Fungicide evaluation to rate efficacy to control leaf late blight for the Euroblight table Results 2006 - 2009

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Summary

Late blight caused by *Phytophthora infestans* is the most important foliar disease in the cultivation of potatoes. It is important to use fungicides that effectively protect leaves against this disease. A whole range of fungicides was or became registered in 2007 and 2008. New fungicides to control late blight will enter the market in future. Each fungicide has its own mode of action and efficacies and therefore has specific characteristics. To evaluate each characteristic a Euroblight -Table is set up to get an overview of the value of each characteristic. Until recently the ratings were based upon expert judgement, both from Agrochemical companies and independent researchers. To evaluate the effectiveness of fungicides harmonised protocols were discussed at Tallinn. At Hamar the first decimal ratings for preventative efficacy of fungicides were presented.

In fact 13 field experiments were set – up to compare the effectiveness against leaf late blight by measuring the protection of leaves against infection by late blight caused by application of a fungicide in a standard 7-day spray schedule (this standard spray schedule is not necessarily related to the label recommendations). Dose rates were the highest preventative doses registered in Europe.

During the growing season the percentage foliar infection was assessed at least weekly. To evaluate the epidemic, the Area Under the Disease Progress Curve (AUDPC) was determined.

Not all fungicides were tested at every location in each year. Ratings of fungicides for the EU-table are possible when field experiments are carried out over at least 2 years in a minimum of 3 European countries. Thus fungicides were tested in a various number of experiments, with a minimum of 6. REML analysis was conducted to analyse the data, using GENSTAT 12. Based on the average stAUDPC, ratings for the effectiveness of the fungicides to control late blight were calculated, according to formula 1. Ratings were calculated for the whole season (Table 0).

$$\mathrm{ER}_k = 3\frac{\mathrm{MAX}(y) - y_k}{\mathrm{MAX}(y)} + 2, \qquad (0)$$

ER_k = efficacy rating of the fungicide *k* to control potato late blight during the whole growing season.
y = mstAUDPC
MAX (y) = mstAUDPC of the fungicide with the highest mstAUDPC determined in the series of experiments.

Table 0. Effectiveness of fungicides to control potato late blight during the **whole season**.

Fungicide	**Active ingredient**	Dose rate Kg or L /ha	StAUDPC[1]	Decimal[2,4] Rating 2006-09	Decimal[3,4] Rating Hamar
Acrobat DF (Invader)[5]	dimethomorph + mancozeb	2.0	15.9	3.0	2.8
Consento (Tyfon)	fenamidone + propamocarb	2.0	-[6]	2.5	2.5
Dithane DG	mancozeb	2.0-2.25	23.4	2.0	2.0
Infinito	fluopicolid + propamocarb	1.6	9.0	3.8	3.8
Initium MZ	-	2.5	10.8	3.6	
Ranman + adjuvant	cyazofamid	0.2 + 0.15	9.0	3.8	3.6
Revus	mandipropamid	0.6	7.7	4.0	3.8
Sereno (Sonata)	fenamidone + mancozeb	1.5	-	2.6	2.6
Shirlan	fluazinam	0.4	16.2	2.9	2.6
Tattoo C (Merlin)	chlorothalonil + propamocarb	2.7	-	3.4	3.4
Unikat Pro (Electis)	zoxamide + mancozeb	1.8	17.0	2.8	2.6
Valbon	benthiavalicarb + mancozeb	2.0	10.4	3.7	3.5

[1] : Value established by REML Analysis.
[2] : Decimal ratings based on a minimum of 6 and a maximum of 13 experiments in years 2006-2009; D 3; DK 2; NL 4 and UK 4.
[3] : Decimal ratings based on 10 experiments, published in PPO Special Report 13 (2009): 177-182.
[4] : The ratings are intended as a guide only and will be amended in future if new information becomes available.
[5] : Fungicides were not tested in each experiment; for details see Materials & Method section
[6] : No new data available

A new, more dynamic rating system for fungicide efficacy in controlling leaf blight was implemented in Hamar. 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 Bologna meeting in 2007. Another advantage is that there is scope for future, more effective fungicides to be rated higher than 3, the maximum up until Bologna. Now the maximum rating will be 5. Furthermore ratings once given are not fixed, thus relative changes in the effectiveness of fungicides can be made apparent. In comparison to the table presented in Hamar small changes in efficacy were observed. Most fungicides were rated a little better. The ratings proposed are exclusively based on the results of the 13 trials described in this report.

1 Introduction

Late blight caused by *Phytophthora infestans* is the most important foliar disease in the cultivation of potatoes. The crop needs to be protected from *P. infestans* by spraying fungicides regularly during the growing season. It is important to use fungicides that effectively protect leaves against this disease. A whole range of fungicides was or became registered in 2007 and 2008. Each fungicide has its own mode of action and efficacies and therefore has specific characteristics. To evaluate each characteristic a Euroblight-Table is set up to get an overview of the value of each characteristic. Until now the ratings are based upon expert judgement, both from Agrochemical companies and independent researchers. To evaluate the effectiveness of fungicides harmonised protocols were discussed at Tallinn. It was proposed that ratings of fungicides for the EU-table are possible when field experiments are carried out over 2 years in 3 European countries. In the beginning of 2008 it was decided to add another 3 trials in 2008. Another three experiments were carried out in 2009 in 3 European countries. In fact 13 field experiments were set – up to compare the effectiveness against leaf late blight by measuring the protection of leaves against infection by late blight caused by application of a fungicide in a standard 7-day spray schedule (this standard spray schedule is not necessarily related to the label recommendations). This protection originates from the protectant and/or curative properties of the active ingredients and in the rapid growth phase of the crop also protection of new growth can contribute to the effectiveness of the fungicide for leaf blight control. Dose rates were the highest preventative doses registered in Europe. The results of the trials were used to re-evaluate the effectiveness of fungicides to control potato late blight. This report describes the analysis of the efficacy of fungicides to control potato late blight during the whole season. The method to establish efficacy ratings is described and discussed.

2 Materials and methods

2.1 Trial set up

Experiments were conducted in Denmark, Germany, The Netherlands and United Kingdom. Full details are contained in the individual trial reports. Experiments were carried out in four consecutive years, 2006, 2007, 2008 and 2009. The experiments were carried out according to the harmonised protocol as discussed during the Workshops of the "European network on Potato Late Blight in Tallinn (2005), Bologna (2007) and Hamar (2008). The protocol can be found on the Euroblight website (http://www.euroblight.net/EuroBlight.asp) and is given in Appendix 1.
In general the trials conformed to local good agricultural practice, only the fungicide sprayings against *P. infestans* were carried out as mentioned in Table 1 in a more or less weekly scheme. The trials were carried out in four replicates. The experiments were carried out in accordance with GEP.

2.2 Fungicides

In the Netherlands fungicide applications were carried out using a SOSEF-sprayer with Teejet XR110.04 nozzles approximately 50 cm above the foliage. Sprayings were carried out with 250 l/ha.
In Denmark Hardi flat fan (ISO) LD 025 was used. The fungicides were sprayed with pressure of 3.0 bar, at 4.0 km/h and with 300 l water / ha.
In the UK in 2006, 2008 and 2009 fungicides were applied using a tractor-mounted AZO compressed air sprayer with Lurmark F03-110 nozzles. Fungicides were applied in 300 litres of water per hectare at a pressure of 3.5 bar. In the UK in 2007 fungicides were applied using a hand held Oxford Precision Sprayer in 250 litres of water per hectare operating at 200 kPa through 110° flat fan nozzles.
Potato plants were sprayed for the first time at 100 % emergence or when the foliage was meeting along the rows (UK 2006, UK 2008, UK 2009) in each experiment. Fungicides were sprayed in a weekly scheme, according to protocol. Fungicides evaluated are listed in Table 1. If necessary the crop was sprayed full field with Signum or Amistar to control early blight.

Table 1. Fungicides sprayed in the experiments.

Fungicide	Active ingredient	Dose rate	Company
Acrobat DF (Invader)	dimethomorph + mancozeb	2.0 kg/ha	BASF
Consento (Tyfon)	fenamidone + propamocarb	2.0 l/ha	Bayer CropScience
Dithane DG [1]	mancozeb	2.0 kg/ha for first spray then 2.25 kg/ha	DOW Agrosciences
Infinito	fluopicolide + propamocarb	1.6 l/ha	Bayer CropScience
Initium MZ	-	2.5 kg / ha	BASF
Ranman + adjuvant	cyazofamid	0.2 l/ha + 0.15 l/ha	Belchim Crop Protection
Revus	mandipropamid	0.6 l/ha	Syngenta
Sereno (Sonata)	fenamidone + mancozeb	1.5 kg/ha	Bayer CropScience
Shirlan	fluazinam	0.4 l/ha	Syngenta
Tattoo C (Merlin)	chlorothalonil + propamocarb	2.7 l/ha	Bayer CropScience
Tattoo C (Merlin) [2]	chlorothalonil + propamocarb	2.0 l/ha	Bayer CropScience
Unikat Pro (Electis)	zoxamide + mancozeb	1.8 kg/ha	Gowan
Valbon	benthiavalicarb + mancozeb	2.0 kg/ha	Certis Europe B.V.

[1]: DK: 2006 Dithane NT 2.0 kg/ha, 2007 Tridex DG 2.0 kg/ha (Cerexagri), UK: 2009 Laminator Flo 3.3 for first spray then 3.7 L / ha.
[2]: Tattoo C at a dose rate of 2.0 L / ha was included in the experiments in 2008. Tattoo C at 2.0 L/ha was not included in the analysis, since only three of the required six experiments were carried out. The same is true for a number of experimental products that were included.

2.3 Experimental conditions

The experimental conditions are presented in Tables 2, 3, and 5. Artificial inoculation was not necessary in 2007 in the Netherlands and the UK. One plant in the spreader rows adjacent to each plot was artificially inoculated with a mixture of *P. infestans* isolates in 2006. The artificial inoculation was carried out 1 or 2 times (Table 2).

Table 2. Experimental conditions at the different locations in 2006.

	The Netherlands 2006	Denmark 2006	UK 2006
Location	Lelystad	Flakkebjerg	Ayr
Soil	Clay	Clay	Sandy loam
Planting	3 May	6 May	May
Variety		Dianella	King Edward
Rotary tillage	9 May	Approx. 7 June	-
Inoculation 1	2 June	27 June	24 July
Inoculation 2	26 June	4 July	-
Specific sprayings June	2, 8, 16, 23 and 29 June	28 June	-
Haulm killing spreader rows			-
Specific sprayings July	6, 13, 20 and 27 July	5, 13, 21, 28 July	13, 20, 27 July
Specific sprayings August	3, 9, 16, 23 and 30 August	3, 9, 16, 22, 31 August	5, 14, 22, 31 August
Specific sprayings September	6 and 13 September	6, 13, 21 September	8, 19, 26 September
Haulm killing	19 September		29 September

Table 3. Experimental conditions at the different locations in 2007.

	The Netherlands 2007	Denmark 2007	UK 2007	D 2007
Location	Lelystad	Flakkebjerg	Llaniar, Aberystwyth	Kirchheim near Munich
Soil	Clay	Clay	Clay loam	Pararendzina
Planting	15 May	19 April	2 May	28 March
Variety	Bintje	Folva	King Edward	Maxilla
Rotary tillage	24 May	Approx 11 May		
Inoculation	-	20 June		
Specific sprayings June	13, 19, 26 June	12, 19, 26 June	28 June	11, 19 June
Haulm killing spreader rows	9 July			
Specific sprayings July	2, 9, 16, 23, 30 July	3, 12, 23, 25 July	7, 15, 23, 30 July	3, 7, 17, 31 July
Specific sprayings August	6, 13, 20, 27 August	1, 8, 12 August	5, 13 August	15 August
Haulm killing	29 August			

Table 4. Experimental conditions at the different locations in 2008.

	The Netherlands 2008	Germany 2008	UK 2008
Location	Lelystad	Kirchheim near Munich	Auchincruive Estate, Ayr
Soil	Clay	Pararendzina	Sandy Loam
Planting	7 May	11 April	16 May
Variety	Bintje	Maxilla	King Edward
Rotary tillage	14 May		-
Inoculation	11 June		15 July
Specific sprayings June	6, 12, 20, 27 June	9, 16, 24 June	-
Haulm killing spreader rows			-
Specific sprayings July	4, 10, 17, 25, 31 July	1, 7, 15, 22, 29 July	4, 11, 20, 28 July
Specific sprayings August	8, 15, 22, 29 August	5, 11, 19, 26 August	5, 11, 19, 26 August
Specific sprayings September			2 September
Haulm killing	5 September		4 September

Table 5. Experimental conditions at the different locations in 2009.

	The Netherlands 2009	Germany 2009	UK 2009
Location	Lelystad	Kirchheim near Munich	Auchincruive Estate, Ayr
Soil	Clay	Pararendzina	Sandy Loam
Planting	5 May	5 April	30 May
Variety	Bintje	Maxilla	King Edward
Rotary tillage	12 May	-	-
Inoculation	25 June	-	15 July
Specific sprayings June	12, 19, 26 June	18, 29 June	-
Haulm killing spreader rows	-	-	-
Specific sprayings July	3, 9, 16, 23, 29 July	9, 16, 21, 28 July	7, 14, 23, 29 July
Specific sprayings August	4, 10, 17, 24 August	4, August	5, 12, 21, 27 August
Specific sprayings September	-	-	4 September
Haulm killing	1 September	-	11 September

2.4 Disease observations

During the growing season the percentage foliar infection was assessed in a weekly interval. To evaluate the epidemic, the Area Under the Disease Progress Curve (AUDPC) was determined. stAUDPC values were calculated by dividing the AUDPC value by the number of days between the first and last disease observation. The number of days from the first to last disease observation varied for each experiment and ranged between 29 and 71 days. The stAUDPC provides an indicator for the efficacy of the fungicides during the whole growing season. Appendix 2 lists stAUDPC values for fungicides tested in each experiment, for each replicate separately.
Due to circumstances a spray interval of more than 8 days was applied in some of the experiments. We have carefully looked at all the trials and we decided that in the trials carried out in DK in 2006 and 2007 the long spray intervals coincided with critical periods. We therefore restricted the AUDPC data from these trials to the period in which spray intervals were according to the protocol. Therefore stAUDPC values for the Danish experiments were calculated until 29 August 2006 and 10 July 2007.
The last spray application in Germany was on 4 August 2009. Therefore we decided to include the disease rating of 12 August, but leave out the disease observation on 23 August. At 23 August potato late blight disease severity might have been partly the result of an infection on an insufficiently or unprotected crop.
At the end of the season the crop senesces and it becomes more difficult to assess potato late blight accurately. Therefore we skipped the last two disease observations in The Netherlands in 2009.

2.5 Statistical analyses

Thirteen experiments were carried out. Each experiment was laid out as randomised block design with one treatment factor, being the fungicides to be tested, and four replicates. A mixed model analysis (REML) was performed on stAUDPC measured per experimental plot. Because the measurement period was not equal in all trials stAUDPC was analysed instead of AUDPC and stAUDPC equals the quotient of AUDPC and the number of days between first and final measurement of disease incidence. The code of the Genstat 12 program (Payne et al., 2009) used for the statistical analysis and the essential output are presented (Appendix 3). A mixed model consists of fixed treatment terms (here fungicide) and random block terms (here experiment, block and plot):

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

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

Units with high residuals were determined to establish non – consistent performance of fungicides. Replicates 1 and 2 of the 2006 experiment in the Netherlands were omitted from the analysis. The stability of the effectiveness of the fungicides between experiments was evaluated. The mean stAUDPC per fungicide (mstAUDPC) is reported in Appendix 3.
Based on the average stAUDPC (mstAUDPC), ratings for the effectiveness of the fungicides to control late blight were calculated, according to formula (2)

$$\mathrm{ER}_k = 3\frac{\mathrm{MAX}(y) - y_k}{\mathrm{MAX}(y)} + 2, \qquad (2)$$

ER_k = efficacy rating of the fungicide k to control potato late blight during the whole growing season.
y = mstAUDPC
MAX (y) = mstAUDPC of the fungicide with the highest mstAUDPC determined in the series of experiments.

The stability of the effectiveness of the fungicides between experiments was evaluated. Arrhythmic means (mstAUDPC) of the fungicides performance given as a stAUDPC value were calculated. REML Analysis on mstAUDPC was carried out. Units with high residuals were determined to establish non – consistent performance of fungicides. REML analysis was used while not each fungicide was present in all 13 experiments. The experiments were conducted in four countries during four seasons. Disease pressure varied with each experiment. The REML directive takes the specific conditions of the experiment into account. Assume that fungicide A was tested in experiments with a relatively high disease pressure and fungicide B in experiments with a relatively low disease pressure. Then the arrhythmic mean of mSTAUDPC of fungicide A would be adjusted with a decrease and fungicide B would be adjusted with a rise of mSTAUDPC. By doing so the disease pressure for all the fungicides is adjusted to the same level, making a fair comparison between fungicides possible.

Literature

Montgomery, D.C. and Peck, E.A., (1982). Introduction to Linear Regression Analysis. John Wiley & Sons. New York.

Payne, R.W., Harding, S.A., Murray, D.A., Soutar, D.M., Baird, D.B., Glaser, A.I., Channing, I.C., Welham, S.J., Gilmour, A.R., Thompson, R., Webster, R. (2009). *The Guide to GenStat Release 12, Part 2: Statistics*. VSN International, Hemel Hempstead.

3 Results and discussion

3.1 Late blight epidemic

The late blight epidemic started well after flowering in 2006 (Table 6). During the first part of the season hardly any rain fell. At the end of July, a period of consecutive days with precipitation started. This led to the start of the potato late blight epidemic, but also triggered new growth of the crop as was witnessed in the UK.
Due to very favourable circumstances for the development of late blight early in the growing season artificial inoculation was not necessary in 2007 in the Netherlands. The late blight epidemic already started in June.
The late blight epidemic started relatively late in the UK in 2008. Both in Germany and The Netherlands the late blight epidemic started about a month earlier than in the UK.
Late blight occurred first in The Netherlands, followed a week later in Germany and three weeks later in the UK, in 2009.

Table 6. First observation of *P. infestans* infected foliage in the untreated control and in treated plots, during the experiments.

	Untreated				Treated			
Year	D	DK	NL	UK	D	DK	NL	UK
2006	-	20-7	4-8	18-8	-	20-7	4-8	25-8
2007		4-7	19-6	8-7		28-6	19-6	8-7
2008	19-6	-	< 27-6	< 2-8	2-7	-	27-6	2-8
2009	4-7	-	-	<27-7	14-7	-	8-7	27-7

-: no experiment.

The effectiveness of fungicides to control potato late blight epidemic for each experiment separately is given in Figures 1-13

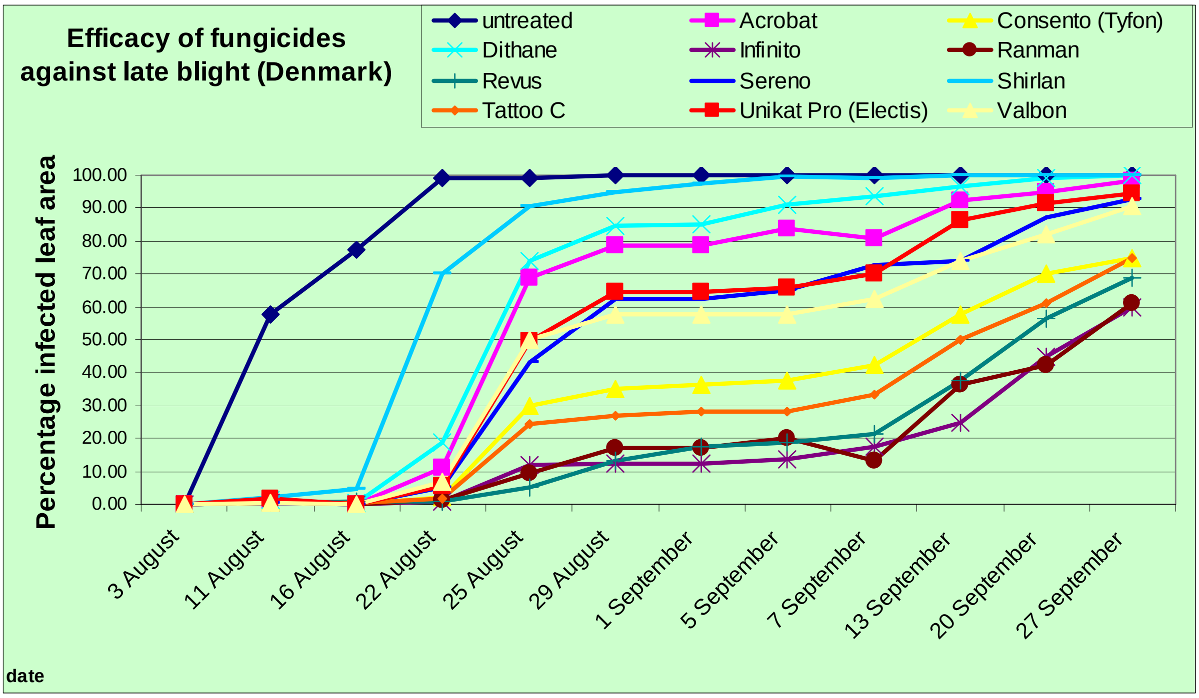

Figure 1. The development of foliar blight during the growing season in Denmark 2006.

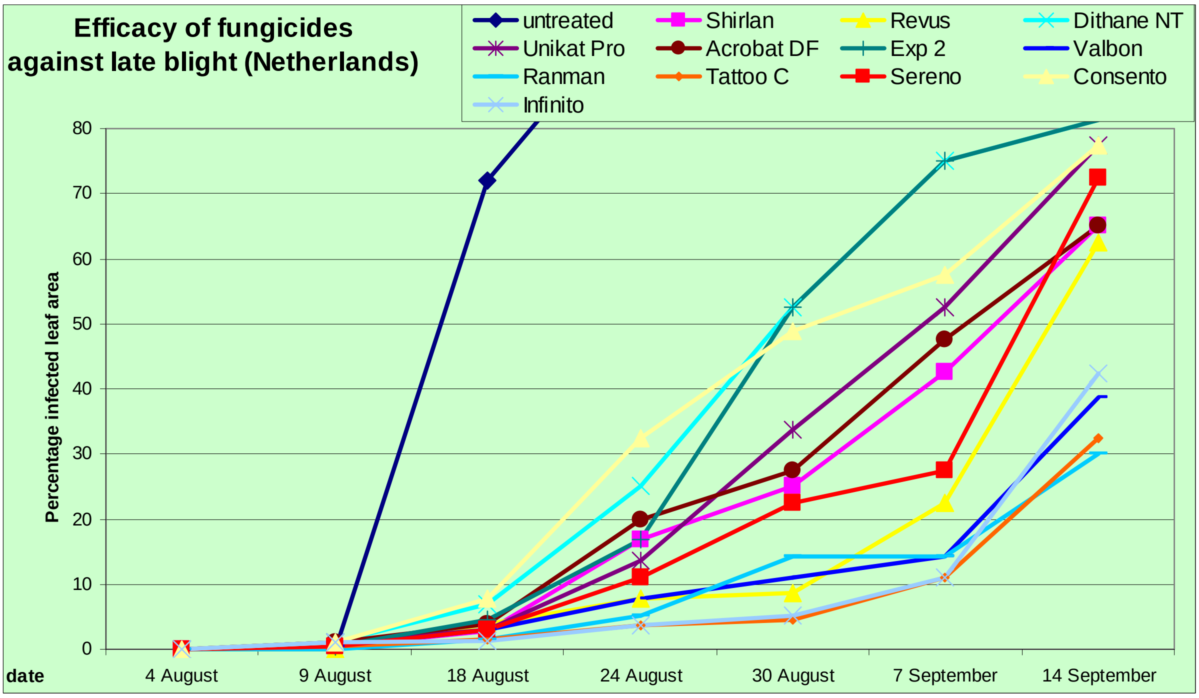

Figure 2. The development of foliar blight during the growing season in the Netherlands 2006.

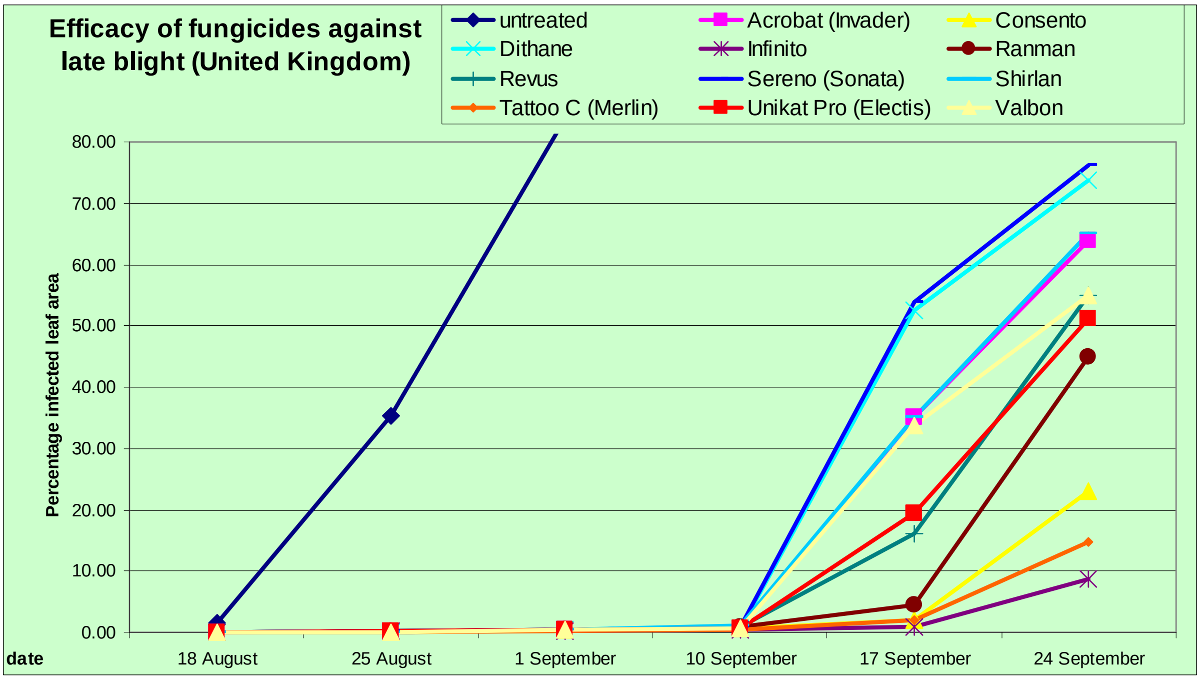

Figure 3. The development of foliar blight during the growing season in the United Kingdom 2006.

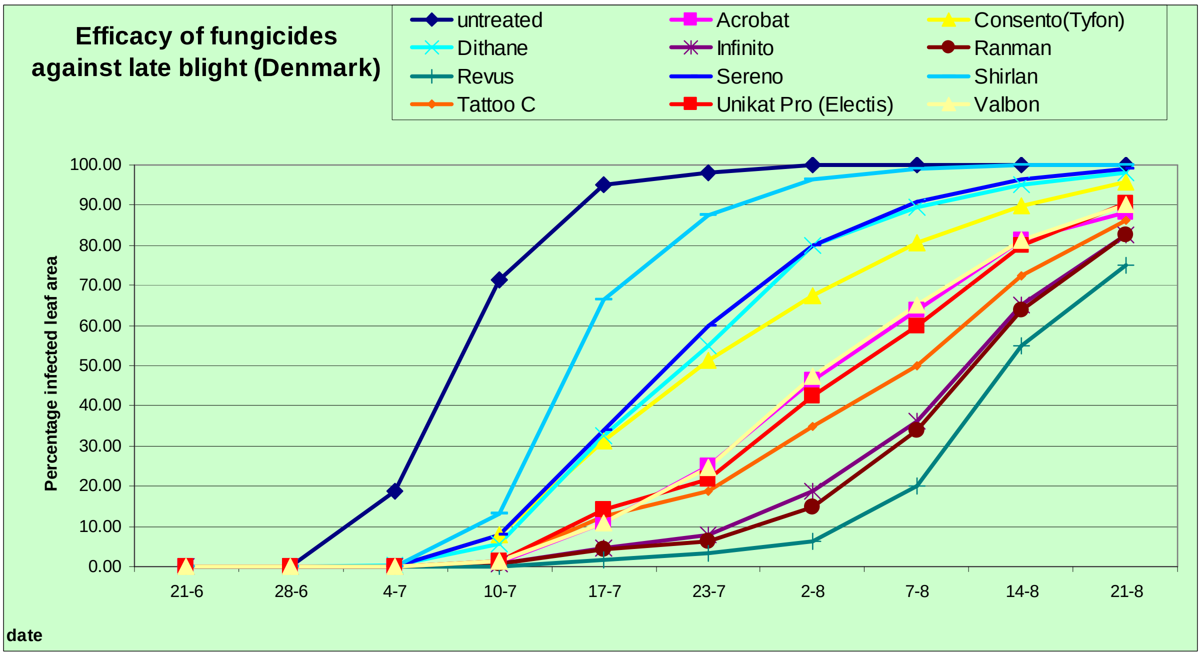

Figure 4. The development of foliar blight during the growing season in the Denmark 2007.

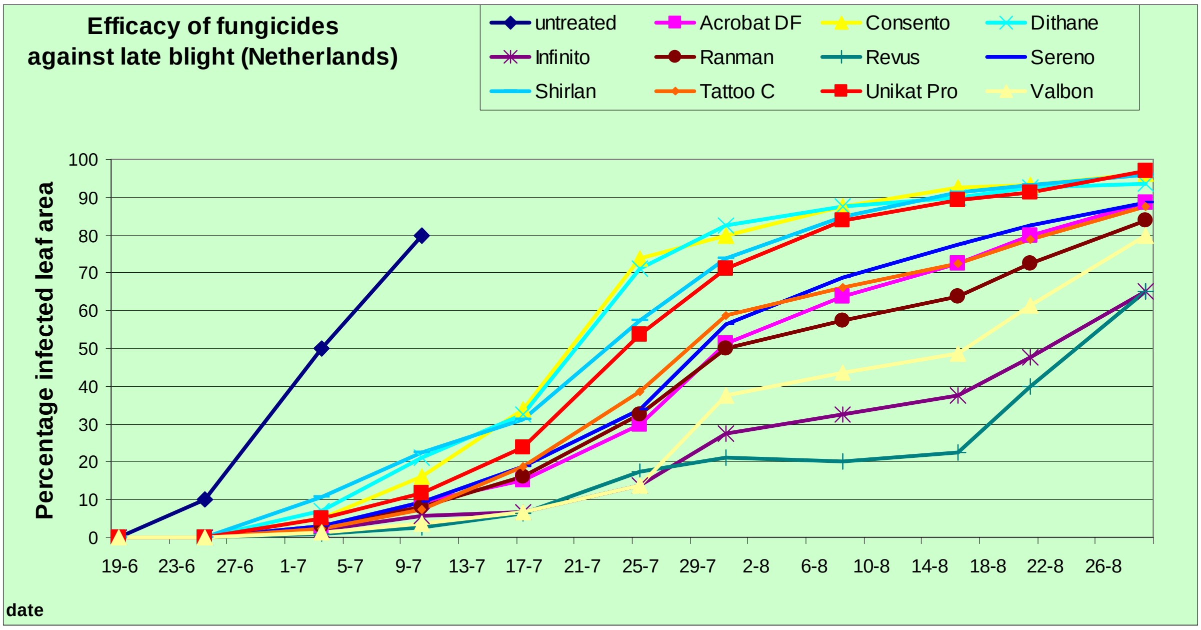

Figure 5. The development of foliar blight during the growing season in the Netherlands 2007.

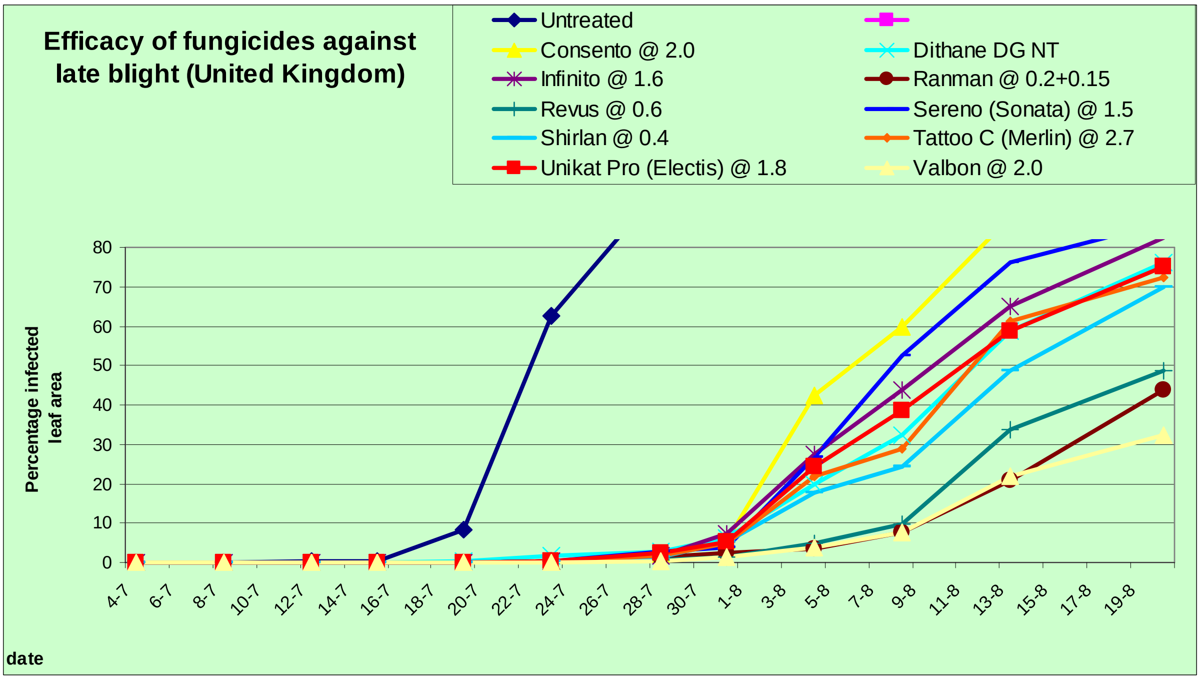

Figure 6. The development of foliar blight during the growing season in the United Kingdom 2007.

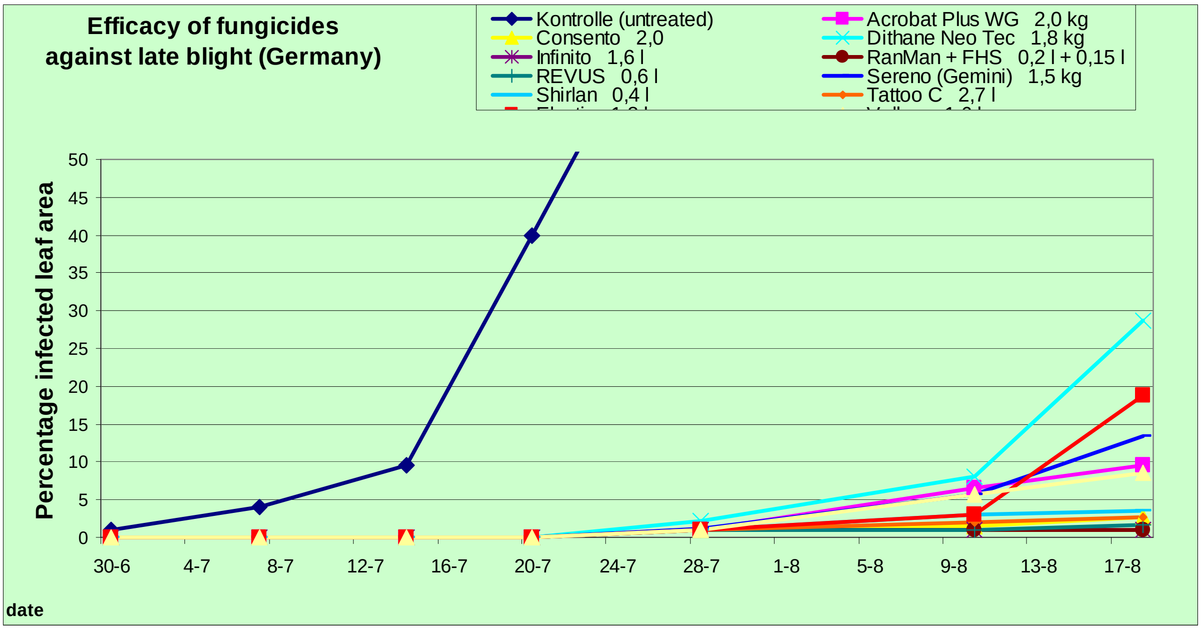

Figure 7. The development of foliar blight during the growing season in Germany 2007.

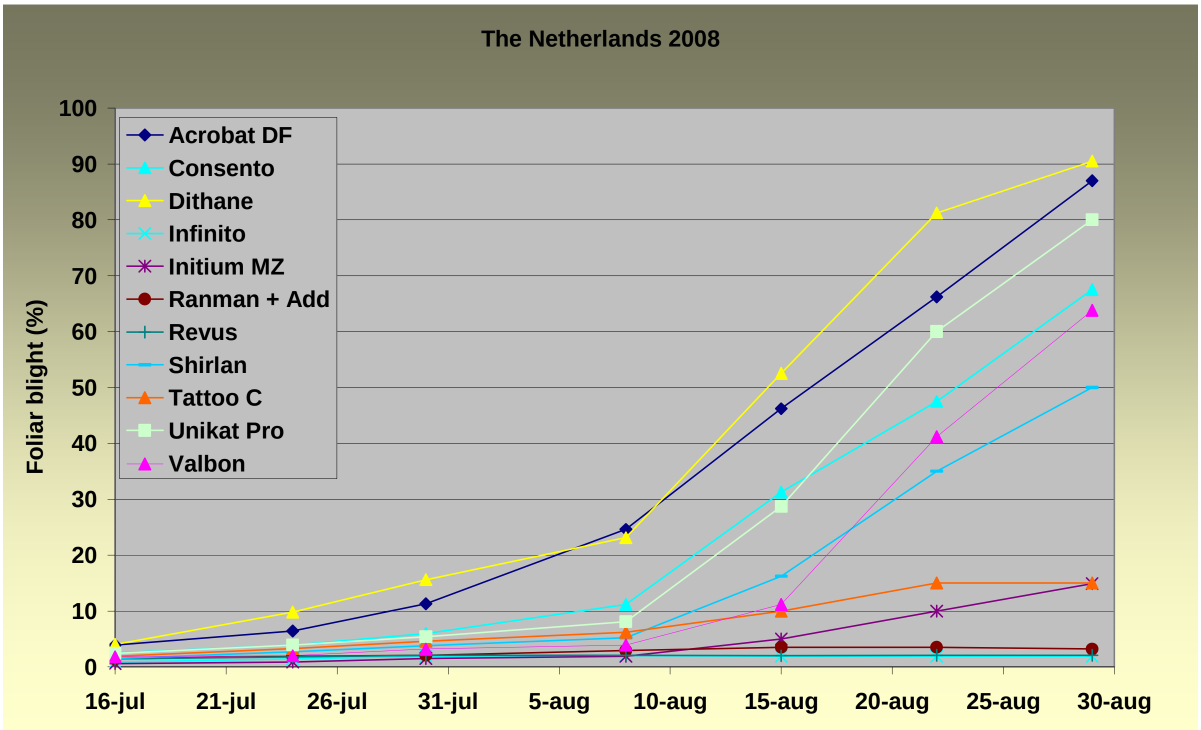

Figure 8. The development of foliar blight during the growing season in the Netherlands 2008.

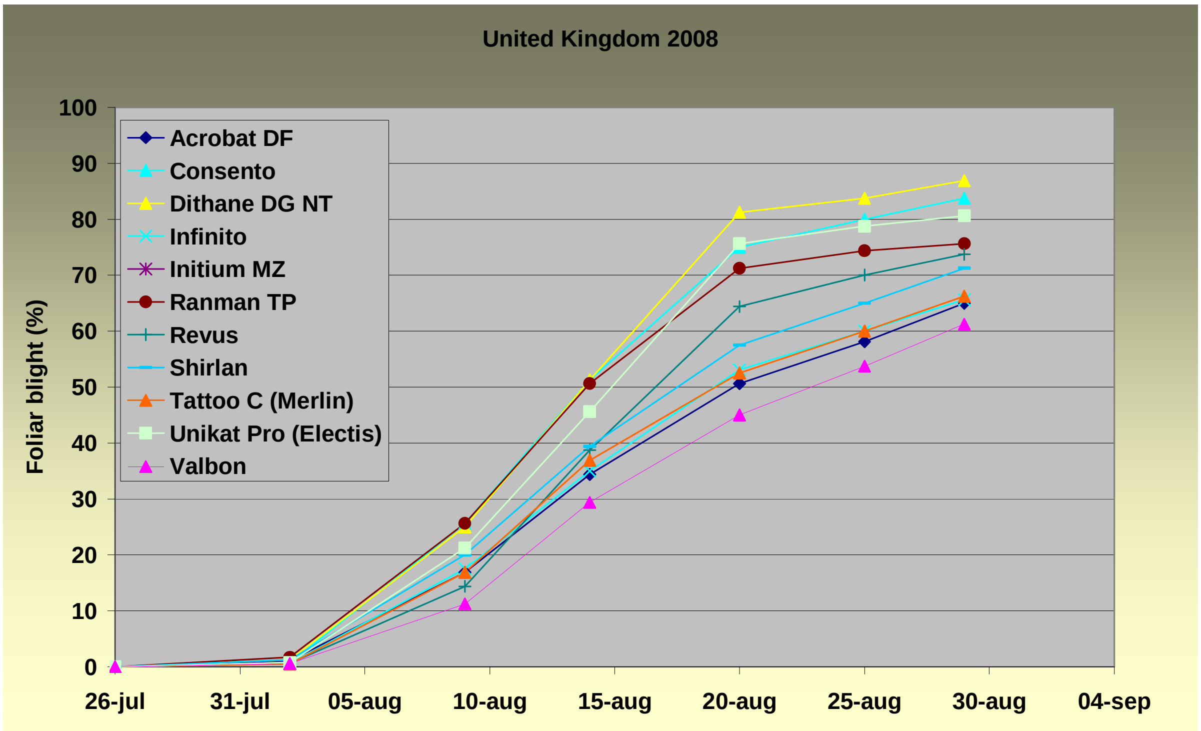

Figure 9. The development of foliar blight during the growing season in the United Kingdom 2008.

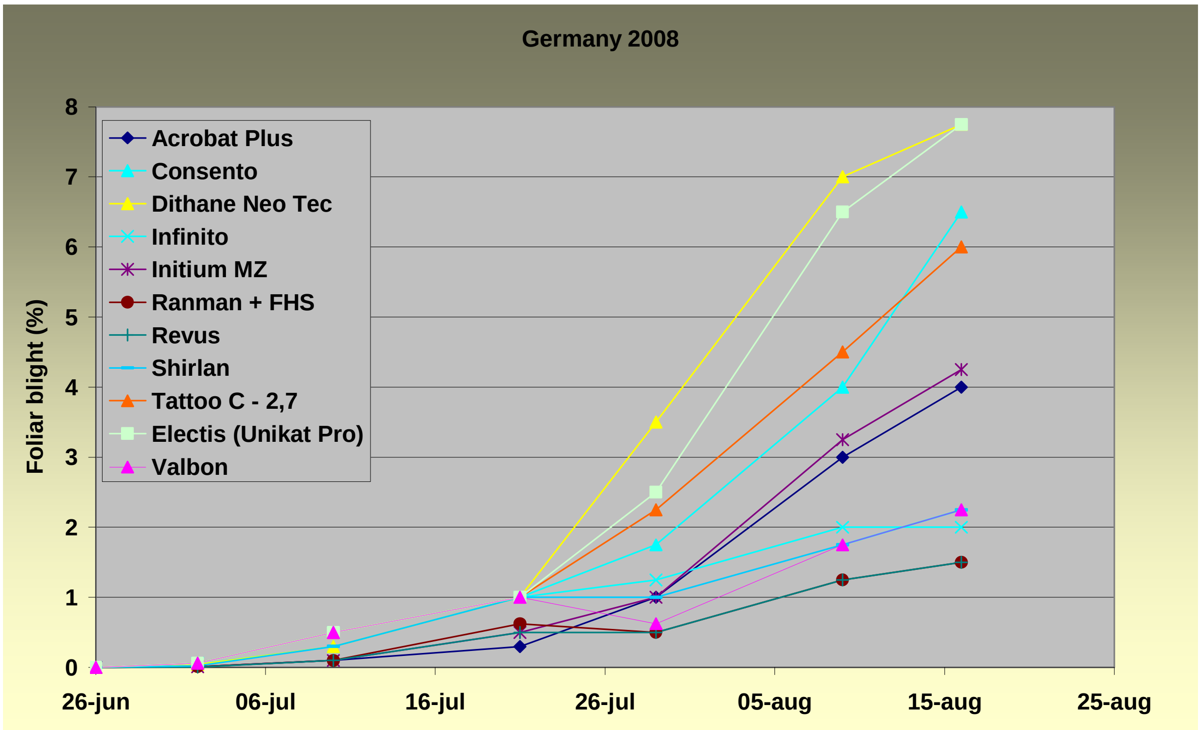

Figure 10. The development of foliar blight during the growing season in Germany 2008.

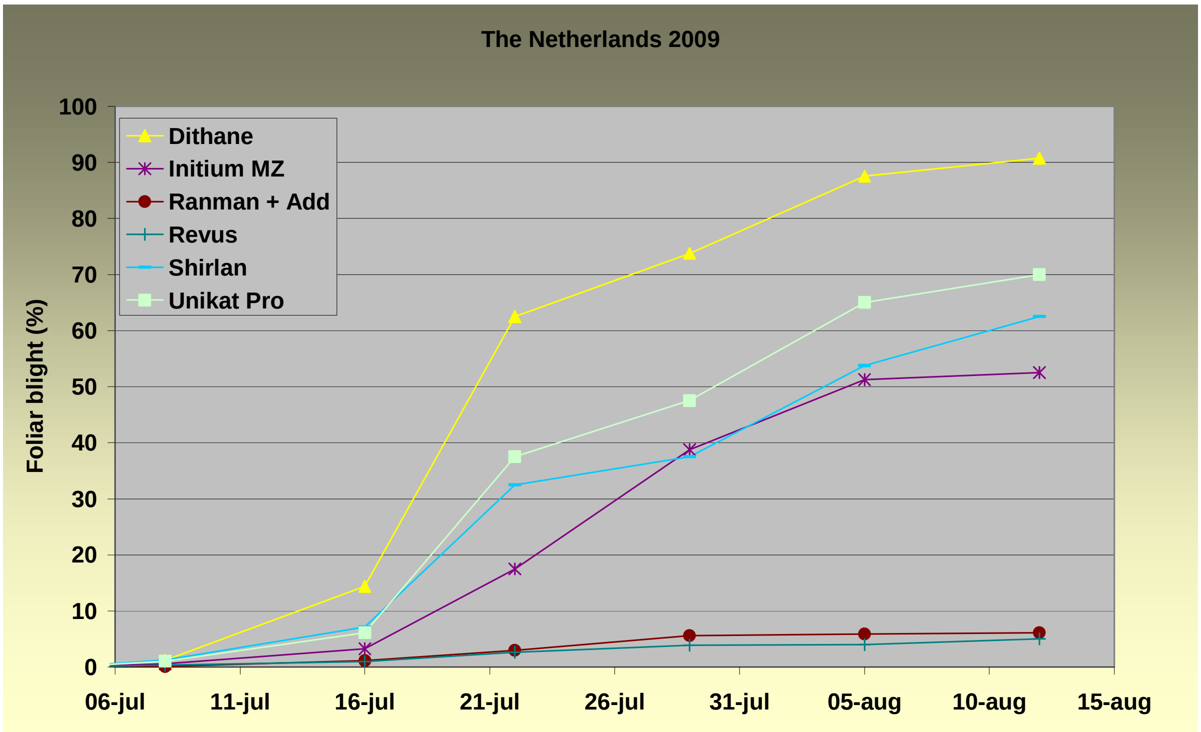

Figure 11. The development of foliar blight during the growing season in the Netherlands 2009, last two assessment dates not shown

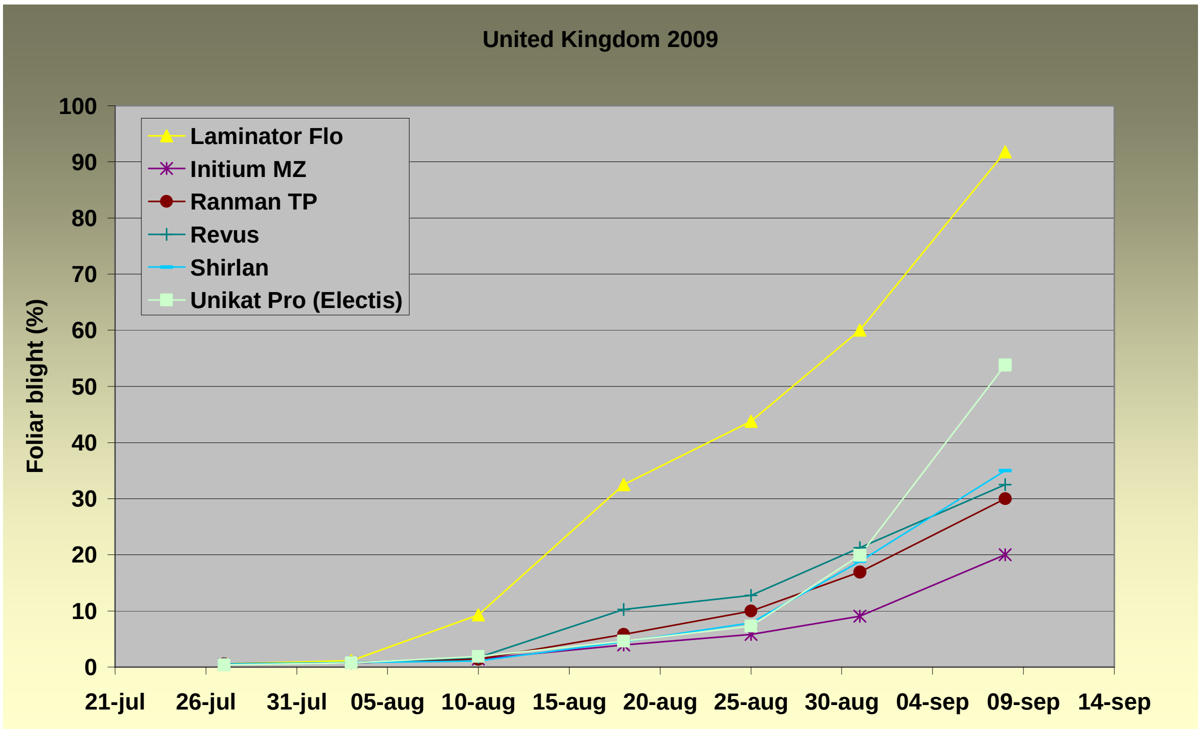

Figure 12. The development of foliar blight during the growing season in the United Kingdom 2009.

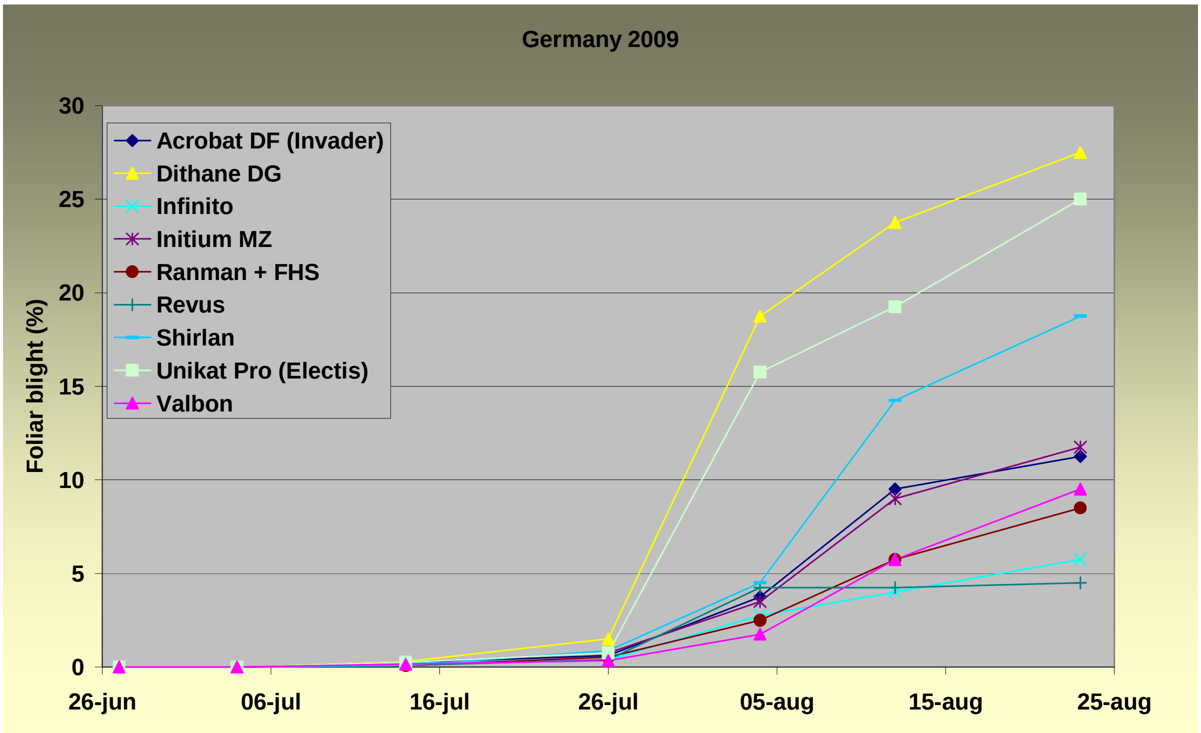

Figure 13. The development of foliar blight during the growing season in Germany 2009.

3.2 Effectiveness of the fungicides (stAUDPC)

The AUDPC or the stAUDPC can be used as a measure for the severity of the late blight epidemic. Control of late blight by fungicides will decrease the rate of the epidemic, and therefore reduce the AUDPC and stAUDPC value.
Spray intervals longer than 8 days occurred in some of the experiments. As a consequence the stAUDPC for the Danish experiments was adjusted, because the prolonged spray interval occurred during a period with high infection risk. In other experiments the prolonged spray intervals did not occu during periods with high infection risks. Adjusting the stAUDPC values for these trials had only minimal effect on the final ratings. Therefore the stAUDPC was not adjusted in these experiments.
Prolonged spray intervals occurred in Germany and UK in 2009. Spray intervals of 11 and 10 days were applied in June and the beginning of July, due to bad weather circumstances in Germany. However late blight was observed first in the middle of July, almost equally for each treatment. Therefore we assume that the prolonged spray interval had no effect on the performance of the fungicides.
Between July 14th and 23rd no fungicides were sprayed in the UK trial due to bad weather. Late blight was found first on July 27th. Significant differences between the fungicides tested were not found at that time, except for Unikat Pro. However at the next assessment date Unikat Pro had the same effciacy as the other fungicides tested, except for Laminator Flo which had a higher disease severity than all other treatments. Therefore we assume that the spray interval of 9 days at the beginning of the season had no or little effect on the preventative performance of the fungicides.
A REML analysis was performed on stAUDPC values. Analysis of Variance analysis assumes orthogonality between experiments, replicates and treatments. However some fungicides were not tested in 2009, whereas Initium MZ was not tested in 2006 and 2007. Therefore REML analysis was used.

Disease severity differed between the 13 trials and the range of observed stAUDPC's was higher in trials with high disease pressure. Evaluation of the power transformation according to Box and Cox (Montgomery and Peck, 1982) showed the log transformation stabilized the variance. However we did not use this transformation because in that case trials with low and high disease incidence will have more or less equal weight. Without transformation results of trials with high disease incidence will be of more influence on the arithmetical means for each fungicide. Another argument to abandon the logarithmic transformation was that interaction between trials and fungicide was only partly reduced by the logarithmic transformation. Scaling the AUDPC to values between 2 and 5 for each trial separately, transforms absolute differences to relative differences. Also in that case trials with low disease intensity get equal weight relative to trials with higher disease intensity. The interaction between trial and fungicide remained significant. Therefore we decided to analyse the stAUDPC without transformation and use the arithmetical means for scaling to a score between 2 and 5.

Tables 7 and 8 list stAUDPC values after spraying fungicides during the whole season. In general it can be assumed that the efficacy of the fungicide is higher when the stAUDPC value is lower.

Table 7. Effectiveness of the fungicides to control potato late blight as represented by the stAUDPC

Fungicide	2006				2007				
	DK	NL	UK	Average	DK	NL	UK	D	average
Acrobat DF (Invader)	11.3	25.5	12.6	16.5	0.2	37.0	-[1]	4.0	14.9
Consento (Tyfon)	4.8	35.9	2.7	14.5	1.2	53.1	27.6	1.3	20.8
Dithane DG	13.0	38.9	16.8	22.9	1.0	53.3	18.5	7.7	20.1
Infinito	1.9	8.4	1.2	3.8	0.1	20.7	21.2	0.9	10.7
Ranman	1.9	9.7	5.3	5.6	0.1	34.6	7.1	0.9	10.7
Revus	1.3	14.3	8.4	8.0	0.0	16.5	9.3	1.0	6.7
Sereno (Sonata)	7.6	19.5	17.3	14.8	1.3	39.5	23.5	4.4	17.2
Shirlan	21.6	23.1	12.8	19.2	2.1	51.5	15.5	1.9	17.8
Tattoo C (Merlin)	3.8	7.3	1.9	4.3	0.2	38.8	18.0	1.5	14.6
Unikat Pro (Electis)	8.5	27.6	8.6	14.9	0.2	48.0	19.1	4.0	17.8
Valbon	8.1	10.8	11.5	10.1	0.2	25.8	6.3	3.6	9.0
Grand Total	7.6	20.1	9.0	12.2	0.6	38.1	16.6	2.8	14.5

[1]: Acrobat DF was not included in the UK experiment in 2007
[2]: Tridex DG was used in DK in 2007 instead of Dithane

Table 8. Effectiveness of the fungicides to control potato late blight as represented by the stAUDPC

Fungicide	2008				2009				4 year
	NL	UK	D	Average	NL	UK	D	Average	average
Acrobat DF (Invader)[1]	21.1	-	1.3	17.0	-	-	2.0	-	16.2
Consento (Tyfon)	14.2	40.6	2.1	19.0	-	-	-	-	17.5
Dithane DG	24.0	42.3	3.3	23.2	50.3	32.4	7.0	29.9	23.4
Infinito	1.3	29.3	1.2	10.6	-	-	1.2	-	9.0
Initium MZ	2.9	32.3	1.5	12.2	24.5	5.3	2.0	10.6	10.9
Ranman	2.0	38.9	0.7	13.9	3.3	8.5	1.3	4.4	9.0
Revus	1.4	33.0	0.6	11.7	2.5	10.7	1.5	4.9	7.7
Sereno (Sonata)	-	-	-	-	-	-	-	-	16.8
Shirlan	9.3	32.3	1.1	14.2	28.9	8.6	2.7	13.4	16.2
Tattoo C (Merlin)	5.3	29.4	2.3	12.3	-	-	-	-	11.2
Unikat Pro (Electis)	15.2	38.7	3.0	19.0	34.0	10.6	5.7	16.8	17.0
Valbon	9.8	24.9	1.0	11.9	-	-	1.1	-	10.4
Grand Total	9.7	33.6	1.6	15.0	25.9	12.7	2.7	13.2	13.7

[1]: Acrobat DF was applied at a higher dose rate in the UK experiment in 2008, and was therefore omitted from the analysis.

3.3 Effectiveness of the fungicides during the whole season

A new rating system became necessary since fungicides were introduced on the market with better control properties than existing fungicides. At the Tallinn and Bologna meetings it was decided to re-evaluate the fungicide ratings. A protocol for rating the efficacy of fungicides during the whole season was agreed upon and is given in Appendix 1.
Fungicides were rated according to formula 1 in which the stAUDPC was transformed into a decimal rating (Table 9). It was decided to give the decimal rating and not round off. The decimal rating reflects the preventative efficacy of a fungicide more accurately than the rounded off value.
Although the relative rankings of fungicides are different at different sites/years, none of the units had large residuals. Therefore it can be concluded that the performance of the fungicides in the experiments were all consistent.

Table 9. Effectiveness of fungicides to control potato late blight during the **whole season**.

Fungicide	**Active ingredient**	Dose rate Kg or L /ha	StAUDPC[1]	Decimal[2] Rating 2006-09	Decimal[3] Rating Hamar	Bologna Table [4,5]
Acrobat DF (Invader)[6]	dimethomorph + mancozeb	2.0	15.9	3.0	2.8	2.5
Consento (Tyfon)	fenamidone + propamocarb	2.0	-[7]	2.5	2.5	2.5
Dithane DG	mancozeb	2.0-2.25	23.4	2.0	2.0	2
Infinito	fluopicolide + propamocarb	1.6	9.0	3.8	3.8	3
Initium MZ	-	2.5	10.8	3.6	-	-
Ranman + adjuvant	cyazofamid	0.2 + 0.15	9.0	3.8	3.6	3
Revus	mandipropamid	0.6	7.7	4.0	3.8	3
Sereno (Sonata)	fenamidone + mancozeb	1.5	-	2.6	2.6	2.5
Shirlan	fluazinam	0.4	16.2	2.9	2.6	3
Tattoo C (Merlin)	chlorothalonil + propamocarb	2.7	-	3.4	3.4	2.5
Unikat Pro (Electis)	zoxamide + mancozeb	1.8	17.0	2.8	2.6	3
Valbon	benthiavalicarb + mancozeb	2.0	10.4	3.7	3.5	3

[1] : Value established by REML Analysis.
[2] : Decimal ratings based on a minimum of 6 and a maximum of 13 experiments in years 2006-2009; D 3; DK 2; NL 4 and UK 4.
[3] : Decimal ratings based on 10 experiments, published in PPO Special Report 13 (2009): 177-182.
[4] : The ratings are intended as a guide only and will be amended in future if new information becomes available.
[5] : Values published in PPO Special Report 12 (2007): 107-110.
[6] : Fungicides were not tested in each experiment; for details see Materials & Method section
7 : No new data available

Using formula 1 the minimum rating will be 2, and is given to the fungicide with the highest stAUDPC value over all the experiments. In these trials that would be Dithane. Therefore the proposed rating for Dithane is 2, and that is in accordance with the rating in the Tallinn and Bologna tables. A disadvantage of this method is that Dithane is used as a reference. If Dithane would be omitted from the experiments the ratings for the fungicides would shift, with the second best fungicide would be rated 2.
The highest possible rating is 5. A fungicide can only be rated 5.0 exactly when no late blight occurs in any of the experiments. Obviously a rating of 5 is almost impossible to achieve, because some late blight occurs in the experiments unregarding the treatment.
Formula 1 generates a 2-5 scale. Obviously the scale can be adjusted to 1-5 or even a 1-9 scale if desired by changing the formula. The 2-5 scale was proposed in Hamar because it stays close to the ratings in the Bologna table and provides differentiation for the better fungicides. In the present situation there is no need to change.
The ratings of the fungicides are linearly, negatively correlated with the average stAUDPC established in the

trials. An advantage of the method proposed is that fungicides with a better performance than the fungicides with the highest performance so far can be rated better. For instance new fungicides like Infinito and Revus are rated the maximum 3 in the Bologna table. Another advantage of the method is that ratings once given are not fixed. With new data a rating could be adjusted to the current performance of the fungicide. However when the database expands changes in the ratings will become rare. For instance adding the 2008 data, and including the German data of 2007 to the database led to changes in the decimal rating of 0.1 to 0.2. Including the data of the 2009 experiments most ratings went up 0.2 points. Possibly this was due to the relative good performance of the tested fungicides relative to fungicides containing Mancozeb solo.

3.4 Conclusions

In Hamar a more dynamic ratings system for fungicide efficacy in controlling leaf blight was presented. 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 Bologna meeting in 2007. Another advantage is that there is scope for future, more effective fungicides to be rated higher than 3, the current maximum. Furthermore ratings once given are not fixed, thus relative changes in the effectiveness of fungicides can be made apparent.
The ratings proposed are exclusively based on the results of the 13 trials described in this report.

Appendix 1. Protocol for testing "Effectiveness: leaf late blight" (*Phytophthora infestans).*

Huub Schepers, Bent Nielsen, Nick Bradshaw and Ruairidh Bain E-Mail: huub.schepers@wur.nl

Purpose/aim of trials

To compare the "Effectiveness to leaf late blight" by measuring the protection of leaves against infection by late blight caused by application of a fungicide in a standard 7-day spray schedule (this standard spray schedule is not necessarily related to the label recommendations). This protection originates from the protectant and/or curative properties of the active ingredients and in the rapid growth phase of the crop also protection of new growth can contribute to the effectiveness of the fungicide for leaf blight control.

EPPO guideline PP 1/2 (3) (revised in 1996) describes the standard requirements of the field trial.

Specific additional requirements:

- A susceptible local ware potato variety. The growth habit of the cultivar should be recorded i.e. determinate or indeterminate growth.
- In order to obtain a long-lasting infection pressure, one or more measures can be chosen according to local conditions.
    - o 2 untreated spreader rows along the complete length of the trial that consist of a susceptible (Bintje) and an intermediate resistant variety (for example Nicola)
    - o Spreader rows with one variety and selective fungicide use on the spreader row
    - o Surrounding the trial with maize
    - o Include untreated plots in every replicate
- Individual plants in the spreader rows are artificially inoculated with a recently isolated, metalaxyl-sensitive, *P. infestans* isolate (or a mixture). When the length of the plots is eg. 10 m, 1 plant is infected per 10 m. So, one plant (susceptible) adjacent to each plot is inoculated with *P. infestans*. 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 and disease is not progressing.
- Each treatment consists of applications of the fungicide to be tested throughout the season, regardless of the limited application numbers on the label
- First spray depends on local conditions, but needs to be applied before the first attack (preventive).
- Crop cover provides information on how much of the fungicide spray was intercepted by the crop. Crop cover is defined as the percentage of the soil surface obscured by foliage when viewed from above. A grid divided into 20 equal squares allows cover to be assessed to the nearest 5%. Assess by holding the grid at a fixed height above the crop and estimate what percentage of the grid area is filled by leaf material. Assessments should be made at each fungicide application until crop cover reaches 100%. They can also be made if cover declines from 100% towards the end of the growing season.
- Crop growth stage should be recorded on the days that the trial is sprayed. The BBCH key should be used.
- Spray frequency is **every 7 days** (+/- 1 day) until desiccation
- Dose rate is highest preventative dose registered in Europe
- Assessment: every week (or more frequently when necessary) in spreader rows and plots by rating the % infected leaf area. To assess blight we recommend using the assessment key in the EPPO-guideline combined with the key published in Trans. Brit. Mycol. Soc. 31 (1947): 140-141 (is attached). It is also possible to use the Dutch PD scale guideline.
- Although the trial is carried out to assess effectiveness to leaf blight, we recommend to also

assessing stem blight when stem lesions occur. We recommend assessing stem blight by placing a 0.5 m square quadrate at four to six places in the plot and assess the surface area of visible stem that has symptoms of stem blight. The scale used is 0, 0.1, 0.5, 1, 2.5, 5, 7.5, 10, 12.5, 15, 17.5 and 20% and then increasing in 5% increments. The assessments should be made when the stem tissue is still mainly green otherwise it is difficult to distinguish stem blight from other symptoms.

- Desiccation: timing and method according to GAP.
- It is not strictly necessary to harvest the trial. To assess tuber blight a specific protocol is made.
- A method for determining the rating for the "Euroblight Fungicide Table" will be proposed when 6 successful trials (2 seasons x 3 trials) have been carried out by independent research institutes in at least 3 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 leaf blight".

N.B. A successful trial is one that is strictly carried out according to this protocol and late blight is observed in the plots (>10% foliar infection in the worst treatment). The rating is set by determination and comparison of the AUDPC's of the 6 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.** It will be investigated whether it is possible to determine a rating for "Effectiveness leaf blight"

- o Until flowering
- o During the whole growing season

Dividing the rating in this way will account for the specific additional characteristics of products in specific growing phases of the crop.

Appendix 2. Raw data

Plot data of late blight stAUDPC from each experiment in 2006 and 2007

fungicide	rep	DK 06	NL 06	UK 06	DK 07	NL 07	UK 07	D 07
Acrobat DF	1	11.6	30.9	17.7	0.2	37.1		2.5
Acrobat DF	2	10.9	20.1	10.9	0.3	35.9		1.9
Acrobat DF	3	10.5		15.0	0.2	36.1		2.5
Acrobat DF	4	12.2		6.7	0.1	38.8		1.8
Consento	1	6.7	33.5	5.1	1.6	51.7	26.6	0.5
Consento	2	5.2	38.3	3.0	2.4	58.2	27.7	0.8
Consento	3	3.9		1.1	0.8	52.1	31.7	0.6
Consento	4	3.4		1.8	0.2	50.6	24.6	0.8
Dithane	1	13.9	40.2	19.6	1.7	48.2	31.5	4.2
Dithane	2	9.8	37.5	17.3	1.3	50.7	13.1	4.4
Dithane	3	13.8		16.4	0.6	57.8	14.8	3.8
Dithane	4	14.5		13.6	0.2	56.6	14.6	4.2
Infinito	1	3.0	8.0	1.8	0.1	23.0	19.9	0.5
Infinito	2	3.0	8.8	1.3	0.2	19.4	23.1	0.5
Infinito	3	0.9		0.8	0.2	24.3	17.9	0.5
Infinito	4	0.6		0.8	0.0	16.0	24.1	0.5
Ranman	1	4.1	7.8	7.7	0.1	32.9	11.9	0.5
Ranman	2	1.6	11.6	3.5	0.1	29.4	7.0	0.5
Ranman	3	1.0		4.5	0.1	36.5	7.2	0.5
Ranman	4	0.9		5.5	0.0	39.8	2.5	0.5
Revus	1	2.2	15.3	10.4	0.0	14.5	13.9	0.5
Revus	2	1.0	13.4	7.7	0.0	15.6	6.6	0.5
Revus	3	0.8		8.1	0.0	14.5	7.4	0.6
Revus	4	1.1		7.3	0.0	21.3	9.4	0.5
Sereno	1	7.4	16.9	21.6	0.8	36.0	25.3	2.3
Sereno	2	6.8	22.0	17.0	1.6	35.3	25.9	2.3
Sereno	3	8.3		13.2	0.3	47.1	19.3	2.8
Sereno	4	7.8		17.4	2.4	39.6	23.8	2.1
Shirlan	1	23.6	28.0	12.8	4.0	50.0	23.7	1.0
Shirlan	2	21.6	18.3	15.1	2.5	47.7	13.7	1.1
Shirlan	3	20.5		11.4	0.8	62.9	14.8	1.0
Shirlan	4	20.5		12.0	1.1	45.2	9.7	1.0
Tattoo C	1	3.9	7.3	4.6	0.2	42.1	15.6	0.8
Tattoo C	2	3.2	7.2	1.3	0.3	35.3	15.4	0.7
Tattoo C	3	3.8		1.2	0.2	33.2	21.0	0.8
Tattoo C	4	4.4		0.7	0.2	44.8	20.0	0.8
Unikat Pro	1	9.0	19.6	10.4	0.3	45.2	28.3	2.3
Unikat Pro	2	9.2	35.6	9.5	0.3	45.0	18.9	1.9
Unikat Pro	3	8.0		8.6	0.1	53.2	18.2	2.3
Unikat Pro	4	7.6		5.9	0.1	48.5	11.0	2.3
Valbon	1	8.4	11.7	8.0	0.2	22.4	4.3	1.8
Valbon	2	8.9	9.9	14.1	0.5	21.9	6.0	1.8
Valbon	3	8.2		12.6	0.1	29.5	8.6	1.8
Valbon	4	7.0		11.3	0.1	29.4	6.4	2.5

Plot data of late blight stAUDPC from each experiment in 2008 & 2009

fungicide	rep	NL 08	UK 08	D 08	NL 09	UK 09	D 09
Acrobat DF	1	9.9	-	1.4	-	-	2.1
Acrobat DF	2	22.5	-	1.0	-	-	2.0
Acrobat DF	3	17.4	-	1.9	-	-	1.7
Acrobat DF	4	34.8	-	1.0	-	-	2.3
Consento	1	9.1	42.8	2.6	-	-	-
Consento	2	9.1	38.4	2.2	-	-	-
Consento	3	20.6	43.4	1.6	-	-	-
Consento	4	17.9	37.9	2.1	-	-	-
Dithane	1	14.0	40.9	3.4	42.6	29.4	7.6
Dithane	2	36.5	41.2	2.4	53.6	30.7	5.7
Dithane	3	17.3	41.1	3.1	63.7	31.1	7.2
Dithane	4	28.2	46.0	4.0	41.3	38.6	7.5
Infinito	1	0.6	30.3	1.1	-	-	1.3
Infinito	2	0.9	30.1	1.4	-	-	0.8
Infinito	3	1.8	26.3	1.3	-	-	1.2
Infinito	4	1.6	30.4	0.8	-	-	1.3
Initium MZ	1	1.5	25.0	1.3	18.2	5.2	2.0
Initium MZ	2	1.7	32.4	1.3	24.5	4.6	1.7
Initium MZ	3	4.5	37.4	2.2	31.3	5.2	2.3
Initium MZ	4	3.7	34.4	1.1	23.8	6.3	1.9
Ranman	1	1.4	34.0	0.5	1.8	6.1	1.2
Ranman	2	2.0	42.2	0.9	1.9	7.2	1.5
Ranman	3	2.2	42.4	0.6	7.8	16.0	1.1
Ranman	4	2.2	36.9	0.6	1.8	4.4	1.3
Revus	1	1.3	28.8	0.5	2.5	7.4	1.7
Revus	2	1.6	36.9	0.6	2.4	6.7	1.8
Revus	3	0.4	30.3	0.5	3.3	20.3	1.0
Revus	4	2.2	35.7	0.9	2.0	8.3	1.5
Shirlan	1	4.6	32.2	1.1	17.8	9.6	3.0
Shirlan	2	5.2	26.0	1.2	21.1	6.7	2.6
Shirlan	3	11.2	32.6	0.9	48.5	10.3	2.5
Shirlan	4	16.1	38.2	1.1	28.1	8.0	2.8
Tattoo C	1	2.5	25.7	2.3	-	-	-
Tattoo C	2	6.2	25.0	1.6	-	-	-
Tattoo C	3	8.2	32.5	2.6	-	-	-
Tattoo C	4	4.4	34.3	2.8	-	-	-
Unikat Pro	1	12.3	35.1	2.5	26.2	7.7	4.9
Unikat Pro	2	15.6	36.5	3.2	25.7	8.1	5.2
Unikat Pro	3	13.8	39.6	3.7	48.4	14.5	6.7
Unikat Pro	4	19.2	43.5	2.6	35.6	12.2	6.0
Valbon	1	10.7	23.4	0.8	-	-	1.1
Valbon	2	9.6	23.8	1.4	-	-	1.1
Valbon	3	8.1	19.1	1.1	-	-	1.2
Valbon	4	10.7	33.1	0.8	-	-	1.1

Appendix 3. REML and fungicide rating

```
IMPORT 'M:/evenhuis/2009/euroblight2009/DataEuroblight 06070809.xls'; \
   ISAVE = isave;                                                      \
   SHEET = 'genstat'

TABU [ CLASS = jaar, Exp; PRIN = c ]
TABU [ CLASS = jaar, country; PRIN = c ]
TABU [ CLASS = Exp, herhaling; PRIN = c ]

GETA [ ATTR = label ] fungicide; SAVE = save
TEXT [ VAL = #save[] ] label

BLOC Exp / herhaling
TREA expr * fungicide

VCOM [ FIXED = fungicide ] Exp / herhaling

TABU [ CLASS = jaar; PRIN = mean; IP = as ] AUDPC,   stAUDPC


FOR [ INDEX = i ] y =     AUDPC,   stAUDPC  ; \
                  m   =  mAUDPC,  mstAUDPC ; \
                  mSq = SqAUDPC, SqstAUDPC,
  REML [ PRIN = #, mean ] SQRT(y); RESI = resi; FITT = fitt
  VKEE fungicide; MEAN = MEAN
  VARI [ VAL = #MEAN ] mSq
  GRAP [ NR = 21; NC = 51 ] resi; fitt

  REML [ PRIN = #, mean ] y; RESI = resi; FITT = fitt
  VKEE fungicide; MEAN = MEAN
  VARI [ VAL = #MEAN ] m
  GRAP [ NR = 21; NC = 51 ] resi; fitt

ENDFOR

PRIN label, mAUDPC, mstAUDPC; F = 10
DSCA        mAUDPC, mstAUDPC


FOR [ INDEX = i ] y = mAUDPC, mstAUDPC,

    CALC y = 3 * ( MAX ( y )  - y ) / MAX ( y ) + 2

ENDFOR

CAPTION '2 - 5'; META
PRIN label, mAUDPC,  mstAUDPC,  F = 10

STOP
```

REML variance components analysis

Response variate:	stAUDPC
Fixed model:	Constant + fungicide
Random model:	Exp + Exp.herhaling
Number of units:	392

Residual term has been added to model

Sparse algorithm with AI optimisation

Estimated variance components

Random term	component	s.e.
Exp	137.58	56.78
Exp.herhaling	-0.20	1.46

Residual variance model

Term	Factor	Model(order)	Parameter	Estimate	s.e.
Residual		Identity	Sigma2	45.70	3.56

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
fungicide	221.52	8	27.69	330.4	<0.001

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
fungicide	221.52	8	27.69	330.4	<0.001

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

Table of predicted means for Constant

13.26 Standard error: 3.272

Table of predicted means for fungicide

fungicide	Acrobat DF	Dithane	Infinito	Initium MZ	Ranman
	15.91	23.36	9.00	10.80	8.99

fungicide	Revus	Shirlan	Unikat Pro	Valbon
	7.71	16.22	16.99	10.40

Standard errors of differences

Average:	1.502
Maximum:	1.881
Minimum:	1.352

Average variance of differences: 2.281

PRIN label, mstAUDPC; F = 10

label	mstAUDPC
Acrobat DF	15.91
Dithane	23.36
Infinito	9.00
Initium MZ	10.80
Ranman	8.99
Revus	7.71
Shirlan	16.22
Unikat Pro	16.99
Valbon	10.40

```
FOR [ INDEX = i ] y = mstAUDPC

  IF i .IN. !(1)
    CALC y = 3 * ( MAX ( y )  - y ) / MAX ( y ) + 2
  ENDIF


ENDFOR


CAPTION '2 - 5'; META
PRIN label, mstAUDPC,
```

label	mstAUDPC
Acrobat DF	3.0
Dithane	2.0
Infinito	3.8
Initium MZ	3.6
Ranman	3.8
Revus	4.0
Shirlan	2.9
Unikat Pro	2.8
Valbon	3.7