Mira but not the more susceptible King Edward.

KEYWORDS

Phytophthora infestans, curative fungicides, decision support, varietal resistance, control strategies

INTRODUCTION

In northern Europe late blight of potato is controlled by routine applications of fungicides, usually at no greater than 7-day intervals (Hansen et al., 2016). All fungicide applications are intended as prophylactics, i.e. to prevent the establishment of infections within the crop. However, several active ingredients (a.i.s) of commonly used fungicide formulations have some mobility *in planta*, and can act curatively. Curative activity is defined as pathogen control that occurs post infection, but before the development of visible symptoms (Ivic 2010). Whilst it is inadvisable to use late blight fungicides solely as curatives, curative activity is an important component of many late blight spray programs – particularly when fungicide treatments are scheduled immediately following periods when the risk of infection is very high.

P. infestans has a rapid life cycle and the efficacy of curative fungicides declines as the pathogen develops, meaning there is a short 'curative window' in which they offer good control (Pirondi et al., 2017). Timing is therefore of great importance, with mistimed applications unlikely to contribute to effective disease control. However, growers and agronomists currently have somewhat limited information to guide them when considering their use of curatives. Published ratings for curative activity are provided in the EuroBlight table (Bain. 2016), and whilst these are of great utility they are nevertheless qualitative, and are derived from subjective opinion. Additionally, there is some evidence that the curative window can be modified by factors that alter the rate at which leaf tissue is colonized by *P. infestans* (Genet et al*.,* 2001) but which factors are of greatest importance and the extent to which they attenuate or enhance curativity is not well understood.

The purpose of this project is to produce a simple decision aid that can be used to support the use of curatives in integrated control of late blight. The final decision aid will incorporate some of the major modifying factors, such as temperature, pathogen lineage (Cooke et al., 2014) and the varietal resistance of the individual crop. Of key importance is that the aid is (i) based on empirical data, and (ii) applicable to the field situation. This paper briefly describes some of the methods used to gather this information.

MATERIALS AND METHODS

The curative fungicide Infinito (Bayer CropScience; 62.5 g fluopicolide + 625 g propamocarb l^{-1}) was applied at the recommended field dose of 1.6 l ha^{-1} in 200 l water in all bioassays and field trials described below. This product was selected as a representative 'good' (++ rated) curative fungicide using the information in the EuroBlight fungicide table. Artificial inoculations used spore suspensions of *P. infestans*, adjusted to 10^5 sporangia ml^{-1}. These suspensions were prepared from 7 day-old infected leaflets. Each inoculation site received a 20 µl droplet, placed on the adaxial leaf surface, avoiding large veins.

Curative threshold bioassays

Foliage was collected from 7 week-old, glasshouse-grown King Edward (foliage resistance rating 3) potato plants. Leaf discs (12 mm diameter) were cut from this material using a cork borer. The discs were then placed within a 170 mm x 170 mm Perspex frame, into which holes had been drilled, each frame accommodating 64 discs. Cut edges were covered by Parafilm strips leaving a 1 cm^2 area of tissue exposed. Discs were then individually inoculated with 20 µl droplets of *P. infestans* (isolate 2012_9922C, isolated from Great Britain) sporangial suspension. Inoculated discs were sealed within transparent plastic boxes lined with damp tissue paper. Boxes were in turn placed within a controlled climate chamber (16h / 8h day-night cycle, 18^{o}C). At timings corresponding to 4-hour intervals between 8 and 72 hours post inoculation, selected frames were removed from the climate chamber and treated with Infinito using an AZO compressed air precision sprayer. Frames were returned to incubation conditions immediately following treatment. Seven days from the initial inoculation frames were assessed for disease development on discs. A disc that was completely necrotic or showed signs of sporulation was classified as a successful infection, whilst one that showed no symptoms or small arrested lesions was classified as effective control.

Varietal resistance field trials

Potato plants of varieties King Edward, Cara (foliar resistance rating of 5) and Sarpo Mira (7) were grown in small propagation pots within a poly-tunnel for approximately 7 weeks. When high risk weather was forecast (Smith criteria met) plants were transported to a trial field where a late blight epidemic was in progress. Plants were placed within open trays on ridges and were left exposed for 2 hours. The plants were then sealed within plastic sheeting and placed within a climate chamber (16h / 8h day-night cycle, 18^{o}C). After two days incubation, 12 plants per cultivar were treated curatively and returned to the climate chamber. Seven days after exposure to inoculum, the number of late blight lesions per plant was counted. The trial was repeated at a later date with the following modifications: cultivars King Edward and Cara were used, and three separate Infinito treatment times were included: 1, 2 and 3 days post exposure.

RESULTS

Curative threshold bioassays

Figure 1 shows data for three runs of the leaf disc bioassay with the same isolate (9922c). At early time points (8 – 24 hours) curative sprays generally offered good control on the leaf discs, protecting between 60 – 100% of discs. This control is then rapidly lost from 24 – 40 hours, and at time points greater than 40 hours curative sprays rarely prevented more than 30% of infection sites from developing into lesions. The data are best described by a sigmoid curve (R^2 = 0.67) with the formula $y = 0.89 / (1 + e^{[-0.1 * \{x - 30.9\}]})$.

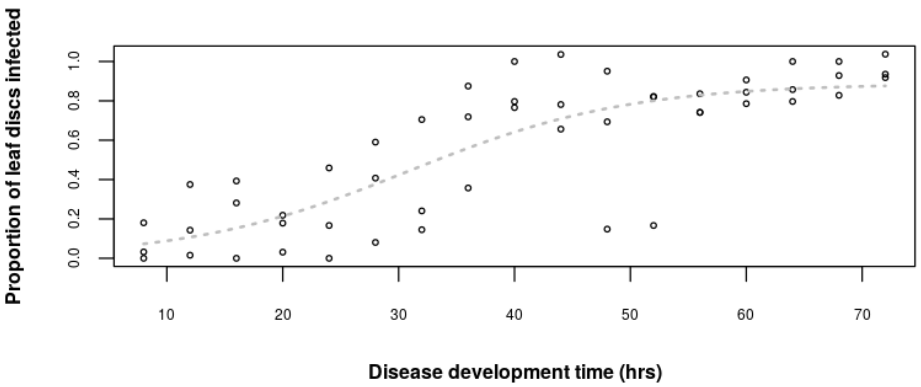

Figure 1. *Proportion of leaf disc infection (n=64) in relation to curative fungicide timing (hours at 18 °C from inoculation to treatment with Infinito). Data from three runs of the bioassay are shown, all using isolate 2012_9922C (genotype 13_A2).*

Varietal resistance field trials

In the first experiment using small plants grown in a polytunnel that were later exposed to field inoculum at 43-hour post-infection, curative fungicide treatment was effective on the two more resistant cultivars (Cara and Sarpo Mira) but not the most susceptible cultivar (King Edward) (Figure 2A). In the repeat experiment treating the susceptible King Edward (3) curatively after more than 1 day gave a lack of control similar to no fungicide, however there was a significant benefit from Infinito applied to Cara both 2 and 3 days after infection (Figure 2B).

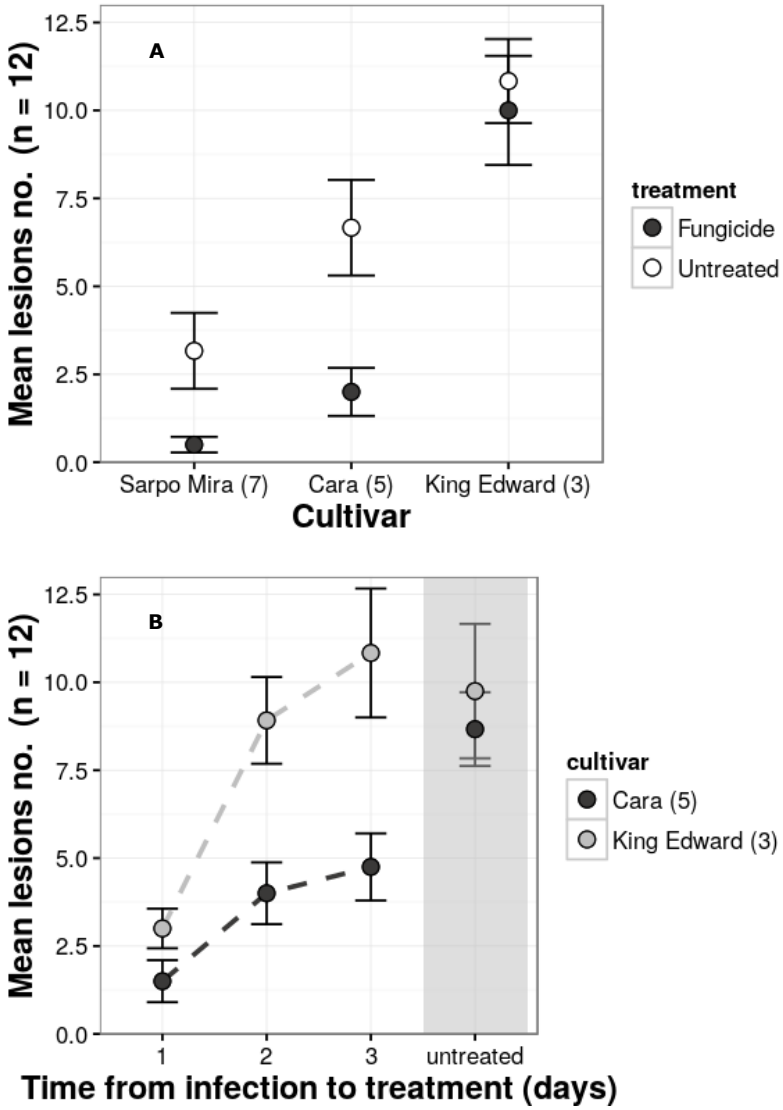

Figure 2. *Mean lesion count ± SE on plants exposed to natural inoculum for 2 hours and subsequently sprayed with curative fungicide after 2 days (43 hours) incubation at 18 °C (A) or after 1, 2 or 3 days incubation at 18 °C (B).*

DISCUSSION

An integrated management program is most likely to be effectively implemented if practitioners have a range of flexible tools which in combination with personal experience and knowledge of local conditions can inform decision making (Barzman et al., 2015). Data presented here will help form the basis of the decision aid and it is envisaged that the final aid will be used in the UK in conjunction with existing support systems such as the Hutton Criteria.

Results from this investigation confirm that curative activity is time limited, particularly on cultivars that are very susceptible to infection by *P. infestans*. The results of the small plant varietal resistance field trials support the inclusion of crop variety within the decision aid, as varieties with higher foliar resistance ratings appeared to have an extended time window for curative control. However, it is not clear if this is generally applicable or is specific only to the tested cultivars. This is being investigated further. Quantitative resistance to *P. infestans* is probably based on a range of difference mechanisms (Poland et al., 2009), which may vary between cultivars. It is conceivable that some of these may not impact on the rate at which the pathogen colonizes tissue, and so would be not act as a modifying factor on the curative effect.

It has been demonstrated previously that air temperature acts as a major modifying factor (Genet et al*.,* 2001) with temperatures that are sub-optimal for pathogen development extending the time period from infection to treatment over which a curative treatment gave good control. Temperature data from the experiments carried out will allow the final decision aid to operate in thermal time, which should greatly enhance its infield utility. Pathogen lineage is another potential modifying factor, with some more aggressive lineages displaying a more rapid life cycle (Cooke et al*.,* 2012; 2014); the described bioassay has been repeated with a less aggressive genotype (data not shown) and aggressiveness differences will be taken account of in the final decision aid.

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