

Efficacy of fungicides to control early blight: results of EuroBlight experiments to calculate decimal ratings

BERT EVENHUIS¹, BENT J. NIELSEN², RUAIRIDH BAIN³, HUUB SCHEPERS¹ & HANS HAUSLADEN⁴

¹ Wageningen University and Research, P-AGV, PO Box 430, 8200 AK Lelystad, The Netherlands

² Aarhus University, Department of Agroecology, Flakkebjerg, Denmark

³ SRUC, John Niven Building, Auchincruive Estate, Ayr, KA6 5HW, Scotland, UK

⁴ Technische Universität München, Am Hochanger 2, D-85350 Freising-Weihenstephan, Germany

SUMMARY

Early blight is becoming an increasing problem in potato crops. Early blight is caused by *Alternaria* species, predominantly *A. solani*. In agricultural practice, early blight is controlled by applying fungicides in the second half of the season. Up until July 2017 the ratings of the fungicides to control early blight were based upon expert judgement from independent researchers. At the EuroBlight workshop in Brasov it was proposed that decimal ratings for fungicides for the efficacy table should be calculated after field experiments have been carried out over two years in three European countries, in accordance with the agreed experimental protocol. Ratings for fungicides with specific activity against *Alternaria* were tested using a 14-day spray interval whereas late blight fungicides with such activity were sprayed at 7-day intervals. Furthermore, some control strategies that used both groups of fungicide were also included. In July 2017 the first decimal ratings were published on the EuroBlight web site. This paper describes the set-up of the trials and the procedure for awarding a decimal rating.

KEYWORDS

Alternaria solani, early blight, potato, *Solanum tuberosum*

INTRODUCTION

Early blight caused by *Alternaria solani* is the second most important foliar disease of potatoes after potato late blight. The potato crop needs to be protected from *A. solani* by spraying fungicides regularly during the second half of the growing season. It is important to use fungicides that effectively protect leaves against this disease.

Some fungicides are approved specifically to control early blight. Some fungicides used to control potato late blight also contribute to the control of early blight. Until July 2017 the ratings of the fungicides to control early blight listed on the EuroBlight website were based upon expert judgement from independent researchers. At first the ratings scale was 0 to +++, in which 0 was no efficacy and +++ was excellent efficacy. In 2013 at the EuroBlight workshop in Cyprus it

was decided to adapt the scale to 0 to +++++. Nevertheless, the need was felt to base the ratings on experiments rather than expert judgement.

To evaluate the effectiveness of fungicides a harmonised protocol was developed at the Brasov workshop. It was proposed that the ratings of fungicides for the EuroBlight table should be calculated using the results from a minimum of six field experiments, carried out over two years in three European countries, in a system similar to that used to generate the fungicide ratings for potato late blight. In 2015 the first three experiments were carried out in Germany, Denmark and the Netherlands. In 2016 another three experiments were made in the same countries. The effectiveness of fungicides against early blight was compared by measuring the protection of leaves using standard 14- or 7-day spray schedules (these spray schedules do not necessarily comply with the product label recommendations). Protection against early blight derives from the protectant and/or curative properties of the active ingredients. The dose rates tested were the highest preventative doses registered in Europe. The results of the trials were used to re-evaluate the effectiveness of fungicides to control early blight. This report describes the protocols used and the analysis of the efficacy of fungicides to control early blight during the second half of the season.

MATERIAL AND METHODS

Experiments

In both 2015 and 2016 three experiments were carried out in Denmark, Germany and The Netherlands. The fungicides were sprayed at 7- or 14-day intervals or as a combined spray strategy. Combined spray strategy treatments comprised two or more fungicides, at least one of which was sprayed with a 7-day interval and one with a 14-day interval. The spray applications coincided with those of the other treatments. Spray strategy treatments starting earlier or ending later are allowed in the experiments but a rating is not permitted. Table 1 gives the number of treatments in each experiment carried out in 2015 and 2016.

Table 1. *The number of treatments included in the EuroBlight early blight fungicide rating experiments according to spray strategy applied.*

Fungicide	2015			2016		
	D	DK	NL	D	DK	NL
14-day interval	5	4	3	6	5	5
7-day interval	7	7	7	8	8	8
Combined strategy	2	2	2	2	2	2
Reference ¹	3	3	3	3	3	3

¹: *the reference included an untreated control and mancozeb (1500 g active ingredient/ha) in a 7- or 14-day spray interval.*

Spraying to control early blight started approximately at the end of flowering. In Denmark and Germany the last spray application date was the same regardless of the 7- or 14-day spray interval, whereas in the Netherlands the last spray application for the 14-day interval was 1 week before the last spray application for the 7-day interval.

During the growing season the percentage foliar blight severity caused by *Alternaria* spp. was assessed at weekly intervals. To evaluate the epidemic, the Area under the Disease Progress Curve (AUDPC) was determined. The number of days from the first to the last disease observation varied for each experiment therefore StAUDPC values were calculated by dividing the AUDPC value by the number of days between the first and last disease observation. For each fungicide within any one experiment the same number of days was used. The StAUDPC is an indicator of the efficacy of the fungicides during the whole growing season and is the basis for calculating a decimal rating.

Statistics

Each experiment was laid out as a randomised complete block design with one treatment factor, the fungicides being tested, and four replicates. A mixed model analysis (REML) was performed on StAUDPC values calculated per experimental plot. REML analysis was used because not every fungicide was present in all six experiments. A mixed model consists of fixed treatment terms (here fungicide) and random block terms (here experiment, block and plot; formula 1).

$$stAUDPC_{ijkp} = \mu + E_i + B_{ij} + \beta_k + P_{ijp}, \quad (1)$$

where

- μ = overall mean
- E_i = effect of experiment $i \sim N(0, \sigma_E^2)$
- B_{ij} = effect of block j within experiment $i \sim N(0, \sigma_B^2)$
- P_{ijp} = effect of plot p within block $B_{ij} \sim N(0, \sigma_P^2)$
- β_k = effect of fungicide k

Based on the mean StAUDPC (mstAUDPC), ratings for the effectiveness of the fungicides to control early blight were calculated, according to formula 2.

$$ER_k = 5 \frac{\text{MAX}(y) - y_k}{\text{MAX}(y)}, \quad (2)$$

- ER_k = efficacy rating of the fungicide k to control potato early blight during the whole growing season.
- y = mstAUDPC
- $\text{MAX}(y)$ = mstAUDPC of the fungicide with the highest mstAUDPC determined in the series of experiments, i.e. the untreated control.

RESULTS

At the 2017 EuroBlight workshop in Aarhus some deviations from the original protocol (that had been produced at the Brasov workshop) were discussed and accepted:

- The untreated control will be used as the reference, instead of mancozeb
- Combined spray strategies can be rated if they fit within a 7- and 14-day spray schedule

The adapted protocol is described in the appendix to this paper. The results of the dedicated trials in 2015 and 2016 led to the first EuroBlight table in which fungicides were assigned decimal ratings. The table was published on 31 July 2017 on the EuroBlight website <http://euroblight.net/alternaria/early-blight-fungicide-table/early-blight-fungicide-table-new/>

DISCUSSION

In the past a decimal rating system was set up to assess the efficacy of fungicides to control potato late blight, later the system was extended to tuber blight as well. New decimal ratings are published regularly on the EuroBlight website. In the mean time early blight caused by *Alternaria* became a more important disease of potatoes. The need to expand the decimal rating system also to include early blight was recognised.

In the *Alternaria* subgroup meeting at Munich in 2014 a more dynamic ratings system for fungicide efficacy in controlling early blight was discussed. A draft protocol for a trial was prepared. The protocol was presented at the EuroBlight meeting in Brasov in 2015 and accepted. In 2015 three experiments were carried out, followed by another three in 2016. In Aarhus in 2017 the first results were presented, but the fungicides were not identified, only codes were supplied. A number of fungicides met the criteria to allow a rating to be awarded. The ratings are based on non-transformed StAUDPC values. The main advantage is that ratings are determined using a system that is more objective than that used to produce table ratings up until the Brasov meeting in 2015. Another advantage is that there is scope for future, more effective fungicides to be rated higher than 4, the maximum until 2016. Furthermore, ratings once given are not fixed, thus relative changes in the effectiveness of fungicides can be made apparent. It was agreed at the Aarhus meeting that as soon as new ratings are calculated from trials and are approved the fungicide table on the EuroBlight website will be updated. In fact the new ratings were published on 31 July 2017.

The ratings proposed are exclusively based on the results of the trials carried out according to the EuroBlight protocol. The ratings are calculated for the highest fungicide doses registered in Europe. In agricultural practice lower dose rates are and will be used. The ratings do not reflect the fungicide efficacies when lower dose rates are used. Initially the reference treatments were expected to be mancozeb sprayed at a 7-day or 14-day interval. However, in Aarhus in 2017 it was decided that the untreated control should be the reference treatment for the early blight experiments. The advantage of the untreated control being the reference is that the rating for the untreated is by default 0, i.e. no efficacy to control early blight. In contrast, if mancozeb had been chosen as the reference a rating would have to have been awarded by expert subjective opinion, not based on experiments. For potato late blight a fungicide reference was inevitable because the disease progress curve for the untreated control is normally very different from those of the fungicide treatments. For early blight the epidemic usually starts later in the season and the gap in disease severity between fungicide treatments and the untreated is considerably smaller.

Details of the experiments can be found on the EuroBlight website.

CONCLUSIONS

The experiments were set up to calculate decimal ratings for fungicides controlling early blight.

- The untreated control was introduced as the reference and rated 0 by default.
- The decimal rating is scaled from 0 to a maximum of 5.
- A rating is based on a minimum of six experiments and is calculated using the StAUDPC values.
- A rating can be awarded only when the fungicide is registered somewhere in Europe.

- The first early blight fungicide table was published on 31 July 2017 and comprised one fungicide sprayed with a 14-day spray interval, five fungicides sprayed using a 7-day interval and two combined strategies. In these two cases one of the fungicides was sprayed at a 7-day and the other fungicide at a 14-day interval. The time frame for test fungicide application should be the same for all treatments.

ACKNOWLEDGEMENT

We like to thank Wim van den Berg from Wageningen University & Research P-AGV for valuable assistance with the statistics.

ADAPTED PROTOCOL FOR THE EVALUATION OF THE EFFICACY OF FUNGICIDES TO CONTROL EARLY BLIGHT

The protocol for testing effectiveness to control early blight was prepared by Huub Schepers, Jürgen Leiminger, Bent Nielsen, Hans Hausladen, Jan Spoelder, Jozefa Kapsa, Pieter Vanhaverbeke, Dani Shtienberg and Bert Evenhuis and is published below.

Purpose/aim of trials

To compare the “Effectiveness against early blight” by measuring the protection of leaves against infection by early blight resulting from the application of a fungicide according to this protocol. This spray schedule is not necessarily related to the label recommendations. This protection originates from the protectant and/or curative properties of the active ingredients. EPPO guideline PP 1/2 (3) (revised in 1996) describes the standard requirements of the field trial.

Specific additional requirements:

- A susceptible local ware or starch potato variety. The growth habit of the cultivar should be recorded, i.e. determinate or indeterminate growth.
- Potato late blight is controlled in a weekly scheme using fungicides with no efficacy to control early blight. For instance start with mandipropamid and end the spray schedule using cyazofamid.
- Preferably the experiment is carried out with natural infection. However if conditions are less suitable inoculation may be carried out with *A. solani*-infested grain kernels on the soil within the plot. The artificial inoculation is carried out 3 days before the first spray until 7 days after the first spray. When the inoculation is not successful it will be repeated.
- Misting is permissible, when conditions are exceptionally dry.
- Each treatment consists of applications of the fungicide to be tested regardless of the limited application numbers on the label.
- First spray depends on local conditions, but needs to be applied before the start of the epidemic and should be timed approximately at 7-8 weeks after crop emergence.
- Crop growth stage should be recorded on the days that the trial is sprayed. The BBCH key should be used.
- Untreated plots are part of the field experiment. In 2017 the untreated control was accepted as a reference for future trials but also retrospectively for earlier experiments.
- A reference treatment (two variants) is part of the field experiment i.e. 1500 g a.i. mancozeb. Sprayed in a 14-day interval and in a 7-day interval. From 2017 onwards the

mancozeb references are not necessarily part of the experiments, an untreated control is mandatory.

- Spray frequency is every 7-days (+/- 1 day) or every 14-days (+/- 1 day), to be chosen by the participant sponsors. A spray strategy with more than one fungicide is allowed, even if this means that one fungicide is sprayed with a 7-day interval and the other using a 14-day interval. The time frame of the spray applications should be the same for all treatments.
- The efficacy of the early blight fungicide(s) was to be compared to one of the two reference treatments accordingly. However, from 2017 onwards the efficacy is compared to the untreated control, allowing also spray strategies to be included in the trials.
- The number of sprays depends on the early blight epidemic and the spray interval chosen.
- Dose rate is the highest dose registered in Europe
- Assessment: every week (or more frequently when necessary) of plots by rating the % leaf area with symptoms. To assess early blight we recommend using the assessment key in the EPPO-guideline PP 1/263 (1).
- Desiccation: timing and method according to GAP.
- It is not strictly necessary to harvest the trial.
- A method for determining the rating for the "EuroBlight Fungicide Table" will be proposed when six successful trials (two seasons x three trials) have been carried out by independent research institutes in at least three different growing regions/countries in Europe. The proposed methodology will be agreed by independent researchers and the agrochemical manufacturers and where possible will be used to analyse data from registration trials, in which the relevant standard products are included. In this way a robust dataset will form the basis of the rating given for the "Effectiveness against early blight".

N.B. A successful trial is one that is carried out strictly according to this protocol and sufficient early blight is observed in the plots (>10% foliar severity in the worst treatment). The rating is set by determination and comparison of the AUDPCs of the six successful trials. A validation of this method will have to be carried out with existing trial data to find out whether a linear, a logarithmic or another transformation has to be carried out on the data.