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Preface

Integrated control of potato late and early blight

A Concerted Action entitled “European network for development of an integrated control strategy of potato late blight (EU.NET.ICP)” encouraged participants to a yearly Workshop. After four years and four Workshops (Proceedings comprised in four PAV-Special Reports: 1, 3, 5 and 6) the Concerted Action came to an end, but through enthusiastic participants and sponsoring by companies active in late blight control the series of Workshops continued. In 2000, 2001, 2002 and 2004 the fifth, sixth, seventh and eighth Workshop were organised in Munich (Germany), Edinburgh (Scotland), Poznan (Poland) and Jersey (Channel Islands). The Proceedings of these Workshops are published in PAV-Special Report no.7 and PPO-Special Reports no’s 8, 9 and 10. The Proceedings are now also available on the internet www.lateblight.nl.

The Jõgeva Plant Breeding Institute, Estonia organised the ninth Workshop in Tallinn, Estonia from 19-23 October 2005.

Belchim, Bayer, Certis, Dacom, Dow, DuPont, Germicopa and Syngenta sponsored the Workshop.

The Workshop was attended by 85 persons from 15 European countries, the United States of America, Russia and Japan. Representatives from all countries presented the late blight epidemic in 2004 and 2005 and recent research results regarding integrated control, decision support systems, resistance of varieties and population biology of the late blight pathogen in potatoes. Since early blight seems to be an increasing problem in Europe, also reports on this disease are included. The papers and posters presented at the Workshop and discussions in the subgroups are published in these Proceedings, PPO-Special Report no. 11.

For further information please contact the network secretariat where also additional copies of this Proceedings can be ordered.

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Introduction

From 19-23 October 2005 a Workshop was held in Tallinn Estonia on control of *Phytophthora infestans*. Representatives from 16 countries (Europe, USA, Japan) presented the development and control of late blight in their country in 2004-2005. In this paper these presentations are summarised. The weather conditions of 2004-2005, the disease progress and the input of fungicides are presented and condensed in Table 1 and 2.

Weather conditions & late blight epidemic

In the Po valley of **Italy** (2004), a relative dry and warm season was unfavourable for late blight in potatoes. The first occurrence of late blight was observed in the end of May. The disease pressure in June and July was low to medium. The number of sprays depended on the level of irrigation. Usually sprays were carried out before irrigation. In potato 5-7 sprays were applied and 8-10 in tomato.

In organic crops just a few lesions were observed. Due to the dry weather conditions these an epidemic did not develop. There were no problems with tuber blight.

In 2005 a relative dry and warm season was unfavourable for late blight in potatoes. The first occurrence of late blight was observed in the end of May. The disease pressure in June and July was low to medium.

Early blight occurred at the end of the growing season. There are 6-7 fungicides registered to control early blight in potatoes. In high risk areas, control started after flowering. In low risk areas, sprays started when first symptoms were visible.

In **Germany** (2004), an extensive network of governmental crop protection services monitored fields for the occurrence of late blight. In 2004 the first blight was detected in a plastic covered crop on May 6th. Later on in the season, blight was detected on a small scale in some irrigated fields, allotment gardens and dumps but symptoms in “normal” potato fields were very scarce. Disease pressure was low to medium. The number of treatment varied from 4-7 in regions (Sachsen, Rheinland Pfaltz) with moderate disease pressure to 7-10 in regions (Nedersachen) with high disease pressure.

In 2005 the first blight was detected in a plastic covered crop on April 28th. Later on in the season, blight was detected on a small scale in some irrigated fields, allotment gardens and dumps but symptoms in “normal” potato fields were very scarce. Disease pressure was low to medium. The number of treatment varied from 4-5 in regions (Sachsen) with moderate to low disease pressure to 7-10 in regions (Nedersachen) with high disease pressure.

In **France** (2004) the disease pressure was relatively low till the second half of July. After that the disease pressure increased. In August the disease pressure was constantly high.

In 2005 the epidemic of late blight started early in the north of France. The first late blight was found on dumps at the end of April. At the end of May an explosion of the symptoms was observed on dumps. There were also problems with volunteers. In the beginning of July the disease pressure increased. Disease returned in July on dumps, gardens and volunteers and this led to more problems with the disease at the end of July and later on. Often a product containing cymoxanil had to be used. During the phase where foliage was growing quick systemic products were sprayed to protect the new growth.

Later on fungicides (fluazinam, cyazofamid) with tuber protection were sprayed. The number of sprays varied from 8 in resistance varieties (Kardal) up to 13 in susceptible varieties (Bintje). Many problems with late blight were reported in organic crops. A lot of fields were destroyed in the end of July.

In 2004 in Flanders (**Belgium**) potatoes were planted early (< 30 April) because of the early spring with low precipitation in March. The first blight was found on dumps in the third week of May. Because of the unfavourable conditions, disease did not spread out much. In the second week of July infected volunteers caused a further spread of the disease. In August only a few favourable days were observed caused by a high precipitation. The average number of sprays to control late blight was 15. Mancozeb was the most widely used fungicide (<30%) followed by Shirlan (20%), Acrobat (7-10%) and cymoxanil (6-10%). Ranman and

Unikat Pro both (3-6%) and Tattoo C, Epok and Sereno (1-3%) are the other product used in Flanders.

In 2005 potatoes were planted from 30 April till the end of May. Due to the rainfall the planting period was very long. The first blight was found on dumps in the first week of May. Later that month and in the beginning of June more infections were observed.

In July and August the weather was very favourable for late blight. The disease mainly originated from infected volunteers. In August many fields were infected and problems did occur. In 2005 the average number of sprays was 16. Mancozeb was the most used fungicide (<30%) followed by Shirlan (20%), Acrobat (>7%) and cymoxanil (6-10%). Fungicide use was comparable to the use in 2004. The use of Ranman, Tattoo C, Epok and Sereno increased compared to 2004. The use of Unikat Pro slightly decreased in 2005.

In 2004, about 164.000 ha of potatoes were grown in the **Netherlands**. The first late blight was reported on May 10th on a dump. Disease did not spread out very much during May and June due to low disease pressure. In July and August disease pressure was high. The summer had the highest precipitation rate since 1951. In general the yield was good and there were little problems with tuber blight. In 2004, 10-15 sprays were carried out during the season. Shirlan was still the most commonly used fungicide, followed by cymoxanil-containing products. The market share of Tattoo C, Ranman and Sereno is limited. Since late blight occurred late, organic crops could grow undisturbed and produce good yields. Some tuber blight infections were reported but problems were not serious. Serious Alternaria infections were reported in August.

In 2005, planting was up to 3 weeks later than average. In spite of the cold spring the first late blight was found on a dump pile on May 4th. The precipitation in 2005 was about normal, in June till September it rained frequently. Disease pressure was moderately high in May and June. In July, disease pressure was high and led to problems in some areas.

In 2005, 8-14 sprays were carried out during the season. Shirlan was still the most commonly used fungicide, followed by cymoxanil-containing products. In this year the use of Curzate M (mancozeb/cymoxanil) was higher than in previous years. Tuber blight was very limited in 2005. In 2005 less Alternaria infections were reported compared to 2004. However, at the end of the growing season (early September) some serious infections were reported. These did not lead to serious reductions in yield.

In **Jersey** (2004) the first late blight was found in a protected crop on January 4th. In outdoor crops it was recorded on March 2. The number of outbreaks in 2004 (94) was higher than in 2003 but lower than the average over the years 1999-2002. In 2005 the first late blight was again found in a protected crop on January 4th. In outdoor crops it was recorded on April 14th. The number of outbreaks in 2005 (38) was lower than in 2004 and much lower than the average over the years 1999-2002. In Jersey more than eleven different active ingredients, in even more products, were used to control late blight. The most commonly used active ingredients are mancozeb, cymoxanil and fluazinam. In 2005, metalaxyl-M was also used. The total use of fungicides was slightly more than in 2004. Tuber blight and *Alternaria* were not recorded in early salad crops.

In **England, Scotland & Wales** (2004) a few early outbreaks were recorded in crops during May (12 May in England & Wales) and in July (6 July) in Scotland. Most subsequent outbreaks were reported in July and August. The average number of sprays applied was 11.5. Despite the relatively low disease pressure and robust spray programmes in England and Wales, tuber blight was a major cause of store breakdown in 2004/2005 at levels not seen since 1992/93. The main variety affected was Maris Piper. The scale of the problem was due not only to the susceptibility of Maris Piper, but also to the proportion of the GB potato area (approximately 30%) planted with this variety. These levels of tuber infection occurred despite robust spray programmes and were almost certainly a reflection of the wet conditions in the post desiccation period. In Scotland there were many extended periods of high risk during late July and August.

In 2005, planting was extended over a relatively long period because of the 'catchy spring'. Despite this, virtually all main crops in England & Wales had been planted by the end of May. Blight infection was confirmed in England & Wales on three dumps (now called outgrade piles) during late May/early June. The first of these outbreaks was recorded on 27 May. In Scotland, the first crop outbreak was recorded on 31 May. The risk of blight infection coming from potato volunteers was also a concern as there were reports of volunteers growing in hedge bottoms and on set-aside land. So, after the late developing blight epidemic in 2004 and the relatively mild winter with no sustained spell of hard frosts increasing the potential disease carryover, it was thought prudent to consider the 2005 crop to be at a higher risk than normal.

Whilst conditions in the south of England and west Wales during early June were certainly favorable for blight development, low night temperatures ($<10^{\circ}\text{C}$) were a feature in many other areas and this would have delayed disease development. In the latter half of June and up to mid July there were sustained periods of unsettled weather with some particularly heavy thunder storms in places. Flushes of Smith Periods were recorded in many areas of England although they were often quite localized. When taken together with an increasing number of blight outbreaks, this prompted a general warning of high blight risk and the need to maintain spray programmes at minimum permitted intervals. These concerns were subsequently borne out by the number of confirmed blight outbreaks in crops which peaked at 50 during July.

With a few notable exceptions, the wet weather did not disrupt spray programmes too much and intervals between applications were not greatly extended. A hot, dry and settled spell of weather in the second and third weeks of July allowed growers to bring spray programmes back on track where there had been some slippage. The dry weather also dampened down blight development. Nevertheless there were reliable reports that blight had become established in crops at very low levels in several parts of the country and particularly in the Southwest of England. Despite the dry conditions in the Southwest, new infections continued to develop and actively sporulating stem lesions were very common. Intensive spraying almost certainly prevented a very serious epidemic in the Southwest as unsettled conditions returned in many areas in the latter part of July.

The dry weather also prevented blight development elsewhere, and together with effective spray programmes, kept the disease well under control. Blight risk reduced considerably during August and there were only 19 confirmed crop outbreaks during the whole of August. As a result of the reduced level of blight activity, growers were reported to be extending spray intervals and/or using less expensive fungicides. This was an appropriate strategy where the disease was known to be absent in a locality but demanded considerable confidence in the ability to respond rapidly should the situation change. Despite initial concerns, foliar blight was not a significant problem in most parts of England, Scotland & Wales during 2005 although there were localized hot spots of activity.

In **Northern Ireland** (2004) dry weather early in the season resulted in fewer outbreaks than usual (14 by the end of July). Crops received 4-14 fungicide applications. In the beginning of the season the most commonly used fungicides were Merlin (Tattoo C), Fubol Gold, Shirlan and mancozeb. In mid-season Invader, Curzate M and Shirlan were the most frequently used

products. At the end of the season Shirlan was sprayed most. Very few cases of tuber blight were found. Only 3 seed stocks out of 75 examined showed a low level of tuber blight.

In 2005, the weather in June was wetter than usual and 50 reports of outbreaks were recorded by the end of July. Crops received 5-14 sprays during the season. The spraying strategy was comparable to 2004. In Northern Ireland, organic potatoes are grown on a very limited scale (5-10 ha). In organic crops, copper-based products are sprayed to control late blight.

In **Poland** (2004), the first late blight in a field was observed on June 16 on the variety Aster in the province Dolnoslaskie. The most common program to control late blight in commercial fields consists of two fungicide treatments. Fungicides belonging to the phenylamide-group (Fubol Gold/Sandofan) were the most frequently sprayed products, followed by mancozeb, chlorothalonil and Curzate M. The first symptoms of early blight occurred early June. Eighty percent of the fields were infected.

In 2005, the first late blight in a field was observed on June 16 on the variety Ruta in the province Dolnoslaskie.

In **Latvia** (2004), the first blight symptoms were observed in the second week of June. The weather was warmer than average and more precipitation was recorded. Due to the weather the blight pressure was high especially in the second part of June. 1-3 sprays were carried out with systemic fungicides. Sprays start when rows are closing. Intervals are varying from 10-14 days. These sprays are followed by 2-3 sprays with contact/translaminair fungicides. Spray intervals vary from 7-10 days. Less attention is paid to tuber blight in Latvia. Controlling late blight in organic crops is managed by choosing a resistant variety. *Alternaria* can be a problem, although not very important. By spraying mancozeb-based fungicides against late blight, early blight is also controlled.

In 2005, the first blight symptoms were observed in the third week of June. The weather was cooler than average and less precipitation was recorded. Due to the weather the blight pressure was moderate during the whole year.

In **Estonia** (2004), due to the cold spring, potatoes emerged late (about mid June). Potatoes in home gardens and commercial fields were infected at the same time. The first outbreaks of late blight were recorded in the period from 5-8 July. Many farmers were late with the first treatment and therefore they had to spray a systemic fungicide to control the disease. The weather conditions were favourable during the whole season. The number of fungicides used increased rapidly since 1999. In five years the total amount of fungicides used tripled

although the total acreage of potato land was reduced by 50%. The most frequently used fungicide is Tattoo, followed by Acrobat Plus, Dithane and Ridomil Gold. The use of Shirlan is very limited in Estonia. Tuber blight was a problem in 2004. Due to the wet weather before/during harvest many tubers were infected.

Due to the cold spring, potatoes emerged late (about mid June) in 2005. The first late blight was reported on June 26th in home gardens. More infected plants in home gardens were reported after that. Due to the dry weather in mid July infection disappeared. The first disease outbreaks in commercial fields were detected on July 22nd. Disease pressure till the end of the season can be characterized as low. In 2005 farmers did start early with the application of fungicides and sprayed 4-7 (in a few cases up to 10) times during the season, despite of the low disease pressure. Propamocarb, metalaxyl, dimethomorph were the most widely used fungicides, followed by mancozeb, fluazinam and fenamidone. The last few years, early blight is a minor problem. Mancozeb, or mancozeb based fungicides (Electis), provide a good control.

In **Denmark** (2004) most crops emerged in the period May 15-30. During this period the weather conditions were relatively dry. The first infection was found on July 2. One week after that, more (11) infections were recorded. In 2004, there were no indications of early infections from oospores. In June, July and August the weather based risk of late blight development was moderate. In September the disease pressure was low.

In 2005, most crops emerged in the period May 15-30. During this period the weather conditions were wet. Fifteen fields with infections were found in the second week of June. In several of these, numerous infections were found on small plants (BBCH<30) which indicate soil born infections (oöspores). One week after that more (9) infections were recorded, all at BBCH > 30.

In June the weather based risk for late blight was low. In the second half of July and August the disease pressure was medium to high. 7-8 applications were carried out to control the disease. In comparison with previous years the use of Dithane, Shirlan and Ranman increased. The use of Tattoo and Acrobat decreased. In 2005, Ridomil was also used (dispensation) due to very early attacks with indications of infections from oöspores. The Ridomil applications stopped the early attacks. In organic crops, early attacks in June were reported. Some fields did not produce a yield. In general, attacks took place in July and resulted in low yields and tuber blight problems.

In **Norway** (2004) the first late blight was found on May 20th. The number of late blight risky days according to Forsunds rules in July and August was 13 (Roverud). This was comparable with the number of days in 2003. The number of blight risky days in Rygge was low (6). The risk for late blight was low to medium in the south and middle of Norway. This resulted in less infected fields in these areas. In the north more infected fields were observed. In general, few problems with late blight occurred. Mainly Shirlan and Tattoo (propamocarb + mancozeb) were sprayed to protect the crop. 4-8 sprays were applied. More and more dynamic dose rates of Shirlan were used at a weekly spray interval. In 2004 only incidentally problems with tuber blight were reported.

In 2005, the first late blight was found on June 3rd. The number of late blight risky days according to Forsunds rules in July and August was 17 (Roverud). This was higher than in the previous years. The number of blight risky days in Rygge was 15 and it was comparable with the number of days in 2002 and 2003. The risk for late blight was low to medium in the south and middle of Norway. This resulted in less infected fields in these areas. Alternaria is no problem in Norway.

In **Sweden** (2004) the first attacks were reported in the southwest late May, one week later than usual. Compared to recent years the number of early infected fields was very low. In the south the occasional late blight attacks in ware and processing potatoes were observed in the first week of July. In mid Sweden the late blight attacks were reported in the end of July and were not heavy. In the north of Sweden hardly any attacks were reported. Overall, late blight was easy to control in 2004. The standard fungicide used is Shirlan. Epok is mainly recommended as the second and/or third/fourth spray to protect the new growth. It is also used as a curative fungicide. The new fungicides (Ranman and Tanos) are used in an increasing amount. In some areas there were a few reports of tuber blight. There were little problems in organic crops with late blight (unusual).

In 2005, a cold spring resulted in a long time between planting and emergence. In the southwest, the first attacks were reported late May, one week later than usual. In this area a large number of field were attacked in the beginning of June, despite of the low precipitation in this period. In July the warm and dry weather resulted in a few infected fields. The favourable weather in August resulted in more infections and some growers had problems to control late blight. In the north of Sweden the first late blight was observed in home gardens in late August. Commercial growers had no problems with control late blight in 2005.

In **Finland** (2004) blight was first observed in a commercial field on 27 June which is comparable to recent years. It was very rainy end of May beginning of June and whole July. At some places daily rainfall over 100 mm/day was recorded. The monthly rainfall in many locations was three times higher than normal. The infection pressure was exceptionally in July. At the end of the season blight was present to some extent at most fields in spite of fungicide treatments. Some commercial conventional fields were totally destroyed by August. Although some applications could not be carried out in time due to continuous rain and wet soil, 5-9 sprays were applied in 2004. The fungicides used were fluazinam (46%), mancozeb (41%) and Acrobat, Tanos, Electis and Tattoo (< 4% each). The 2004 season was a catastrophe for organic crops; no marketable yield could be harvested except for very early fields. Despite serious leaf blight, no specific problems were recorded regarding tuber blight. No *Alternaria* problems occurred; there was no need for chemical control.

In 2005, the first infected field was a covered crop (23 June), the first infected normal field was observed on 6 July which was somewhat later compared to recent years. May was dry, June was normal. Almost no rain at all was recorded in July, whereas in August heavy local rains were recorded. The infection pressure was exceptionally low, except in August. The first epidemic outbreaks were seen in unprotected crop during the second week of August; in crops treated with fungicides no blight was observed at all. Due to serious problems in 2004, growers started very early although the risk was low and continued spraying throughout the extremely dry period. Fungicide use was comparable to 2004. Ranman was introduced on market and Epok was reintroduced. For organic crops it was the easiest year in 2000's. Reasonable yields were recorded for most varieties. Despite a low incidence of leaf blight, quality problems occurred and up to 5% tuber blight was reported. After a long warm and dry period in July *Alternaria* was present in susceptible varieties. Moderate outbreaks were recorded on fields where blight protection was based on non-mancozeb products.

In **USA (Maine)**, crop emergence was around June 15th 2004. The 18 severity values were reached at June 24th. The first blight was noticed at July 19th. Due to the favourable weather conditions, the disease pressure was very high in July and disease was widely spread. Serious attacks were reported and there were serious problems to control late blight, resulting in a high level of tuber blight. Because of high disease pressure in July late blight in organic crops was a disaster (very heavy attacks). 12-15 sprays were carried out. Chlorothalonil and EBDC materials are mostly used. Serious problems with tuber infections were reported.

In 2005, crop emergence was around June 15th. The 18 severity values were reached at June 18th. The first blight was noticed at July 27th, a week later than in 2004. Due to the favourable weather conditions, the disease pressure was high in July and disease was spread locally. Locally disease pressure was high and resulted in serious attacks. In areas with foliar infections, tuber blight was observed. In areas with fewer problems with foliar blight, less tuber blight was observed. 12-15 sprays were carried out. Chlorothalonil and EBDC materials are mostly used. Some tuber blight infections were reported. In organic crops, late blight was not a large problem this year (due to localization).

In **Japan** (2005), on average 6 applications were carried out. However, farmers who grow high quality (seed) potatoes apply more sprays. Most commonly sprayed product is mancozeb. After flowering products with better characteristics are sprayed. In Japan, early blight is a serious problem but many late blight fungicides have an acceptable level of efficacy against this disease. Therefore growers usually do not have a problem to control Alternaria.

In the European regions of **Russia**, the weather conditions in 2004 were very favourable for late blight. The first late blight was observed early (before rows closed). The infection pressure remained high during the whole season. Serious problems with tuber blight were reported.

In 2005, severe development of late blight was registered in northern, south-western and partially in central regions. In the north-west regions late blight occurred shortly before harvest. Many infections started early originating from infected seed potatoes (due to tuber blight problems in 2004). However, the dry conditions caused stagnation in the further development of the epidemic. Hot and dry weather in August and September resulted in low level of tuber blight. However the weather conditions in August and September caused early blight. Four treatments with fungicides were not sufficient to control early blight. In 2004 and 2005, 2-11 sprays were applied to control late blight. The most important fungicides used are based on mancozeb, chlorothalonil, cymoxanil, dimethomorph, fenamidone and metalaxyl.

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Table 1. The estimated use¹ of fungicides to control *P. infestans* on potato in 1999-2005.

	Average number sprays/season						
	1999	2000	2001	2002	2003	2004	2005
Austria	4-12	4	4-7	3-12			
Belgium							
* Flanders	14	16	15	14	11	15	16
* Wallonia	11-15	13-16	11-13	12-16			
Denmark	7.5	7-8	8-9	8-9	7	7-8	7-8
Estonia			3-5	3-5	2-6	5-7	4-7
Finland	2-6	5-9	4-8	4-8	3-7	5-9	4-8
France							
*Nord-Pas-de-Calais	15	16-17	10-19	12-13	10-14		8-13
Germany	4-5	2-14	2-16	3-14	3-11	2-10	1-10
Italy	8-10	6-8	4-7	5-8	4-5	5-7	5-7
Latvia	?	2	4	2	1-2	5-6	4-5
Netherlands	7-16	15-20	10-18	8-16	12-13	10-15	8-14
Norway	5-6	6-7	5.5	6-8	6-7	4-8	3-8
Poland	2	2	1-8	1-5	1-6	1-10	1-12
Spain (Basque Country)	4-5	2-6	2-3	3-4			
Sweden	4-11	?	?	2-8	2-10	3-10	3-10
Switzerland	6-10	7	6.3	5-6	5		
United Kingdom							
*Northern Ireland	4-14	3-12	3-14	3-14	4-12	4-14	5-14
*England,Wales,Scotland	8,2	8,0	8-12	8-14	9.9 ²	11-12	10-11
*Jersey	4-5	4-5	3-5				
Russia						2-11	2-11
Japan	?	?	?	?	?	?	6
USA (Maine)	8-10	9-12	8-10	10-12	9-14	12-15	12-15

¹ estimations can unfortunately not be separated in "minimum to maximum" and "mean" number of sprays.

² source of data from British Potato Council/potatocrop.com

Table 2. Weather conditions favourable for the development of late blight and dates of first recorded outbreaks of blight in potato in 2004 and 2005.

	May	June	July	Aug.	Sept.	First outbreak	May	June	July	Aug.	Sept.	First outbreak
						2004						2005
Austria												
Belgium												
* Flanders	*	*	**	**		May 13	**	**	***	***		April 4
* Wallonia												
Denmark		**	**	**	*	July 2		*	**	***	**	June 10
Estonia	*	***	***	***	**	July 5	*	**	*	***	*	June 26 ⁵
Finland	*	***	***	***	*	June 27	*	*	*	***	*	June 23 ¹
France												
*Nord-Pas-de-Calais		**	***	***			***	**	***	***		May 15 ²
*Brittany												
Germany	*	*	**	**	**	May 6 ^{1,2,5}	*	*	**	**	**	April 28 ^{1,2,5}
Italy	*	*	*			May 20	*	*	*			Not found
Ireland												
Latvia	**	***	**	**		July 7	**	**	**	**		July 1
Netherlands	*	*	***	***	**	May 10 ²	**	**	***	***	***	May 4 ²
Norway	*	*(*)	*(*)	*(*)		May 20 ¹	*	*(*)	*(*)	*(*)		June 3 ¹
Poland						June 16						June 16
Spain (Basq Country)												
Sweden	*	*	**	**	**	July 5	*	*	*	**	*	June 7
Switzerland												
United Kingdom												
*Northern Ireland		*	**	***		June 9		**	**	*		June 8
*England/Wales		*	*	**		May 12/25 ²		*	**	*	*	May 11/27 ²
*Jersey	*	**				Jan 4	**	**				Jan 4
*Scotland		*	***	***	***	July 6		*	*	*	*	May 31
Russia	**	**	***	***	***	?	*	*	**	*	*	?
Japan								**	**	***		July
USA (Maine)		*	***	**		July 19		*	**	**		July 27

* = *low risk*; ** = *moderate risk*; *** = *high risk*

¹ *polythene covered crop*; ² *waste piles*; ³ *volunteers*; ⁴ *oospores possibly involved*; ⁵ *allotment garden*

Information that DSS builders can find in the Eucablight database

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Summary

The pan-European Concerted Action on late blight 'Eucablight' was set up and launched in 2003, with the aim of providing tools for investigating variation in both the host and the pathogen. Objectives include the construction of a database, (www.Eucablight.org) containing information on past and current potato cultivars and late blight populations available in the participating countries, and the design, testing and recommendation of protocols for testing host resistance and pathogen diversity. The database is structured, and made accessible, in such a way that DSS builders can access the model parameters they need to construct locally adapted forecasting systems.

Keywords: *Phytophthora infestans*, late blight, resistance, pathogen population

Introduction

Integrated strategies for the control of potato late blight using reduced fungicide inputs require reliable information about the aggressiveness of the late blight population and the level and stability of resistance in the potato cultivars in the region. The current European data on pathogen aggressiveness and host resistance are fragmented and the methods used to collect this data are often not well documented.

The Eucablight project, a concerted action funded by the European Union, is undertaking to improve this situation. It will collate the available data into a harmonised and readily accessible database which will assist the construction of Decision Support Systems.

The Eucablight project started in February 2003 and will run for three years. Eucablight includes 24 member institutions from EU countries and representatives from several non-EU countries. It operates on both a thematic (host or pathogen) and a regional basis. This dual structure favors interactions between members. Objectives include the construction of a database containing reliable information available in participating countries on late blight populations and past and current potato cultivars, and the design, testing and recommendation of protocols for testing pathogen diversity and host resistance.

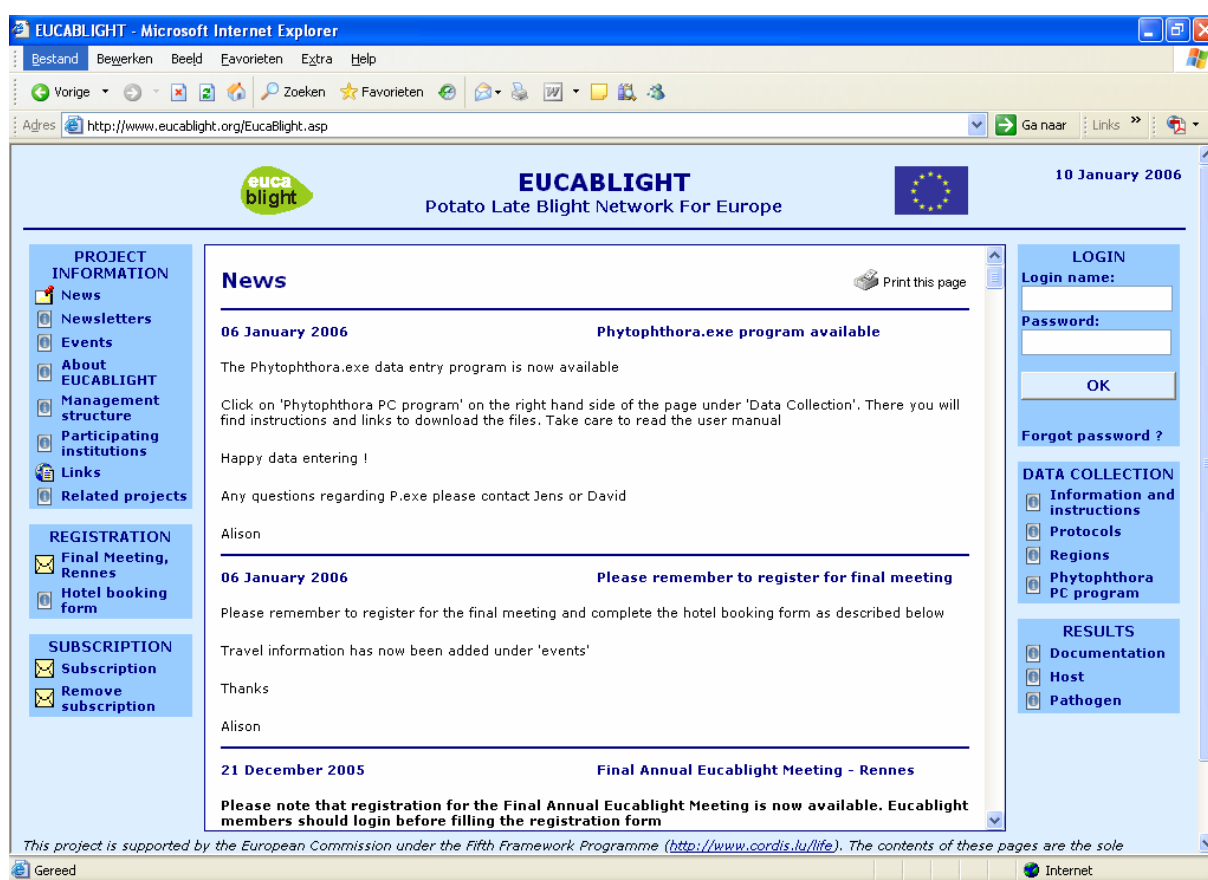


Figure 1. Homepage of www.eucablight.org.

The database

The database (www.Eucablight.org) has been created, and is hosted, by the Danish Institute of Agricultural Sciences (DIAS) at Foulum, Denmark. The technical details of the database are described by Lassen & Hansen (2005). The information in the database consists of

phenotypic data from a number of late blight strains and potato cultivars. All the information is associated with specific years and geographic areas, allowing direct comparisons of specific pathogen events (introduction of a new genotype of the pathogen) to specific host events (e.g. breaking of a new resistance gene).

The data can readily be enriched by new entries using two specially designed software programs, *Phytophthora.exe* and *Cultivar.exe*, developed by the project.

An important characteristic of the database is that the data contributed (primary data) can only be viewed directly, or retrieved by the contributors themselves. This will ensure that the copyright of the original data remains with the contributor. Both the host and pathogen data will be processed into secondary variables and displayed on the website as tables, graphs and maps. Examples are frequency of metalaxyl sensitivity or area under the disease progress curve (AUDPC). This will provide synthetic overviews of the diversity of the pathogen population, the resistance of the cultivars and their distribution in time and space across Europe. The displays, automatically updated when new data are added to the database, will be made available to Eucablight members and non members through the Eucablight website.

The database was built in 2003 and the first data were entered in 2004. Encouragingly, there were also contributions from outside the Eucablight consortium, which indicates that the concept appeals to the scientific community. In 2005, the collection of data was continued and efforts were concentrated on the outputs that will be made available on the website. This required a number of choices to be made relating to statistics and to the disease models used to transfer the disease readings into secondary variables. To date, the database contains over 4 000 potato cultivar entries and 13 000 pathogen entries from countries across the whole of Europe.

Protocols

Protocols for assessing biological, pathogenic and genetic diversity vary between laboratories engaged in host resistance and population analyses of *P. infestans* worldwide, but also in Europe. These differences make the comparison of data collected by different teams difficult, and sometimes downright impossible. Furthermore, technologies for the analysis of genetic and phenotypic diversity evolve rapidly. Therefore, one of the main objectives of Eucablight is to collate, formalise, assess and recommend the most suitable protocols, through the collective work of its members. These protocols are available through a dedicated section of

the Eucablight website, and formed the basis of training courses available to both members and non-members. The overall aim is to provide reliable, standardised methodologies generating readily comparable data, and to facilitate the use and adoption of improved protocols for future work. The protocols were compiled by members of the ‘host’ and ‘pathogen’ technical groups of Eucablight, and discussed during project meetings before validation as ‘Eucablight Recommended protocols’.

Pathogen data

The pathogen data in the Eucablight database mainly represent isolates collected since 1990, and contain both phenotypic (e.g. mating type, phenylamide resistance, virulence) and genotypic (e.g. isozymes, mtDNA fingerprints, SSR alleles) information. The database is designed to accommodate new markers as these become widely available.

The reliability of virulence tests has been questioned repeatedly, and Eucablight has therefore designed experimental validation trials in the form of blind ring tests. The virulence ring test involves 10-12 laboratories within the Eucablight Consortium who, in 2005, tested ten coded isolates according to an agreed protocol and on the same set of differential clones (provided in 2004 by SASA).

A small core collection of isolates, characterised for most or all of the traits entered in the database, was compiled from donations received from the existing collections of Eucablight participants and is maintained as reference material by SCRI. The purpose of this core collection is to serve as a set of controls for laboratories wishing to calibrate and operate a technology, as well as a set of reference genotypes with which to develop new technologies.

These Eucablight activities will be valuable for the description, analysis and understanding of the evolution of *P. infestans* populations in Europe, and thus aid both current and future strategies for late blight control.

Host data

The Eucablight database contains resistance data from trials that include seven standard cultivars and which have been scored using standard disease assessment methods. The standard cultivars have been chosen on the basis of their availability and the expected durability of the resistance, and represent the extremes of susceptibility and resistance in the three maturity classes ‘first early’ (Eersteling and Gloria), ‘maincrop’ (Bintje and Escort) and

'late' (Alpha and Robijn). Sarpo Mira, was added as a representative of the highest resistance class, although the durability of its resistance has yet to be established. To facilitate the dissemination of the seven standards, they have been distributed as seed potatoes and are also being made available from the Scottish Agricultural Science Agency (SASA) in East Craigs as *in vitro* cultures. In addition to these standards, the inclusion of SASA's 11 single R gene differentials R1 – R11 in the trials is also recommended to ensure that high resistance scores are not due to a simple pathogen race structure.

A requirement of the trials is the use of standard protocols to carry out resistance assessments. Protocols for foliage and tuber resistance include a field trial, a detached leaflet assay and a whole plant glasshouse assay, and a field trial, a whole tuber lab test and tuber slice lab test, respectively. A protocol relating to plant maturity is also available, since this trait is highly correlated with resistance to late blight in the foliage. All protocols and other information are available as Pdf documents at www.Eucablight.org.

In order to allow monitoring of the resistance of a cultivar from the time of first selection, the database contains data from both cultivars and breeding lines. A database containing details of more than 4 000 cultivars will help to link the identities of breeding lines to cultivars, and to avoid duplicated entries due to misspellings. This section of the Eucablight database also contains data relating to presence of R genes, fertility, use (ware, processing or starch) and ploidy level of the germplasm, collated from published and unpublished sources.

Data that can be used for Decision Support Systems

Region-specific parameters required for DSS both for pathogen and host, can be derived from the database.

For the pathogen, useful parameters are:

- Mating type. The occurrence of both A1 and A2 mating types in the area in recent years indicates if there is a chance of oospores, and a need for early fungicide treatments if water logging of the soil occurs;
- Metalaxyl resistance, indicating if metalaxyl can be used;
- Virulence, in order to select those varieties with R genes functioning against the prevailing pathogen population.

For the host:

- Disease curves and number of days till the first symptoms appear, which can be used to predict the expected start of epidemic of specific varieties once blight has appeared in the area;
- Delta a and delta t. These parameters indicate for a specific variety if the disease appears early or progresses slowly relative to the susceptible variety Bintje. From this information the risk of resistance breakdown in the area can be estimated (Andrison et al, 2004);
- Apparent infection rate and 1-9 scale values for foliage resistance. From these parameters can be estimated if reduced fungicide dosage is possible, usually if foliage score is higher than 7;
- Infection resistance of tubers, relevant for spraying schemes after onset of tuberization;
- Tuber flesh resistance (should be low so infected tubers disappear).

Conclusion

A particular advantage of the Eucablight database is that it generates region-specific information on host resistance and pathogen characteristics that are required as parameters in DSS. This makes the database an important instrument to follow the co-evolution of host and pathogen in Europe and inform the use of appropriate resistance genes and control measures. New contributors are welcome and can contact Alison Lees at alees@scri.ac.uk.

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References

- Andrison, D, D Ellissèche & R Pellé*, 2004. Assessing resistance types and levels in potato from late blight progress curves. Page 131-136 in: CE Westerdijk & HTAM Schepers (Eds.). Proceedings of the Eighth Workshop of an European network for development of an integrated control strategy of potato late blight, Jersey, England-France, 31st of March – 4th of April 2004.
- Lassen, P and JG Hansen*, 2005. EUCABLIGHT database: collecting, storing and analysing data related to potato late blight. 5th Conference of the European Federation for Information Technology in Agriculture, Food and Environment, Vila Real, Portugal, July 25-28, 2005 (ISBN 972-669-646-1): 575-582.

Assessing resistance to late-blight disease in new Sárpo clones

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Summary

Field trials at three sites in western U.K. became infected with wild populations of *Phytophthora infestans* in early July, 2005. Resistance as measured by disease progression and RAUDPC showed that new Sárpo clones had a high or complete resistance to the disease at all three sites. At one site in North Wales, the resistance of most of the Sárpo clones was greater than that shown by the EUCABLIGHT standard cultivar Robijn.

Keywords: Sárpo, late-blight, resistance, *Phytophthora infestans*

Introduction

Sárpo clones, bred by Sárpo KFT in Hungary for resistance to common virus diseases and to late-blight disease, have been assessed in many European countries. Field trials and laboratory experiments have allowed clones with consistently high, non-specific resistance to be identified. Some of these have been grown successfully under heavy disease pressure without protection and offer a solution for organic and low-input cultivation.

Our previous work in North Wales has determined the progression of late-blight disease on selected Sárpo clones compared to that on a range of susceptible and resistant cultivars available in UK. Total and marketable yields were assessed and susceptibility to tuber blight and other tuber defects assessed; this allowed potential commercial value to be estimated (Shaw and Johnson, 2004).

Researchers across Europe belonging to the EU concerted action, EUCABLIGHT (www.eucabligh.org), have agreed to include the same set of standard varieties in trials of foliage blight resistance in field trials. Sárpo Mira, a late-maturing variety, was adopted in 2005 as a standard showing a very high level of foliage resistance. One of our 2005 trials has assessed the foliage resistance of several new clones in the field using EUCABLIGHT standards; the same Sárpo clones were assessed at two other sites without the EUCABLIGHT standards.

Material and method

Three trials were conducted in 2005, two in Wales and one in Cornwall, SW England. Triplicated 30-tubers plots at each site were planted with spreader rows of susceptible cv. Charlotte. Trials relied on natural infection by wild blight strains and were not irrigated.

The field trial near Llanbedrgoch, North Wales comprised 20 new Sárpo clones. This trial included the six EUCABLIGHT standards: Eersteling, Bintje, Alpha (susceptible), Gloria Escort, and Robijn (more resistant). The Sárpo cv. Axona was used as a substitute for the high resistance standard, Sárpo Mira, due to scarcity of seed. Two UK varieties with moderately high resistance, cvs Stirling and Lady Balfour, were included. This trial was managed under conventional agronomic practice but did not receive any fungicides and was planted on 11 April, 2005.

The second field trial near Llanrhystud, Mid-Wales was in collaboration with ADAS, Pwllpeiran and contained 13 Sárpo clones plus cvs. Orla, Cara and Desirée as standards. This trial was managed under organic agricultural practice. The trial was planted on 11 May, 2005.

The third field trial near Helston, Cornwall, was part of a collaboration with the Organic Studies Centre, Duchy College and contained 21 Sárpo clones. This organic trial was planted on 9 May, 2005.

Scoring of the percentage of late-blight on foliage was done according to the illustrated key of Cruikshank *et al.*, (1982). Blight scoring started at the first observation of late blight symptoms in the field. Observations were made at 3-5 day intervals until the last week of

August, 2005. Relative Area Under the Disease Progression Curve (RAUDPC) values for all clones in each trial were calculated (Fry, 1978). The time period used for calculation of the RAUDPC was 0 to 52 days after first infection.

Results

Natural blight populations attacked all three trials and were first observed during the first week in July.

Trial at Llanbedrgoch

Blight-conducive weather allowed a rapid progression of the disease on plots of susceptible standards, Eersteling and Bintje, as expected (Fig. 1). Progression on cv. Alpha, the late-maturing, susceptible standard was clearly slower. Progression on the other Eucablight resistant standards in order of their increasing resistance was: early-maturing Gloria, mid-season Escort and late-maturing Robijn (Fig. 1). The resistances of Stirling and Lady Balfour, bred at Scottish Crop Research Institute, was similar to that of Escort and Robijn.

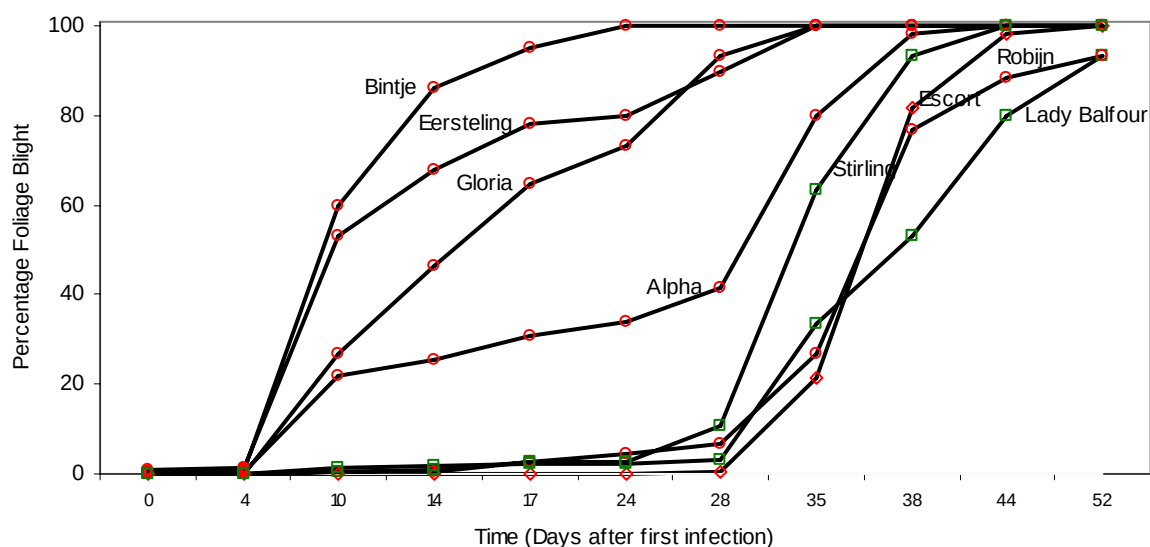


Figure 1. Progression of foliar blight at Llanbedrgoch. Disease progression curves on six EUCABLIGHT standards and on UK cultivars, Stirling and Lady Balfour at Llanbedrgoch.

Fig. 2 shows that Sárpo clones, with the exception of Dawn and Quentin are more resistant than Lady Balfour. Clone Quentin, although becoming infected early, shows a uniquely slow progression.

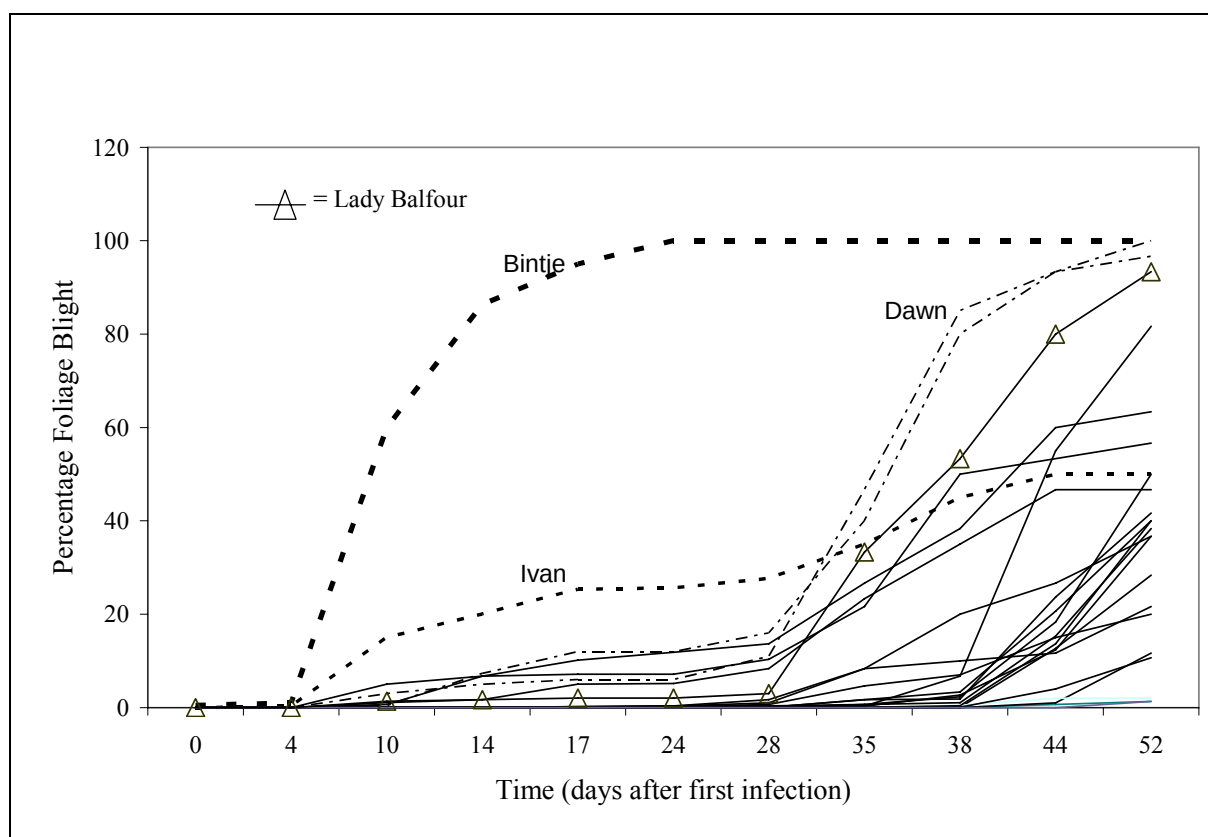


Figure 2. Progression of foliar blight at Llanbedrgoch. Disease progression curves of new Sárpo clones (continuous black lines, with the exception of the line marked with triangles (cv. Lady Balfour). Less resistant Sárpo clones, Ivan and Dawn and Quentin are marked with dashed lines.

The RAUDPC values for the Sárpo clones in the Llanbedrgoch trial (Table 1) were all lower than the standards Bintje (0.81), Eersteling (0.74), Gloria (0.69) and Alpha (0.52). All Sárpo clones had a lower RAUDPC than cv Stirling (0.37) and all Sárpo clones except Dawn and Quentin had a lower RAUDPC than cv. Lady Balfour (0.27). The commercially available Sárpo variety Axona had an RAUDPC < 0.01.

Trials at Helston and Llanrhystud

RAUDPC values at Helston and Llanrhystud are shown in Table 1. It is clear that more of the Sárpo clones (ones grown at all three sites) remained healthy at Helston (5) and at Llanrhystud (6) than at Llanbedrgoch (1). Three cvs., Cara, Desiree and Orla, with moderate blight resistance were grown in the trial at Llanrhystud and had higher RAUDPC values than any of the Sárpo clones.

Table 1. RAUDPC (Fry, 1978) values for Sárpo clones at the three trial sites.

Llanbedrgoch		Helston		Llanrhystud	
Dawn	0.35	Dawn	0.37	Dawn	0.20
Quentin	0.35	Quentin	0.19	Quentin	0.14
Ivan	0.29	Ivan	0.12	Harry	0.10
Alfie	0.23	Harry	0.09	Ivan	0.03
Harry	0.21	Paddy	0.05	Bob	0.02
Bob	0.17	Alfie	0.05	Una	0.02
Carrie	0.14	Bob	0.05	Olive	0.00
Paddy	0.09	Will	0.02	Ginny	0.00
Sally	0.07	Nan	0.02	Jackie	0.00
Eric	0.07	Val	0.01	Sally	0.00
Ginny	0.06	Tammy	0.01	Val	0.00
Jackie	0.05	Una	0.01	Rob	0.00
Nan	0.05	Axona	0.00	Carrie	0.00
Kate	0.05	Kate	0.00	Cara	0.208
Leo	0.05	Ginny	0.00	Desiree	0.41
Will	0.05	Leo	0.00	Orla	0.53
Olive	0.04	Sally	0.00		
Mary	0.01	Eric	0.00		
Val	0.01	Carrie	0.00		
Una	0.00	Jackie	0.00		
Tammy	0.00	Mary	0.00		
Axona	0.00	Olive	0.00		

Discussion

The Sárpo clones tested showed a range of resistance as measured by disease progression and RAUDPC values at all three sites. Comparisons with standards at Llanbedrgoch and at Llanrhystud have shown that the levels of resistance are at least as high and mostly higher in the Sárpo clones than in resistance standards.

In general, more disease developed at the Llanbedrgoch site, shown by the higher RAUDPC values at that site. This could have been due to more conducive weather or to more aggressive pathogen genotypes or to the older age of the plants at this site or to a combination of factors. A comparison of the disease on each clone at each site (Table 1) shows that the ranking from the most diseased clones to the healthy clones was broadly similar at each site. For example, Dawn, Quentin and Ivan rank among the four most diseased clones at each site. It can be concluded that there is little or no evidence of strain-(population)-specificity of the resistance.

Conclusions

From the results it is clear that the majority of the Sárpo clones were highly resistant to foliage blight under heavy disease pressures of three populations of blight in western UK.

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References

- Cruikshank G, HE Stewart and RL Wastie*, 1982. An illustrated key for foliage blight of potatoes. Potato Research 25:213-214.
- Fry, WG*, 1978. Quantification of general resistance of potato cultivars and fungicide effects for integrated control of potato late blight. Phytopathology, 68:1650-1655.
- Shaw, D and L Johnson*, 2004. Progress in the selection of cultivars with resistance to late-blight disease. PPO-Special Report no.10:203-209.

**Sensitivity of potato late blight epidemics and potato yield to variation in
initial inoculum density: a model-based analysis with implications for
predicting atmospheric transport of spores**

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Introduction

Epidemics of potato late blight have an important spatial component (e.g. Zadoks and Zwankhuizen, 1992). Nevertheless, little is known on the nature and extent of dispersal processes. In decision support systems spatial phenomena are either implicitly accounted for in parameter values of the epidemic forecast or factored in using monitoring data and rules of thumb. We set out to investigate whether improvements in forecasts are possible by using information on the state of the atmosphere, dispersal capabilities of the pathogen and its survival during transport in the atmosphere.

Modeling of atmospheric transport of gasses and particles has gone through major advances over the last decade, to the degree of being capable of informing air pollution legislation in various countries. Few of these models have been applied in plant pathology. Different types of models are available with their specific balance between accuracy and practicability. A prime requirement of any atmospheric transport model is predictive skills in the relevant range of spore input levels. This paper aims at answering the question which amount of spore influx into a potato field is relevant for decision making. More specifically, the research

questions are: how sensitive is simulated potato yield to variation in initial inoculum density; what is the effect of variety, fungicide regime, weather and type of epidemic on yield sensitivity; and which are the implications for the choice of atmospheric transport models as part of future decision support systems?

Theory and methods

A spatio-temporal integro-difference equation model of the potato late blight pathosystem, BLIGHTSPACE, was developed. The original model, developed by Skelsey *et al.* (2004) simulates the life cycle of the pathogen, as well as the temporal and spatial development of general and focal late blight epidemics for various scales and patterns of host genotypes. In this study, the original model was adapted to include the growth of the potato host plant, environmentally dependent host-pathogen interactions and the influence of fungicide applications. Details will be provided in a journal paper.

BLIGHTSPACE was utilized to investigate the consequences of uncertainty in influx of *Phytophthora infestans* spores on disease dynamics and potato yield through a study of the yield response of potato cultivars to initial inoculum densities. Initial inoculum densities are considered to be predictions of spore fluxes arriving at a target crop. Impact of initial inoculum density on yield was investigated for four cultivar types (combining resistance, full and none, with maturity type, early and late) under four fungicide regimes (sixteen management scenarios). The fungicide regimes included (i) no application, (ii) adaptive regime based on weather suitability for late blight infection, (iii) adaptive regime but first spray completely missed, (iv) fixed 7 day schedule. Hourly temperatures between 9 and 27 °C and relative humidity greater than 90% define a 'blight-hour'. Average temperature during consecutive blight-hours determined the number of blight-hours required for an infection event. Ten years of historical weather data provided a realistic range of conditions for crop growth and potato late blight epidemic development under Dutch conditions.

Results and discussion

The sixteen management scenarios may be classified as causing low, intermediate or high vulnerability to potato late blight. For the low vulnerability management scenarios, yield response to initial inoculum was minimal. These scenarios included combinations of resistant, early varieties with focal epidemics. On the other hand, major yield losses resulted from even

the lowest inoculum densities in the high vulnerability management scenarios, where susceptible, late maturing cultivars were attacked by general epidemics. Knowledge of spore dispersal would be of little relevance in low or high vulnerability situations, because in low vulnerability situations, fungicides are not needed, even at high spore inputs, whereas in high vulnerability situations, sprays are *always* needed if conditions are suitable for infection, even if spore inputs are very low.

In the intermediate vulnerability situations, yield depends critically on spore input. A yield response to spore influx occurred at initial inoculum densities of 10^3 spores m^{-2} and higher. A maximum yield loss of up to 13 tons (DM) ha^{-1} resulting from a single erroneous decision not to apply fungicides, demonstrated that accuracy in the predictions of a spore dispersion model is important.

The future role of atmospheric transport models in potato late blight decision support therefore lies in its use in situations in which the level of vulnerability is intermediate; here, there is potential to reduce the fungicide input of potato late blight control through a more accurate quantification of infection pressure. Calculation of flexible, situation-specific risk-zones around target crops is proposed as one potential use of such models.

References

- Skelsey, P, WAH Rossing, GJT Kessel, J Powell and W van der Werf, 2004. Influence of host diversity on development of epidemics: an evaluation and elaboration of mixture theory. *Phytopathology* 95(4): 328-338.
- Zwankhuizen, MJ and JC Zadoks, 2002. *Phytophthora infestans*'s 10-year truce with Holland: a long-term analysis of potato late-blight epidemics in the Netherlands. *Plant Pathology* 51: 413-423.

Blight management in the Nordic countries

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Introduction

The mating type A2 was recorded in Sweden in the 1980's (Kadir & Umaerus, 1987) and in the early 1990's in Norway and Finland (Hermansen *et al.* 2000). Later mating type A2 was found in Denmark in 1996 (Bødker *et al.* 1998) and in Iceland in 1999 (Olafsson and Hermansen 2001). Oospores have been observed in samples of leaves from the field (Hermansen *et al.* 2000; 2002; Lehtinen and Hannukkala. 2004; Dahlberg *et al.*, 2002). Recent results indicate that the distribution of A1 and A2 is close to 1:1 in most of the Nordic region (Hannukkala *et al.*, 2005). The data from genotypic and phenotypic studies of *Phytophthora infestans* indicate that sexual reproduction contributes significantly to the genetic variation of *P. infestans* in the Nordic countries (Brurberg *et al.* 1999). Oospores are also believed to give rise to earlier starts of epidemics under certain weather conditions (Lehtinen & Hannukkala, 2004; Andersson *et al.* 1998; Bødker *et al.*, this proceeding)

Recent studies have shown that the "new" populations of *P. infestans* in Europe and USA are more aggressive than "old" populations (Day & Shattock, 1997; Flier *et al.*, 1998; Flier & Turkensteen, 1999; Kato *et al.*, 1997; Goodwin, 1997). Knowledge of the weather

requirements related to the epidemiology of the new isolates of *P. infestans* is a major gap in our knowledge of this pathogen (Hansen, 2000; Andrivon, 2000; Schepers, 1998).

The existing forecast- and decision support systems used in the Nordic countries are based on data for temperature and humidity influence on *P. infestans* epidemiology obtained under controlled conditions from the 1930's and the 1950's (Crosier, 1934; Harrison, 1992). Only a few studies in recent time have tried to verify and update the "old" rules (Hartill *et al.*, 1990; Harrison & Lowe, 1989; Mizubuti & Fry, 1998).

In 2003 a four-year research project funded by the Contact Organisation of Agricultural Research in the Nordic Countries was initiated to make a survey of the phenotypic and genetic properties of the Nordic *P. infestans* population. The aim of the project is to determine the frequency of the two mating types, response of the *P. infestans* isolates to fungicides (metalaxyl and propamocarb), and occurrence of virulent races in the Nordic countries. The variation in aggressiveness properties and genetic diversity of the population are also studied. The ultimate goal of the project is to update blight forecast and decision support systems in the Nordic countries based on a Nordic DSS framework, sharing knowledge and experimental facilities.

In this paper we present preliminary results for aggressiveness tests, studies in climate chambers of the lower temperature threshold for sporulation, semi-field tests of sporulation and survival of sporangia as well as tests of a simple DSS for chemical control of late blight.

Methods

Aggressiveness test

In 2003, isolates were collected from 50-75 fields in each country (Denmark, Norway, Sweden and Finland). Twenty-five isolates from each country were selected for aggressiveness studies. Tests of the Danish isolates were divided between Norway, Sweden and Finland. Five Danish isolates were selected as a control and were tested in laboratories in all three countries. Latency Period (LP), Lesion Growth Rate (LGR), Sporulation rate (SR) and Final Lesion Size (FLS) were measured on detached leaflets. Infection efficiency of the isolates was tested on leaf disks. All tests were carried out at 15°C and 100% relative

humidity. Two cultivars were used for the experiments, Matilda with medium resistance to late blight and Bintje, susceptible to blight. The statistical analyses of the results were done using a resolvable row-column design (Williams *et al.* 2002) with three or five replicates.

Semi-field test of sporulation and viability of sporangia

Five leaves with distinct lesions were sampled from four different potato cultivars every morning during an epidemic. Sporangia from each lesion were washed off and counted under microscope. The lesion sizes were determined with digital measurements. To measure the infection efficiency (IE) a mixed spore solution from five leaves was diluted to 10.000 spores/ml. After preparation of a dilution series (factor 4): 10.000, 2.500, 625, 156, 39 spores/ml, ten small leaf discs were inoculated by 0,01 ml at each dilution. The numbers of leaf discs with infection after incubation were counted. The IE was estimated by the method, “most probable number” formulated as a generalised linear model and programmed in SAS (Procedure GENMOD).

Climate chamber experiment

Pots with Bintje plants were placed randomly in three climate chambers with conducive humid conditions for late blight development (>95 % Rh) at 7, 10 and 15 °C, respectively. Plants were inoculated with *P. infestans* sporangia, harvested from fresh leaves inoculated with a spore suspension from agar plates. Incubation period, latency period, infection efficiency and sporulation were determined for two Danish and two Norwegian isolates of *P. infestans*.

Blight Management (DSS)

Instead of varying the spraying intervals, a simple, 7-day spray-schedule-DSS (Blight Management) was developed integrating reduced dosages of fluazinam (Shirlan), host resistance, infection pressure and epidemic phase. The general idea is that the current resistance of the host, the infection pressure and protection by the fungicide determines the risk of infection. Secondly, weekly fungicide applications early in the season – even at low dosage – are assumed to protect new leaf growth from infection.

Several blight risk indices including NegFry DRV, Smith, MISP, Blitecast and some new, were tested by Hansen, 2002. The index, Hours of SPOrulation (HSPO) obtained a relatively

good correlation to sporangia production, estimated in semi-field trials in Denmark and Switzerland using Burckard traps. HSPO is defined as number of hours in periods of 10 or more hours when $R_h > 90\%$ and temperature at the same time is between 10°C and 24°C (Figure 1). HSPO is used to calculate the infection pressure defined as the running sum of HSPO for a window including current date, 2-day weather forecast and four days of historic weather, in total 7 days.

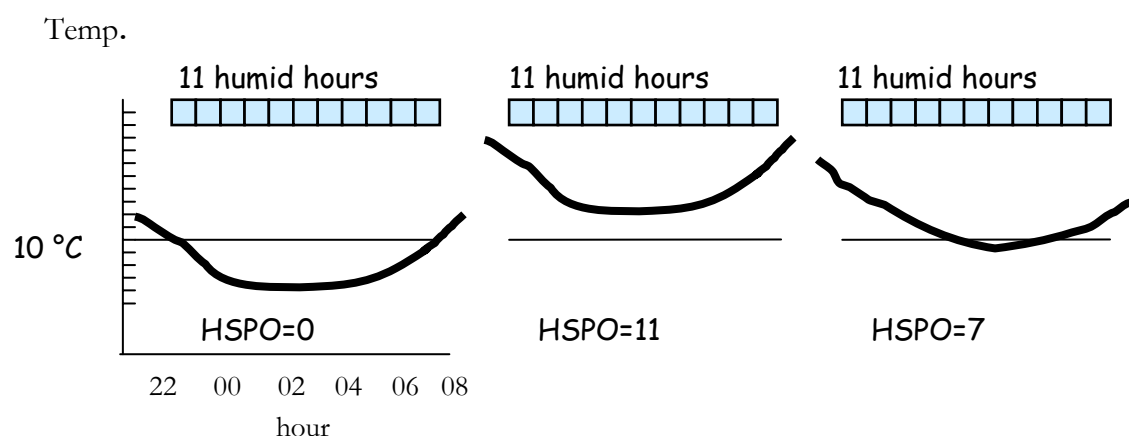


Figure 1. In this example combinations of temperature and humidity during three different nights are presented. Left: 11 humid hours ($>90\%$), temperatures in all the hours are below 10°C . HSPO is then 0. Centre: 11 humid hours ($>90\%$), temperature in all the hours are above 10°C . HSPO is then 11. Right: 11 humid hours ($>90\%$), temperatures in 7 of 11 hours are above 10°C . HSPO is then 7.

To take the presence of inoculum into account and also to some extent age dependent host resistance, the blight season was divided into three phases (Table 1)

Table 1. Epidemic phases used in Blight management for decision making on fungicide dosage.

Phase 1	Phase 2	Phase 3
<u>Before</u> attack in the <u>region</u> in the	<u>After</u> attack in the <u>region</u> in the	<u>After</u> attack in the <u>field/trial plot</u>
cultivar or in cultivars with similar resistance	cultivar or in cultivars with similar resistance	in the cultivar or in cultivars with similar resistance

Blight attacks are monitored in all the Nordic countries using the Web-blight late blight monitoring system (Hansen *et al.*, 2001)

Finally, the cultivars are grouped in susceptible, moderate susceptible and moderate resistant cultivars. In the beginning of the season the influence of resistance level on the dosage rate is

high. Towards the end of the season, more or less all cultivars are considered as susceptible in the system.

All cultivars are sprayed first time preventively during the period of row closing, the more resistant cultivars with low dosage. During the season the dosage of Shirlan is dynamically adjusted according to resistance level, infection pressure and phase of the epidemic development. The fixed 7-day spraying interval is lowered from 7 to 5 days, only in phase three and at very high infection pressure.

Results for Blight Management were compared with Shirlan 0.3 l/ha, 7-day routine schedule.

Simulation

The Cornell simulator, LB2004 (Andrade-Piedra *et al.*, 2005) was used to evaluate the results from the aggressiveness test. Secondly the simulator and its sub-models separately will be used to analyse the biological data collected in semi-field trials from all the Nordic countries. First step in this process is to evaluate if it is possible to simulate an epidemic under Nordic conditions using the simulator. Parameters for different single isolates were used for parameterization of the model.

Results

Climate chamber experiment

The isolates tested were very aggressive under optimal conditions. The incubation period was 76 hours and the latency period was 86 hours after inoculation at 15 °C, for three of the four isolates tested. *P. infestans* was able to grow and sporulate at both 10 and 7 °C. However, the incubation and latency period were significantly prolonged and two of the four isolates (DK03-02, NO03-459) were not able to sporulate at 7 °C within 420 hours. Our existing model for daily risk of sporulation uses 10°C as lower temperature threshold. The obtained data indicates that this threshold is still valid based on the isolates tested (Figure 2).

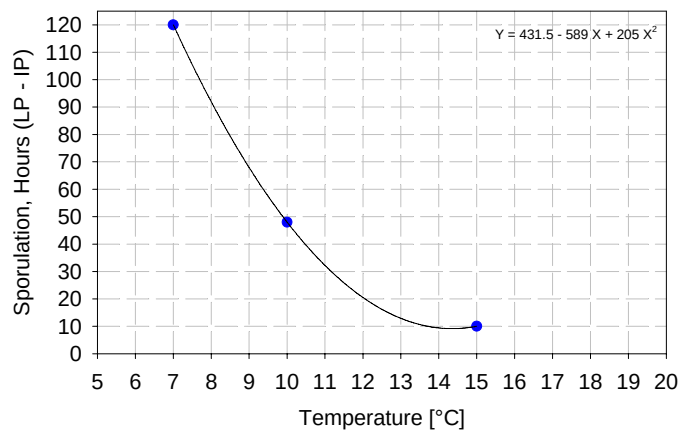


Figure 2. The number of hours from formation of necrosis (latency period, LP) to sporulation (IP) for isolates tested in climate chamber at three different temperatures and RH constant at 95%. Identical results were obtained for three different isolates, two Danish and one Norwegian.

Semi-field test of sporulation and viability of sporangia

Sporangia were present in lesions every day tested – from a few hundreds to more than 200.000 per cm² lesion. For sporangia washed off the lesions, 0-25% (mean 5.3%) of the sporangia were able to infect leaflets in the laboratory. Based on the number of sporangia present in lesions and the percentage that were able to infect leaflets in the laboratory, it is then estimated, that on most days, several thousands of sporangia are viable and are able to give rise to new infections (Figure 3). Sporangia were collected during 35 days, 27 June to 1 August. During this period the number of days with risk of sporulation based on HSPO was only 11 days.

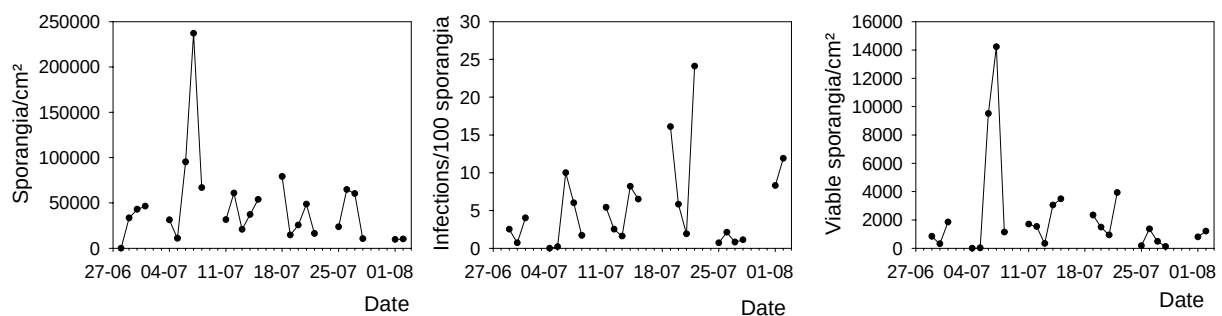


Figure 3. Left: Number of sporangia in lesions/cm² on Bintje in a semi-field trial, Denmark, 2005. Center: Infections on leafletss/100 sporangia washed of from the lesions. Right: Estimated viable sporangia/cm² lesion combining data from figure 4, left and center.

Aggressiveness test and simulation

The mean latency period was approximately 4 days at 15°C for the isolates tested. Mean lesion growth rate was between 6 and 7 mm radius per day. The sporulation rate varied between 1 and 2×10^8 sporangia/m²/day. Parameters obtained in the NorPhyt project are comparable with default parameters used in the Cornell simulator, LB2004 (Andrade-Piedra *et al.*, 2005)

In the example given below, we used parameters for isolates collected in 2003 on an epidemic in Bintje, Flakkebjerg, 2004. Parameters for single isolates are given in Table 2. Isolate, NO259, collected in Norway, has a relatively low aggressiveness index, characterized by a relatively long latency period (5.1 day) and a relatively slow lesion growth rate 4.8 mm/day. Isolate, DK33, collected in Denmark has a medium level aggressiveness index characterized by a relatively high lesion growth rate but a low sporulation rate. Isolate, DK 7, collected in Denmark has a relatively high aggressiveness index, characterized by a short long latency period, a high lesion growth rate and a very high sporulation rate.

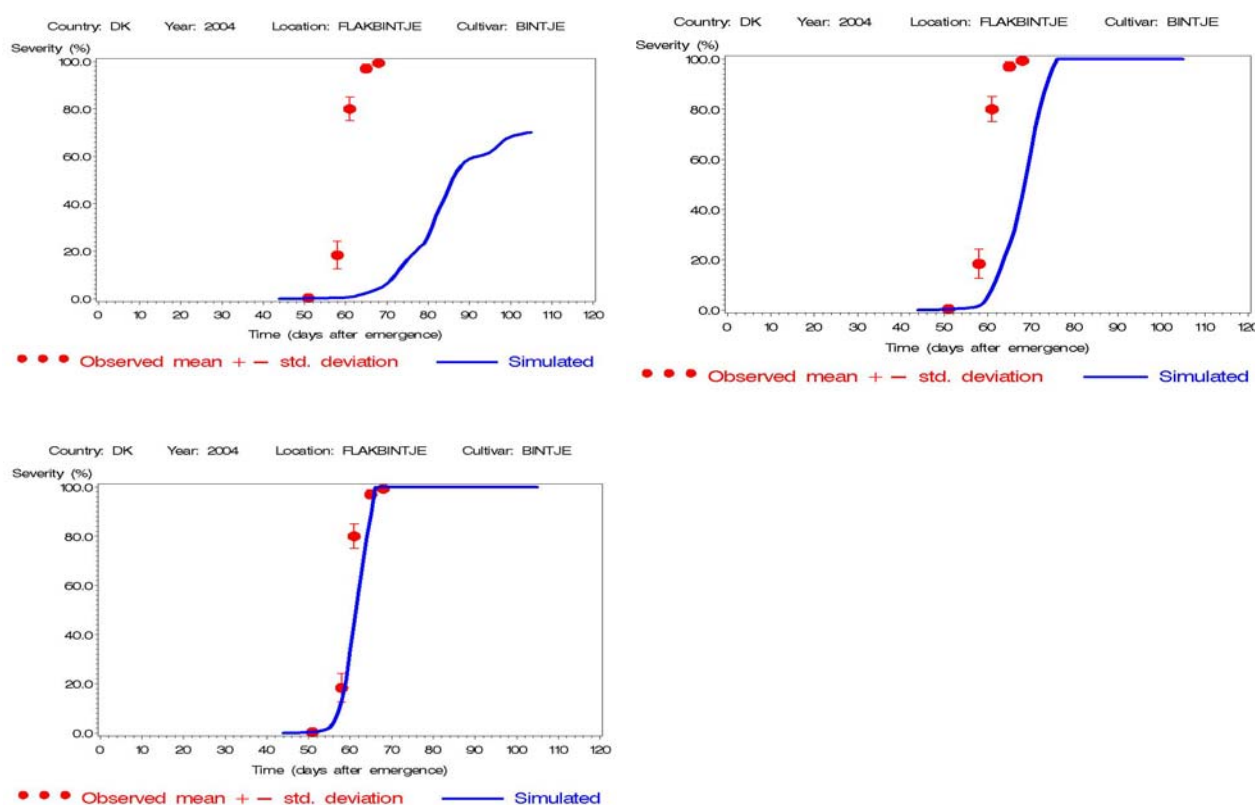


Figure 4. Simulation of a late blight epidemic in untreated Bintje at Flakkebjerg, 2004 using aggressiveness data from single isolates. Upper left: Isolate, NO259. Upper right: Isolate DK33 and lower left: Isolate, DK7.

Table 2. Parameters for single isolates used in the Cornell simulator.

Isolate	Latency period [days] (LP),	Lesion Growth Rate [m/day] radius (LGR)	Sporulation rate*10 ⁸ [Sporangia/m ² /day] (SR)	Aggressiveness index: 1/LP*LGR*SR
NO259	5.1	0.00483	0.46	0.43
DK33	3.9	0.00756	0.45	0.88
DK7	3.7	0.00826	1.30	2.88

Results in Figure 4 show the variability in simulated epidemics using aggressiveness parameters from single isolates collected in Norway and Denmark. The results indicate that the Cornell simulator, LB2004 can be used to simulate epidemics under Nordic country conditions.

Blight Management (DSS)

Blight Management (BM) was tested at several locations in all four countries. This paper is not intended to report the results from all trials, but only to introduce general results and discussion of the method.

At the trial site Ytteborg in Denmark, early symptoms were recorded in the region mid June. Due to these attacks, the first application was applied in mid June, related to Epidemic Phase 2 (Table 1). Shirlan was applied at 0.1 l/ha for the first 4 applications due to relatively low weather-based infection pressure (Figure 5). Higher dosages were used in August complementing a higher infection pressure and at the same time a shift into Epidemic Phase 3 in early August, when the untreated plots were infected. According to BM, 13 applications, but only 2.2 l/ha Shirlan was used. Disease severity end of season was 1.7% infected haulm and no tuber blight was recorded. This corresponds to 6-7 applications using normal dosage (0.3-0.4 l/ha). Routine treatment: 13 applications and 4.2 l/ha Shirlan used. Disease end of season was 1.2% severity. No tuber blight was found. Notice that not all dosages applied follow strict the level of infection pressure. This is to some extent due to the fact that the infection pressure during the season included the 48-hour weather forecast, and data given here are all based on measured data.

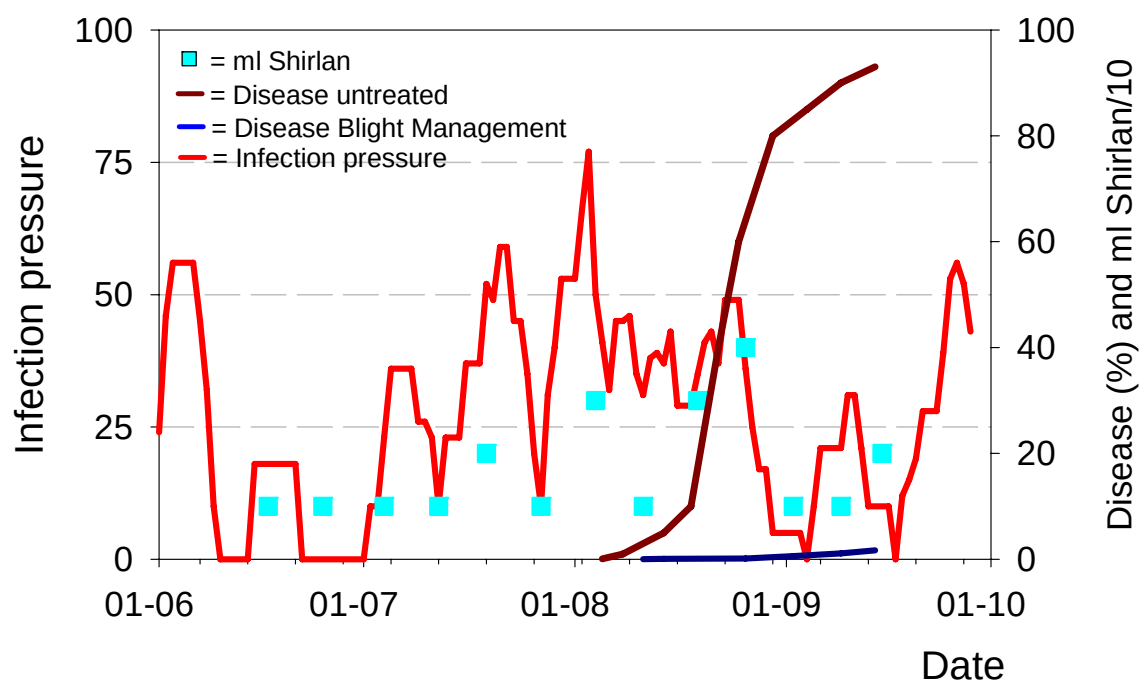


Figure 5. Test of Blight Management at Ytteborg, North of Jutland, DK, 2005 in the cultivar Kuras. The four dosage levels (■) used for Shirlan represent 0.1; 0.2; 0.3 and 0.4 l/ha. See method section for explanation of infection pressure.

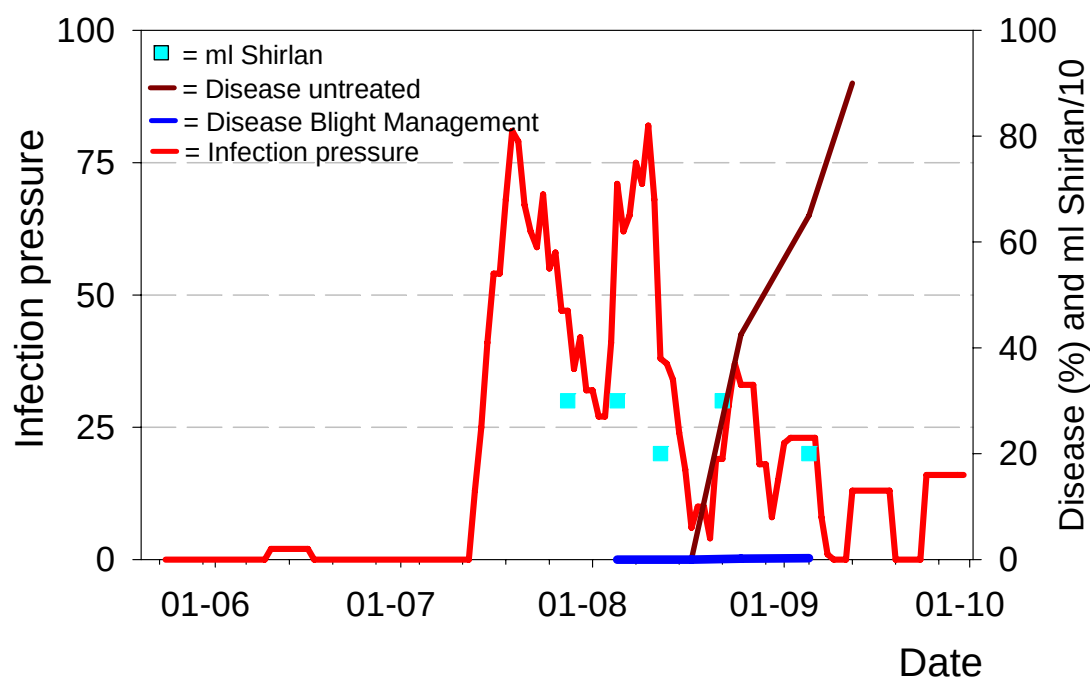


Figure 6. Test of Blight Management at Roverud, Norway, 2005 in the cultivar Asterix. The four dosage levels (■) used for Shirlan represent 0.1; 0.2; 0.3 and 0.4 l/ha. See method section for explanation of infection pressure.

At the trial site Roverud in Norway, infection pressure was extremely low until mid July when weather turned into very favourable blight conditions (Figure 6). Late blight was found in the region shortly after that. Late blight appeared in the untreated plot in mid August. Five applications, using 1.3 l/ha Shirlan was enough to keep disease at a very low level (0.3%). A similar effect was obtained with four routine applications of 0.3 l/ha.

Discussion and conclusions

Based on all available data from phenotypic and genotypic analysis of isolates, semi-field experiments and observations in farmers fields, we can conclude that the old clonal blight population has been replaced by a new sexually reproducing population in all the Nordic countries. There are small but statistically significant differences between isolates in all measured aggressiveness parameters, and there seems to be a correlation between the aggressiveness indices obtained in the laboratory and results from field experiments with inoculation with the same isolates (unpublished). There exists no data on aggressiveness for the “old” Nordic population of *P. infestans*, but it is most likely that aggressiveness factors in the “new” populations are more variable and that some single isolates are more aggressive than in the “old” ones corresponding to what has been reported from other European countries (Day & Shattock, 1997; Flier & Turkensteen, 1999; Flier *et al.*, 2002). The quantitative differences in aggressiveness components found in this study probably contributes to host specificity of *P. infestans* in the Nordic countries.

The temperature influence on the incubation period and the latency period was tested under controlled in climate chamber. The time from necrosis to sporulation was 10 hours at 15 °C, but 47 and 120 hours at 10°C and 7 °C respectively. As sporulation happens during the night, and temperatures during the night under Nordic conditions seldom exceeds 15-17°C, it is concluded still to use 10°C as the lower temperature threshold for calculation of sporulation in Blight Management.

The Cornell simulator was originally parameterised with data from South America. The newest version of this model, LB2004, was evaluated with success in Ecuador, Mexico, Israel, and the USA (Andrade-Piedra *et al*, 2005). Results from this study indicate that the simulation model is suitable also for Nordic conditions. The modelling work has only started, and its

sub-models will be analysed with data from the semi-field trials, and it will be used to analyse the importance of the variation in aggressiveness among Nordic isolates.

The conclusion that viable sporangia are always present in a blighted field under Nordic conditions influenced the strategy in our DSS. Keeping relatively short intervals and use of dynamic dosages of fungicide, not only protects new growth, but also insures that fungicide is always present in the crop. Developing the strategy we hypothesized that a higher resistance was enough to complement a low dosage of fungicide under low infection pressure. This was confirmed in the test of the DSS, as use of relatively low dosages under low infection for more resistant cultivars, gave a good protection. Test of these ideas was all ready initiated in late 1990s (Hansen *et al.*, 2002, Nærstad 2002).

Under Nordic conditions, the number of farmers decreases, but at the same time the area with potato grown by each farmer increases. One farmer can have more than 200 hectares with potatoes divided into more than 10 different fields. The DSS using fixed 7-day spray schedule and use of dynamic dosages address the problems of modern potato growers. Due to logistic problems they are reluctant to vary the spraying intervals, but use of dynamic dosages is easier to handle.

References

- Andersson, B, M Sandström & A Strömberg, 1998. Indications of soil borne inoculum of *Phytophthora infestans*. Potato Research 41, 305-10.
- Andrade-Piedra JL, GA Forbes, D Shtienberg, et al., 2005. Qualification of a plant disease simulation model: Performance of the LATEBLIGHT model across a broad range of environments. Phytopathology 95 (12): 1412-1422
- Andrade-Piedra JL, RJ Hijmans, GA Forbes, et al., 2005. Simulation of potato late blight in the Andes. I: Modification and parameterization of the LATEBLIGHT model. Phytopathology 95 (10): 1191-1199.
- Andrison, D, 2000. Report of the meeting of the Subgroup Epidemiology. In: Schepers, Huub and Bouma, Erno (eds.): Proceedings of the Workshop on the European Network for Development of an Integrated Control Strategy of Potato Late Blight, PAV-special report no 6, February 2000, 19-22.
- Bødker, L, R Kidmose, JG Hansen and S Holm, 1998. Kartoffelskimmel før og nu. 15. Danske Planteværnskonference - Sygdomme og Skadedyr. DJF-rapport nr. 3, 81-87
- Bødker L, H Pedersen, L Møller, K Kristensen, A Lehtinen & A Hannukkala, 2006. Influence of potato crop history on disease incidence and severity of potato late blight. (This proceedings)
- Brurberg, MB, A Hannukkala and A Hermansen, 1999. Genetic variability of *Phytophthora infestans* in Norway and Finland as revealed by mating type and fingerprint probe RG57. Mycological Research 103:1609-1615.
- Crosier, W, 1934. Studies in the Biology of *Phytophthora infestans* (Mont.) de bary. Cornell University Agricultural Experimental Station Memoir No 155, 40 pp.
- Dahlberg J, B Andersson, B Nordskog and A Hermansen, 2002. Field survey of oospore formation by *Phytophthora infestans*. In: C. Lizárrage (ed), Late Blight: Managing the Global Threat. Proceedings of the Global Initiative on Late Blight Conference, July 11-13, 2002, Hamburg, Germany, Poster Abstract. Page 134 - 135.
- Day, JP and RC Shattock, 1997. Aggressiveness and other factors relating to displacement of populations of *Phytophthora infestans* in England and Wales. European Journal of Plant Pathology 103, 379-391.
- Flier, WG & LJ Turkensteen, 1999. Foliar aggressiveness of *Phytophthora infestans* in three potato growing regions in the Netherlands. European Journal of Plant Pathology 105, 381-388.
- Flier, WG, LJ Turkensteen, & A Mulder, 1998. Variation in tuber pathogenicity of *Phytophthora infestans* in The Netherlands. Potato Research 41, 345-354.

- Flier, WG, GJT Kessel, GBM van den Bosch & LJ Turkensteen, 2002. Impact of new populations of *Phytophthora infestans* on integrated late blight management. In: Schepers, H.T.A.M. & Westerdijk, C.E. (eds.): Proceedings of the workshop on the European Network for Development of an Integrated Control Strategy of Potato Late Blight. Applied Plant Research, AGV Research Unit, Wageningen, PPO-Special Report no 8, April 2002, 111-124.
- Goodwin, SB, 1997. The population genetics of *Phytophthora*. *Phytopathology* 87, 462-473.
- Hannukkala, A, B Andersson, JG Hansen, A Hermansen, B Nielsen, A Lehtinen & J Yuen, 2005. Phenotypic characteristics of Nordic potato late blight population. 16th Triennial Conference of the EAPR, July 17-22, 2005, Bilbao, Basque Country. pp.
- Hansen, JG, 2000. Report of the discussions of the Subgroup DSS. In: Schepers, Huub and Bouma, Erno (eds.): Proceedings of the Workshop on the European network for development of an integrated Control Strategy of Potato Late Blight, PAV-special report no 6, February 2000, 27-34.
- Hansen, JG, P Lassen & M Röbrig, 2001. Monitoring of potato late blight based on collaborative PC- and Internet applications. In: Schepers, H.T.A.M (editor): Proceedings of the Workshop on the European network for development of an integrated Control Strategy of Potato Late Blight, PAV-special report No 7, February 2001, 39-54.
- Hansen, JG, 2002. Evaluering af risikotal for udvikling af kartoffelskimmel (*Phytophthora infestans*). DJF intern rapport 167, 70 pp.
- Hansen, JG, L Bodker & BJ Nielsen, 2002. Implementation of variety resistance in control strategies of potato late blight. In: Schepers, H.T.A.M. & Westerdijk, C.E. (eds.): Proceedings of the workshop on the European Network for Development of an Integrated Control Strategy of Potato Late Blight. Applied Plant Research, AGV Research Unit, Wageningen, PPO-Special Report no 8, April 2002, 111-124.
- Harrison, JG, 1992. Effects of the aerial environment on late blight of potato foliage – a review. *Plant Pathology* 41, 384-416.
- Harrison, JG & R Lowe, 1989. Effects of humidity and windspeed on sporulation of *Phytophthora infestans* on potato leaves. *Plant Pathology* 35, 585-591.
- Hartill, WFT, K Young, DJ Allan & WR Henshall, 1990. Effects of temperature and leaf wetness on the potato late blight. *New Zealand Journal of Crop and Horticulture Science*. Vol 18: 181-184.
- Hermansen, A, A Hannukkala, RH Naerstad and MB Brurberg, 2000. Variation in populations of *Phytophthora infestans* in Finland and Norway: mating type, metalaxyl resistance and virulence phenotype. *Plant Pathology* 49, 11-22.

- Hermansen, A, B Nordskog & MB Brurberg, 2002. Studies on formation and survival of oospores of *Phytophthora infestans* in Norway. In: Schepers, H.T.A.M.& Westerdijk, C.E. (eds.): Proceedings of the workshop on the European Network for Development of an Integrated Control Strategy of Potato Late Blight. Applied Plant Research, AGV Research Unit, Wageningen, PPO-Special Report no 8, April 2002, 77-80.
- Kadir S & V Umaeus, 1987. *Phytophthora infestans* A2 compatibility type recorded in Sweden. In: 10th Triennial Conference of the European Association for Potato Research, Ålborg, Denmark: 223.
- Kato, M, ES Mizubuti, SB Goodwin & WE Fry, 1997. Sensitivity to protectant fungicides and pathogenic fitness of clonal lineages of *Phytophthora infestans* in the United States. *Phytopathology* 87, 973-978.
- Lehtinen, A & A Hannukkala, 2004. Oospores of *Phytophthora infestans* in soil provide an important new source of primary inoculum in Finland. *Agricultural and food science*. Vol 13, 399-410.
- Mizubuti, ESG & WE Fry, 1998. Temperature effects on developmental stages of isolates of three clonal lineages of *Phytophthora infestans*. *Phytopathology* 88 (8), 837-843.
- Nørstad, REH, 2002. Exploitation of cultivar resistance in potato late blight disease management and some aspects in the variation in *Phytophthora infestans*. Agricultural University of Norway, Doctor Scientiarum Theses 2002:21, Paper I, 23 pp.
- Olafsson, S & A Hermansen, 2001. Outbreak of potato late blight and first reports of mating type A2 and metalaxyl resistance of *Phytophthora infestans* in Iceland. *Plant Disease* 85, 559
- Schepers, HTAM, 1998. Epidemiological parameters in decision support systems. In: Schepers, Huub and Bouma, Erno (eds.): Proceedings of the Workshop on the European network for development of an integrated Control Strategy of Potato Late Blight, PAV-special report no 3, January 1998, 30-36.
- Williams ER, AC Matheson and CE Harwood, 2002. Experimental design and analysis for tree improvement. CSIRO Publishing. 2nd edition.

**Influence of crop history of potato on early occurrence and disease severity
of potato late blight caused by *Phytophthora infestans***

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Summary

The first appearance and severity of potato late blight caused by *Phytophthora infestans* were studied in 186 Danish and 150 Finnish potato fields. The surveys indicate that late blight infections appear earlier and more severe in fields with a narrow potato crop history with less than three years free of potato. Although initial symptoms in some fields indicated the presence of oospores as the primary inoculum source, the study cannot conclude oospores as the primary inoculum in all early infections. However, the survey support the expectation that soil borne inoculum serves as a source of primary inoculum in Nordic countries and that the viability and infectivity in soil decrease between 2-4 years. Crop rotation should be considered as a part of an integrated control strategy against potato late blight.

Introduction

During the 1980's, a new population of *Phytophthora infestans* with both mating types A1 and A2 migrated from South America in Europe and replaced the old clonal lineage (Fry *et al.*, 1993). As a consequence of the presence of the both mating types, oospores started to occur in potato fields (e.g. Anderson *et al.* 1998, Lehtinen & Hannukkala 2004). Oospores can survive in a field under very different climatic conditions from several months (Drenth *et al.* 1995, Mayton *et al.* 2000, Medina & Platt 1999, Pittis and Shattock 1994, Turkensteen *et al.* 2000, Fernández-Pavía *et al.* 2004, Singh *et al.* 2004) up to four years (Turkensteen *et al.* 2000).

There is circumstantial evidence for oospores serving as a primary inoculum of blight epidemics (Drenth *et al.* 1995, Anderson *et al.* 1998, Zwankhuizen *et al.* 2000, Fernández-Pavía *et al.* 2004, Lehtinen & Hannukkala 2004). However, the description of these suspected oospore derived infections and their correlation with a narrow crop rotation have often been of anecdotal character.

Crop rotation is a natural management tool to prevent oospore-derived epidemics and avoid accumulation of oospores in the field soil. The aim of these studies is to investigate the effect of a potato free period on the onset time and severity of potato late blight epidemics.

Methods

In Denmark, 186 randomly selected fields were investigated in a three-year survey for early occurrence of late blight. The investigation was restricted to three defined areas with a diameter of approximately 5-10 km. The fields were inspected when the first blight occurred in the area. Within each area, all fields were scored within 1-2 days.

Each field was investigated by walking in a W pattern through the field for presence:

- no blight present or blight present;
- and severity:
- 0: no attack;
 - 1: one or few foci less than 1/m²;
 - 2: one or few foci 1 – 5/m²;
 - 3: one or few foci 5 – 25/m²;
 - 4: one or few foci more than 25/m²;
 - 5: 0 – 0.5 % of the canopy with lesions;
 - 6: 0.5 – 1 %;
 - 7: 1 - 5 %;
 - 8: 5 - 10 %;
 - 9: 10 - 25 %;
 - 10: More than 25 % of the canopy with lesions.

A plant sample from every primary finding in a field was verified after incubation in moist chamber for 24 hours and microscopic examination in the laboratory. After harvest, information on crop rotation, spraying dates and fungicide use was collected from the farmers.

In Finland, the first appearance of late blight was recorded in a registration net for potato late blight including 150 fields in the period 1998-2002. Information on crop rotation included only the precrop and was classified in two groups: potato and not potato.

Result and discussion

Despite a low number of fields with narrow crop rotation in the Danish survey (Table 1), there was an indication that three years break between potatoes reduced the frequency of fields affected by late blight in the early season and lowered the disease severity (Fig 1 A,B). However, there was a strong interaction between variety, year and area. Thus, it was not possible to draw a significant conclusion on the influence of a break between potatoes on frequency and severity of late blight.

Table 1. Number of fields in a three-year survey (1999-2001) on influence of crop history of potato on early occurrence and disease severity of potato late blight.

Year	Year between potatoes					Total
	0	1	2	3	>3	
1999	6	1	2	35	18	62
2000	13	4	21	16	7	61
2001	6	5	18	17	17	63

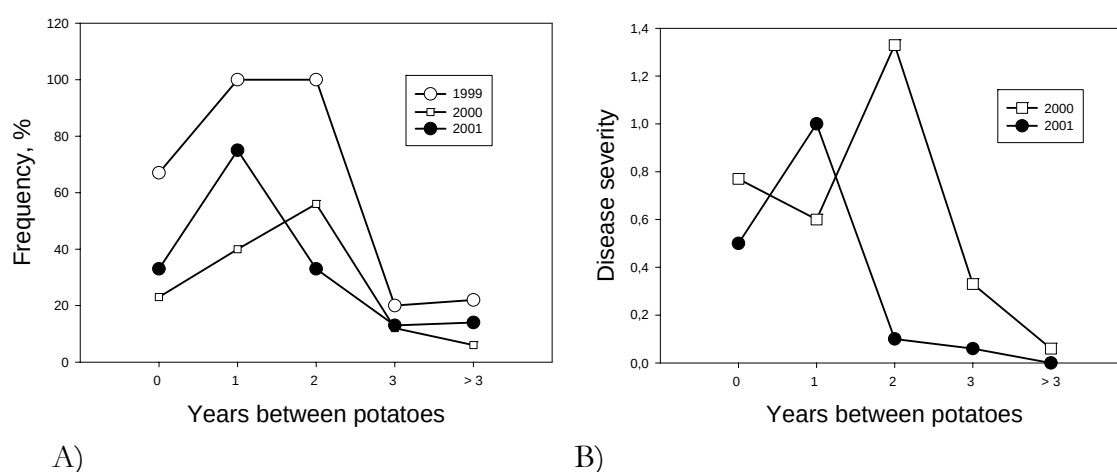


Figure 1. Relationship between number of years from the last potato crop and the frequency of fields affected with late blight (A) or the disease severity (B) in a three-year survey (1999-2001) of 186 potato fields.

In Finland potato late blight appeared nine days earlier in fields where potato was grown in previous year (Table 2).

Table 2. The difference in days from planting to the first appearance of late blight in fields with potato or not potato as precrop in 1998-2002.

Previous crop	No. Fields	Days	Std	Difference in days	F-value	P-value
Potato	95	54	13.8	-9	17.44	<0.001
Not potato	55	63	11.3			

The investigations in Denmark and Finland indicate that there is a correlation between crop rotation and incidence and severity of late blight. The results cannot conclude the influence of oospores as the primary reason for the early appearance of late blight. However, these indications and the fact that oospores are present in the field and are infectious after several years in the soil emphasize the need for further investigations on the importance of soil borne inoculum of *P. infestans* and on the climatic conditions which are conducive for the production, germination and infection of potato plants from oospores of *P. infestans*. There are several well-known reasons for avoiding monoculture in potato. This survey indicated crop rotation also should be considered as mean to avoid early appearance of late blight.

Literature

- Andersson B & M Sandström, 1999. Late blight in Sweden - new problems with an old disease. Abstracts of Conference Papers, Posters and Demonstrations, EAPR '99, s 62-63.
- Andersson B, M Sandström og A Strömberg, 1998. Indication of soil borne inoculum of *Phytophthora infestans*. Potato research 41, 305-310.
- Fry WE, SB Goodwin, AT Dyer, JM Matuszak, A Drenth, PW Tooley, LS Sujkowski, YJ Koh, BA Cohen, LJ Speilman, KL Deahl, DA Inglis & KP Sandlan, 1993. Historical and Recent Migrations of *Phytophthora infestans*: Chronology, Pathways, and Implications. Plant Disease/July 1993, s 653-661.
- Drenth, A, EM Janssen, & F Govers, 1995. Formation and Survival of Oospores of *Phytophthora-Infestans* Under Natural Conditions. *Plant Pathology* 44: 86-94
- Fernández-Pavía, SP, NJ Grunwald, M Díaz-Valasis, M Cadena-Hinojosa, and WE Fry, 2004. Soilborne oospores of *Phytophthora infestans* in central Mexico survive winter fallow and infect potato plants in the field. *Plant Disease* 88: 29-33
- Lehtinen, A & A Hannukkala, 2004. Oospores of *Phytophthora infestans* in soil provide an important new source of primary inoculum in Finland. *Agricultural and Food Science* 13: 399-410.
- Mayton, H, CD Smart, BC Moravec, ESC Mizubuti, AE Muldoon, & WE Fry, 2000. Oospore survival and pathogenicity of single oospore recombinant progeny from a cross involving US-17 and US-8 genotypes of *Phytophthora infestans*. *Plant Disease* 84: 1190-1196.
- Medina, MV & HW Platt, 1999. Viability of oospores of *Phytophthora infestans* under field conditions in northeastern North America. *Canadian Journal of Plant Pathology* 21: 137-143.
- Pittis, J E & RC Shattock, 1994. Viability, germination and infection potential of oospores of *Phytophthora infestans*. *Plant Pathology* 43, 387-396.
- Singh, BP, J Gupta, S Roy, & DK Rana, 2004. Production of *Phytophthora infestans* oospores in Planta and inoculan potential of in vitro produced oospores under temperate highlands and sub-tropical plains in India. *Annals of Applied Biology* 144: 363-370
- Turkensteen, LJ, WG Flier, R Wanningen, & A Mulder, 2000. Production, survival and infectivity of oospores of *Phytophthora infestans*. *Plant Pathology* 49: 688-696
- Zwankhuizen, MJ, F Govers, & JC Zadoks, 2000. Inoculum sources and genotypic diversity of *Phytophthora infestans* in Southern Flevoland, The Netherlands. *European Journal of Plant Pathology* 106: 667-680.

Alternaria: a review of potato fields around the world

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Summary

The importance of *Alternaria solani* and the possible yield losses are very different in the regions around the world. In some regions, controlling *A. solani* is most important as it can cause great yield losses. In other regions, the control is taken care of by controlling *Phytophthora infestans* and in some regions in the world *A. solani* is not a concern.

In some aspects, *A. solani* is comparable to *P. infestans*. However the unique characteristics make the appearance and the control under specific conditions very special.

In this overview, we will explain the life cycle of *A. solani* and review the impact in different parts of the world. We have cooperated with potato growers and research institutes in these countries and gained experience over many years.

Keywords: *Alternaria solani*, infection event, PLANT-Plus,

Introduction

Dacom Plant Service BV is a provider of Decision Support Systems for crop management with PLANT-Plus. The company has been active since 1987 and operates international from her office in Emmen, the Netherlands. Based on the information generated by the system, the slogan of Dacom is “*Growing in confidence*”. One of the models integrated in the PLANT-Plus system is the *A. solani* model. We will analyse how growers and researchers in Russia, Japan, Australia, South Africa, Egypt, Chile, the USA, Canada and the Netherlands controlled and/or should have controlled *A. solani* based on the calculations of the PLANT-Plus system. With these different experiences, some points for discussion are put forward.

Disease Cycle *Alternaria solani*

The primary infection cycle of *A. solani* starts with the production and release of spores on debris from last year. Under the right conditions, some spores will establish on the leaves of a potato plant. After the incubation period, infected spots will be visible as necrotic area's with concentric rings. From these lesions a secondary infection cycles with the production of new spores. As well as for the production of spores as for the germination and penetration of the spores into the leave surface, *A. solani* prefers higher temperatures then *P. infestans*. Although the life span of an ejected *A. solani* spore is much longer then the life span of a *P. infestans* spore, the availability of viable spores at unprotected leaf area's has the same relation to a spore production event as for *P. infestans*. Spores probably land on harmless places where they are locked in place.

Because only fungicides with a protective action are available, it is most important that the potato crop gets treated just before an infection event.

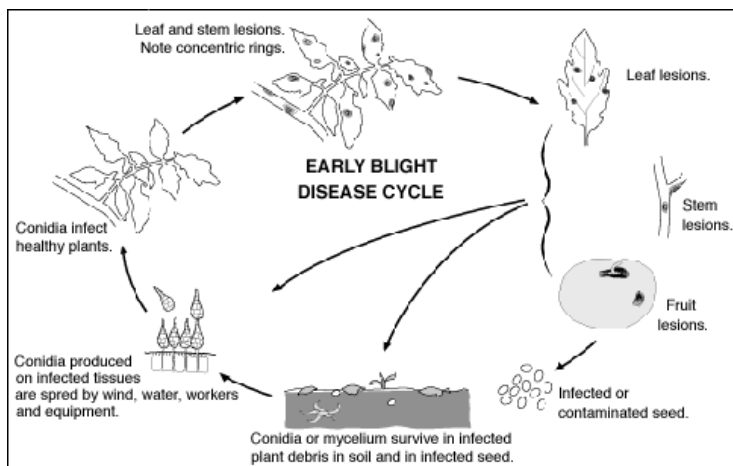
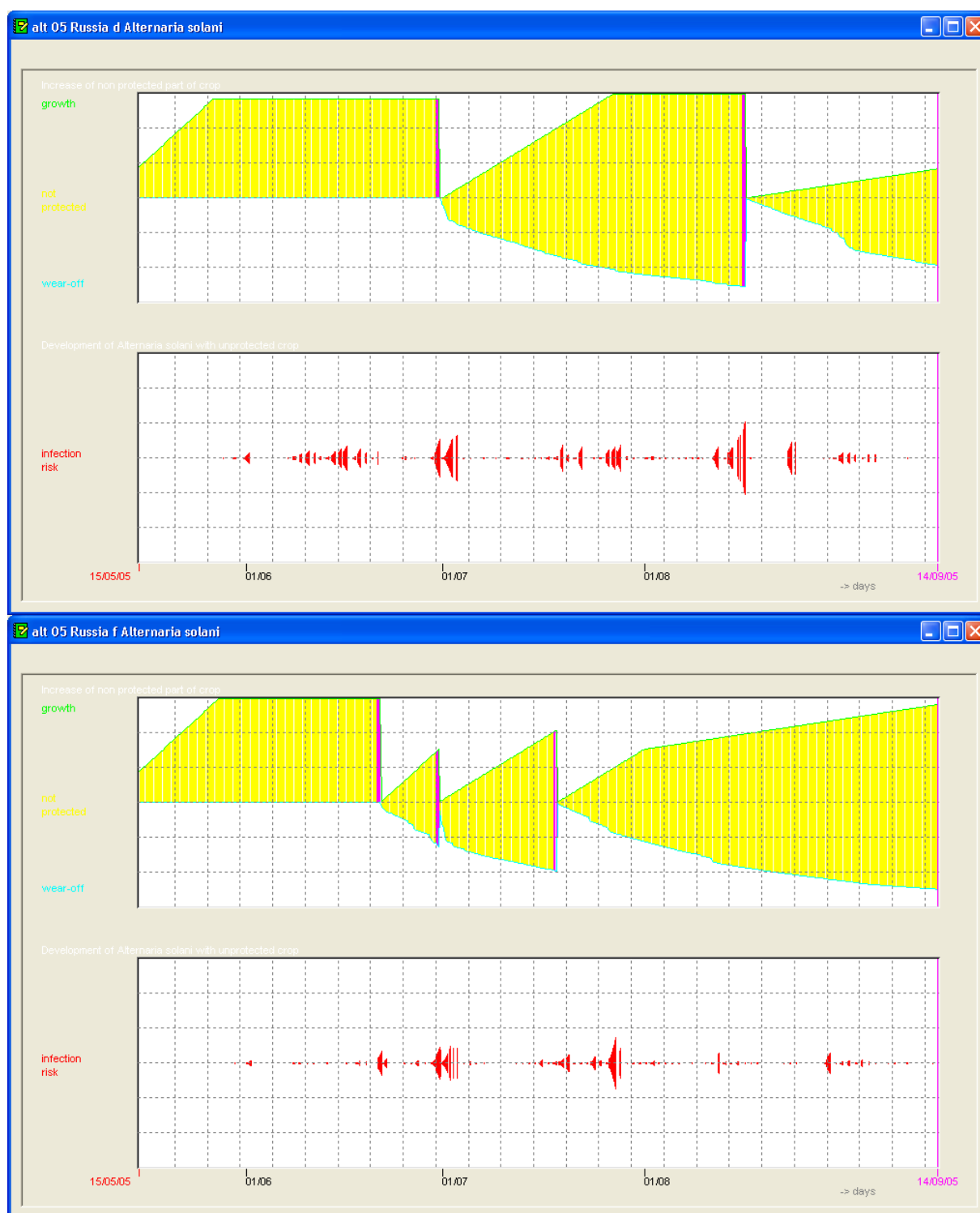


Figure 1. Early blight disease cycle.

Going around the world

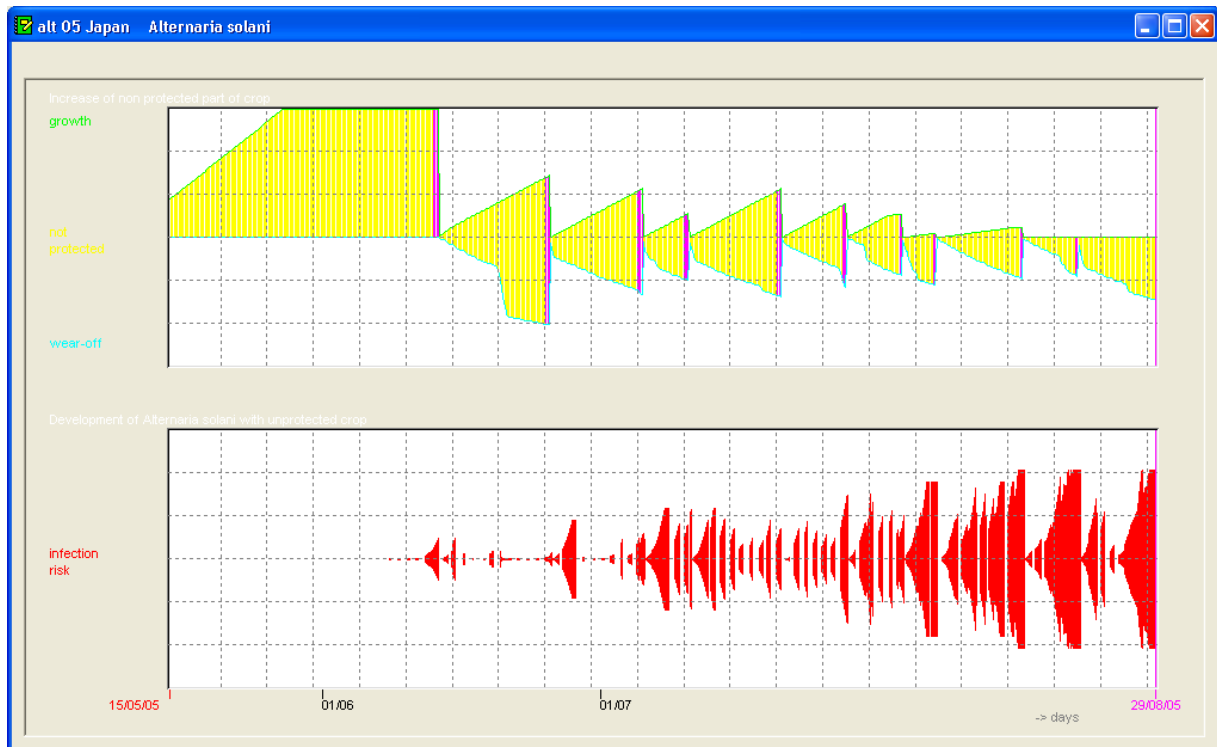
In order to make a comparison between the different countries possible some adaptations and assumptions had to be made in the PLANT-Plus system. Matching the growing season, the parameters for crop growth, crop density and crop stage have been entered with the same values for all countries. The parameter for the disease pressure for *A. solani* has been set to a minimal figure. The weather data from local weather stations have been used. For the calculation of the optimum spraying according to PLANT-Plus, the product Amistar has been used.

Russia



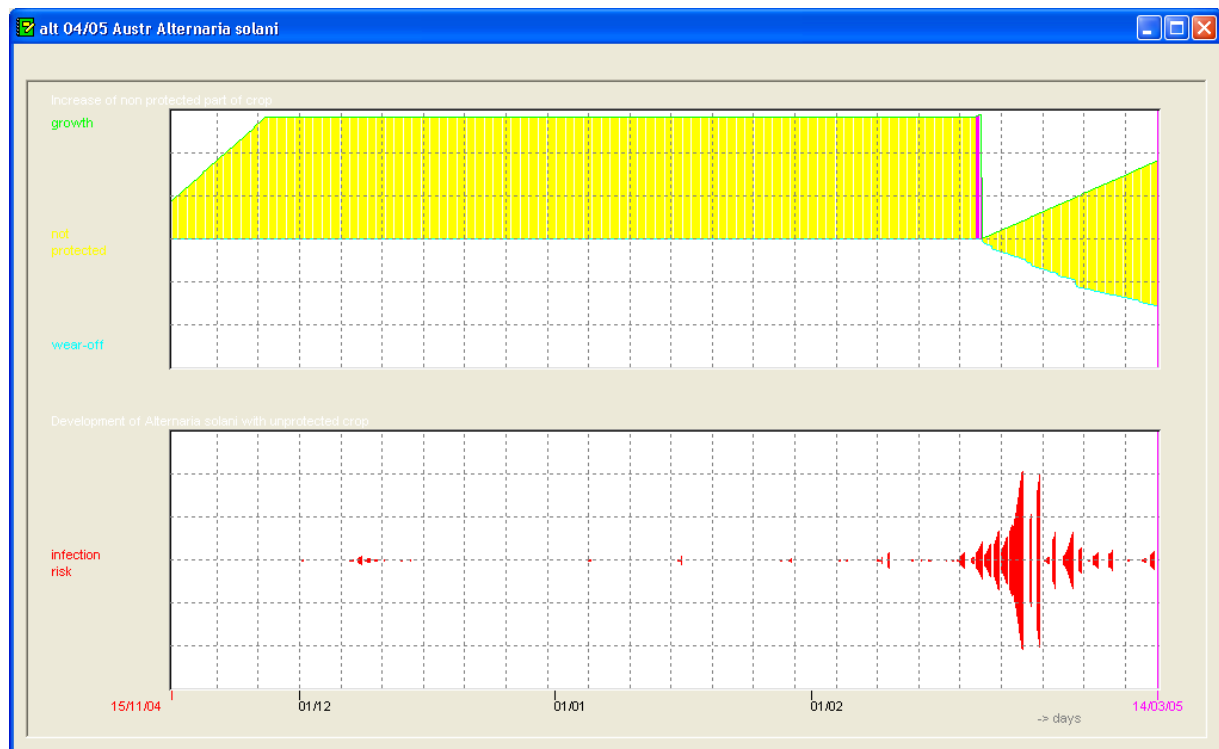
In Russia Dacom is active in a number of locations: some 300 kilometres South of Moscow and also North West of Moscow. In both cases, the pressure by *A. solani* is not an issue and is taken care of by the control of *P. infestans*. If that had not been the case, 2 – 3 treatments against *A. solani* would have been sufficient.

Japan



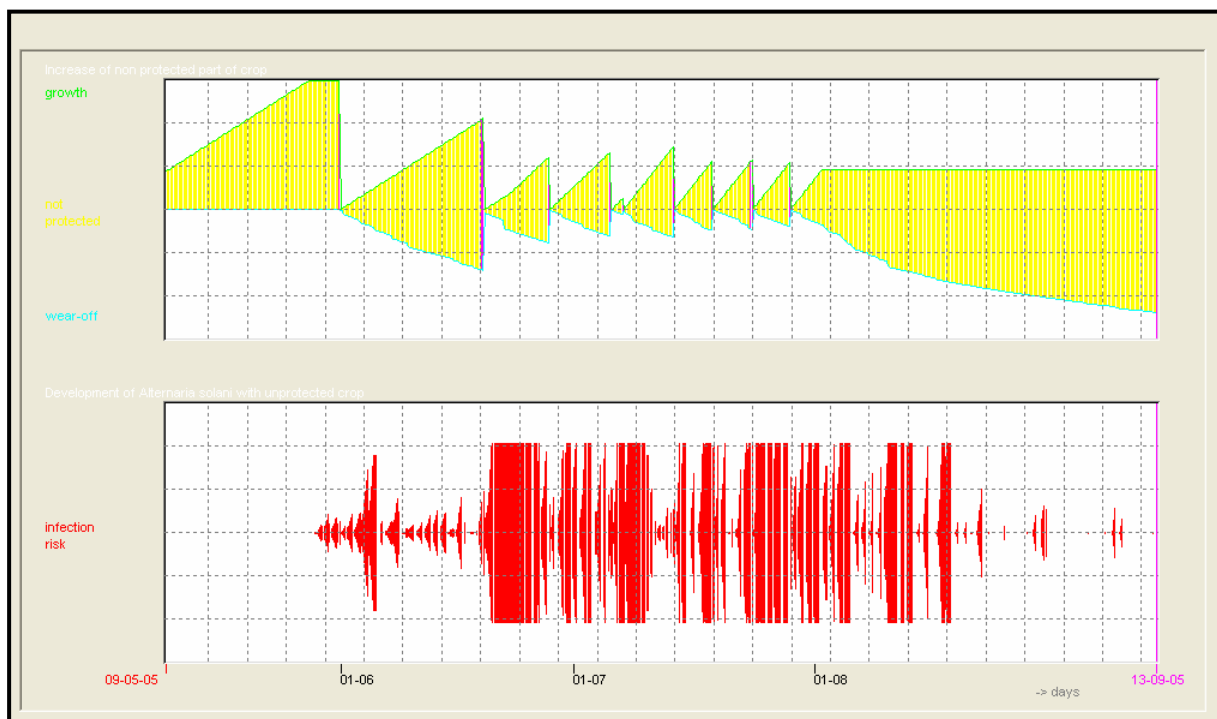
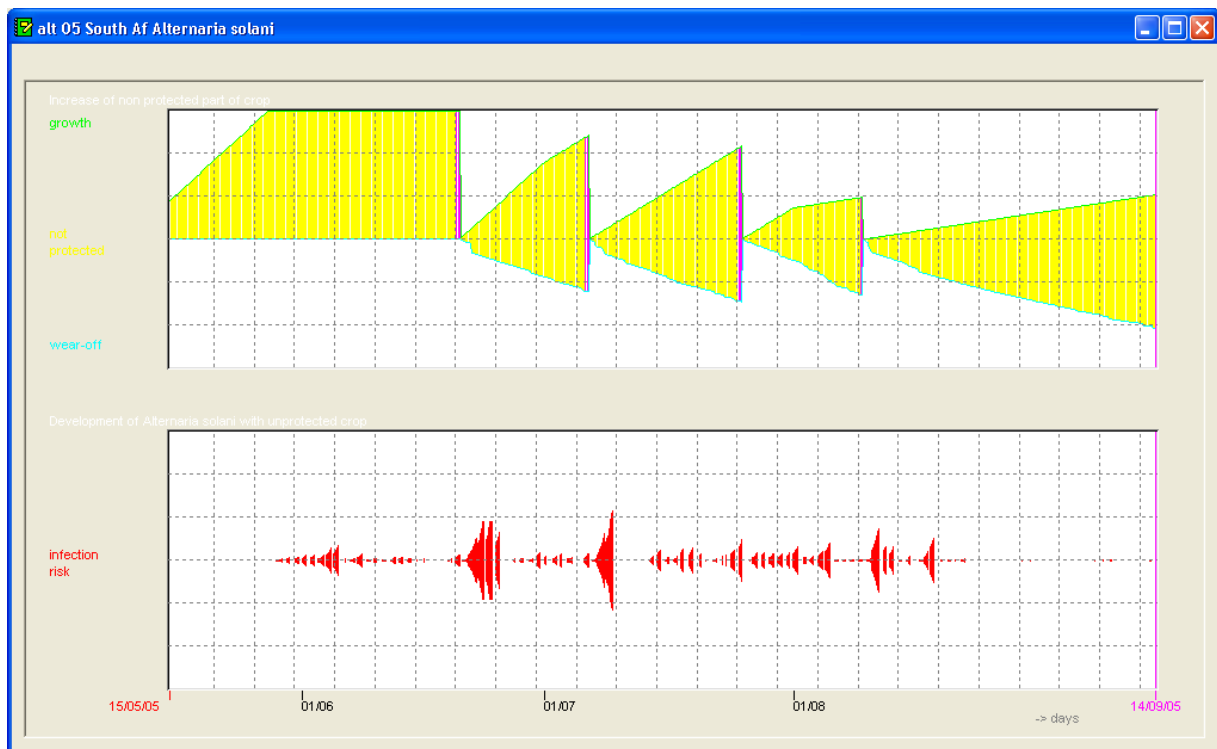
In Japan many years of experience have been gathered on the island Hokkaido in the North of Japan. Although the situation differs from region to region on the island, the control of *P. infestans* is a continuous struggle for the Japanese farmer. The control methodology is very much influenced by government regulation and differs from what we are used to in the Western world. Although the conditions are favourable for *A. solani* infections there is not much attention for this disease. This is due to the over-reaction in *P. infestans* control. Without this, in 2005 about 10 spays would have been necessary to controll *A. solani*.

Australia



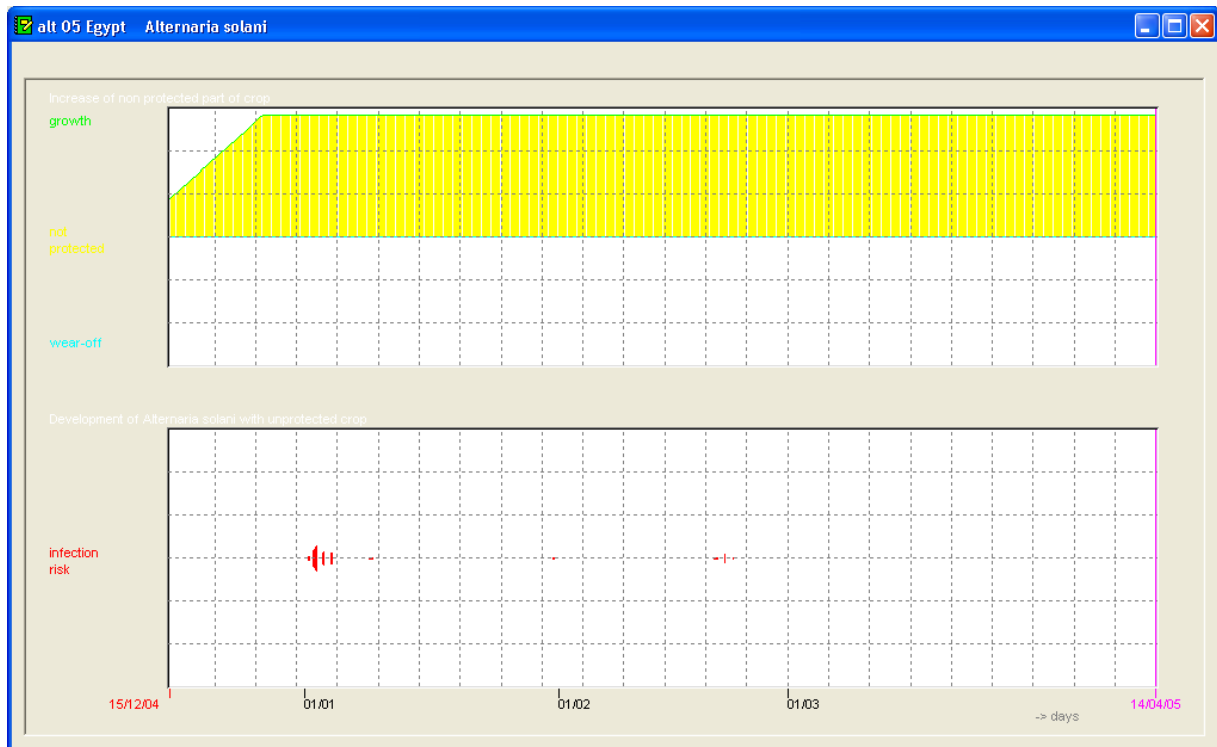
Based on two years of experience in Australia, we can conclude that *A. solani* is no issue and is controlled by the treatments for *P. infestans*. Otherwise one spray at the end of the season would have controlled *A. solani*.

South Africa



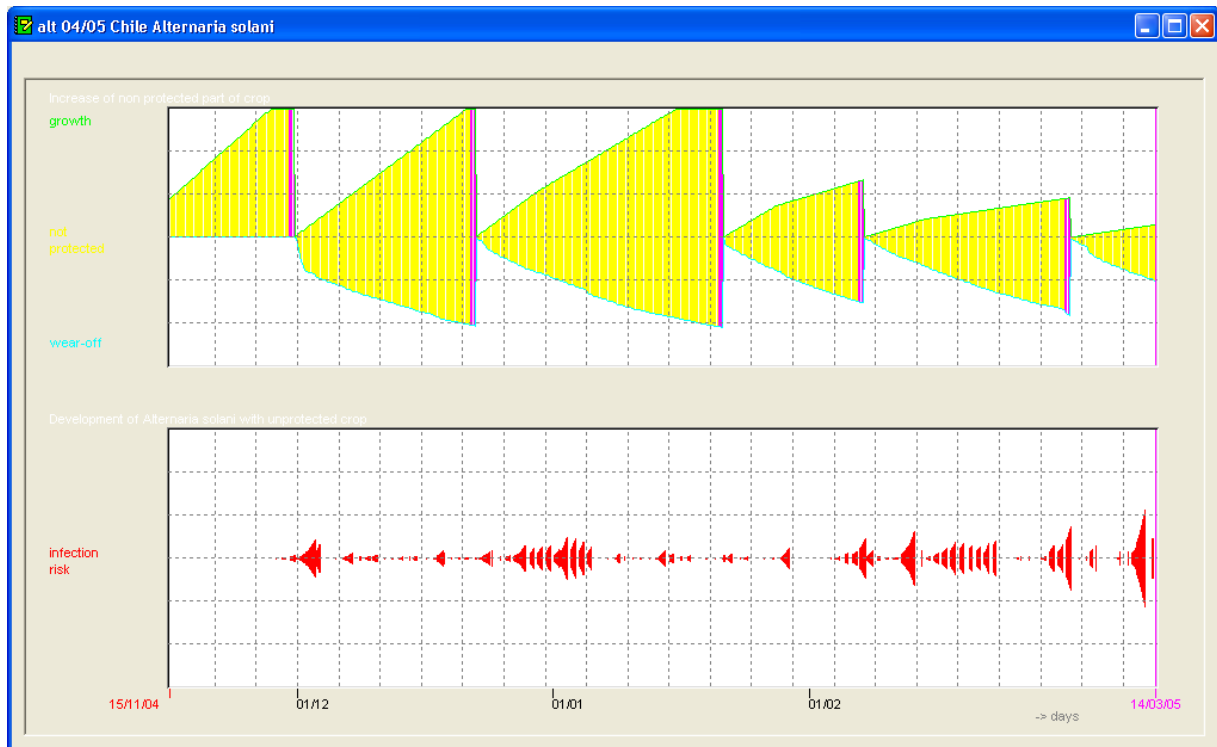
In some regions of South Africa *A. solani* is the sole concern for blight control. The infection event starts early in the growing season and continues till the end. Extensive crop losses can occur because of *A. solani*. Ten applications and more are no exception.

Egypt



In Egypt, we have extensive experience in Blight control over a number of years and locations. In the example of the winter crop, it is clear that *A. solani* is no issue in this case. No treatments were needed. However, sometimes in off-season crops, *A. solani* can be a big issue, even in younger crops that are supposed to be resistant. Like in South Africa, the conditions are too favourable to depend on the early stage resistance.

Chile



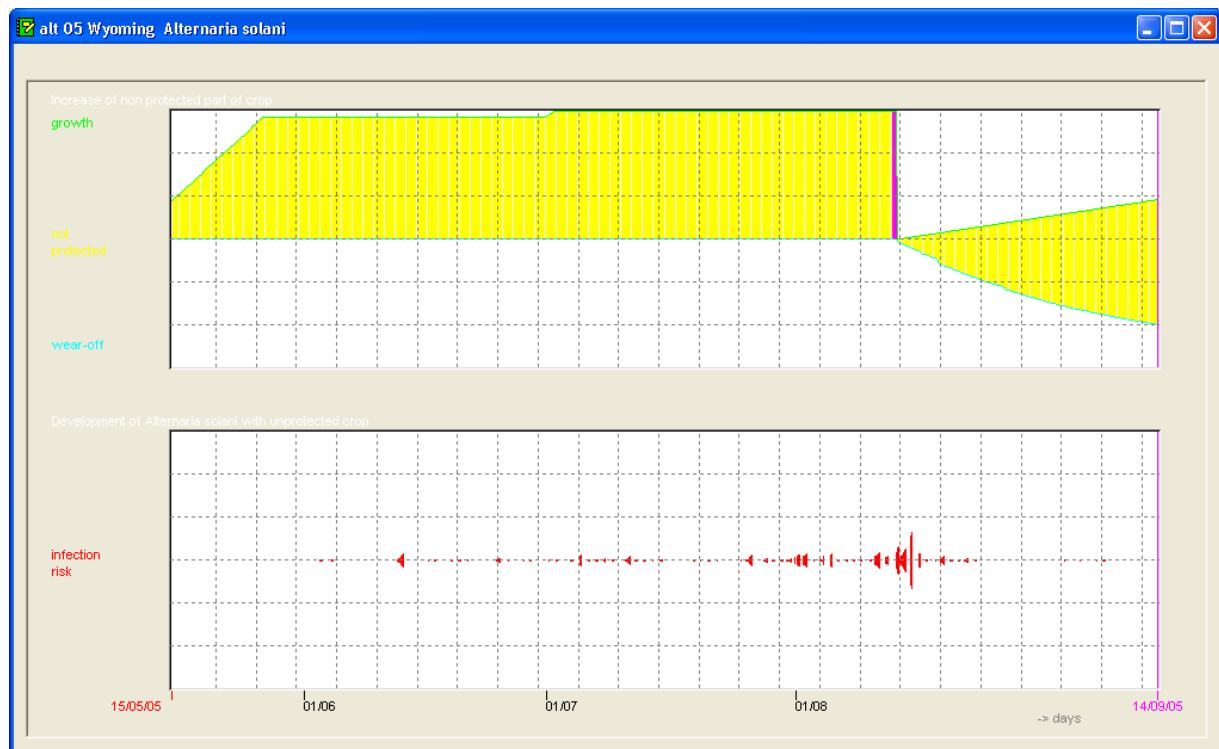
In Chile, Dacom is involved in a *P. infestans* project. Based on the weather data we have from the 2005 season and the reports we get from our project partners, *A. solani* is not an issue in Chile and is taken care of by *P. infestans* treatments.

The USA

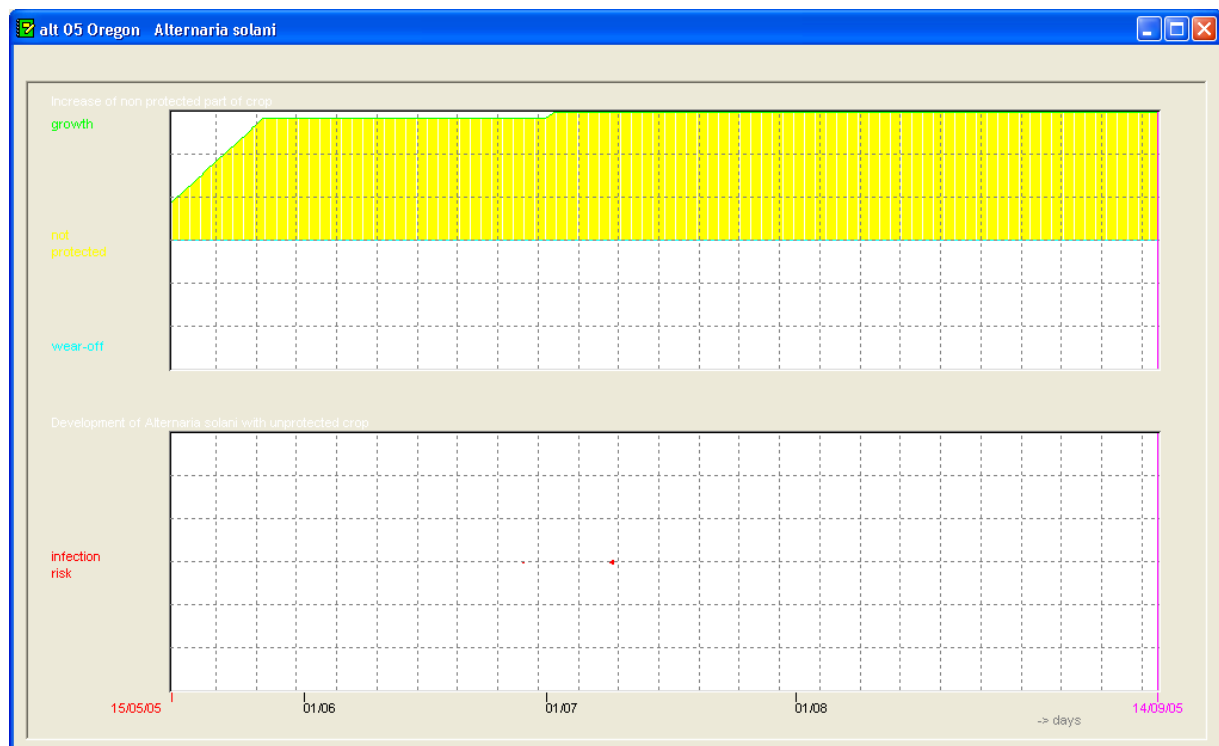
Dacom is involved in different projects across the USA. Depending on the location, *A. solani* is more or less a problem. In general, the Eastern part of the US has an overruling problem with *P. infestans*, while in the Mid West, *A. solani* is the major concern. In this overview, we look at locations in the Mid West, Wyoming and in the North West Pacific area, Oregon .

In 2005 in both locations the pressure of *A. solani* was minimal. The trial in Oregon had a spectacular result of not one application without any appearance of *A. solani*. In general, farmers in this region stick to a weekly to a 10 day spraying schedule.

USA 1



USA 2



Canada

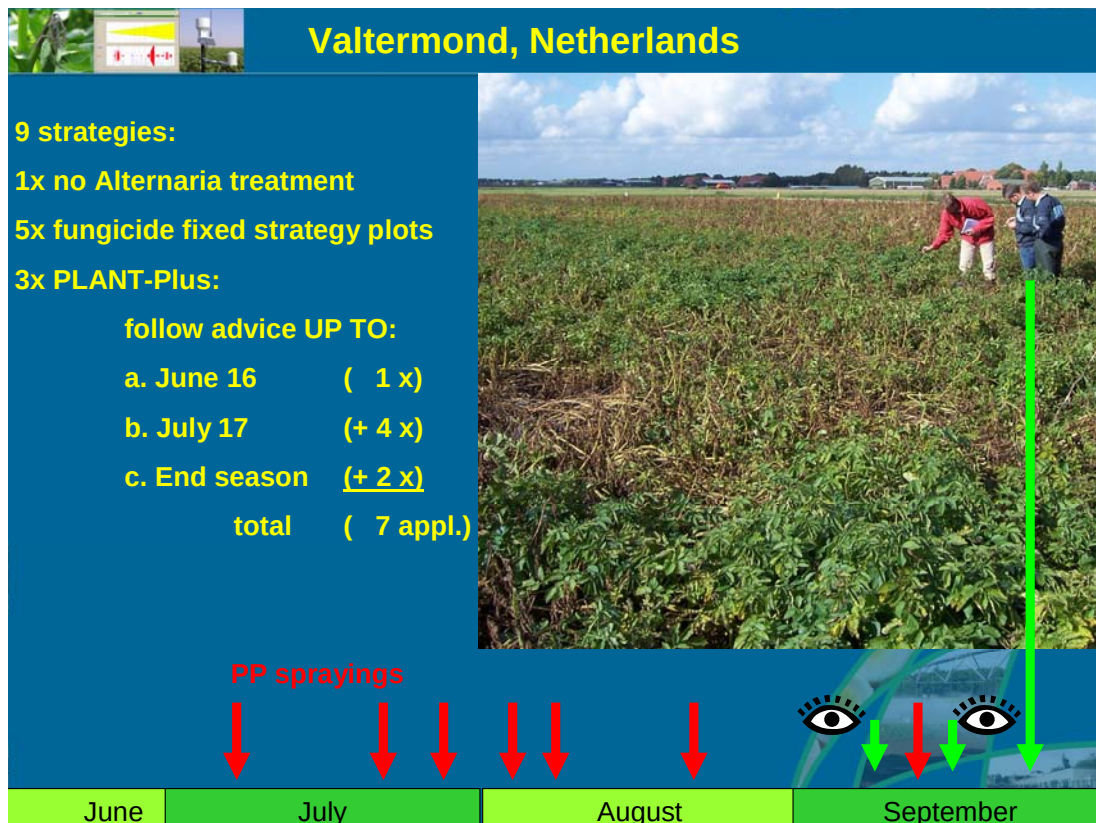


For Canada we look at Alberta where *A. solani* is the main concern. Further to the East the pressure of *P. infestans* will increase whereas on Prince Edward Island *A. solani* is the only concern. In a trial we did with the Potato Growers Association of Alberta, 2 applications for the control of *A. solani* were needed. Because of a scare for *P. infestans* based on the appearance in one field, most farmers put on a fungicide application right after the publication.

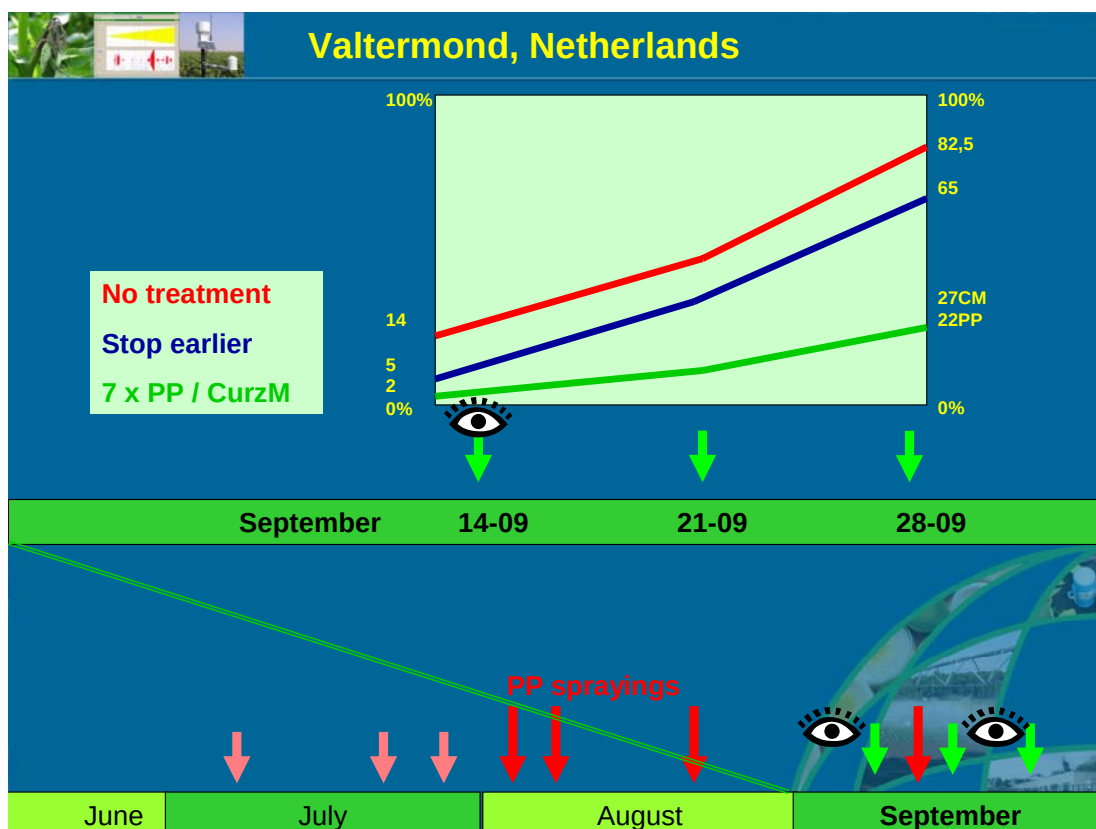
The Netherlands

In the Netherlands, Dacom has participated in extensive *A. solani* trials over the last two years. In the past *A. solani* was controlled by the *P. infestans* treatments. Currently because of product choice, possible nitrogen usage and different weather patterns, *A. solani* is becoming a problem. In the trial we compared two PLANT-Plus driven strategies: a) to spray till haulm killing and b) to stop in the middle of September. Some conclusions of these trials and the practical experience in the Netherlands:

- no treatments for *A. solani* will result in considerable yield loss;
- treatments only in the first part of the season seem to have little effect on the disease control;
- treatment only in the second half of the season show good results;
- in practice, dual action product should be used in the last part of the season.



Strategies, PP sprayings and crop observation dates



Disease development at the end of the season in the Netherlands

Remarks and considerations

- No kick-back products are available to treat potatoes for *A. solani* infections.
- Tuber infection: only possible on damaged tubers during harvesting.
- Disease assessment around the world is not uniform”:
 - number of lesions per assessed leaf;
 - disease severity as percentage of leaf area showing blight;
 - disease incident as percentage of leaves showing blight;
 - percentage of affected total leaf area.
- *A. solani* is present around the world but the severity of the infection pressure depends on the climatic conditions:
 - moderate climates:
 - appearance later in the season, treatments in that period are most effective;
 - in general limited damage if any at all;
 - coincide with *P. infestans* treatments.
 - dry and hot climates:
 - possibility of early infections;
 - yield damage if not controlled.

Questions

- Are early infections of *A. solani* worthwhile to control?
- What happens to released spores:
 - life span supposed to be 2 – 3 weeks;
 - in that case, infections should occur much more intensive.

Conclusions

- *solani* is a sneaky disease that can cause extensive damage under the right conditions.
- A reliable model combined with a good weather prediction is needed for a perfect timing of preventive applications.
- Such a model makes it a perfect way for “Growing in confidence”.

Signum, a novel fungicide for the control of *Alternaria* spp in potatoes

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Summary

Signum is a combination of boscalid and pyraclostrobin and an effective fungicide against *Alternaria solani* in potatoes. The dose rate of 0.2 kg/ha is sufficient to give an excellent control as shown in field trials in the Netherlands 2002-2005. Both active ingredients show no cross resistance and the product can be used as an effective tool for resistance management.

Introduction

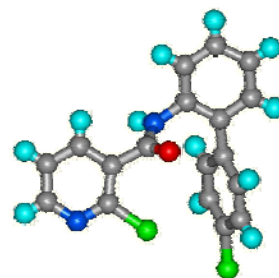
Signum, the trade name for the combination of boscalid and pyraclostrobin, is registered in a number of countries as broad spectrum fungicide in a number of crops. BASF develops this product also for the control of *Alternaria* spp. in potatoes.

In this paper the for *Alternaria* control relevant aspects of both active compounds are described and the results of a 3 year field trial program presented.

Boscalid.

Boscalid was discovered and developed by BASF AG in Ludwigshafen, Germany.

Common name:	BOSCALID
BASF Code No:	BAS 510 F
Chemical class:	Anilides
Chemical name (IUPAC):	2-Chloro-N-(4,-chlorobiphenyl- 2-yl)-nicotinamide



From the chemical of anilides fungicides are well known. Boscalid however belongs to this class but shows a different biological spectrum compared to the former anilides.

Old Anilides:

Carboxin Vitavax

Oxycarboxin Plantvax

Flutolanil Moncut



Ascomycetes



Basidiomycetes



Deuteromycetes



Oomycetes

BAS 510 F:

Boscalid



Ascomycetes



Basidiomycetes



Deuteromycetes



Oomycetes

The mode of action of Boscalid is the inhibition of complex II of the mitochondrial electron transport chain in the inner mitochondrial membrane. As it is a part of the energy building processes in the respiration chain, this electron transport chain is crucial for the pathogen's energy supply. On the other hand, complex II forms a part of a second important physiological process of the fungus: the tricarboxylic acid cycle.

In the TCA cycle many important carbonic acids are synthesised, which are then used to build many other essential compounds in other cell compartments. It is a new mode of action for the target fungus *Alternaria*.

Boscalid is by his mode of action very active against spore germination.

In the greenhouse 16-63 ppm are necessary to control ALTESO to a 100 %.

At these concentrations, especially at 16 ppm, some of the spores manage to germinate, but however, the growth of the germtube and the infection are subsequently stopped. Boscalid is a highly active preventative fungicide against *Alternaria* spp.

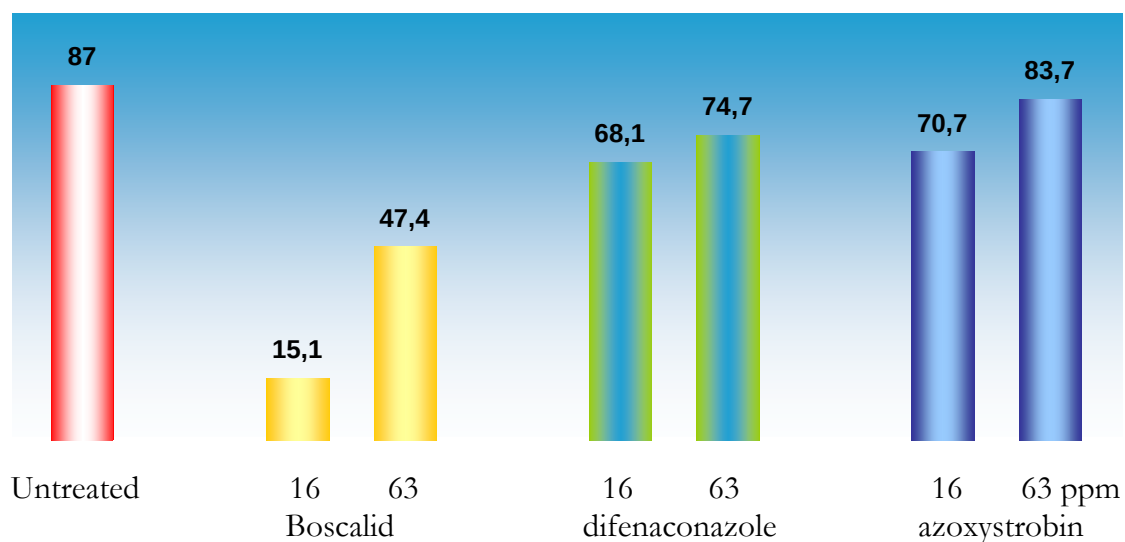


Figure 1. Effect of BOSCALID on Spore Germination - *Alternaria solani*, % germinated spores.

Pyraclostrobin

The second active of Signum is pyraclostrobin or F500, which belongs to the chemical class of strobilurins (Quinone outside Inhibitors).

Common name:	PYRACLOSTROBIN
BASF Code No:	BAS 500 F (F500)
Chemical class:	Strobilurin (QoI)
Chemical name (IUPAC):	Methyl N-(2-{[1-(4-chlorophenyl)-1H-pyrazol-3-yl]oxymethyl}-phenyl)N-methoxycarbamate

The biological profile from Pyraclostrobin is broad and includes fungi from the classes ascomycetes, basidiomycetes, deuteromycetes and oomycetes.

F500 displays an exceptionally high intrinsic activity.

The mode of action of Pyraclostrobin.

Pyraclostrobin interferes as all strobilurines with the Quinone Outside of the cytochrome bc1-complex in the mitochondrial respiration chain; it disrupts the fungal energy supply and has a protective effect by means of inhibition of spore germination.

There is no cross resistance with boscalid. The combination of these two active ingredients is a good resistance management tool.

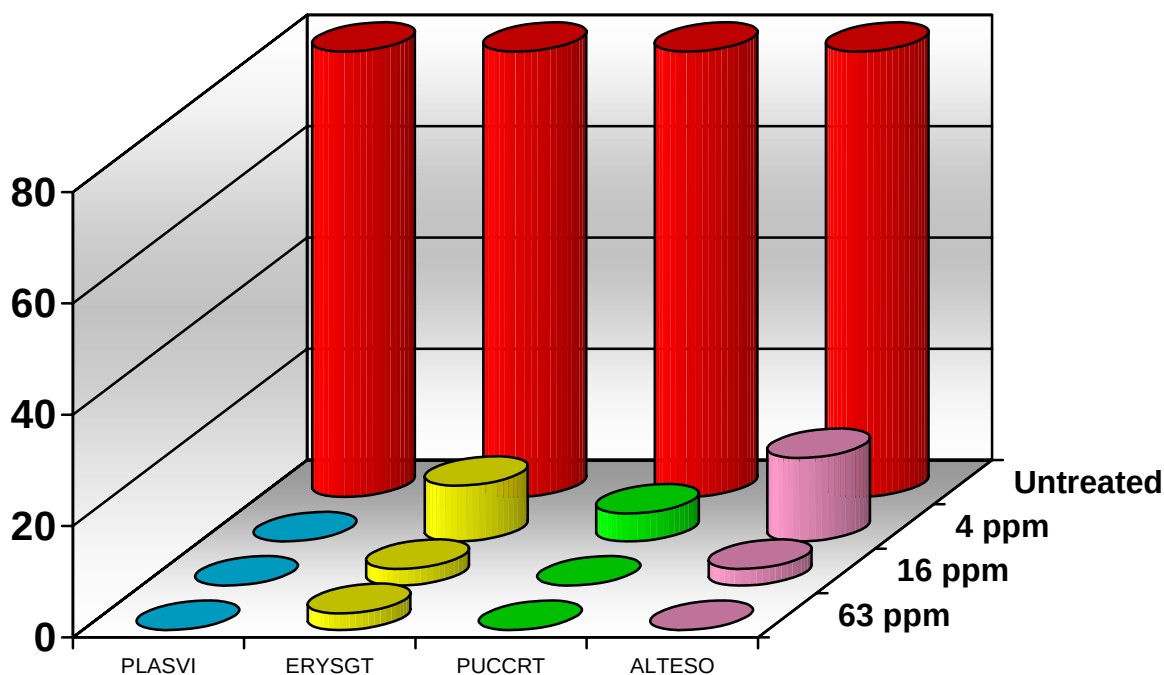


Figure 2. Disease severity in greenhouse trials with leaf application of pyraclostrobin.

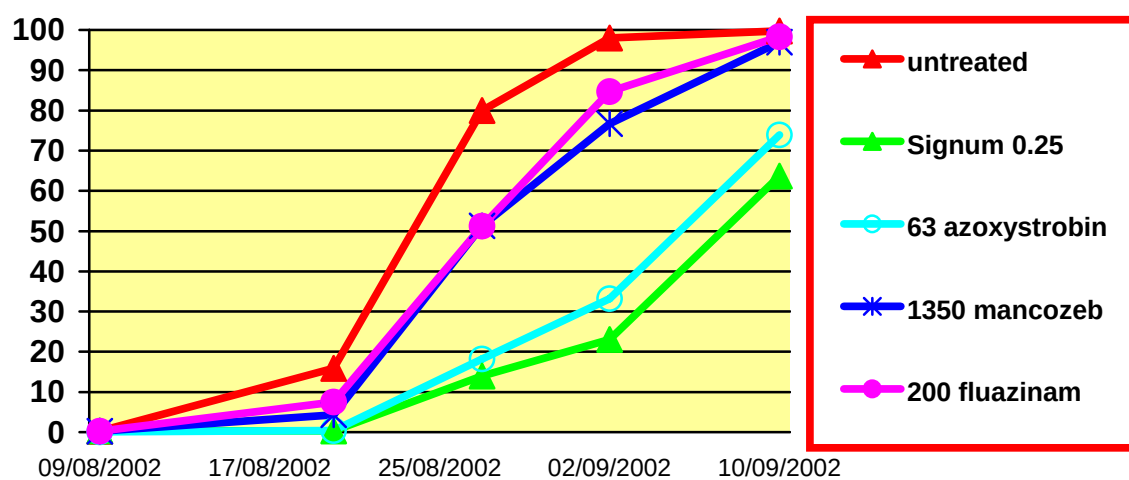
Signum:

Signum is developed as a fungicide for the control of *Alternaria* spp in potatoes. The product contains 267 g boscalid and 67 g pyraclostrobin per kg. Signum is formulated as a wettable granule. It has an excellent effect against *Alternaria solani*, a good effect against *Rhizoctonia solani* and a moderate effect against *Phytophthora infestans*.

Materials and Methods

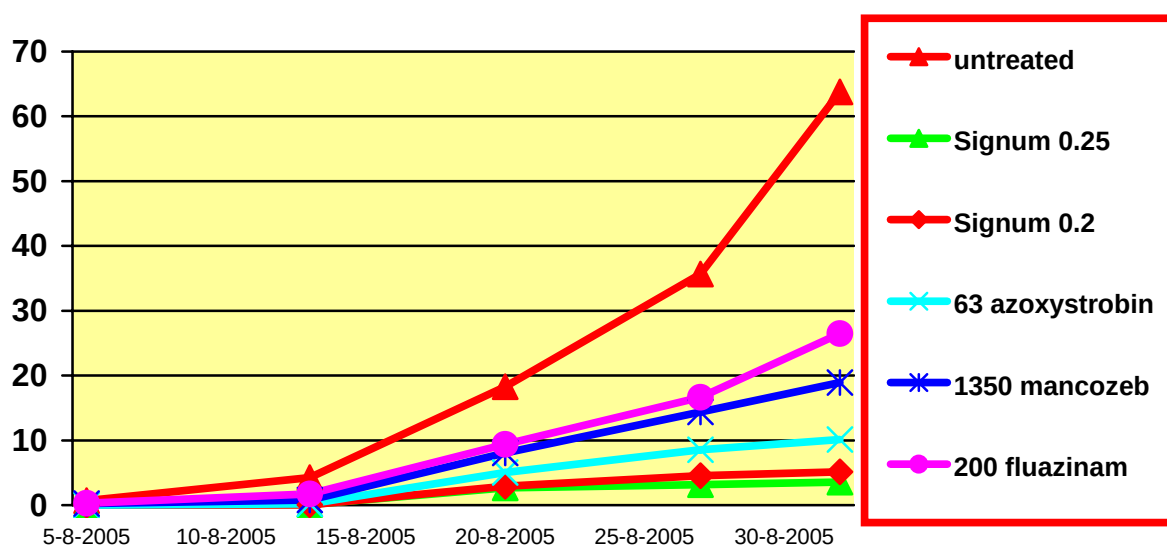
From 2001 to 2005, large numbers of field trials were conducted in Western Europe with boscalid+pyraclostrobin. The trials from 2002-2004 from the Netherlands are presented here to illustrate the properties of the product. All trials were conducted according to Good Agricultural Practice following the EPPO guidelines. The trials were laid down as fully randomized block design with four replicates. Late blight was controlled in all the trials with cyozafamid.

Results



Date of applic. Trial: 2 and 20 Aug; trial 2: 9 and 22 Aug

Figure 3. % leafattack by *A. solani*. Trials NL 2002 (n=2).



Date of applic. July 10, +14d, +14d, +14d

Figure 4. % leafattack by *A. solani*. Trials NL 2003 (n=2).

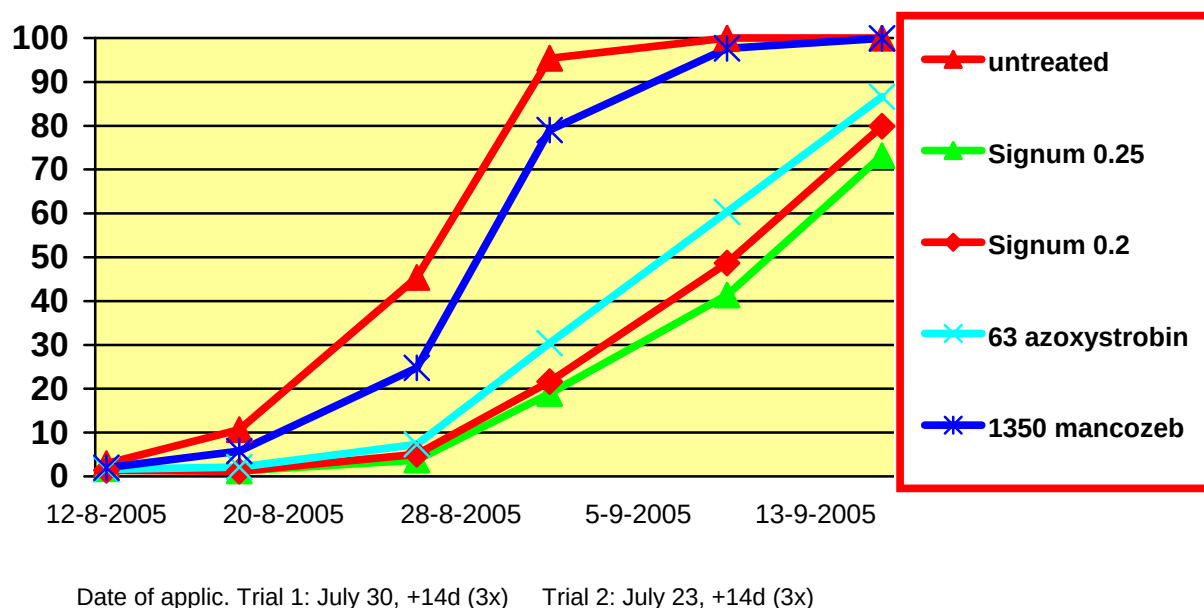


Figure 5. % leafattack by *A. solani*. Trials NL 2004 (n=2).

The results are expressed as the percentage leaf area infested by *Alternaria solani*. The lesions were visually inspected and identified as *A. solani*. In case of doubt a microscopic study was done in the lab on the form of the spores. In all cases *A. solani* was identified.

In 2002 and 2004 the disease progress was strong and fast, in 2003 the epidemic developed slower. The results show that in years with heavier infestations 2-4 applications with mancozeb are not sufficient to control *A. solani*. Azoxystrobin was very effective, the combination of boscalid +pyraclostrobin outperformed azoxystrobin however. There was a small dose rate effect between 0.25 and 0.2 kg Signum.

In 2 trials in 2005 the comparison was made between 2 and 3 applications. In this year the *Alternaria* infestation was moderate. Fig 6 shows that 3 applications of azoxystrobin or boscalid+pyraclostrobin perform better then 2 even in a moderate *Alternaria* year.

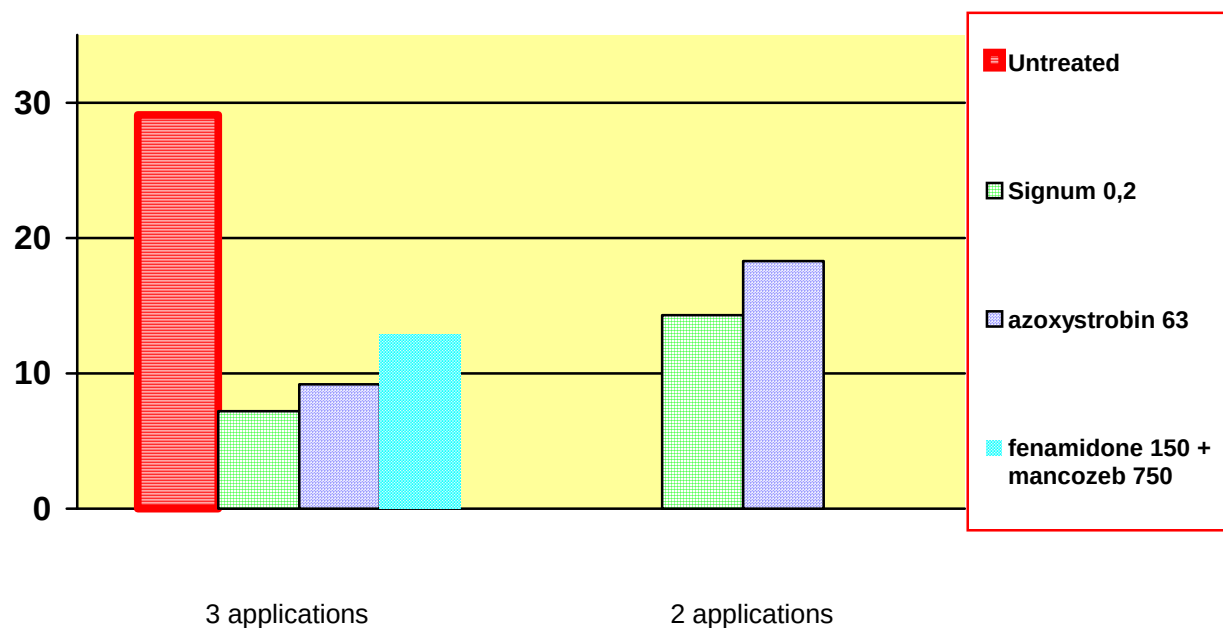


Figure 6. % leafattack by *A. solani*. Trials NL 2005 (n=2).

Conclusion

The combination of boscalid and pyraclostrobin is an effective fungicide against *Alternaria solani* in potatoes. The dose rate of 0.2 kg/ha is sufficient to give an excellent control when applied in July and August, during the onset of the disease. At least 3 applications were needed to give adequate control. Boscalid+ pyraclostrobin outperformed azoxystrobin, which gave also very good results.

The combination of boscalid+pyraclostrobin is an effective tool for resistance management as no cross resistance have ever been noticed between both compounds and is not expected due to the different mode of action.

Infinito[®]: Profile of a novel potato late blight fungicide. Summary of three years of development trials in Europe

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Abstract

Infinito[®] is a new generation fungicide for control of potato late blight, combining the new fungicide fluopicolide with propamocarb-HCl. Fluopicolide is an innovative active ingredient from the new chemical class acylpicolides, which has a novel mode of action and excellent fungicidal properties. In field trials conducted throughout Europe since 2002, Infinito[®] consistently provided outstanding control of late blight on leaves and stems of potatoes. Long persistence of activity and excellent anti-sporulant properties resulted in high yields and excellent protection against tuber blight. Combining the different modes of action of two fungicides, Infinito[®] is a powerful new tool in the management of resistance of *Phytophthora infestans* shown by existing fungicides. Infinito[®] is under development in most potato growing countries and following its first European registration it will be available to UK growers in 2006.

Keywords: fluopicolide, propamocarb-HCl, *Phytophthora infestans*, late blight, tuber blight

Introduction

Infinito[®] is an easy to handle liquid formulation (SC) containing 62.5 g/L fluopicolide and 625 g/L propamocarb-HCl.

The product has been specifically developed for long lasting control of potato late blight and is particularly effective, even under severe disease conditions. This paper describes the fungicidal and agronomic characteristics of Infinito and gives a summary of three years of field trials, demonstrating the superiority of Infinito to commercial fungicides for control of potato late blight. The following features will be discussed in detail:

- fluopicolide: a novel mode of action
- solid pro-active anti-resistance management
- favourable toxicological, environmental and residue profile
- anti-sporulant and translaminar properties
- consistent high level of control of potato late blight on leaves
- protection of new growth
- control of stem blight
- protection against tuber blight
- rainfastness
- long lasting activity
- curative activity
- yield enhancement

Fluopicolide: a novel mode of action for late blight control

The biochemical mode of action of fluopicolide is novel (Tafforeau *et al.*, 2005b). Biochemical studies conducted following standard methods (Beffa, 2004) showed that it is clearly different from fluazinam (oxidative phosphorylation), metalaxyl (rRNA synthesis) and strobilurins or other respiration complex III inhibitors, such as fenamidone. In addition, fluopicolide has no effect *in vitro* on tubulin polymerization (zoxamide).

Fluopicolide is effective at all stages of the life-cycle of *P. infestans*: sporulation, zoospore and cyst formation, zoospore mobility, cyst germination, penetration into the plant tissues and mycelium growth. It is active on both the direct and the indirect germination of sporangia of *P. infestans*, providing a strong and reliable activity against this disease whatever the temperature.

The rapid effect of fluopicolide on zoospore mobility at very low dose rates is remarkable ($LC_{90} < 0.05$ ppm on *P. infestans*). Microscopic observations show that fluopicolide application immediately stops the movement of zoospores, and makes them burst within a few minutes.

Solid pro-active anti-resistance management

To provide sound anti-resistance management, fluopicolide has been exclusively developed in combination with fungicides with different modes of action such as propamocarb-HCl in potato. After more than 15 years of successful use in potato, *P. infestans* has not shown any resistance to propamocarb-HCl. This fungicide has a very low risk of resistance.

Infinito controls both A1 and A2 mating types of *P. infestans*, as well as strains resistant to phenylamide fungicides. Infinito can be included in spray programmes for control of potato late blight, giving farmers a new and powerful tool to support a strong long term anti-resistance strategy.

Infinito - a modern tool for use in integrated crop management (ICM)

Overall, Infinito has a very favourable toxicological, environmental and residue profile (Tafforeau *et al.*, 2005a). Infinito has low acute toxicity to mammals and is neither carcinogenic nor mutagenic. Infinito has no developmental or reproductive toxicity and is safe to birds, bees and other non-target organisms. Following applications of Infinito according to the recommended uses, no residues of fluopicolide or propamocarb-HCl have been detected above the limit of quantification ($LOQ = 0.01$ mg/kg) in potato tubers and processed potatoes.

Glasshouse performances

Infinito offers enhanced biological activity, optimum uptake and distribution of the compounds in the plant. Propamocarb-HCl quickly penetrates into the potato leaves and moves through the plant tissues where it inhibits mycelial growth and development of sporangia. After application, fluopicolide is distributed on the leaf surface, providing protection against the pathogen. Some fluopicolide is also taken up by the leaves, redistributed *via* the xylem and translocated into the leaf tissues, thus providing translaminar

activity. In laboratory conditions the penetration of fluopicolide in potato leaves increases two fold when formulated with propamocarb-HCl.

Infito has a very strong translaminar effect against *P. infestans* based on the movement of both a.i.'s from the upper surface to the lower surface of the leaflets. Infito applied at dose rates equivalent to 1.2 and 1.6 litre/ha effectively controlled late blight development (Figure 1). These properties are particularly important in practical field situations where spray coverage may not always be optimal.

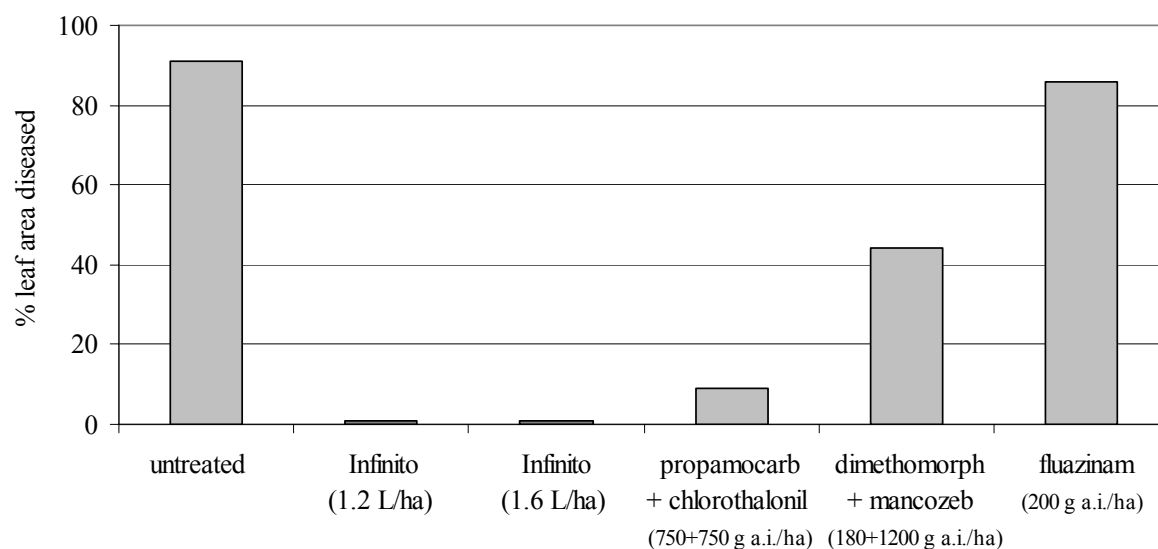


Figure 1. Translaminar activity of Infito (greenhouse trial, application at the upper leaf surface, inoculation to the lower leaf surface 72 hours later, assessment 7 days after inoculation).

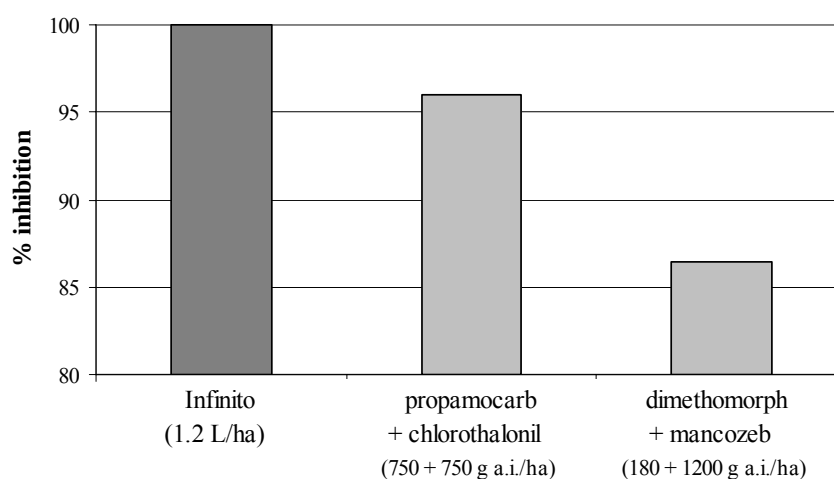


Figure 2. Antisporulant effect of Infito on *P. infestans* in potato (application 24 hours after inoculation, counting of sporangia washed off from leaflets 7 days after inoculation).

The anti-sporulant effects of Infinito observed under field conditions were quantified in a glasshouse trial conducted in 2003 (Figure 2). Infinito exhibited strong anti-sporulant activity compared to the reference dimethomorph + mancozeb.

Field performance

Materials and methods

Field experiments were conducted in 2002-2004 for registration of Infinito in Germany, France, United Kingdom and Netherlands in small plot trials in comparison with different commercial fungicides applied at uniform dose rates (Table 1). Foliar applications of the products were made at 7 day intervals in preventative programmes (except in specific trials to assess curative effects or long lasting efficacy). Disease progression on leaves for each treatment in individual trials was summarised using the RAUDPC calculation (Relative Area Under the Disease Progress Curve, Tukey, 1977). Efficacy was calculated where necessary (% Abbott). In the case of tuber blight, only the trials with high infection levels (> 10 % in untreated control) are presented.

Table 1. Dose rates of Infinito and commercial fungicides applied in field trials.

Treatments	Dose rates	
	(L or Kg product / ha)	(g a.i./ha)
Infinito (fluopicolide + propamocarb-HCl)	1.2	75 + 750
Infinito (fluopicolide + propamocarb-HCl)	1.6	100 + 1000
propamocarb + chlorothalonil	2.0	750 + 750
dimethomorph + mancozeb	2.5	180 + 1200
cymoxanil + mancozeb	2.5	113 + 1700
oxadixyl + cymoxanil + mancozeb	2.5	200 + 80 + 1400
metalaxyl-M + mancozeb	2.5	100 + 1600
fluazinam	0.4	200
cyazofamid (+ 150 ml adjuvant)	0.2	80
mancozeb	2.1	1575

Reliable and high level of leaf blight control

In all the field trials carried out since 2002, Infinito demonstrated excellent crop safety on a wide range of potato varieties. Applied throughout the season in a 7 day spray programme

(Figure 3), Infinito gave excellent protection of the foliage. Results clearly demonstrate excellent control of the disease on leaves with a shallow dose response at rates from 1.2 to 1.6 litre/ha. Even at 1.2 litre/ha, Infinito consistently performed better than the commercial standards and offered high reliability of late blight control.

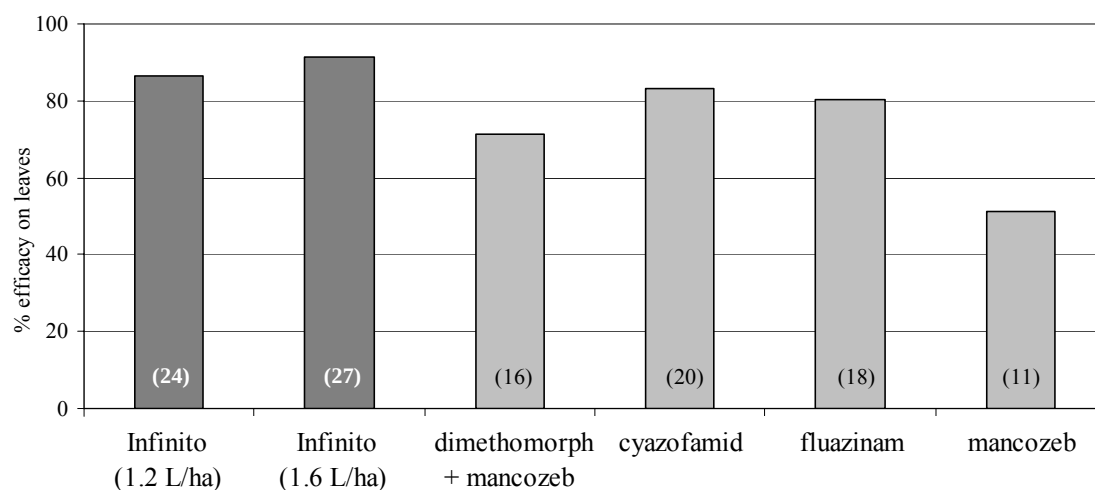


Figure 3. Efficacy of Infinito for control of *P. infestans* on leaves (source: 29 field trials in Europe from 2002 to 2004, numbers of trials per product are mentioned in brackets).

Protection of new growth

When late blight is assessed on leaves developed after application (figure 4), Infinito offers a protection of these new shoots comparable to the standards propamocarb + chlorothalonil or oxadixyl + cymoxanil + mancozeb.

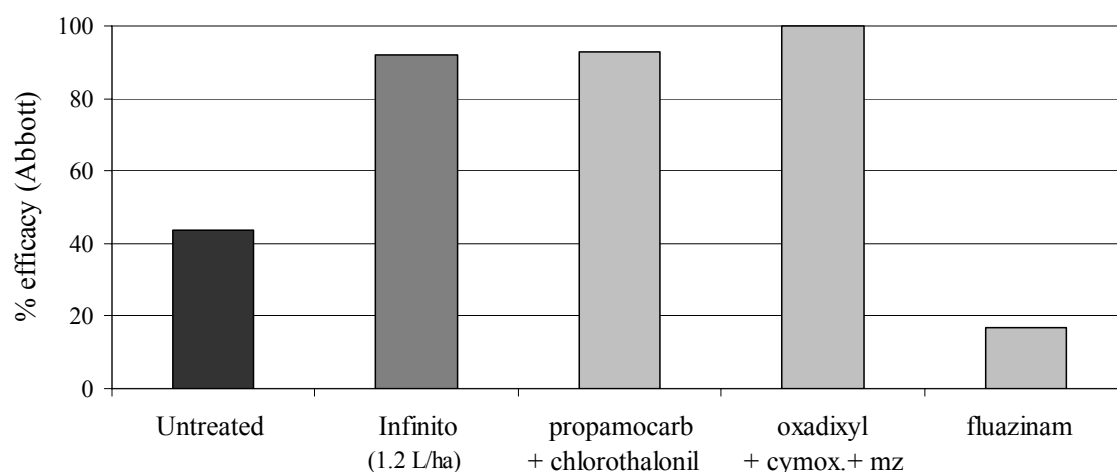


Figure 4. Protection of new leaves against potato late blight. Field trial in France (2002), 2 applications, 24 and 72 hours after artificial inoculation, assessment on new shoots 6 days after treatment.

Control of stem blight

Infinito reduces the disease severity of stem blight significantly, performing better than propamocarb + chlorothalonil (figure 5).

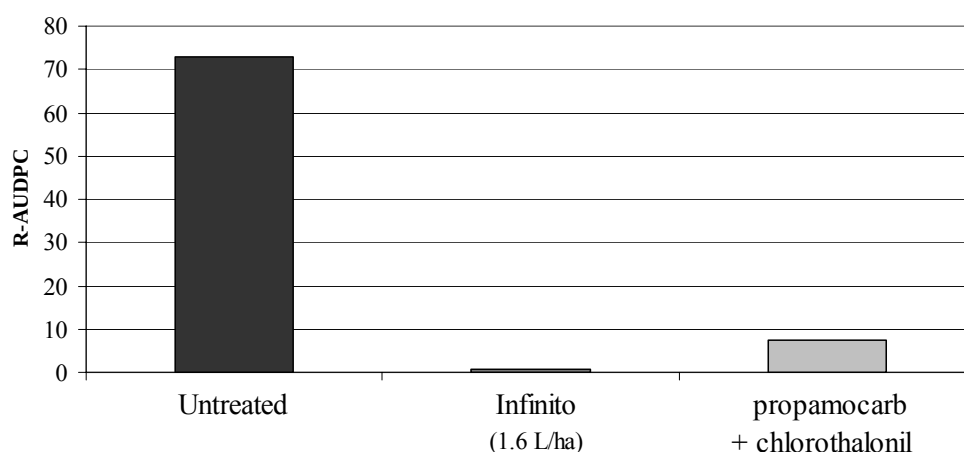


Figure 5. Control of *Phytophthora infestans* disease on stems. Mean of 3 trials conducted in Germany (2001-2003).

Protection against tuber blight

Figure 6 (below) shows that Infinito applications throughout the entire season provided excellent protection against tuber blight in comparison to fluazinam and cymoxanil + mancozeb.

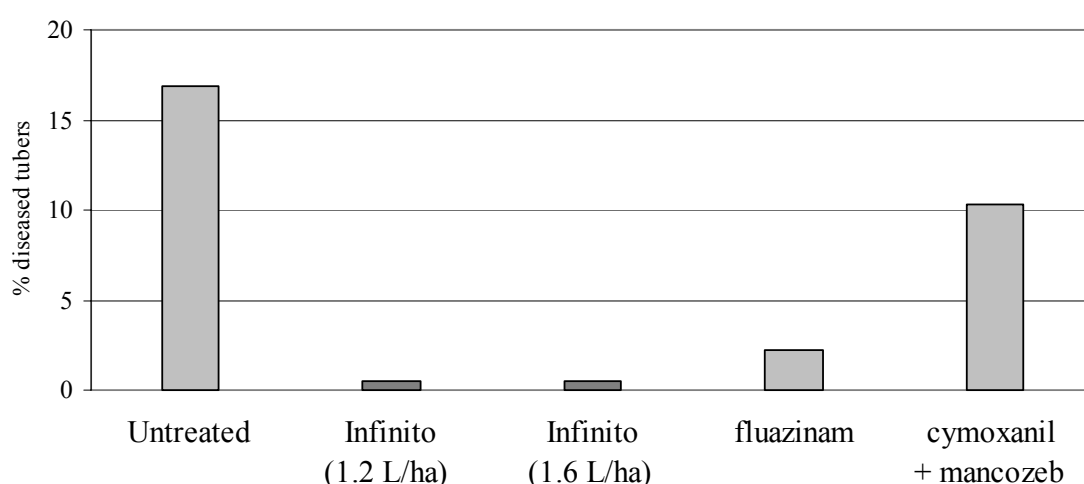


Figure 6. Efficacy of Infinito against tuber blight (means of 4 trials, Netherlands, 2004).

Rainfastness

Rainfastness was investigated using a standard method developed by PPO at Lelystad, The Netherlands (Spits, 2002). Rain was simulated by application of 40 mm of water within 40 minutes starting one hour after fungicide treatment. Two years of testing demonstrated the good rainfastness of Infinito, comparable to fluazinam (figure 7).

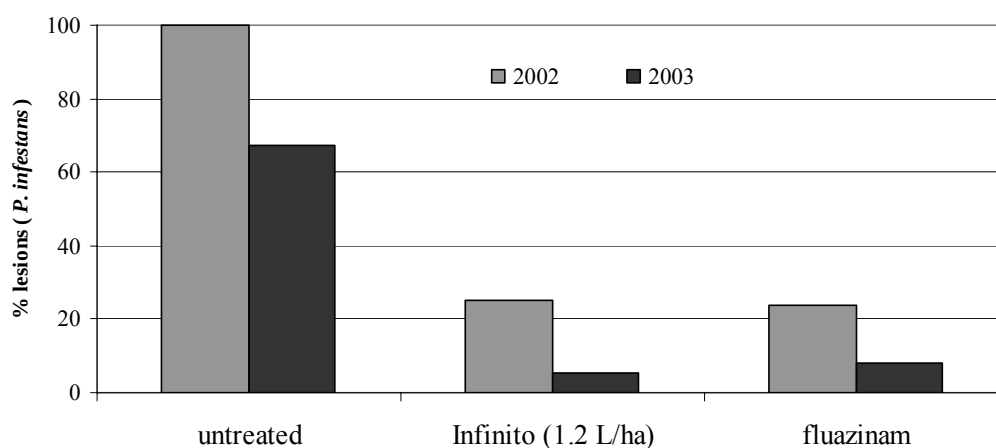


Figure 7. Efficacy of fungicides after simulated rainfall. Summary of 2 trials, inoculation 4 days after application, PPO (The Netherlands, 2002-2003).

Long lasting protectant activity

Infinito demonstrated remarkable long lasting protectant activity in field conditions. Specific trials were conducted in 2004 to confirm its long lasting potential. Fungicides were applied only twice at disease onset (full flowering). Disease progress curves are shown in Figure 8. Thanks to the outstanding protectant properties of Infinito, the development of *P. infestans* was delayed by more than one week during the main period of rapid disease progress.

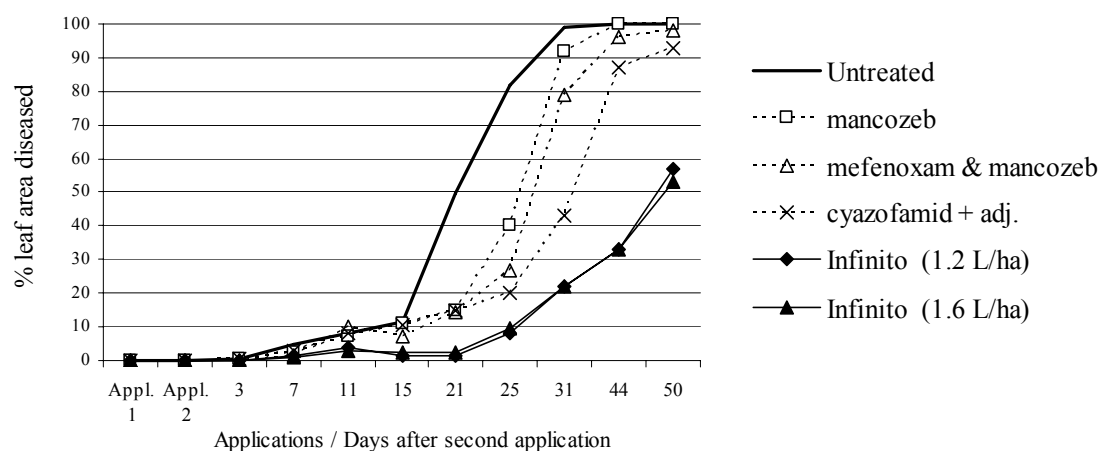


Figure 8. Long lasting activity of Infinito against *P. infestans* (field trial on cv 'Bintje', France, 2004).

Curative activity

The curative activity of Infinito was evaluated in field trials in France and Germany (figure 9). In comparison to cymoxanil + mancozeb and metalaxyl-M + mancozeb, Infinito provided good curative control of late blight, with dose rate response between 1.4 and 1.6 L/ha. The lowest dose rate of Infinito was equivalent to the cymoxanil-based standard. Applied at the highest dose rate of 1.6 L/ha, Infinito was slightly inferior to metalaxyl-M + mancozeb. The curative potential of Infinito provides farmers with additional flexibility and security in late blight control under adverse conditions.

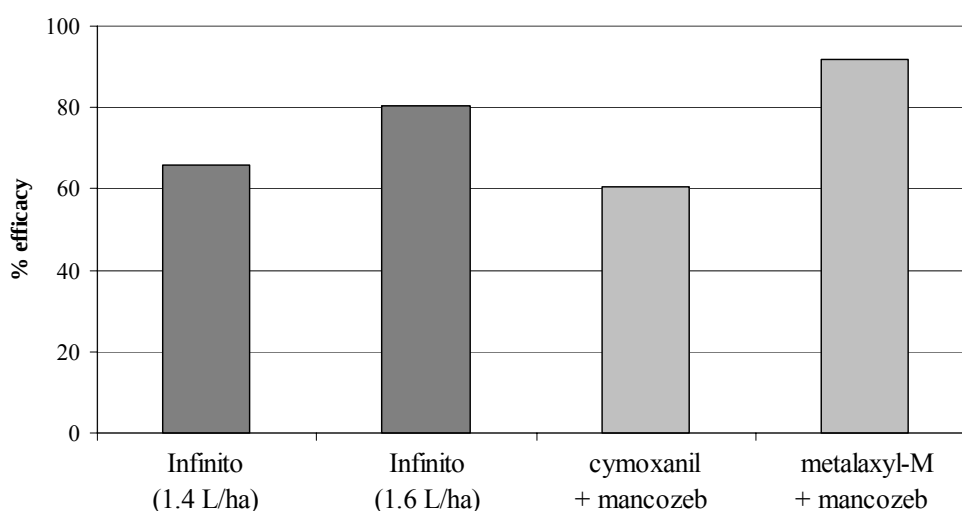


Figure 9. Curative activity of Infinito against potato late blight. Mean of 3 trials, France and Germany (2003). Applications 24 and 72 hours after inoculation, disease assessment 5 days after second application - 40% disease severity in untreated Plots.

Yield enhancement

Yield was assessed in trials conducted in France and results were expressed as percentage of yield relative to untreated (Figure 10). Both dose rates of Infinito gave higher yields than standard products, and moreover, exhibited a clear dose response as a consequence of better leaf, stem and tuber disease control.

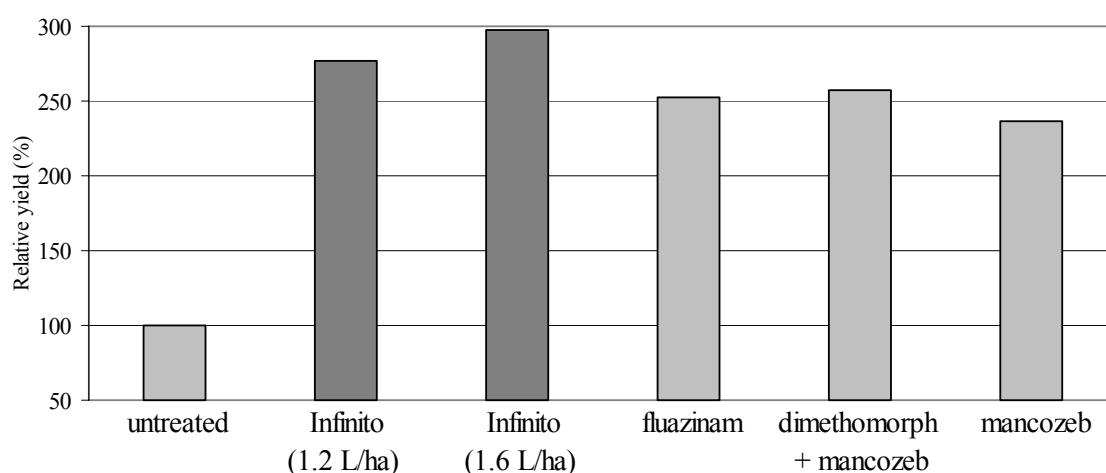


Figure 10. Yield enhancement with Infinito compared to commercial standards (7 registration trials in France in 2002 and 2003, preventive applications at 7 day spray intervals).

Activity rating of Infinito

The effectiveness of the key commercial fungicides in controlling *P. infestans* is rated and listed by the European Working Group on Phytophthora. The latest table was updated in Jersey (Bradshaw, 2004) and was amended at the Tallinn Conference, Estonia, in autumn 2005. The research work done on the control of late blight with Infinito will be reflected in a rating in the B-table for new products in the Tallinn table (Bradshaw, 2005).

In the extensive field trial programme from 2002 to 2004, Infinito provided robust foliar protection superior to cyazofamid. Protection of new shoots and new growing points was achieved at a level similar to metalaxyl-M. Stem blight was controlled equivalent to the market standard Tattoo C. Tuber blight was also effectively controlled with Infinito, being equivalent to fluazinam.

In addition, Infinito demonstrated a remarkable long lasting activity. The curative potential of Infinito was equal to cymoxanil + mancozeb at low dose rate and slightly inferior to metalaxyl-M + mancozeb at higher dose rate. Infinito has strong translaminar properties. Both propamocarb HCl and fluopicolide move into the leaf tissues, providing excellent anti sporulant activity. The rainfastness profile of Infinito under a regime with 40 mm of rain applied within one hour after application was equal to fluazinam.

Based on the extensive field data, the following proposal is made for the listing of Infinito in the Tallinn table:

Table 2. Provisional ratings for the effectiveness of Infinito for the control of *P. infestans* in Europe.

Products	Effectiveness				Mode of Action			Rainfastness	Mobility in the plant
	Leaf blight	New growing points	Stem blight	Tuber blight	Protectant	Curative	Anti-sporulant		
fluopicolide + propamocarb	+++	++	++	++(+)	+++	++	++(+)	++(+)	translaminar + systemic

Key to ratings : 0 = no effect ; + = reasonable effect ; ++ = good effect ; +++ = very good effect

Conclusions

Infinito combines fluopicolide, a new fungicide with a novel mode of action, and propamocarb-HCl, a well established potato fungicide. This combination provides robust, quick-acting late blight efficacy with strong anti-sporulant activity and long lasting performance, resulting in excellent and consistent control of leaf, stem and tuber blight in late blight programmes.

Infinito has a good environmental profile and is suitable for use in integrated pest management systems in potato crop. Infinito sets a new standard for potato late blight control.

Acknowledgements

The authors would like to thank all Bayer CropScience colleagues and scientists from external institutes who contributed to the development of Infinito.

References

- Andrison, D, 1994. Dynamics of the survival and infectivity to potato tubers of sporangia of *Phytophthora infestans* in three different soils. *Soil Biology and Biochemistry* 26(8), 945-952.
- Bradshaw, NJ, 2004. Discussion of potato early and late blight fungicides, their properties & characteristics: Report of the fungicide sub-group. Proceedings of the eighth workshop of an European network for development of an integrated control strategy of potato late blight. Jersey, England-France, 31st march - 4th April 2004.
- Bradshaw, NJ, 2005. Discussion of potato early and late blight fungicides, their properties & characteristics: Report of the fungicide sub-group. Proceedings of the ninth workshop of a European network for development of an integrated control strategy of potato late blight. Tallinn, Estonia, 19-23 Oct. 2005.
- Beffa, R, (2004). Genomics and biochemistry in the discovery of modern fungicides. *Pflanzenschutz Nachrichten Bayer*, **57**, 46-61.
- Flier, WG, GJT Kessel and HTAM Schepers, 2004. The impact of oospores of *Phytophthora infestans* on late blight epidemics. *Plant Breeding and Seed Science* (50), 5-13.
- Spits, HG and HTAM Schepers, 2002. Effect of rain on the preventive activity of Sereno and other fungicides against *P. infestans*. Praktijkonderzoek Plant & Omgeving BV, Lelystad, The Netherlands (Unpublished)
- Tafforeau, S, T Wegmann, M-P Latorse, P Duvert, J-M Gouot and E Bardsley, 2005a. Fluopicolide, a novel fungicide with a unique mode of action, setting a new standard for Oomycete control. The BCPC International Congress. Crop Science & Technology 2005. Glasgow, Oct. 31st – Nov. 2nd. 2005. Congress proceedings, 2, 79-86.
- Tafforeau, S, M-P Latorse, P Duvert, E Bardsley, T Wegmann and A Schirring, 2005b. Infinito: a novel fungicide for long-lasting control of late blight in potato. Potato in progress. Science meets practice. Potato Emmeloord 2005. Sept. 5-9. 2005. Ed.: Haverkort, A.J. and Struik, P.C., 315-323.
- Tukey, JW, 1977. Exploratory Data Analysis. Addison-Wesley, Reading, Massachusetts.

The effect of dithiocarbamates against *Alternaria* spp in potatoes

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Summary

During 1999-2003 trials were done with metiram and mancozeb to control *Alternaria* in potatoes. Metiram and mancozeb gave comparable results. In spraying schemes trough the whole season *Alternaria* could be sufficiently controlled in dose rates of 1200-1500 g ai/ha. If the applications were limited to 3-5, no sufficient control could be reached up to dose rates of 1700 g ai/ha.

Introduction

The deuteromycete *Alternaria solani* was in North-west Europe seen as a fungus of minor importance. The disease early blight, caused by this pathogen, was normally controlled by fungicidal treatments against *Phytophthora infestans*. In the last years the disease gained in importance. As reasons for this change several reasons were mentioned. Reduction of nitrogen supply to the crop, climatic change, the growing of more susceptible potato varieties and use of new fungicides against late blight with less efficacy against early blight. With these fungicides less or no dithiocarbamates are brought on the field.

Due to the growing importance of *Alternaria* some specific fungicides against early blight were developed in recent years.

In this paper the role of dithiocarbamates are described in comparison with specific fungicides. Also the difference between the dithiocarbamates mancozeb and metiram is addressed.

Material and Methods

The database of BASF AG was screened on data of replicated small plot trials against early blight. Trials with dithiocarbamates were found from Brazil 1999 and from Germany and the Netherlands from 2002 –2005.

In the trials carried out in Brazil a comparison was made between straight mancozeb and straight metiram with 3-5 applications. In 2 trials different rates of both active ingredients were compared where mancozeb was applied in slightly higher dose rates than metiram. In a third trial from both compounds identical dose rates were applied.

In 2002 and 2003 5 trials were carried out in the Netherlands in which products containing mancozeb or metiram were applied in a spray scheme of 11-22 applications.

In 2004 and 2005 mancozeb containing products were 3 times sprayed in July and August against *Alternaria* in comparison with specific *Alternaria* products containing azoxystrobin or a combination of boscalid and pyraclostrobin. The *Phytophthora* control in these trials was done with cyazofamid.

The efficacy data of all available trials in the database (n=12) are summarised in a table and plotted against the active ingredient, the dose rate and the number of applications. The mean efficacy for mancozeb and metiram over all trials, the average dose, and the efficacy at different spray schemes are calculated.

Results and discussion

In the trials from 1999 Brazil the higher rates of the dithiocarbamates (2450-2800 g ai/ha) showed a better result than the lower rates (1400-1600 g ai/ha) after 5 applications. In the third trial the dose dependency was visible between 1400-1680 g ai/ha and 1043 g ai/ha of both compounds. At the lower dose rates metiram was somewhat better than mancozeb. The efficacy after 3 applications was only about 50% at the normal rates of 1400 g ai/ha for metiram and 1680 g ai/ha for mancozeb.

The trials carried out in the Netherlands in 2002 and 2003 showed good results of the dithiocarbamates when applied 11-22 times in a spray scheme. No differences in efficacy could be observed between metiram and mancozeb applied alone or in combination with cymoxanil or dimethomorph.

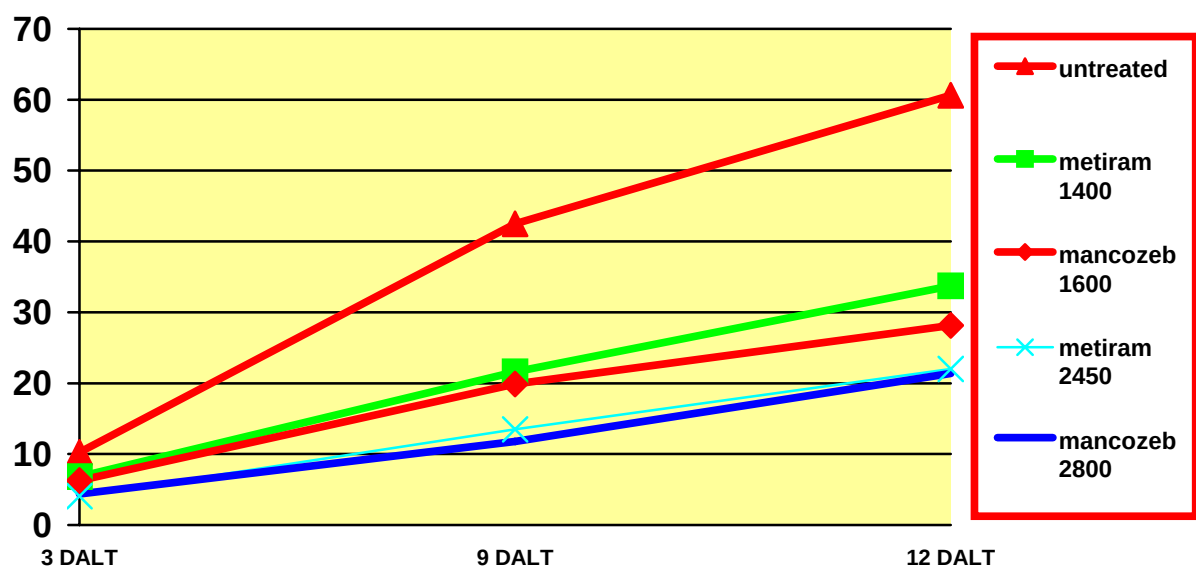


Figure 1. % leafattack of *Alternaria* spp after 5 applications in F1999/BR/817/n=2.

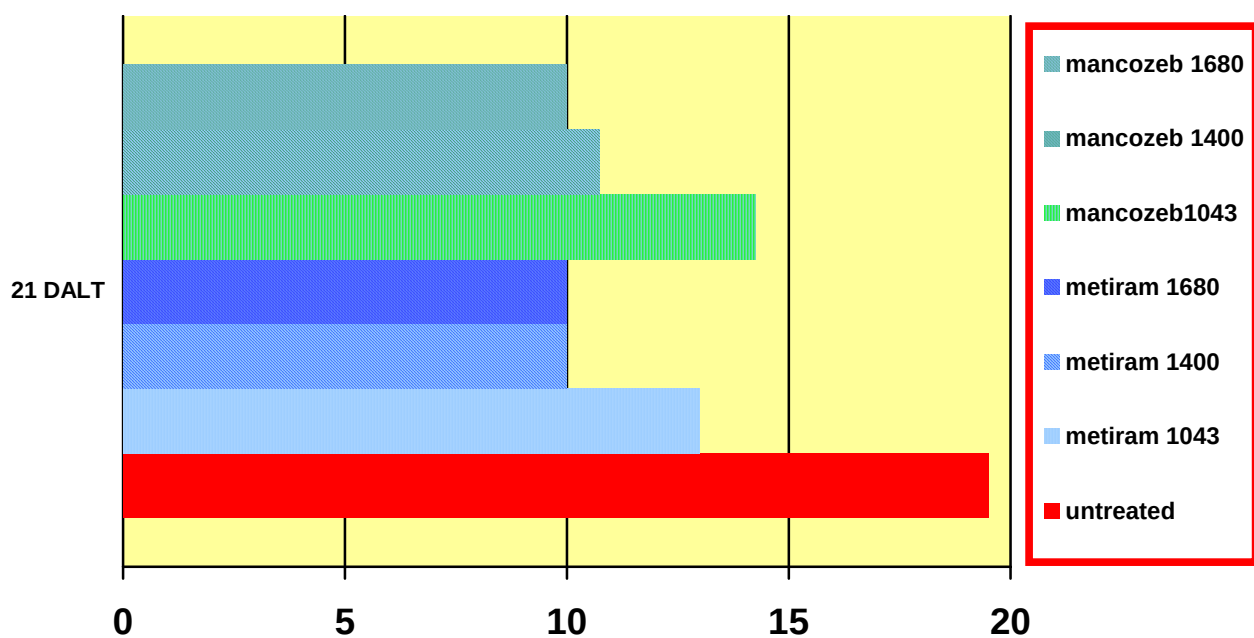


Figure 2. % leafattack of *Alternaria* spp after 3 applications in F1999/BR/P51/n=1.

Table 1: % leafattack of *Alternaria* spp at the end of the season in 5 trials in the Netherlands 2002/2003

	2002			2003		
1425 metiram + dmm	1	0	0	11	9	dmm + metiram 1425
1575 mancozeb	1	0	0	10	10	cym + mancozeb 1333
1200 mancozeb + dmm	1	0	0	10	10	dmm + mancozeb 1340
untreated	10	50	77	74	48	untreated
	4DAA12	4DAA22	5DAA11	5DAA16	10DAA14	

In the trials in 2004 and 2005 the specific *Alternaria* products azoxystrobin and boscalid+pyraclostrobin outperformed mancozeb alone or in combination with fenamidone when applied 3 times at the start of the disease. In 2004 there was a very strong built up of the fungus but in 2005 the disease came very late and did not reach a high level of attack. In 2004 the result of mancozeb alone was insufficient and in 2005 alone or in combination gave mancozeb a moderate effect against *Alternaria*.

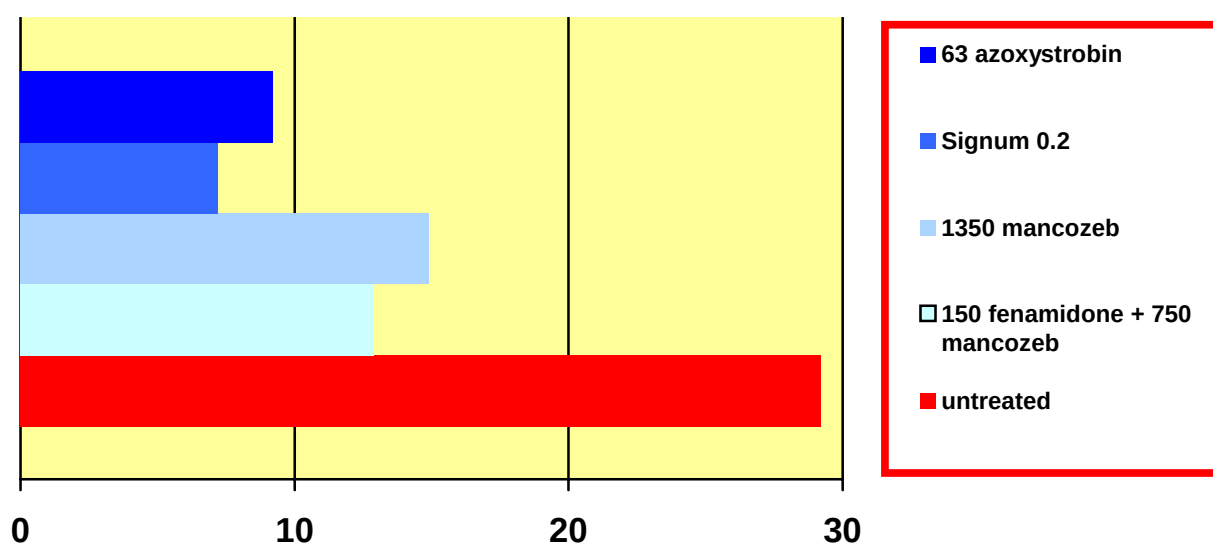


Figure 3. % leafattack of *Alternaria* spp after 3 applications in F2004/NL//n=2 4-8DAA3 F1999/BR/817/n=2

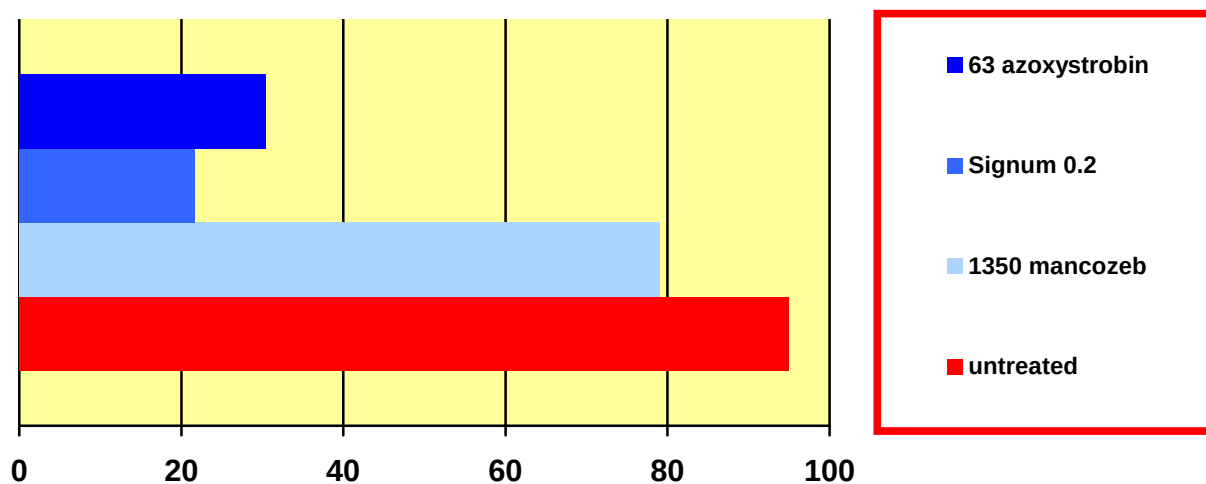


Figure 4. % leafattack of *Alternaria* spp after 3 applications in F2005/NL//n=2 12-16DAA3 F1999/BR/817/n=2

Table 2. % efficacy of metiram and mancozeb against *Alternaria* spp in 12 trials from BR and NL 1999-2003.

gai/ha	metiram	mancozeb	# applc
1043	35	29	3
1260	61, 79		2-4
1350		78, 78	2-4
1400	42, 50, 50	45	3-5
1425	83, 100, 100, 79, 86		> 10
1575		78, 100, 100	> 10
1600		48, 66	5
1680	50	50	3
1700		79, 86	> 10
avg dose	1245	1512	
avg efficacy	68	70	
avg 2-5 appl	52	56	
avg >10 appl	90	89	

From all the trials in which an orthogonal comparison between mancozeb and metiram could be made a table is constructed plotting the dose rate and number of applications against the efficacy of both actives. The result from this comparison is that the efficacy over all the trials is the same for mancozeb and metiram, although the average dose rate from metiram is 267 g/ha lower than mancozeb. The efficacy of up to 5 applications of both dithiocarbamates is only moderate, as the efficacy in a spray scheme through the whole season is 90%.

Conclusion

Dithiocarbamates can control *Alternaria* in potatoes if they are applied in a spray scheme through the whole season. Metiram and mancozeb can both be used in dose rates as recommended in combinations with cymoxanil or dimethomorph i.e. 1200-1500 g ai/ha.

The trials used for this paper did not give clear conclusions on the lowest effective dose rate for controlling *Alternaria* in seasonal spray schemes. Only in trials with 3-5 applications there was a clear dose response between 1000 and 1400 g ai. This can be seen as an indication that the dose rate of dithiocarbamates in combinations with other actives to control *Phytophthora infestans*, should be not below 1200 grams if also an efficacy against *Alternaria* is aimed.

In spray programs however nowadays often products are used without sufficient *Alternaria* control. If the *Alternaria* control starts at the onset of the epidemic, which is normally in July in The Netherlands, special products against this disease are needed. Dithiocarbamates solo are in dose rates up to 1700 g ai/ha not sufficient active to prevent the built up of *Alternaria* with 3-5 applications during that period.

**Report of the fungicide sub-group: Discussion of potato early and late blight
fungicides, their properties & characteristics**

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Objective

The objective of the sub-group meeting was to review and update the ratings given 2004 for the various properties and characteristics of early and late blight fungicides at the Jersey workshop in April 2004 (PPO-Special Report No 10 (2004), 151-156).

Discussions & recommendations

The ratings given in Table 1 are for blight fungicides currently registered in several EU countries and are based on the label recommendations for commercially available products containing one or two active ingredients. The ratings are NOT for the active ingredients themselves. Whilst in previous proceeding, the ratings were for all products containing a specific active ingredient, this point may have been misunderstood. As a result, the Table has been amended and lists the commercially available mixtures of active substances.

The ratings are based on publicly available information and a consensus of opinions based on the experience of both independent sub-group members and representatives from the crop protection industry.

The ratings are an assessment of product performance in practical use. They are intended as a guide only and will be amended in future if new information becomes available.

Table 2 gives provisional ratings for ‘recently introduced’ products and new fungicide formulations. The inclusion of a product in this table is NOT indicative of its registration status either in the EU or elsewhere in Europe. These ratings are based on information from field experiments or minimal practical experience of a product and will be amended at future workshops, as new information becomes available and the body of experience in commercial use increases.

Before the fungicide ratings were discussed, the group heard presentations on the activity of two new fungicide formulations (fluopicolide+propamocarb and benthiavalicarb+mancozeb) and cymoxanil+mancozeb for the control of late blight. Information showing the effectiveness of dithiocarbamates against *Alternaria* blight was also presented. (see papers in this Proceedings).

A presentation by Evenhuis, Spits & Schepers in Jersey 2004 suggested changes to the current definition of ‘new growth (new growing point)’. (PPO-Special Report No 10 (2004), 157-160). Further work in the Netherlands since the Jersey workshop has confirmed that contact and translaminar fungicides can give protection of new growth against late blight. As a result, the subgroup agreed that there should be a new definition for the protection of new growth. This new definition is included in this report. It was proposed by NL that the ratings for ‘protection of new growth’ should be expanded to include both fast and slow rates of foliage growth. However, it was agreed that the proposed ratings for the fungicide products

evaluated in the NL study would not be applied in the Tallinn tables. This would allow all fungicide manufacturers an opportunity to provide data which would be considered at the next workshop. The independent members of the subgroup agreed to prepare a protocol for testing fungicide effectiveness in protecting new growth based on the published NL methodology.

It was agreed that the term ‘eradicant activity’ should be replaced with the term ‘antispore activity’ and that a suitable definition would be included in the report.

Since the start of the publication of fungicide ratings in 1999 (PAV-Special report No 5 (1998), 20-23) a number of fungicide active substances have been withdrawn in Europe and a number of others have been developed. The independent members of the subgroup were concerned that the ratings for the older products may not now be correct and that the basis for the ratings should be reconsidered by the generation of new data. It is important that all products are tested following the same methodology and the independent members of the subgroup agreed to prepare protocols for an evaluation of each of the characteristics in the ratings tables before the next workshop.

Phenylamide resistance

The ratings assume a phenylamide-sensitive population. Strains of *P. infestans* resistant to phenylamide fungicides occur widely within Europe. Phenylamide fungicides are available only in co-formulation with protectant fungicides and the contribution which the phenylamide component makes to overall blight control depends on the proportion of resistant strains within the population. Where resistant strains are present in high frequencies within populations the scores for the various attributes will be reduced.

Definitions

New growth - The ratings for the protection of the new growing point (new growth) indicate the protection of new foliage due to the systemic or translaminar movement or the redistribution of a contact fungicide. New growth consists of growth and development of leaves present at the time of the last fungicide application and/or newly formed leaflets and leaves that were not present.

Protectant activity - Spores killed before or upon germination/penetration. The fungicide has to be present on/in the leaf/stem surface before spore germination/penetration occurs.

Curative activity - the fungicide is active against *P. infestans* during the immediate post infection period but before symptoms become visible, i.e. during the latent period.

Antisporulant activity - *P. infestans* lesions are affected by the fungicide by decreasing sporangiophore formation and/or decreasing the viability of the sporangia formed.

Stem blight control - effective for the control of stem infection either by direct contact or via systemic activity.

Tuber blight control - activity against tuber infection as a result of fungicide application after infection of the haulm, during mid- to late-season i.e. where there is a direct effect on the tuber infection process. The effect of phenylamide fungicides on tuber blight control was therefore not considered relevant in the context of the table as these materials should not be applied to potato crops if there is blight on the haulm, according to FRAC guidelines. Only the direct (biological) effect of a particular fungicide on the tuber infection process was considered relevant and NOT the indirect effect as a result of manipulation or delay in the development of the foliar epidemic.

N.B. The information in Table 1 is based on the consensus of experience of independent scientists from countries present during the Workshop. The ratings refer to all products currently available on the market in the EU which contain those active ingredients either as a single formulation, or in a co-formulated mixture. The ratings given are for the highest dose rate registered for the control of *P. infestans* in Europe. Different dose rates may be approved in different countries.

Whilst every effort has been made to ensure that the information is accurate, no liability can be accepted for any error or omission in the content of the tables or for any loss, damage or other accident arising from the use of the fungicides listed herein. Omission of a fungicide does not necessarily mean that it is not approved for use within one or more EU countries.

The ratings are based on the label recommendation for a particular product. Where the disease pressure is low, intervals between spray applications may be extended and, in some countries, fungicide applications are made in response to nationally issued spray warnings and/or Decision Support Systems. It is essential therefore to follow the instructions given on the approved label of a particular blight fungicide appropriate to the country of use before handling, storing or using any blight fungicide or other crop protection product.

Table 1. The effectiveness of fungicide products for the control of *P. infestans* in Europe. These ratings are the opinion of the Fungicides Sub-Group (independent scientists and representatives from the crop protection industry) at the Tallinn late blight workshop, 2005 and are based on field experiments and experience of the products performance when used in commercial conditions.

Product ¹	Effectiveness				Mode of Action			Rain-fastness	Mobility in the plant
	Leaf blight	New growth	Stem blight	Tuber blight	Protectant	Curative	Anti-sporulant		
benthiavalicarb+mancozeb	+++	?	+(+) ⁴	+(+)	+++	+(+)	+	++(+)	translaminar+contact
chlorothalonil	++	?	(+)	0	++	0	0	++(+)	contact
copper	+	?	+	+	+(+)	0	0	+	contact
cyazofamid	+++	?	+	+++	+++	0	0	+++	contact
dithiocarbamates ²	++	?	+	0	++	0	0	+(+)	contact
famoxadone+cymoxanil	++	?	+(+)	N/A	++	++	+	++(+)	contact+translaminar
fluazinam	+++	?	+	++(+)	+++	0	0	++(+)	contact
zoxamide+mancozeb	+++	?	+ ⁴	++	+++	0	0	++(+)	contact+contact
cymoxanil+mancozeb, metiram or copper	++(+)	?	+(+)	0	++	++	+	++	translaminar+contact
dimethomorph+mancozeb	++(+)	?	+(+)	++	++(+)	+	++	++(+)	translaminar+contact
fenamidone+mancozeb	++(+)	?	+(+) ⁴	++	++(+)	0	+(+) ⁴	++	translaminar+contact
benalaxyl+mancozeb ³	++	++	++	N/A	++(+)	++(+)	++(+)	+++	systemic+contact
metalaxyl-M + mancozeb or fluazinam ³	+++	++	++	N/A	++(+)	++(+)	++(+)	+++	systemic+contact
propamocarb-HCl+fenamidone, or +mancozeb, or +chlorothalonil	++(+)	+(+)	++	++	++(+)	++	++	+++	systemic+translaminar or +contact

Table 2. Provisional ratings for the effectiveness of new fungicide products /co-formulations for the control of *P. infestans* in Europe. These ratings are the opinion of the Fungicides Sub-Group at the Tallinn late blight workshop, 2005 and are based on field experiments and (very) limited experience under commercial conditions.

Product ¹	Effectiveness				Mode of Action			Rainfastness	Mobility in the plant
	Leaf blight	New growth	Stem Blight	Tuber blight	Protectant	Curative	Anti Sporulant		
fluopicolide+propamocarb-HCl	+++	+(+)	++	++(+)	+++	++	++(+)	++(+)	translaminar + systemic

¹ The scores of individual products are based on the label recommendation and are NOT additive for mixtures of active ingredients. Inclusion of a product in the list is NOT indicative of its registration status either in the EU or elsewhere in Europe.

² Includes maneb, mancozeb, propineb and metiram..

³ See text for comments on phenylamide resistance. ⁴ Based on limited data.

Key to ratings : 0 = no effect ; + = reasonable effect ; ++ = good effect ; +++ = very good effect ; N/A = not recommended for control of tuber blight; ? = no experience in trials and/ or field conditions.

Early blight – *Alternaria solani* & *Alternaria alternata*

Problems have been experienced in some countries with the early blight disease complex caused by *Alternaria spp* (*A. solani* and *A. alternata*). Under field conditions, it is not possible to distinguish symptoms caused by the different species although differences in fungicide effects have been recorded when tested in laboratory conditions. There may be differences in fungicide performance against the two species under field conditions, but currently there are insufficient data to give separate ratings. The ratings are based on fungicides used according to the principles of Good Agricultural Practice (GAP) i.e. at the rates and water volumes recommended on the label and the application timings for control of late and/or early blight. In future, data on fungicide activity against the *Alternaria* complex should be generated according to a standard protocol and GAP. Members of the subgroups agreed to draft a suitable protocol.

The information that is available on the efficacy of (late blight) fungicides against this disease complex is presented Table 3. The rating in Table 4 is for products which do not have a registration for control of *Alternaria* and is based on field experiments and very limited experience.

Table 3. Efficacy of fungicides for the control of early blight caused by *Alternaria solani* and *Alternaria alternata*.

Product	Efficacy ¹
azoxystrobin	+++
fluazinam	(+)
metiram/mancozeb ²	++
propineb	++
chlorothalonil	+(+)
famoxadone+cymoxanil	++
fenamidone+mancozeb	++
or propamocarb ³	
zoxamide+mancozeb	++(+)

Table 4. Efficacy of new fungicides for the control of early blight caused by *Alternaria solani* and *Alternaria alternata*. The product(s) listed do not yet have a registration for this use.

Product	Efficacy ¹
pyraclostrobin+boscalid	+++

¹ Key to ratings : 0 = no effect ; + = some effect; ++ = reasonable effect ; +++ = good effect ; ++++ very good effect

² This rating applies to mancozeb containing products when used at the highest dose rates (>1500g/ha). Where less than this rate of mancozeb is used, this rating may not be appropriate particularly where the second active substance is not effective against *Alternaria*.

³ In some trials there were indications that the rating was ++(+)

Comparison of Atmospheric Dispersion Models for the Short-Range Transport of *Lycopodium clavatum* Spores Above a Potato Canopy

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Introduction

A modern disease forecasting system may offer spray recommendations by considering if the historical and forecasted weather conditions are suitable for the development of new disease. Estimation of risk is based at the proportion of a crop that is likely to be unprotected, both in terms of the growth of new leaves and the wear-off and degradation of previous chemical applications. However, little or no consideration is given to spore dispersal processes, despite the fact that over the last 30 years, stricter environmental regulations and the availability of personal computers have fuelled an immense growth in the development and use of mathematical models to predict the dispersal of airborne particles. Prediction of the risk posed to potato fields by distant sources of inoculum could, therefore, become an innovative component of decision support systems for potato late blight control. Atmospheric dispersal models can be categorized on many grounds, e.g. on the spatial scale (global, mesoscale, local), on the temporal scale (episodic models, (statistical) long-term models), on the mathematical formulation (Lagrangian, Eulerian models), on the treatment of various processes (wet and dry deposition, chemistry) and on the complexity of the approach. Relatively few of these dispersion models have been applied in plant pathology (e.g. Aylor, DE, 1998, Jong, MD de *et al.*, 2002 and Spijkerboer, HP *et al.*, 2002) so there is clearly potential for exploration of the suitability of dispersion modeling as a tool to enhance our understanding and predictive capacity of spore dispersal processes and potentially develop them into components in advisory systems for disease management.

Theory

An atmospheric dispersion model is a mathematical simulation of the physics and chemistry governing the transport, deposition and transformation of pollutants/particles in the atmosphere and is a means of estimating downwind air concentrations given information about sources and the nature of the atmosphere. Dispersion models can take many forms and Gaussian plume models (GPM's) are arguably the most widely used, well understood, and easy to apply. GPM's describe the advection of a cloud of particles or gas with the mean wind direction. As the cloud moves further away from the source it spreads outwards and upwards due to the influence of turbulent motions of air. Gaussian distributions are used to describe the shape of spore plumes in the horizontal and vertical directions. The exact width of the plume and the attendant dilution of particle concentration are dependent on the intensity of turbulence in the atmosphere. There are many different parameterization schemes available for GPM's and these differ in the way they characterize the amount of turbulence in the atmosphere and therefore in the expressions used to determine the height and width of these Gaussian distributions. The KNMI and Turner GPM's use parameterization schemes based on a discrete classification of turbulence in the atmosphere by F Pasquill, 1962. A continuous scaling of turbulence is used by GI Taylor, 1921. The fourth parameterization of the GPM we used in this study is called OPS-ST (Operational Priority Substances Short Term). The OPS-ST model is a hybrid model, combining a GPM for horizontal spread with a K-model for vertical spread. The K-theory, or gradient transport theory treats turbulent mixing in a similar manner to molecular diffusion, only much more powerful. The K-model allows for dampening of turbulence near the surface of the ground and allows for the influence of larger and larger eddies of turbulent air (more intense mixing) as the plume grows in height.

Approach

The data set used to test the models was collected over the course of a summer (Spijkerboer *et al.*, 2002). Dried fern spores were released over a potato canopy during 10 minute release sessions. Spore concentrations in the air were measured using two Burkhard 7-day spore samplers and 10 Rotorod spore traps at distances of up to 100m from the source. Spore traps were mounted on wooden masts, which were placed in a grid system of pre-dug holes. Up to four traps were mounted on a pole in order to gain additional measurements of the vertical profile of spores. The wind direction determined the configuration of source and spore traps.

We assessed the goodness of fit of model predictions with data from ten of these measurement sessions.

Results and discussion

Figure 1 shows the results for OPS-ST and Table 1 summarizes preliminary results obtained for all four parameterizations.

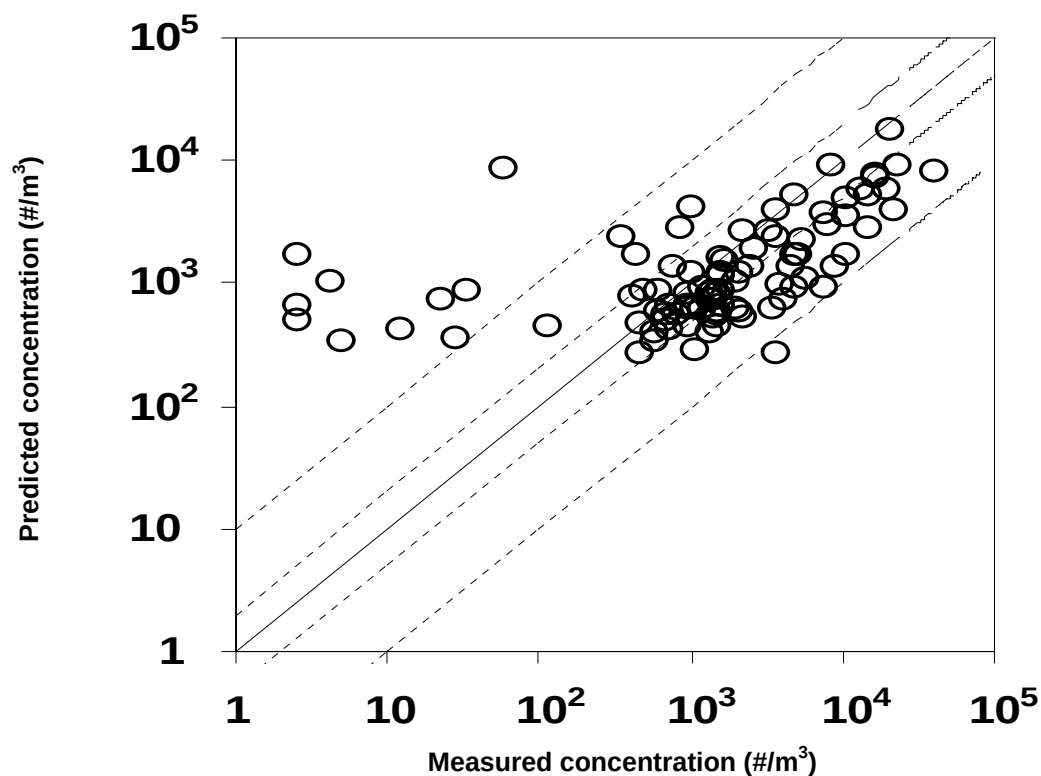


Figure 1. Modeled versus measured spore concentrations for OPS-ST. The outer dashed lines mark the limits of a prediction error of factor 10, the inner dashed lines a prediction error of factor 2, and the solid line is the 1 to 1 line.

Table 1. Quantitative assessment of dispersion model predictions. (n=10)

	KNMI	Turner	Taylor	OPS-ST
Number of overpredictions	80	84	82	39
Number of underpredictions	40	36	38	81
Mean factor of prediction error	9.97	12.91	7.98	4.32

It is immediately clear from the prediction error factors given in the final row of Table 1 that the two parameterizations containing the most atmospheric physics, i.e. the Taylor GPM and OPS-ST, outperform the two models that utilize empirical parameterization schemes, i.e. the KNMI and Turner GPM's. OPS-ST turned out to be the most accurate of the four models tested; the tight clustering of data points around the 1 to 1 line in Fig. 1 visually demonstrates the accuracy of this model. In the near future we aim to improve on short range modelling and to develop a model for spore survival during transportation and link these together. We believe that such a tool for predicting atmospheric disease pressure could prove to be very useful to the makers of DSS.

References

- Aylor, DE*, 1998. The aerobiology of apple scab. *Plant Disease* 82(8):838-849.
- Jong, MD de, GW Bourdôt, GA Hurrell, DJ Saville, HJ Erbrink and JC Zadoks*, 2002. Risk analysis for biological weed control – simulating dispersal of *Sclerotinia sclerotiorum* (Lib.) de Bary ascospores from a pasture after biological control of *Cirsium arvense* (L.) Scop. *Aerobiologia* 18(3-4): 211–222.
- Spijkerboer, HP, JE Beniers, D Jaspers, HJ Schouten, J Goudriaan, R Rabbinge and W van der Werf*, 2002. Ability of the Gaussian plume model to predict and describe spore dispersal over a potato crop. *Ecological Modeling* 155: 1–18.
- Pasquill, F*, 1962. *Atmospheric Diffusion*. Van Nostrand, New York. pp.429.
- Taylor, GI*, 1921. Diffusion by continuous movements. *Proc. Roy. Soc. Ser. A*20, 196-211.

French DSS MILPV : Tool for Monitoring Late blight susceptibility of varieties

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Summary

The DSS MILPV uses the susceptibility of the varieties: departure and speed of the epidemic. This DSS gave good results in 2005, even with a very severe disease. It is useful to collect field information.

Keywords: Late blight, Decision Support System, scouting, variety susceptibility

Some Remind of the DSS

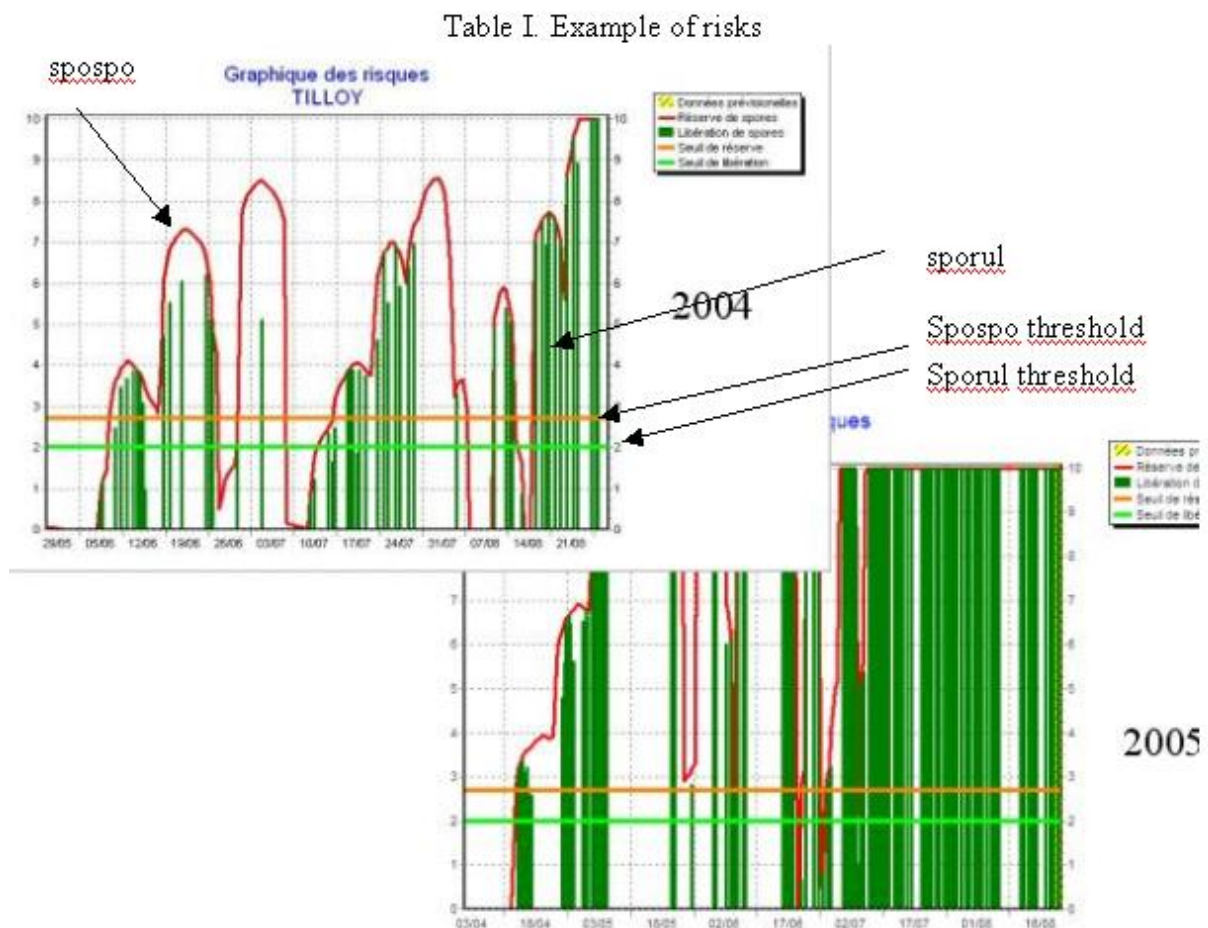
1) Two main topics

- To inform growers :
 - To help growers to control the late blight for each field.
 - To give a lot of information about other pathogens and evolution of regulation, so the publications of the Warning System are joined.
- To increase the number of observations in fields and around them and share this information with the Plant Protection Service and the other growers.

2) There are many tools and methods to build the advice for each field

- Weather data are automatically downloaded from a network of meteorological station each day.
- Each day the data of weather forecast (for 3 days ahead) are introduced.

- A software introduces automatically the data (H° , T° , rain) in epidemiological models (Guntz Divoux and Milsol) and computes the risks.
- The observations on fields (growth of the crop, all diseases and pests, physiological symptoms) and crops surrounding (dumps, volunteers, gardens, organic crops...) are done by PPS technicians and partners (growers, professional technicians...).
- All this information is downloaded on grower computer by the DSS via internet.
- The grower introduces the data of each field: identification, variety, agronomic techniques, stage, observations on the field and surrounding, last spray (product and dose), last and future irrigation, rain.
- The PPS uploads all epidemiological risks and observations to a server on Internet. (Example of risks table I).



- Growers can download risks of the nearest meteorological station of the farm.

- The DSS works with the epidemiological risks and the data of the grower, and gives advices, date of spray and type of fungicide, for each field (Cf example of screen table II).
- Growers can download from Internet all data of the Warning System (regulation, advices map, advices on other enemies...).
- The observations given by the growers can be used by the Plant Protection Service to know the evolution of the disease in each area and to do the monitoring of the strains of *Phytophthora infestans*.

Remark: a third partner can participate: the collector of potatoes, or the technician of the group of growers:

- This one can collect the data of Plant Protection Service on Internet.
- He can put his own data and send them to PPS and to the grower, he can give some information to each grower.
- He can, if the grower authorises, catch the observations and the sprays of the grower.

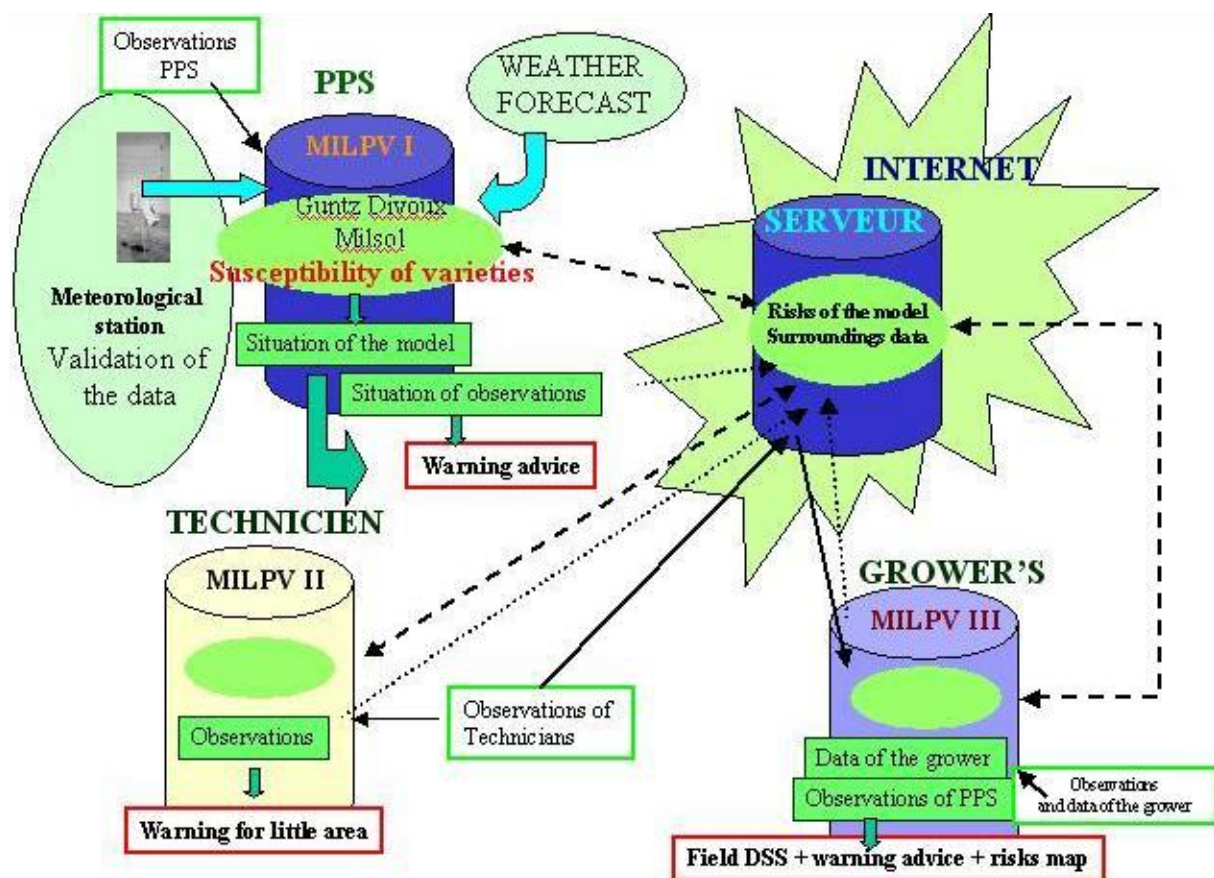


Table II. Example of screen of advice the 7th July 2005.

Récapitulatif des conseils de l'exploitation

à la date du 07/07/2005

Groupe St Pol

Parcelle3 : En fonction de vos traitements aucune intervention n'est à réaliser le 07/07/2005.

Si les prévisions météorologiques se confirment, traiter le 08/07/2005 avec un Contact Elaboré ou un Diffusant

Produits de votre exploitation correspondant :

ACROBAT M DG, SAGAIE, SERENO

Les produits suivants ne peuvent être utilisés à cause de leur limitation du nombre d'application : ACROBAT M DG

Groupe Gomiecourt

Parcelle1 : En fonction de vos traitements aucune intervention n'est à réaliser le 07/07/2005.

Selon les prévisions météorologiques, aucun traitement ne se justifie jusqu'au 10/07/2005.

Connectez-vous régulièrement pour confirmation des prévisions.

Parcelle2 : Un traitement était préconisé le 06/07/2005.

Pour rattraper le retard de traitement, traiter le 07/07/2005 avec un Pénétrant

Translation:

Farm Saint Pol field 3:

According to the previous treatments, no spray needed on the 07/07/05.

If the weather forecast data will be confirmed, you will have to spray on 08th of July with a high level protectant fungicide or diffusant fungicide.

On your farm you have Acrobat MDG, Sagaie, Sereno but according to the registration rules your cannot use Acrobat M because you sprayed it 3 times before.

Farm Gomiecourt field 1:

According to the previous treatments, no spray needed on the 07/07/05.

If the weather forecast data will be confirmed, no spray has to be done until 10th of July but connect us each day to have information.

Farm Gomiecourt field 2:

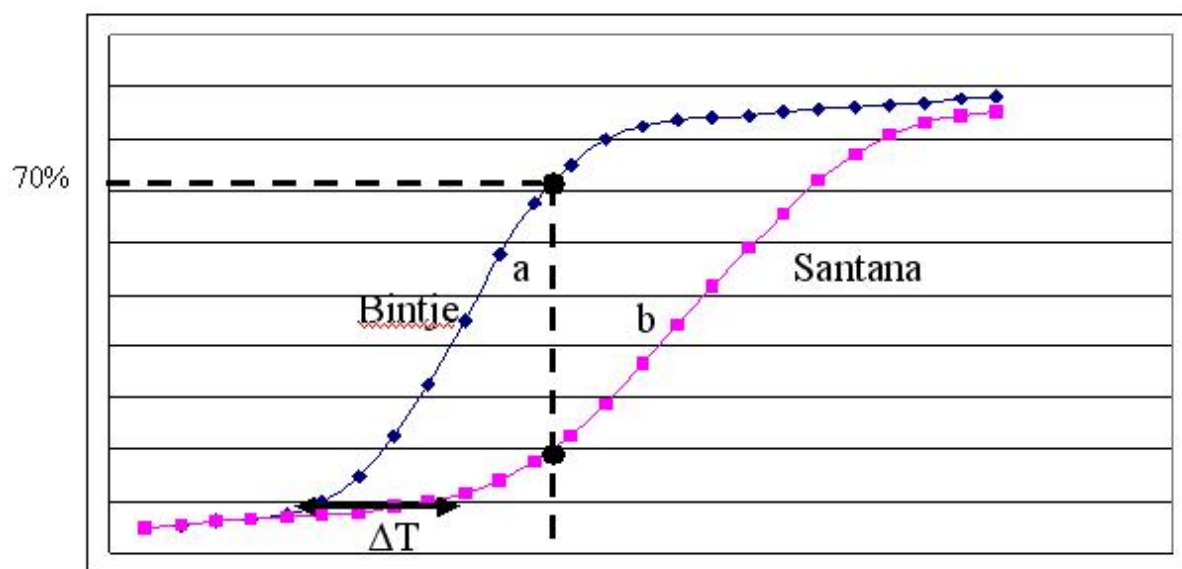
A treatment was advised for the 06th of July, you did not spray, so you have to spray today with a retroactive fungicide (fungicide with cymoxanil).

How we use late blight susceptibility

Two criteria are used:

- The delay of the beginning of the epidemic of the variety compared with bintje.
- The speed of the epidemic , in fact we use the value of the destruction of the variety when bintje is destroyed à 70 % (Cf table III)

Table III. Late blight susceptibility of varieties



ΔT : delay of the beginning of the epidemic

$a > b$: different speeds of the epidemics

The data are obtained from:

- Trials of 12 plants minimum.
- Official list
- Eucablight data
- Scouting of fields and observations of the growers by MILPV, particularly to discover very quickly a change in susceptibility of the variety.

The criteria are:

- First spray with Guntz Divoux

Susceptibility	Example of varieties	First spray at the
Very susceptible	agata, bintje, isabelle, romano	3rd generation
Intermediate	amandine, charlotte, producent, lady clair	4th generation
Resistant	bondeville, naturella, santana	5th generation
Very resistant	eden, kardal	6th generation

➤ Threshold of spray with Milsol

	Spospo	Sporul
Very susceptible	> 2,7	> 2
Intermediate	> 4	> 3
Resistant	> 5	> 4
Very resistant	< 6	> 5

Spospo : potential sporulation - Sporul sporulation

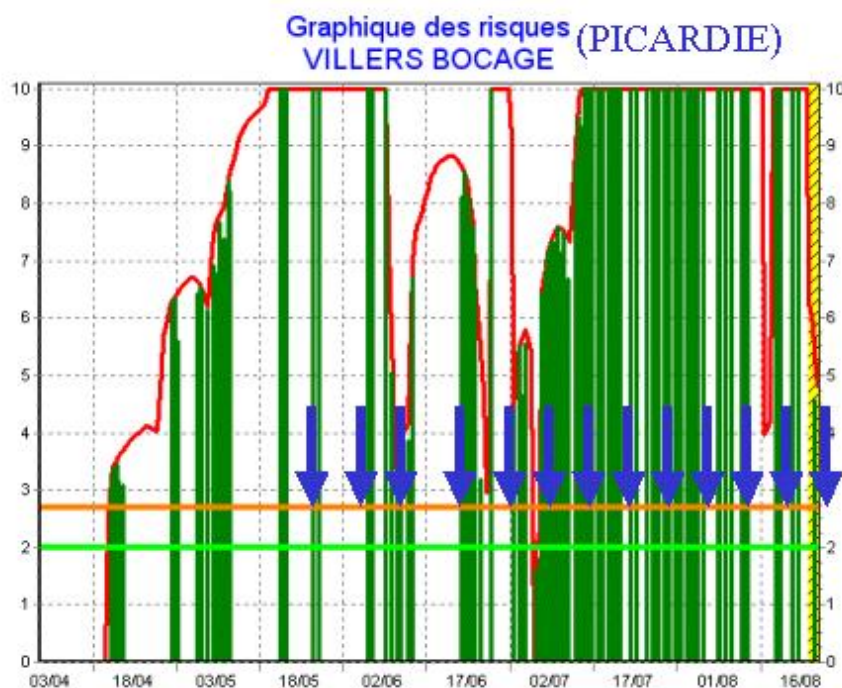
Some results of 2005

In France more than 200 growers have used MILPV in 2005.

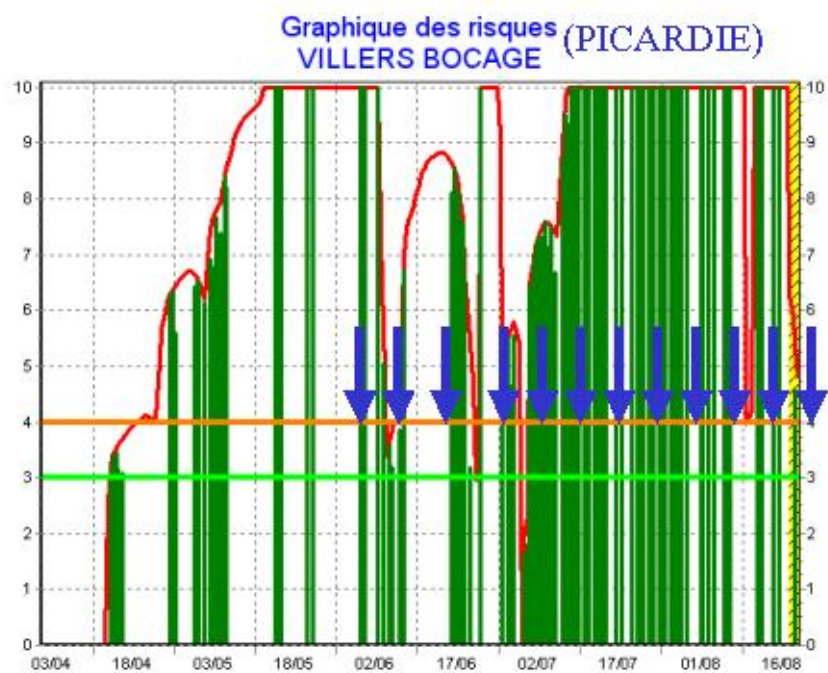
The disease was very severe in North of France, the DDS forecasted correctly the epidemic. A lot of fields with susceptible varieties showed some symptoms at the end of July and beginning of august but the big problems have been rare.

We succeeded to decrease the number of sprays at mid June, but it was impossible to decrease the sprays in July even on less susceptible varieties.

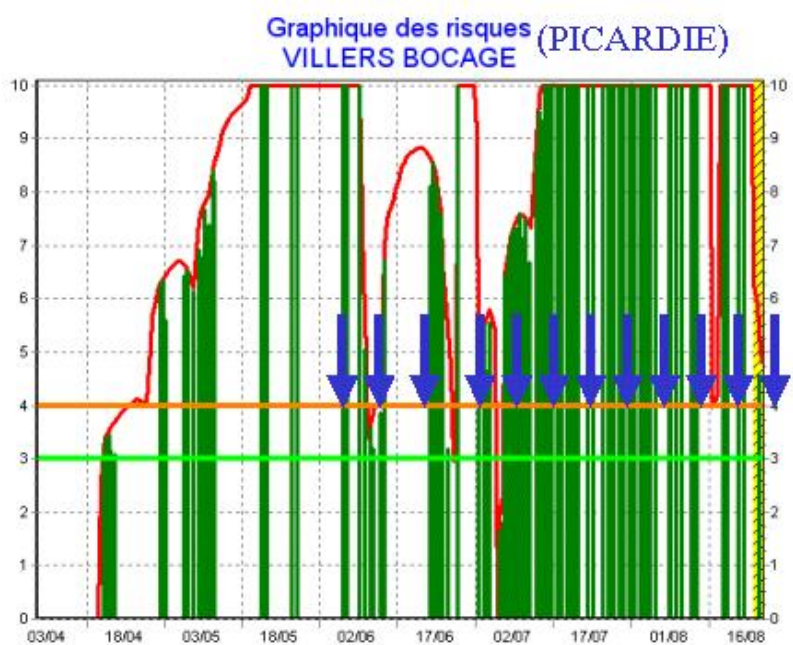
Sprays advised by MILPV on susceptible variety : 13



Sprays advised by MILPV on intermediate variety : 12



Sprays advised by MILPV on resistant variety : 11



What about the resistance ?

We know that the resistance is due to Rgene and we know that there is an erosion and sometime a sudden fall of this resistance.

How to discover these evolutions and to inform very quickly the growers ?

Until now we use data of different sources :

- Trials with the common varieties in different regions set up by the regional Plant Protection Services.
- Trials of other partners :
 - Research program of INRA on the erosion.
 - Trials of FREDON (Regional Federation to control the pests), Arvalis Institut, Mc Cain...
- Scouting of Plant Protection Service.
- Information given by the growers via MILPV DSS

For example : one trial of Arvalis has shown the fall down of the variety Eden in the center of France. The very high susceptibility of Lady clair was observed by the scouting of Plant Protection Service and by MILPV. So we have changed the class of susceptibility immediately by internet. The erosion of Santana has been observed in trials of FREDON and PPS in North of France and we study the possibility to "downgrade" this in some regions.

Conclusions

- MILPV is very useful to advise the growers.
- MILPV is very useful to collect a lot of observations and information.
- MILPV has forecasted correctly the very severe epidemic in 2005 and has succeeded in the majority of the fields.
- According to this difficult campaign in North of France we did (in August, just after the period of high epidemic) a survey on the 200 growers who have subscribed MILPV.
- Around 25 % answered the survey :
 - 72% want to continue with MILPV
 - 22% don't know
 - only 6% want to give up the DSS

Exploiting potato late blight cultivar resistance using DSS's: 4 years of field experiments

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Summary

Dutch commercial DSS's for control of potato late blight generally perform well. A project was carried out to further exploit differences in cultivar resistance to potato late blight to reduce the fungicide input. Purpose built experimental versions of PLANT-Plus and ProPhy were compared with their commercial versions and a WUR system that uses fixed Shirlan reduced dose rates on more resistant cultivars. The date of first spray was mostly not affected for the different cultivars. Date of first observation of potato late blight symptoms was relatively late in the high resistant cultivar Aziza, but relatively early in the high resistant cultivar Karnico. With the cultivars Seresta and Aziza it was very well possible to strongly reduce the dose of Shirlan (fluazinam, 500 g/l) except at the end of the growing season. Often the current resistance figures according to the Dutch variety list seemed not to be appropriate.

Keywords: *Phytophthora infestans*, cultivar resistance, decision support systems, potato late blight, fluazinam, reduced dose rate

Introduction

The DSS's PLANT-Plus (Dacom PLANT-Service B.V.) and ProPhy (Opticrop B.V.) are well known tools for controlling potato late blight (PLB) in potatoes. Although cultivar resistance is used in DSS recommendations, recent research has shown that higher levels of PLB resistance can be used to even further reduce the input of protectant fungicides. In a series of

field experiments, experimental versions of PLANT-Plus and ProPhy, purpose built to further exploit cultivar resistance, were compared to their respective commercial versions and a system (WUR dose rate) in which more resistant cultivars were sprayed with a fixed (reduced) Shirlan dose rate.

The work focused on maximum exploitation of differences in cultivar resistance, not on comparing DSS performance. Two approaches to reduce the fungicide input were used: flexible longer spray intervals and/or (flexible) reduced Shirlan dose rates.

Materials and Methods

A total of eight trials was carried out in the Netherlands from 2002 – 2005. Two trials were conducted each year, one trial on a clay soil at Lelystad and one trial on a sandy reclaimed peat soil at Valthermond. Trials were set up as randomized block experiments with three replications.

DSS's in the trials were: PLANT-Plus, PLANT-Plus-experimental (2003 - 2005), ProPhy, ProPhy-experimental (2003 - 2005) and WUR dose rate, a schedule using fixed combinations of cultivar and Shirlan dose rate (table 1). Spray timing of the WUR dose rate system was based on SIMCAST/WUR-blight (Wander *et al.*, 2003) in 2002 and on PLANT-Plus in all other years. WUR dose rate applied only Shirlan whereas recommendations from the other DSS's advices concerning type of fungicide and timing were followed up. DSS's were applied as described by Spits *et al.*, 2004. For ProPhy spray timing was determined by recommendations for the most susceptible cultivar. Thus all cultivars were sprayed at the same time with (potentially) different dose rates. PLANT-Plus mainly used cultivar resistance to increase the spray interval on the more resistant cultivars.

Cultivars included in the experiments (foliar resistance rating in brackets) were:

- Lelystad: Bintje (3), Santé (4½), Agria (5½), Remarka (6½) (only 2002) and Aziza (7½);
- Valthermond: Bintje (3) and starch potato cultivars Starga (5½), Karakter (6) (2002 only), Seresta (7) and Karnico (8).

Trials were monitored for PLB symptoms every week. A cumulative index of infected leaflets was calculated for each combination of cultivar and DSS by adding up the number of observed stem infections*20 + number of petioles*5 + the number of leaflets over an entire growing season.

The fixed Shirlan dose rates used by the WUR dose rate system are given in Table 1.

Table 1. Shirlan dose rates (l/ha) per cultivar for the WUR dose rate system.

Lelystad			Valthermond		
Cultivar	2002	2003-2005	Cultivar	2002-2004	2005
Bintje	0.40	0.40	Bintje	0.40	0.40
Santé	0.32	0.24	Starga	0.32	0.32
Agria	0.24	0.32	Karakter	0.24	
Remarka	0.16		Seresta	0.16	0.16
Aziza	0.08	0.08	Karnico	0.08	0.24

Results

An overview of the results is given for 2003 – 2005 when all commercial and experimental systems were incorporated in the field experiments. The parameters used are the average number of sprays per season (2003 – 2005) for each location, cultivar and DSS, the average dose rate of the protectants applied and the cumulative index of infected leaflets, a cumulative measure for disease severity throughout the growing season. Results summarizing the spray events and their results for Lelystad and Valthermond are given in Table 2 and Table 3 respectively.

From table 2 it is clear that PLANT-Plus is using cultivar resistance to increase the spray interval. Prophy is using increased spray intervals in combination with reduced dose rates. The WUR dose rate system is only using reduced dose rates but in a much more extreme fashion than Prophy. In general, PLANT-Plus experimental uses 1 – 4 spray applications less on more resistant cultivars than its commercial version. ProPhy experimental also recommends 1- 4 sprays less than its commercial version. The WUR dose rate system uses the same number of sprays on all cultivars but the dose rate on the more resistant cultivars is strongly reduced. Overall, expressed as the number of Shirlan full dose rate equivalent sprays, the WUR dose rate system uses less than 50% of the input on resistant cultivars as compared to susceptible cultivars. Both, ProPhy and PLANT-Plus reduce the fungicide input by 30-40% on more resistant cultivars.

When we look at Table 3 to see whether this reduction of fungicide input was justified, first

we see big differences between years and locations. When we look closer at differences within trials, in 2003 at Valthermond, more blight was observed in Karnico for both, PLANT-Plus exp and Prophy exp. In 2004, and to a lesser extend in 2005, Karnico is severely blighted again in all systems. This effect is further illustrated by Figure 1 where severity is plotted against time for four cultivars under the WUR dose rate system in 2004. Despite its high resistance rating (an eight for foliar blight), Karnico is severely attacked and the plots had to be desiccated prematurely.

In general, the reduced input systems significantly reduced the fungicide input per season although they generally result in slightly more blight than the standard systems. Exceptions are e.g. PLANT-Plus on Karnico and ProPhy on Starga in 2005 where the reduced input systems performed slightly better.

Based on the detailed results of the trials it can be stated that for the cultivar:

- Santé (4½) a lower dose (-10%) and a larger interval is possible as compared to Bintje;
- Agria (5½) should be treated with an equal or higher input as compared to Santé;
- Remarka (6½) should be treated as a low resistant cultivar, specifically end of season;
- Aziza (7½) except at end of season a very low dose protects the cultivar;
- Starga (5½) compared to Bintje the cultivar should be treated the same;
- Karakter (6) compared to Bintje the cultivar should be treated the same;
- Seresta (7) a lower dose (more than 0.16 l/ha Shirlan) or a larger interval is possible;
- Karnico (8) despite its high resistance rating, no possibilities for a lower dose or a larger interval.

Conclusions

- Some of the current cultivar resistance figures are not appropriate for DSS purposes.
- Shirlan dose rates can be reduced at higher resistance levels.
- Interval can be enlarged at higher resistance levels.
- The experimental systems performed well despite the fact that they were meant to maximally reduce the fungicide input.
- More research is necessary to set up resistance specific advices for all cultivars.

Table 2. Average number of sprays and average dose rates applied in Lelystad during the period 2003 - 2005. Curative sprays encompass Curzate M and Tattoo C applications and were always carried out at the 100% dose rate.

Lelystad	Location	Cultivar	Average number of sprays		Shirlan Dose rate	Full dose equivalents Shirlan
			Shirlan	Curative		
PLANT-Plus	Lelystad	Bintje	9.0	0.0	0.4	9.0
	Lelystad	Santé	9.3	0.0	0.4	9.3
	Lelystad	Agria	8.3	0.7	0.4	8.3
	Lelystad	Aziza	8.7	0.3	0.4	8.7
PLANT-Plus exp.	Lelystad	Bintje	8.0	0.7	0.4	8.0
	Lelystad	Santé	6.7	0.3	0.4	6.7
	Lelystad	Agria	6.7	0.3	0.4	6.7
	Lelystad	Aziza	5.7	0.3	0.4	5.7
ProPhy	Lelystad	Bintje	11.7	1.0	0.4	11.6
	Lelystad	Santé	11.7	1.0	0.4	11.3
	Lelystad	Agria	11.3	1.3	0.4	11.2
	Lelystad	Aziza	12.7	0.0	0.3	9.7
ProPhy exp.	Lelystad	Bintje	11.7	0.0	0.4	10.6
	Lelystad	Santé	10.0	0.0	0.3	8.0
	Lelystad	Agria	10.3	0.0	0.3	8.2
	Lelystad	Aziza	8.7	0.0	0.3	5.7
WUR dose rate	Lelystad	Bintje	9.0	0.0	0.4	9.0
	Lelystad	Santé	9.0	0.0	0.2	5.4
	Lelystad	Agria	9.0	0.0	0.3	7.2
	Lelystad	Aziza	9.0	0.0	0.1	1.8
PLANT-Plus	Valthermond	Bintje	11.0	0.3	0.40	11.0
	Valthermond	Starga	11.3	0.0	0.40	11.3
	Valthermond	Seresta	10.0	1.0	0.40	10.0
	Valthermond	Karnico	10.0	0.7	0.40	10.0
PLANT-Plus exp.	Valthermond	Bintje	9.0	0.7	0.40	9.0
	Valthermond	Starga	9.3	0.0	0.40	9.3
	Valthermond	Seresta	6.0	1.3	0.40	6.0
	Valthermond	Karnico	6.7	1.0	0.40	6.7
ProPhy	Valthermond	Bintje	11.7	0.0	0.40	11.6
	Valthermond	Starga	11.7	0.0	0.39	11.4
	Valthermond	Seresta	11.7	0.0	0.33	9.7
	Valthermond	Karnico	11.7	0.0	0.36	10.5
ProPhy exp.	Valthermond	Bintje	10.7	0.0	0.36	9.7
	Valthermond	Starga	10.7	0.0	0.35	9.4
	Valthermond	Seresta	9.0	0.0	0.33	7.5
	Valthermond	Karnico	8.0	0.0	0.30	6.0
WUR dose rate	Valthermond	Bintje	10.7	0.0	0.40	10.7
	Valthermond	Starga	10.7	0.0	0.32	8.5
	Valthermond	Seresta	10.7	0.0	0.16	4.3
	Valthermond	Karnico	10.7	0.0	0.13	3.6

Table 3. Cumulative index of infected leaflets as a measure of the protection level provided by the different DSS's at two locations during the period 2003 – 2005.

		Valthermond				Lelystad			
		Bintje	Karnico	Seresta	Starga	Bintje	Agria	Aziza	Santé
2003	WUR dose rate	0.0	0.3	0.0	0.0	0.01	0.01	0.33	3.67
2003	Plant-Plus	0.0	0.0	1.3	0.0	0.01	0.01	0.01	0.01
2003	Plant-Plus exp	0.0	38.7	8.0	1.7	0.01	0.01	0.01	0.01
2003	ProPhy	0.0	0.3	0.0	0.7	0.30	0.01	0.01	0.01
2003	ProPhy exp	7.0	11.7	0.0	23.0	0.01	0.01	0.01	5.00
2004	WUR dose rate	597	5759	579	554	1	26	844	9
2004	Plant-Plus	413	2213	63	987	3	5	1	0
2004	Plant-Plus exp	527	3103	69	1536	2	45	5	2
2004	ProPhy	623	1695	229	305	1	11	1	0
2004	ProPhy exp	257	3423	154	255	1	32	32	2
2005	WUR dose rate	6	776	2	41	118.0	105	71.7	98.0
2005	Plant-Plus	2	226	3	2	145.0	47.3	10.0	43.0
2005	Plant-Plus exp	0	173	10	19	244.3	127.3	87.7	20.7
2005	ProPhy	3	68	1	18	55.3	10.3	11.0	7.7
2005	ProPhy exp	6	98	3	8	117.0	24.7	11.0	68.0

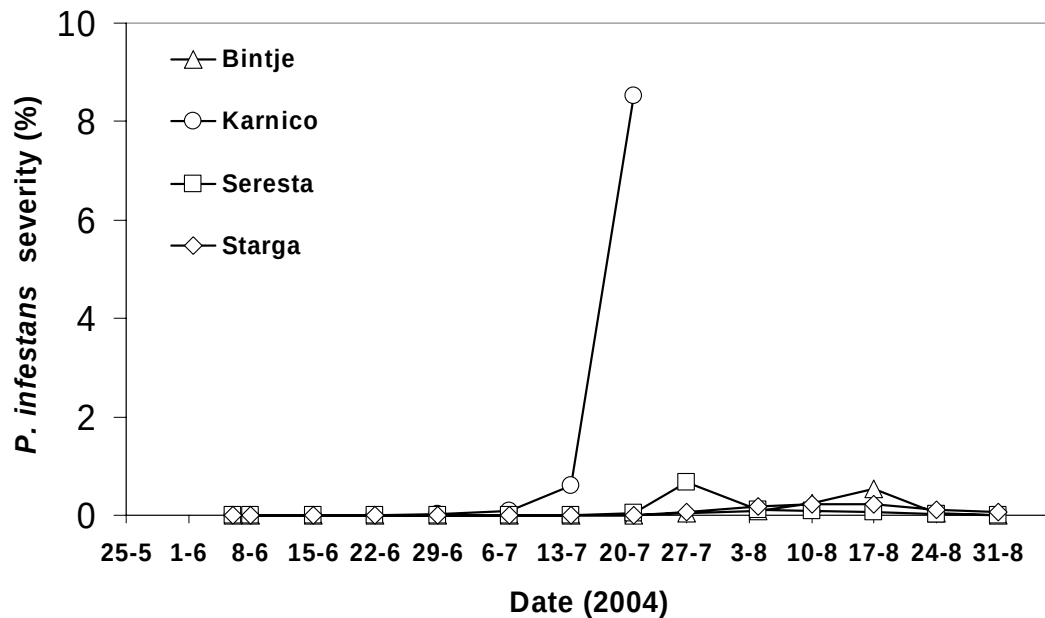


Figure 1. The time course of *P. infestans* severity for four cultivars under the WUR dose rate system in Valthermond in 2004.

References

- Spits HG, JGN Wander and GJT Kessel*, 2004 DSS development focussed on variety resistance in The Netherlands, 2003. Proceedings of the Eight Workshop of an European network for development of an integrated control strategy of potato late blight, Jersey, England-France, 31st March - 4th April 2004; PPO-Special Report no 10; ed CE Westerdijk and HTAM Schepers 10: 215-222
- Wander JGN, HG Spits and GJT Kessel*, 2003 DSS field evaluation focussed on variety resistance in The Netherlands, 2002. Proceedings of the Seventh Workshop of an European network for development of an integrated control strategy of potato late blight, Poznan, Poland, 2 - 6 October 2002; PPO-Special Report no 9; ed CE Westerdijk and HTAM Schepers 9: 121-132

Use of Geographic Information Systems in warning Service for Late Blight

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Abstract

One of the important aims of the German Crop Protection Services (GCPS) is to reduce spraying intensity and to guaranty a friendly crop protection strategy. ZEPP is the central institution in Germany responsible for the development of methods to give the best control of plant disease, so far more than 20 met. data-based models were developed and introduced into practice (Kleinhenz 2001, Racca, *et al.* 2001). This study should show that it is possible to get results with higher accuracy for the models by using Geographic Information Systems (GIS). The influence of elevation, slope and aspect on met. data will be interpolated with GIS and the results were used as input for the forecasting models. The results will be presented as spatial risk maps in which areas of maximum risk and the allocation of the disease are displayed. The modern presentation methods with GIS will help to use the system and to get a higher acceptance by the users.

Introduction

During the last 40 years a lot of weather based forecasting models have been developed to give control for Late Blight (Kleinhenz and Jörg, 2000). Two of these forecasting models SIMPHYT1 and SIMPHYT3 have been established to give the best control of Late Blight in Germany (Gutsche 1999, Gutsche, *et al.* 1999, Hansen, *et al.* 2002, Kleinhenz and Jörg 1999, Kleinhenz and Jörg 2000, Roßberg, *et al.* 2001). SIMPHYT1 calculates the first appearance and SIMPHYT3 calculates the infection pressure for Late Blight.

In the future a combination of the current forecasting models SIMPHYT1 and SIMPHYT3 with analysis and methods from the Geographic Information Systems (GIS) should help to get better forecasting results for local areas between two or more met. stations. Through the use of GIS daily spatial risk maps will be built in which the spatial and the temporal process of the first appearance and the development of Late Blight is documented. That will help to give the best control for Late Blight and will reduce the fungicide intensity. To reach this aim it is necessary to prepare the parameters (meteorological, geomorphologic and plot specific parameters) of the forecasting models with a spatial index (Zeuner 2003). Also, complex statistical interpolation methods are needed. With the result of these interpolations it is possible to calculate the current forecasting models SIMPHYT1 and SIMPHYT3. The results of SIMPHYT1 will be represented as a spatial map, showing the first appearance of Late Blight. Also the result of SIMPHYT3 will be represented as a spatial map showing the plot specific infection pressure of Late Blight for each area in Germany. The results of these computations will be put interactive into an internet application to give the farmers and the advisers a comfortable access to the system.

Fig. 1 and 2 show the difference between the current and the new decision warning maps by the example of “Rhineland-Palatinate” in Germany.



Figure 1. The old presentation indicates the prognosis results at the weather stations with coloured clouds.
(source: www.isip.de)

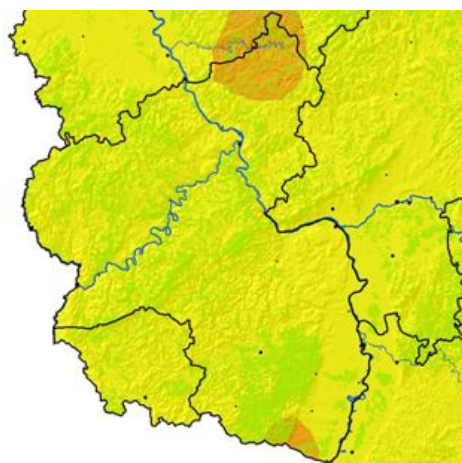


Figure 2. The future new presentation.

Material & Methods

To reach the aims six steps are needed. The first three steps deal with data management. Step one is to get access to the met. data in the weather database to use the hourly met. data of each needed parameter in GIS. Step number two is to give geographic information to each met. station that we can work with the allocation of the station and with typical geographic information of the position of the met. station. Step three is to prepare the geographic basis information to calculate the interpolation. For that a spatial database will be implemented. Step four is the main and the most difficult step. It deals with different kind of interpolation methods to find or modify a method which gives the best results.

To reach step five the forecasting models have to be prepared that they can interact with the interpolated met. data. The results of these calculations will be stored into the spatial database. The last step is to connect the results to an internet application in which the spatial information is displayed as a map for e.g. the first appearance of Late Blight for Germany.

Material: Spatial and weather database

For the steps number 1, 2 and 3 the geographical basis data and the meteorological parameters temperature and relative humidity of 436 met. stations have to be prepared in a database.

To interpolate the temperature and the relative humidity data is needed to characterise the different attributes of the temperature or the relative humidity in the landscape. These data are the digital elevation model (dem), the aspect, the slope and other parameters which are calculated out of the dem (Behrens and Scholten 2002).

To create interpolation zones the following data have been used.

The Climate as a classification over Germany with a climate index which was derived from the temperature amplitude and a precipitation index (www.ifl-nationalatlas.de).

The Soil climate index is a useful classification of the Köppen climate classification and a spatial soil index (Blütchen und Weischet 1982).

The Natural index is a classification of natural zones which are derived from the vegetation index (www.ifl-nationalatlas.de).

And Corine Land Cover (CLC) which is an European Project that calculates the land use out of satellite pictures. In the map of the CLC (Fig. 3) only the arable crop area is displayed because that parameter helps to minimize the calculation time (www.statistik-bund.de).

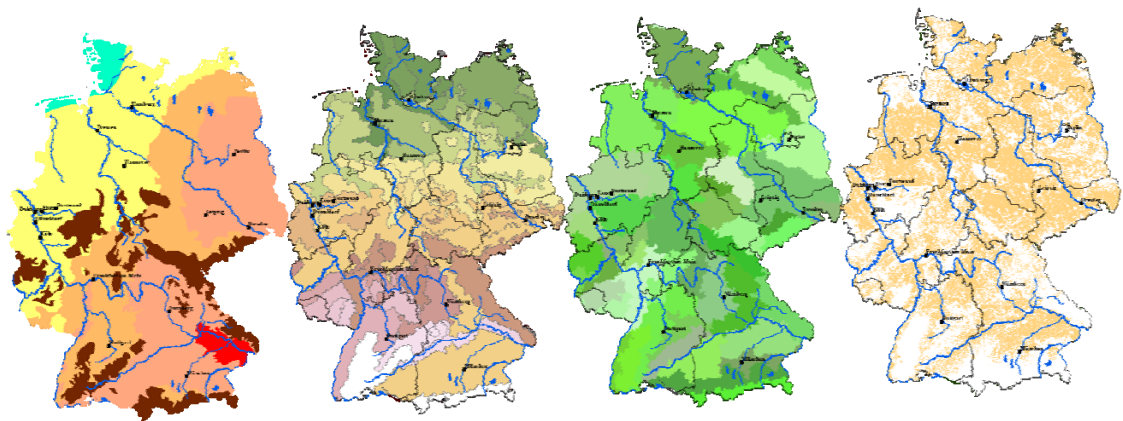


Figure 3. Preparing data to build homogenous zones.

To calculate a plot specific calculation for Late Blight some more data is needed which is also stored in the database, e.g. assessments for *P. infestans*, prevalence of potato crops, soil type, crop rotation, soil tillage, cultivar and statistics.

Methods

To realise step four two methods have to be developed.

The first method defines climatically homogenous zones in Germany. For example it is not possible to use the data of two met. stations of different climatic zones for an interpolation. To find climatically homogenous zones the data in the spatial database have been used to find clusters to regionalise Germany.

The second method is to calculate the interpolation for each of these zones and for every hour of the period. To find the interpolation method with the best results the deterministic and the geostatistical interpolation method have to be modified and to be validated (ESRI, 1991).

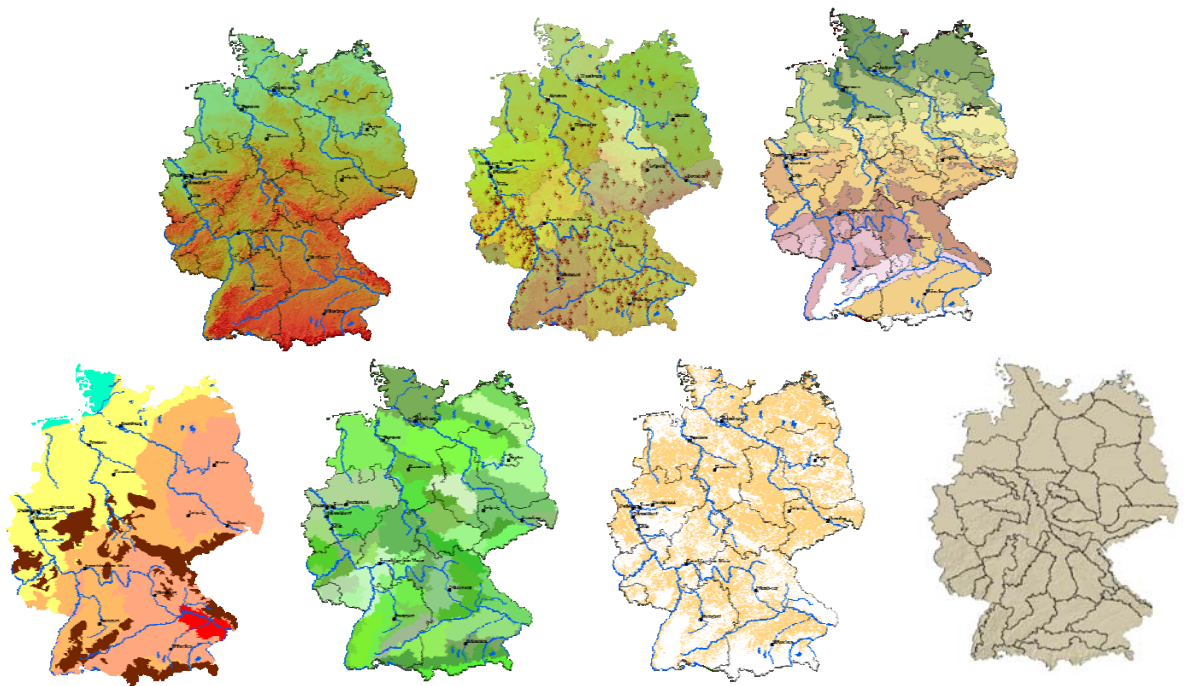


Figure 4. Building interpolation zones.

Results

In the following two examples will demonstrate how ZEPP deals with the six steps to calculate spatial risk maps and how a farmer or an adviser should use the system.

Example how the ZEPP deals with the workflow

After all the input data for the calculations are prepared and saved into the database ZEPP is able to connect to the database and start a GIS- module to calculate the interpolation of the met. data. This example shows the interpolation for one of the interpolation zone in Rhineland -Palatinate near the river Rhine. To interpolate the met. data for this zone it is necessary to start the interpolation module with the interpolation method kriging (Zeuner, 2003). The interpolation of a of three days period requires a 72 times run to get the hourly input data for the forecasting model.

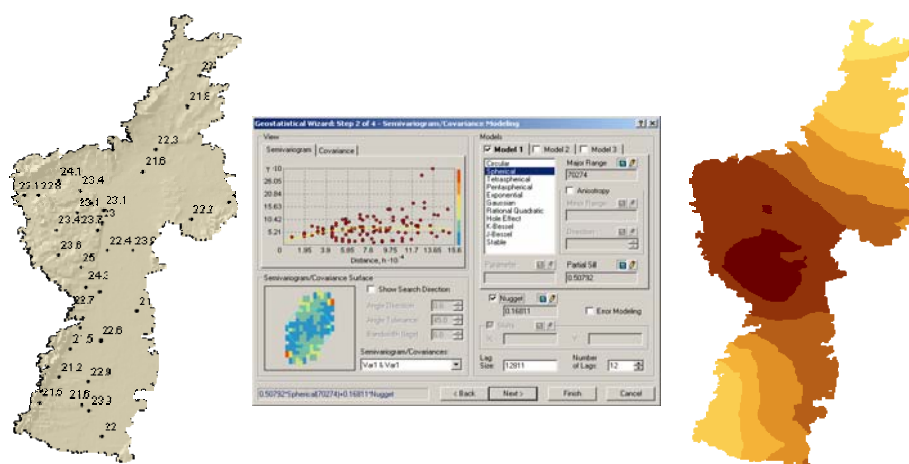


Figure 5. Example of interpolation method kriging.

The result of the interpolation will be presented as a net of virtual met. stations with a cell size of one kilometre. In Fig. 6 the virtual net for only a small region of the interpolation zone is shown as small square. Each number in the square symbolized one virtual met. station. In the table in Fig. 6 the results of the complete interpolation for every hour of each virtual met station is shown. The results of these calculations will be stored as a new column in this table. So it is possible to use a geographic viewer to display the results as a map. This map is then given into an internet application and displays the results of the forecasting models in a simple way to the farmers and the advisers.

Result of the interpolation

Calculating the forecasting model

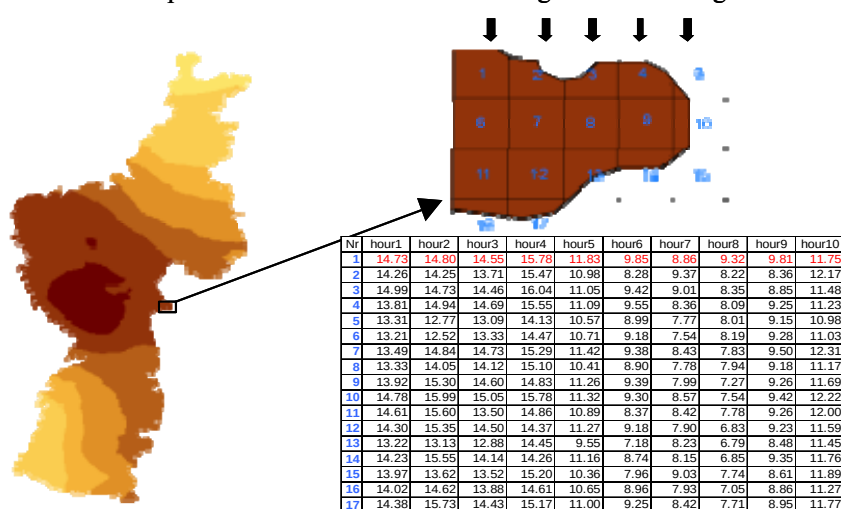


Figure 6. Results of interpolation.

Use of the system by a farmer

The results of the forecasting models will be published at a website. A map of Germany with the 16 German “Bundesländer” allows the farmer to zoom to one of the “Bundesländer” to get more detailed information. In Fig. 7 a map of the “Bundesland” “Rhineland-Palatinate” with the borders of the interpolation zones is displayed. After an interpolation zone is chosen the map will be refreshed showing him a digital photo where he can see the various cultivars in the fields. With a click on a certain field a popup window is opened showing all the information about this field. Information about the infection pressure of Late Blight, the soil, the cultivar and much more is pointed out. A further click on the field opens the next popup window and a plot specific calculation of infection pressure is the output.

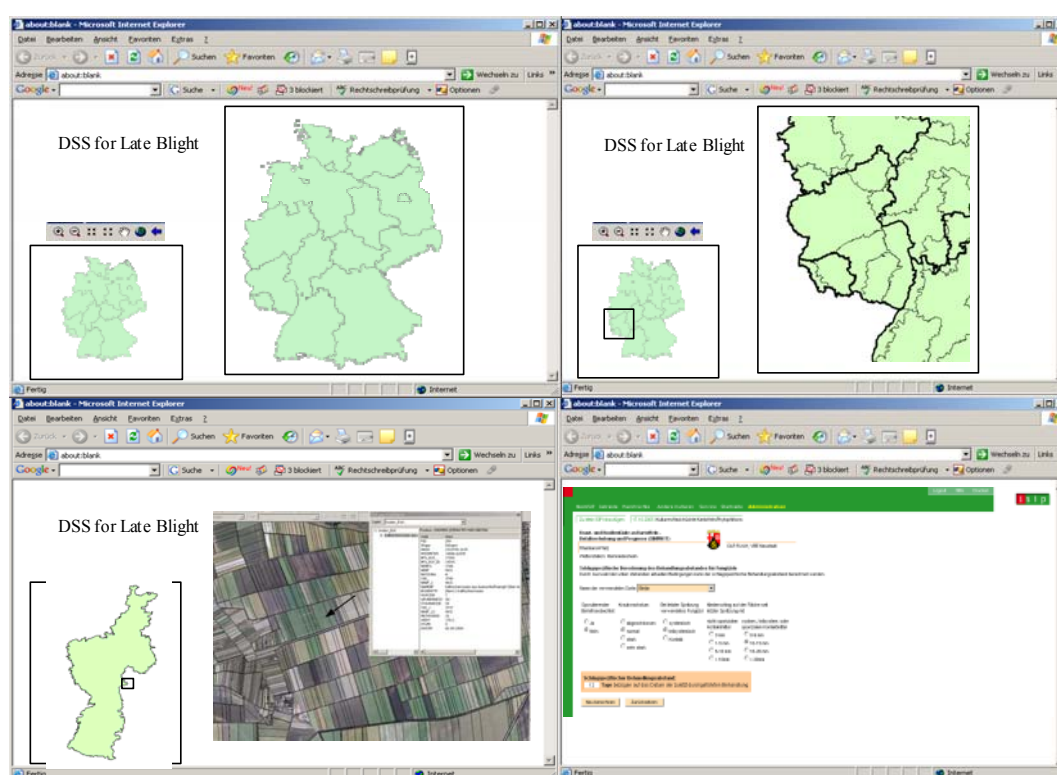


Figure 7. Example of an internet application to present the results of the forecasting model.

Conclusion

With the combination of the current forecasting models and the use of analyses and methods from GIS a milestone in the advising of farmers can be reached. The methods and analyses with GIS will help to do more detailed calculations and get better results as before. It will also be easier to understand and to interpret the results of the forecasting models. The spatial maps will show hot spots of maximum risk. Modification and validation the forecasting models will give better control of Late Blight. The aim to reduce the number of sprayings will

be achieved and that will help to guaranty an environmental friendly crop protection strategy in an economical and ecological way.

Eventually, these descriptive presentation methods of GIS will lead to a simplification and therefore higher acceptance of the warning systems.

Literature

- Behrens, T and T Scholten, 2002. DGMK²⁰⁺ Erstellung der Digitalen Geomorphologischen Karte für das Bundesland Rheinland-Pfalz im Maßstabsbereich 1:25 000 bis 1:50 000, Gießen.
- Blüthgen, J and W Weischet, 1982. Allgemeine Klimageographie, Walter de Gruyter, 3. Auflage.
- Esri, 1991. Arc/Info User Guide Cell-based Modelling with Grid. Analysis, Display, Management, Environment System Research Institute Inc.
- Gutsche, V, 1999. "Das Modell SIMPHYT 3 zur Berechnung des witterungsbedingten Epidemiedruckes der Krautfäule der Kartoffel (*Phytophthora infestans* (Mont.) de Bary)." Nachrichtenbl. Deut. Pflanzenschutz. 51(7): 169-175.
- Gutsche, V, E Jörg, et al., 1999. "Phytophthora - Prognose mit SIMPHYT III." Kartoffelbau 50(4): 128-130.
- Hansen, JG, B Kleinhenz, et al., 2002. Results of validation trials of Phytophthora DSSs in Europe, 2001. Sixth Workshop of an European network for development of an integrated control strategy of potato late blight, Edinburgh, Applied Plant Research BV 304: 231-242.
- Kleinhenz, B, 2001. Das Internet für die Pflanzenproduktion. Pflanzenproduktion 2001, Bonn/Münster/Güstrow, DLG: 12-17.
- Kleinhenz, B and E Jörg, 1999. Validation of SIMPHYT I/II - A decision support system for late blight control in Germany. Workshop on the European network for development of an integrated control strategy of potato late blight, Uppsala, Sweden, Applied Research for Arable Farming and Field Production of Vegetables 5: 115-128.
- Kleinhenz, B and E Jörg, 2000. Results of Validation Trials of Phytophthora DSS in Europa in 1999. Workshop on the European network for development of an integrated control strategy of potato late blight, Oostende, Belgium, Applied Research for Arable Farming and Field Production of Vegetables 6: 180-190.
- Roßberg, D, V Gutsche, et al., 2001. "Prognose von *Phytophthora infestans* mit den SIMPHYT Modellen." Gesunde Pflanzen 53(2): 37-43.
- Zeuner, T, 2003. Geländeklimatologische Untersuchungen im Rheingau. Geographisches Institut. Mainz, Johannes Gutenberg - Universität.
- Internetquellen: www.statistik-bund.de (16.05.2004); www.zepp.info (16.05.2004); www.ifl-nationalatlas.de (16.05.2004)

Forecast-Xtra – A new Blight Service in the UK

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Summary

Forecast-Xtra was developed to fill a gap in the UK DSS market between national and farm-specific systems. Forecast-Xtra is aimed at growers and agronomists not implementing DSS systems, but who require a tool for recording risk, justifying sprays and adjusting the type/frequency of fungicide treatments.

Faxed or emailed twice a week the Forecast-Xtra report gives 3 days historical risk and 4 days forecast risk (included the day of the report). Risk is calculated using PLANT-Plus parameters and is represented numerically from 0-100, where 0-20 is low, 20-50 is medium and 50-100 is high risk. Risk is based on an unprotected crop with moderate blight susceptibility. Five-day weather and spraying forecast is also included on the report.

In 2005 the report was aimed at 2 main groups; crop consultants who used it to support on farm advice and potato agronomists who used it to inform grower groups of blight risk during the season. Uptake in 2005 was encouraging and involved 3 chemical distributors and 5 potato companies. In total 51 different local weather stations were used on the reports covering areas in most of the UK potato growing regions.

Introduction - A history of UK blight DSS's and development of Forecast-Xtra

Potato blight Decision Support Systems (DSS's) were first introduced nationally to the UK in the form of Beaumont periods (Beaumont 1947) in the 1950's, and was subsequently replaced by the Smith Period (Smith 1956), from 1975 to present. In the 1990's in-crop Blight Monitors were developed by Farm Electronics to log Smith hours, however today Smith is used primarily in BlightWatch, an internet postcode system delivered by Potatocrop.com (Barrie 2001), using national meteorological data and interpolated data. Registration is free to this service and by 2004 it had over 3700 registered users.

During the mid 1990's, Hardi promoted the first farm-specific system (Hostgaard 1995), using data remotely from Metpole stations and software for the NegFry model. These were adopted by some farmers but on a limited scale, and now few systems exist.

In 1998 Plantsystems introduced the PLANT-Plus farm-specific system (Hinds 1998) from Holland, an internet delivery system using mainly Adcon remote recording stations with the incorporation of a local weather forecast. PLANT-Plus is the most widely adopted farm-specific blight DSS in the UK, currently influencing spray programmes on 7000-8000 ha of potatoes, and involving over 50 growers and more than 150 local weather stations.

In 2003 Blight Alert from Syngenta was developed to give growers a choice of different levels of DSS sophistication from national to farm-specific systems, however due to commercial reasons the service was discontinued in 2004.

It was from this background, that Plantsystems identified a gap in the market for growers and advisors who required some of the benefits of the farm-specific DSS's, e.g. local and forecast blight risk, but who were not prepared to make the investment in cost and time required to run such systems. In 2005 an automatic report was developed to meet these aims, and became known as Forecast-Xtra. This paper describes Forecast-Xtra, and how it has been used.

What is Forecast-Xtra

Forecast-Xtra is a disease risk assessment for 3 days historically and 4 days forward (including the day of the report) delivered by fax or email (from 2006) sent out twice weekly. Risk is calculated by the PLANT-Plus system from local or regional weather data, and can use data from on farm weather stations. The risk assessment is based on an unprotected crop. Variety susceptibility is based on moderate blight susceptibility e.g. Maris Piper. Risk is represented as a score of 0-100, where 0-20 is low, 20-50 is moderated and 50-100 is high risk.

Report example

For packers or processors the company logo can be included on the report.

Risk is given 3 days back, today and 3 days as a forecast. 4 local stations are included on this report.

The 5 day weather forecast with ETO is included; Spraying conditions for 5 days are given

Comments section can carry key messages, and edited for each report.



LATE BLIGHT RISK ASSESSMENT



Station	06-06	07-06	08-06	Today 09-06	10-06	11-06	12-06
UK JR St. Clements	100	0	0	0	0	0	0
UK JR St. Helier	100	63	37	0	0	0	0
UK JR St. Ouen	100	54	9	0	0	0	0
UK JR Rozel	100	100	96	0	0	0	0

0-20 Low

20-50 Medium

50-100 High

WEATHER FORECAST

HWS UK Jersey

Day	date	Temperature			Rainfall chance mm	Radi- ation	RH min.	Wind		ET0
		av.	max.	min.				dir.	m/s	
th	09-06-05	13.7	14.7	12.6	20 0.00	5.220	64	NE	4.5	2.9
fr	10-06-05	14.3	15.2	13.6	20 0.00	4.610	60	ENE	3.3	2.7
sa	11-06-05	12.5	13.1	11.7	20 0.00	5.245	66	ENE	6.7	2.7
su	12-06-05	12.4	13.5	11.3	20 0.00	3.605	69	NW	2.8	2.3
mo	13-06-05	12.8	13.6	12.2	30 0.90	5.190	73	NW	6.0	2.5

SPRAYING CONDITIONS

HWS UK Jersey

	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
th 09-06						+	+	+	o	o	o	-	-	-	o	o	o	o	o	o
fr 10-06	+	+	++	++	++	++	++	++	+	+	+	o	o	o	-	-	-	-	-	-
sa 11-06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	o	o	o
su 12-06	+	+	++	++	++	++	++	++	o	o	o	o	o	o	o	o	o	++	++	++
mo 13-06	o	o	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

-- Very bad - Bad o Moderate + Good ++ Very good

COMMENTS



How is Forecast-Xtra used

Unlike farm-specific DSS's Forecast-Xtra does not advise the precise time to spray or advise the type of product that should be used. Growers and advisors however can use the system to adjust spray intervals and product choice depending on current and approaching risk. It can also be used for planning spray days using the spraying forecast. Agronomists from potato companies/distributors can also use the reports to produce weekly bulletins to growers.

The sequence below shows that on June 9 report, risk was high for the preceding few days. In this example the decision would be to treat with a kick-back (curative) product if the crop had not been protected for some time. On the June 13 report the risk was low from the preceding days (as forecast in the previous report) and the forecast was for the low risk to continue until 16 June. The indication from this report would be that no treatment was necessary at present, but a protectant fungicide may be necessary before 16 June. By the June 16 report, a high risk period was starting, therefore the decision would be to apply a spray as soon as possible, if one had not already been applied in the last few days.

Report sequence



LATE BLIGHT RISK ASSESSMENT

	Station	Today						
		06-06	07-06	08-06	09-06	10-06	11-06	12-06
June 9 report	UK JR St. Clements	100	0	0	0	0	0	0
	UK JR St. Helier	100	63	37	0	0	0	0
	UK JR St. Ouen	100	54	9	0	0	0	0
	UK JR Rozel	100	100	96	0	0	0	0
	Station	Today						
		10-06	11-06	12-06	13-06	14-06	15-06	16-06
June 13 report	UK JR St. Clements	0	0	0	0	0	0	28
	UK JR St. Helier	0	1	1	0	0	0	28
	UK JR St. Ouen	0	0	0	0	0	0	28
	UK JR Rozel	100	81	2	0	0	0	28
	Station	Today						
		13-06	14-06	15-06	16-06	17-06	18-06	19-06
June 16 report	UK JR Rozel	1	5	18	35	100	100	100
	UK JR St. Ouen	0	5	3	83	100	100	100
	UK JR St. Helier	0	2	18	82	100	100	100
	UK JR St. Clements	0	0	8	28	100	100	100

Forecast-Xtra Uptake – 2005

In the first year 64 reports were set up and sent twice weekly by fax. These included 5 potato companies (supported by Syngenta) and 3 chemical distributors (supported by Bayer). In all 51 local weather stations were used. It is estimated that the reports influenced 100-150 growers covering regions in the South West, East Anglia, East Midlands, North West, North East and Scotland.

Discussion

Forecast-Xtra was developed to increase the practical use of DSS's in the UK, as adoption and implementation of farm-specific DSS's is limited to some of growers, but not others. This is despite the fact that DSS's in European agriculture are widely accepted as good practice by the industry, food retailers, governments, environmentalists and those in the public who are aware of them. So why are DSS's not used universally?

Cost of these systems is one barrier, as they often require investment in a weather station, software/internet registration and support. Farm-specific systems also require time management of crop recording and data input. On some large farms the 'painting of Fourth Bridge' approach to spraying means that there is not enough sprayer capacity to move from routine spray programmes. There is also a certain profile of grower/advisor that is adverse to such changes in management systems.

Perhaps other factors are involved in limiting DSS uptake, such as the way they are delivered and supported, their complexity or lack of it, the accuracy of the model, the variability of host resistance and the disease.

In the future DSS modellers and those transferring DSS technology will need to listen carefully to their customers to find out the type of DSS they want, rather than the type we think they need, if DSS's are to be used on a wider scale.

References

- Barrie LA*, 2001. BlightWatch – A Spatially Interpolated System for the Calculation of Smith-Periods in the UK. EU Blight Workshop – Special Report No.8.
- Beaumont, A*, 1947. The dependence on the weather of the dates of potato blight epidemics. British Mycological Society 31.
- Hinds HD*, 1998. Potato Late Blight disease forecasting – commercial use of Plant-Plus in the UK in 1998. EU Blight Workshop – Special Report No. 5.
- Hostgaard M*, 1995. Local weather data from the Hardi Metpole and disease forecasting. EAPR *Phytophthora infestans* 150.
- Smith, LP*, 1956. Potato blight forecasting by 90% humidity criteria. Plant Pathology 5.

Visualisation of potato late blight protection levels in potato foliage and tubers

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Summary

Within the framework of Agrobiokon an internet application was developed allowing potato growers a simple evaluation of their potato late blight control strategy. The goal of developing this application was to confront the perception of growers regarding the protection level of their crops with an independent calculation of this level. Calculations of the daily infection risk allow growers to retrospectively track periods of under- and over protection of their crops. This form of interactive knowledge transfer is hoped to trigger improvements in growers' potato late blight control strategies with respect to spray timing and fungicide selection.

This internet application is available in 2005 and 2006 after which period its use will be evaluated. Agrobiokon is a joint venture between the Dutch "Main Board for Arable Products" (HPA), AVEBE and "The Northern Netherlands Assembly" (SNN).

Introduction

Potato late blight (PLB) control is no longer a matter of applying protective fungicides every 7 days. The new highly aggressive *P. infestans* population, established in most of Europe, and an increasing societal pressure to reduce the pesticide input urge growers to control potato late blight as efficiently as possible. Ideally, fungicides are applied following a preventive control strategy implemented through adaptive spray schedules in which an application is only recommended prior to a predicted infection event.

Historical, current and predicted weather, remaining fungicide protection and cultivar resistance are some of the factors used to calculate infection risks for the near future. Decision support systems (DSS's) integrate all these factors in a daily recommendation to the grower. With the integration of (automated) DSS's in daily practice, the fungicide input is optimized and fixed spraying schedules can be abandoned.

Apart from an objective calculation of the infection risk as provided by DSS's, growers justifiably have their own perception of the daily infection risks of their crops. From an operational point of view, adaptive spray schedules may even be undesirable. Conflicts between calculated infection risks, risk perception by growers and operational problems to carry out sprays at the desired time, result in over or under application of fungicides with undesirable results in both cases.

To allow potato growers to retrospectively evaluate their own control strategy during or after the growing season, a public internet application was created visualising calculated infection risks for potato foliage and potato tubers (when present). Several control strategies can be easily compared, allowing potato growers to evaluate decisions taken during the past growing season. At the same time it allows growers to monitor current disease pressure in their region and the performance of experimental control strategies in (local) Wageningen - UR (WUR) field experiments.

Concepts and implementation

The internet application developed serves three purposes:

1. Visualisation of the general disease pressure (critical periods) in regions in the Netherlands
2. Monitoring of the performance of experimental control strategies in WUR field experiments (umbrella plan Phytophthora)
3. Retrospective evaluation of grower's control strategies with respect to the daily infection risk to foliage and tubers as a tool to improve growers control strategies in future growing seasons.

These three different aspects of the application are accessed through the tabs at the top of the welcome page. The application can be found through: www.kennisakker.nl, the “advies” tab followed by the link “Visualisatie infectierisico Phytophthora” or directly through www.dacom.nl/kennisakker.

Visualisation of critical periods

This part of the application is only available for the North Eastern potato growing area in the Netherlands. It allows growers to monitor the general infection risk on a daily basis. A map of the area displays available weather stations. Once the weather station of interest is selected, the infection risk of a virtual unprotected, susceptible crop is displayed. Infection risks are calculated using PLANT-Plus algorithms. Daily infection risks are represented by yellow, orange and blue bars representing a low, average and high daily foliar infection risk (Figure 1).

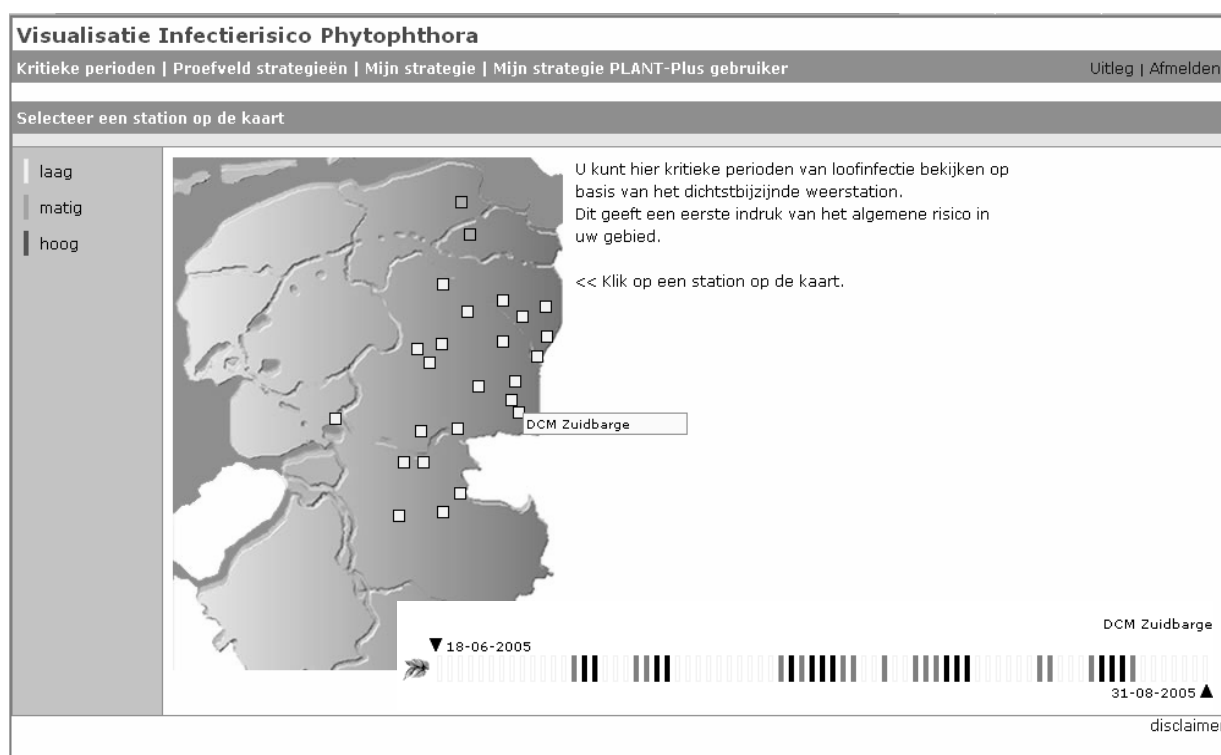


Figure 2. Visualisation of critical periods. Once a weather station (representing a region) is selected, a coloured bar with daily infection risks is displayed. Yellow, orange and blue sub-bars represent a low, average or high daily infection risk. The date of planting is given at the left of the bar whereas today's date and the name of the weather station are given at the right of the bar. Colours of the squares representing the weather stations on the map indicate the current infection risk.

Monitoring of the performance of experimental control strategies

The second tab on the welcome page allows access to a page where, following selection of an experimental farm, the infection risks for foliage and tubers is visualised for the PLB control strategies that are implemented on that farm. The bars representing the daily infection risks are calculated using PLANT-Plus algorithms and identical to the bar described above. Calculation of tuber infection risk is done using experimental PLANT-Plus algorithms developed for this purpose. In this case however the infection risk for foliage and tubers is represented separately and the fungicide applications are incorporated in the calculation of the infection risks. Fungicide applications are graphically represented by the black arrows on top of the infection risk bars. The two sets of bars (Figure 2) represent two (out of four) control strategies that have been selected for visualisation of infection risks.

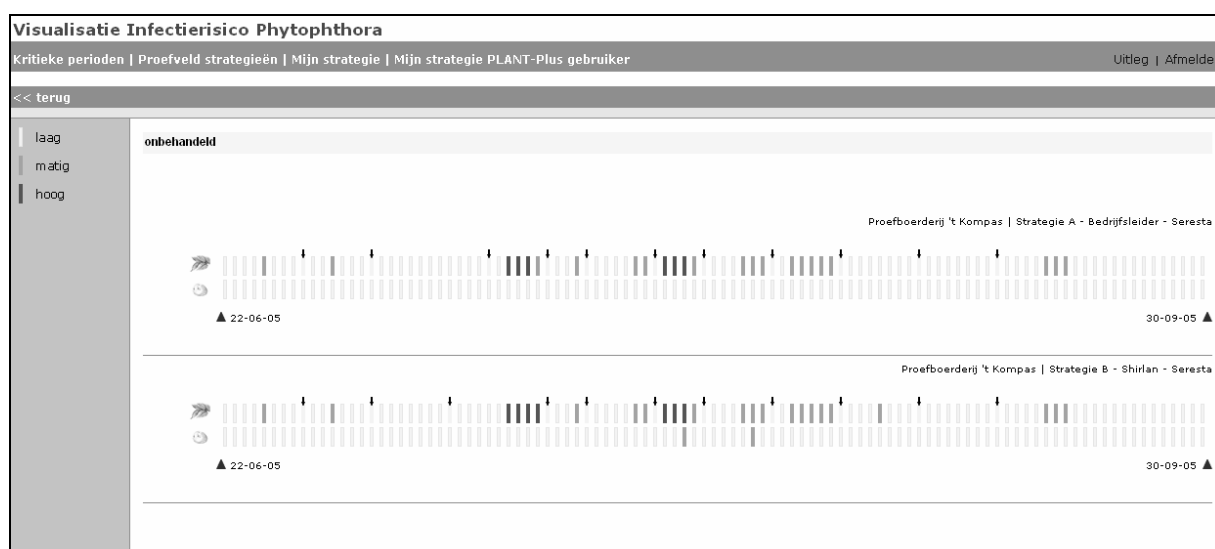


Figure 3. Visualisation of *P. infestans* infection risk to potato foliage and tubers (cv Seresta) for two of the experimental control strategies (“farm manager” and “Shirlan only”) present on experimental farm ” ‘t Kompas” in Valthermond, the Netherlands.

Retrospective evaluation of grower’s control strategies

The third tab (or fourth tab for registered PLANT-Plus users) on the welcome page allows access to a page where potato growers can enter their own crop and fungicide application data. Following data entry they are given the possibility to evaluate the protection levels achieved by their own control strategy and compare the performance of their private control

strategy (or strategies) with the performance of standard or experimental control strategies on a nearby experimental farm. Comparison of the protection levels of the different strategies with the critical periods represented by the top bar will reveal periods where the crop was under - or over protected. This may or may not agree with the farmers own perception of the protection level of his crop throughout the growing season. In both cases a positive effect will be achieved: farmers with periodically over- or under protected crops will be extra alert in the near future to step up the performance of their control strategy. Farmers whose control strategy generally performs well are boosted in their confidence and may incorporate the latest insights from the research arena into their future control strategy.

Discussion

The primary goal of developing the application described above was to give potato growers an independent tool which can be used to evaluate their PLB control strategy. Periods of under- or over protection should be looked at carefully to determine the most likely cause. This knowledge can then be used in discussion with colleagues or advisors and for future improvements on the control strategy. The secondary goal was to stimulate farmers to monitor the latest insights and results from PLB research. All in all, an interactive evaluation and knowledge transfer tool was developed that can be a valuable tool to Dutch potato growers.

**Report of the EU.NET.ICP subgroup meeting Decision support systems
Tallinn, October 2005**

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Follow up on DSS discussion Jersey 2004

As a follow up on the DSS discussion during the Jersey meeting in 2004, EU and EUREPGAP were contacted to bring the beneficials of DSS systems for their specific goals to their attention. No reply was received from the technical standards committee of EUREPGAP. The EU prefers to work with web-based information giving an overview of the advantages and disadvantages of DSS systems for a large number of growing systems and pests/diseases. As this does not exist, EU asked us to consider developing a tool like this within the framework of EU.NET.ICP which then in turn can be used to support new project applications. This was considered not feasible by the group due to lack of funding.

During the present discussion it was concluded that a group like EU.NET.ICP probably is not the most suited to bring pro's and con's of DSS systems to the attention of e.g. EUREPGAP and EU. It was decided not to take further action. Other parties should take the lead in promoting DSS systems to EUREPGAP. EU.NET.ICP and similar groups should work on standardization to make future incorporation of DSS systems into EUREPGAP possible.

Cultivar resistance and DSS's

At the official end of the EU.NET.ICP project, it was concluded that resistance components were probably the most suitable parameters to build cultivar resistance into DSS's. Correct timing of spray applications remains however of prime importance before e.g. dose reductions can be considered on ore resistant cultivars.

The EU concerted action EUCABLIGHT follows up on this by creating a database containing information on pathogen, host and their interaction (the resistance components) for many European countries. With the database it is possible to evaluate stability of the data across Europe.

In general, two approaches are followed to incorporate cultivar resistance into DSS's: The spraying interval is increased or the dose rate is reduced. These approaches are used by different systems across Europe. A breakdown of resistance is the greatest threat to systems using cultivar resistance to reduce the fungicide input. A failure to control blight with e.g. reduced dose rates will undoubtedly be attributed to the system and not to a lack of up-to-date resistance data. Reliable resistance ratings are therefore of prime importance. Question is how to keep track of shifts in virulence/aggressiveness on a yearly basis. The Eucablight database could play a role here by providing the most recent data on these topics from a variety of sources, not just the national cultivar lists which is considered unreliable for use in control strategies by most participants.

Reliable data on cultivar resistance is however not available in most parts of the world. An approach as outlined above could thus only be tried and tested in Europe. A second point to consider is that farmers use risk aversion as THE argument for both adopting a DSS and NOT adopting a DSS. Farmers are therefore only interested in risk aversion, not in cultivar resistance levels, reduced dose rates etc etc. This should be considered when developing control strategies using cultivar resistance. Two – three resistance levels are enough.

In conclusion, cultivar resistance is used in different ways in the European DSS's. Accurate resistance ratings are the key to the success or failure of such systems. Eucablight can contribute to providing accurate resistance ratings. Monitoring of developments within the European *P. infestans* populations remains essential detect changes early on and adapt decision rules accordingly. At the same time the systems should remain simple and easy to use with respect to both spray timing and dose rate.

Merging of EU.NET.ICP and EUCABLIGHT networks

A network of Excellence (NoE) called ENDURE is being developed by a number of European research institutes. Potato is a case study within ENDURE and development of the case will greatly benefit from an active EU.NET.ICP/Eucablight network.

The proposal at hand is to join both existing networks, keep meeting on a voluntary basis and use the networks to influence the direction of future research proposals such as ENDURE.

The group agrees that merging both networks is a good idea provided that EUCABLIGHT data or people can contribute to improvements in DSS's at a European level. A group of key persons from EU.NET.ICP will therefore be invited to the final meeting of EUCABLIGHT, January 2006 in France.

EUCABLIGHT: progress in characterising European *P. infestans* populations

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Summary

One of the aims of the EU-funded Concerted Action project 'Eucabligh't' is to provide tools for examining variation in European *P. infestans* populations. Over the course of the project standard protocols covering many aspects of *P. infestans* characterization from sampling to genotyping have been designed, tested and published. The exploitation of new micro-satellite markers generating objective genotypic data is playing a significant part in the project. Central to the project has been the construction of a database containing information on *P. infestans* collections in many European countries (www.eucabligh't.org). This database is being populated and in January 2006 the database contained information on an unprecedented scale with over 13,600 isolates from 20 European countries. The data is entered, stored and transferred to the EUCABLIGHT database using a PC-program 'Phytophthora.exe'. Data is presented using a series of web interfaces that allow key parameters of the population to be examined on a range of spatial and temporal scales. In this paper an update on the project, its database and analysis tools are presented and the future for the project is discussed.

Introduction

Phytophthora infestans first caused late blight in European potato crops in 1845 when it spread rapidly from Belgium across a large part of Europe causing widespread crop failure and the subsequent, widely reported, economic and socio-political impacts (Bourke, 1964). The early populations are considered to have been largely clonal with recent evidence suggest that initial A1 mating type lineage was subsequently replaced by one of the same mating type but differing in mtDNA haplotype (Ristaino *et al.* 2001; Fry *et al.*, 1992). In the mid 1970s new populations, comprising both the A1 and A2 mating types, were introduced into Europe, probably from the centre of diversity in Mexico, and displaced the initial A1 lineages. Understanding the pathogen population is clearly a significant factor in the planning of effective and durable control strategies but *P. infestans* populations have been in a state of flux and late blight management remains a significant challenge to the industry.

The main tools for disease management are the avoidance of primary inoculum via good cropping practices and quality seed, the timely use of fungicides and the effective deployment of host resistance. The success of each of these options is influenced by the nature of the pathogen population. For example, if both the A1 and A2 mating types are present in a region there is a significant risk of oospores acting as a source of primary inoculum as well as an increase in the rate at which *P. infestans* adapts, or evolves, to overcome other management strategies. The emergence of phenylamide resistance and subsequent control failures (Bradshaw and Vaughan, 1996) demonstrated the threat that fungicide resistance poses and the need to monitor populations for their sensitivity to phenylamides and other active ingredients. Similarly, the tracking of virulence and aggressiveness in *P. infestans* populations has helped to understanding of past failures in R gene deployment and such monitoring is important for planning breeding and future resistance deployment strategies. If resistance is deployed effectively it should create a ‘moving target’ and reduce the impact of late blight on the potato industry. Such *P. infestans* monitoring thus allows the potato industry to be proactive in adjusting its approaches to late blight management according to the data on contemporary pathogen populations and the way they are evolving.

All of the above factors are important on a local to regional scale but there are also significant issues at national and international scales over longer time periods. The global tracking of

major lineages of *P. infestans* will enable the early identification of major changes in population structure suggestive of newly introduced exotic strains, breakdowns of significant sources of resistance or the widespread failure of a key chemical active ingredient. There are also aspects of quarantine and international trade to consider. In the case of *P. infestans* there is a well-documented history of global migrations influencing disease management and statutory bodies need sound data upon which to base their risk assessments. The Eucablight project has collected such data on a European scale.

Materials, Methods and Results

The database

Thematic Group 2 (TG2) in EUCABLIGHT has been responsible for the establishment of a comprehensive network examining the population biology of *P. infestans* across Europe. Via the project meetings a consensus on the types of data needed and the database structure and scope were agreed. Each isolate has key database variables comprising the country, year of collection, 'regionID' and 'isolateID' plus approximately 50 database fields for phenotypic, genotypic and cropping data. The database was constructed by DIAS in Denmark (Lassen & Hansen 2005) and is carefully designed to remain functional and expandable with minimum maintenance beyond the official end of the project in January 2006.

Two types of data have been collated; existing or 'old' data and 'new' data collected and analysed, as far as possible according to revised EUCABLIGHT protocols. The 'old' data is important to set the context for studies on contemporary populations. If DNA or isolates of 'old' isolate collections are available their entries may be updated with, for example, SSR or other genotypic data. 'Old' data has been entered via a predefined Excel spreadsheet but for 'new' pathogen data a PC-program – Phytophthora.exe – has been developed which enables the entry, storage and transfer of data to the EUCABLIGHT database (Hansen et al., 2006). This software and the user manual can be downloaded from the project web-site and submission of data is open to all interested parties subject to its suitability.

The web interface

Data submitted to the web site as detailed above is presented via a series of display tools. Firstly an overview of the number of database entries (isolates) is presented as a table arranged by year and country. Selection of tick boxes relating to key traits indicates the extent of the data for a single trait or a combination of traits (Figure 1). Using the powerful and flexible Graphic Analysis tool a similar table is displayed but in this case a single trait or combinations of up to three traits can be presented as graphs (Figure 2). The user can select an overview of the total dataset or select particular combinations of countries and years. Such data may be viewed as the numbers of isolates or converted into percentages to view the relative frequency of different combinations. The charts are generated directly from the database entries and thus immediately account for any new data entered.

Overview

Graphic analysis

Genotype analysis

Virulence analysis

Documentation

SSR analysis

Map

Pathogen overview

Select one or more traits and press the show button. [Help](#)

☐ Mating type
 ☐ Metalaxyl resistance
 ☐ Aggressiveness
 ☐ Virulence
 ☐ mtDNA
 ☐ AFLP
 ☐ Isozyme
 ☐ SSR
 ☐ All

Show

Country	AT	DE	DK	EE	EN	ES	FI	FR	HU	IE	IT	MA	NI	NL	NO	PL	SC	SE	SK	WA	All countries
Year																					
2005								64					10		1						75
2004				256									24		115	46	272		26		739
2003			20	84			234	7					40	109	328	22	216	88	26		1174
2002	100			89				75	93				58			30			26		471
2001				83			210	112	27				38			149		274	36		929
2000		7		13			675	84	4			42	27	481	197	155		163			1848
1999				12			457	216				25	35		269	149		258			1421
1998					336		538	73	36				78		678	256	22	263		25	2305
1997					630		602	86	7				53		167	147	215		48		1955
1996					143	10	16	156	1	147	10	7	195		493	189	171		97		1635
1995				26	12	1	135						114		1	1	152		16		458
1994					12	117	87					1	64			1					282
1993						3	69	1					60								133
1992						15	83						4								102
1991							56	1		1											58
1990							35														35
1989							22														22
1988							4														4
All years	100	7	20	537	1135	34	2868	1300	234	147	11	75	800	590	2249	1145	1048	1046	114	186	13646

Figure 1. Example of overview table showing the current status of the database. The numbers in the table indicate the number of isolates per year and country and in bold the totals by country and year.

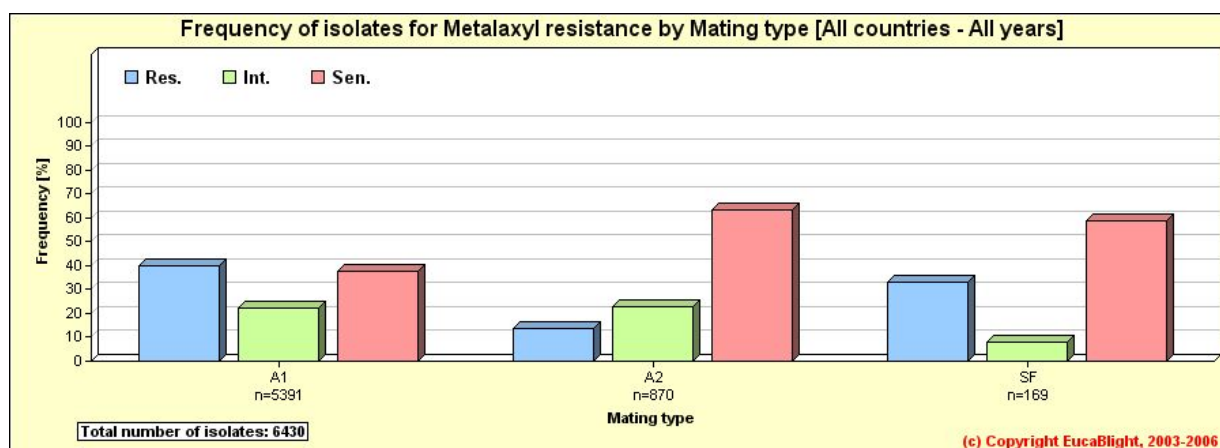


Figure 2 An example of the output from the Eucablight Graphic Analysis tool showing the relationship between mating type and metalaxyl resistance for 6430 isolates from 15 countries.

The Genotype Analysis tool allows a breakdown of the isolates in the database according to a single trait or combinations of traits. Again the format is very flexible and allows the database interrogation and returns plots of any user selected combinations of phenotypic and genotypic characters for any particular year and country combination. For example, the association between mating type and SSR allele combinations may be explored. A third tool presents graphical output of the virulence data either as the frequency of each virulence factor (Figure 3) or the combinations of virulence factors. Limited mating type data is also projected onto a map of Europe as bar charts. All the above data are available on the public side of the Eucablight website.

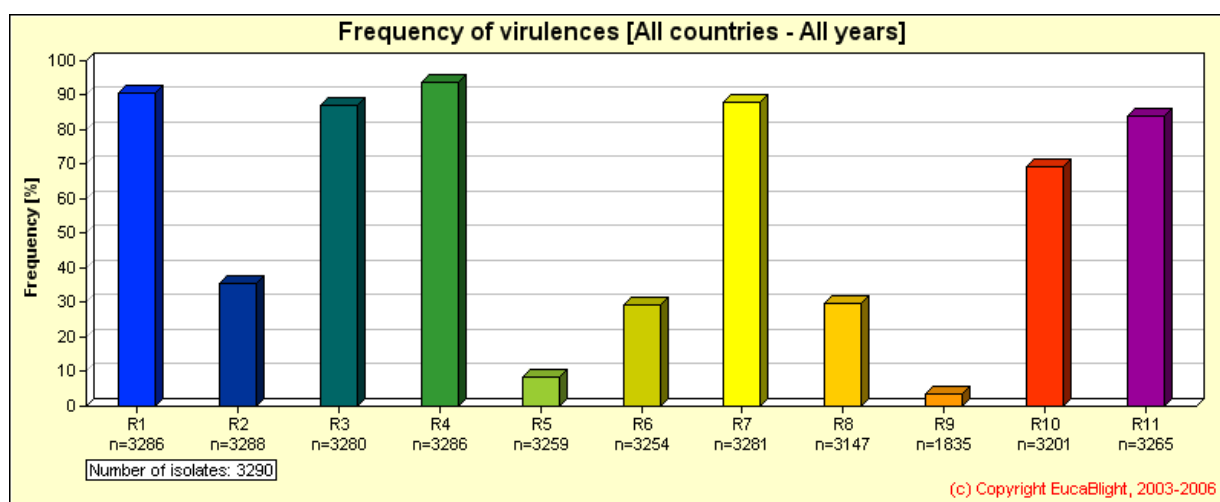


Figure 3 An example of the output from the Eucablight Virulence Analysis tool showing the frequency of each virulence factor in 3290 *P. infestans* isolates from 16 countries.

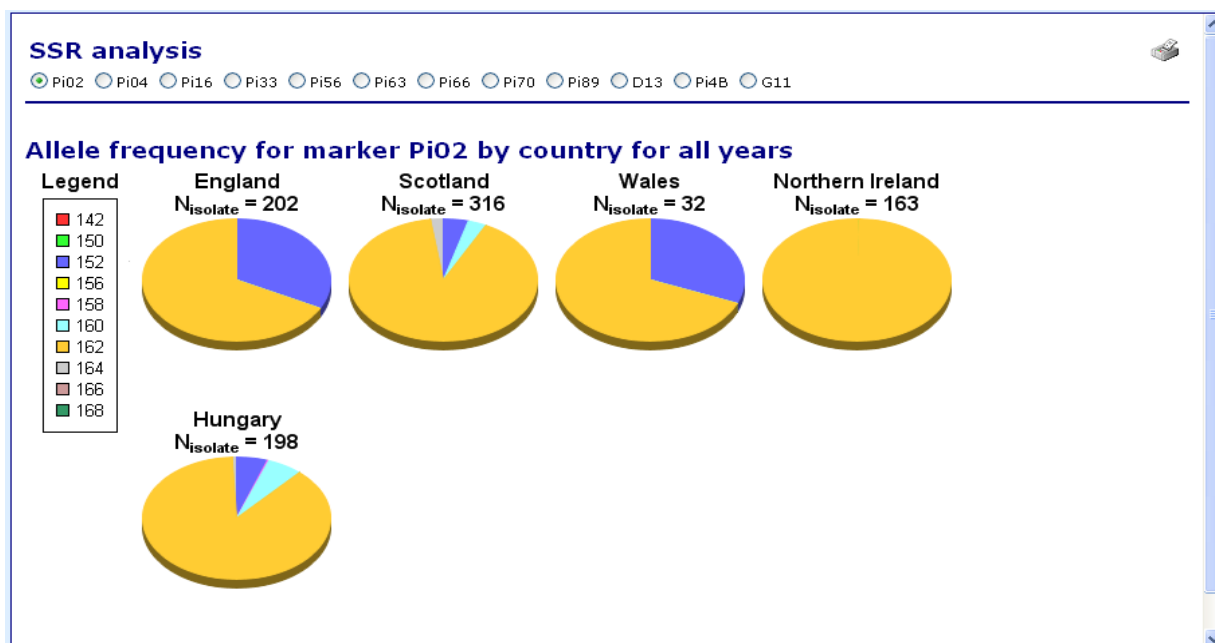


Figure 4 An example of the output from the Eucabligh SSR Analysis Tool showing the frequencies of the alleles of SSR marker Pi02 in a series of 5 countries.

On the members side of the web site (available after log-in) additional data on the SSR allele frequencies is presented (Figure 4) as a series of pie-charts, one for each country. This allows a rapid overview of the broad genetic structure of populations from different countries. Further detailed analysis of the populations will come from joint data analyses by Eucabligh project and other partners later in 2006.

Discussion

The Eucabligh project has assembled many experienced research teams across Europe in a co-ordinated project to standardise and collate the wealth of data available in state research projects into a single comprehensive database. A considerable amount of data has been drawn together and more will arrive in 2006 bringing the estimated total to over 15,000 isolates. There are many technical challenges such as data standardisation and uniform data entry that have been overcome by careful project planning and database and web site construction. There remain many scientific challenges to the analysis of such a dataset. Not least is the consideration that must be given to ensuring that the sampling strategies at various spatial and temporal scales are equivalent or can be adjusted to make them equivalent.

A particular advantage of the Eucablight project has been to facilitate intensive and wide-ranging discussions on pathogen population differences and the drivers behind such changes. It is beyond the scope of this paper to discuss the main findings of the project but it is clear that there are many benefits to having such a large collection of reliable and comparable data. Positive feedback from other parts of the world has influenced the database design and an additional field labelled 'ContinentID' added. This will allow the database and related tools to be customised for data from outside of Europe allowing a move towards a single global database on *P. infestans* variation.

Data submission is open to any group who wish to contribute with data generated according to the standard protocols or their equivalents. The advantages to the submitter are that their data will add resolution to any analysis of the European population structure and they will be part of the project for the planned publications. Furthermore they will have access to the suite of analysis tools that allow comparison between their submitted data and that of other EU states. Submitters can be assured that no raw data will be passed to other users without their permission. Please contact David Cooke at the address shown above for further details.

It is planned that the database will be kept up to date by members of the research community who will continue to submit their results. The database will thus be an important instrument for potato breeders, scientists, advisors and policy makers to follow the co-evolution of host and pathogen in Europe and inform the use of appropriate resistance genes and control measures.

Acknowledgements

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References

- Bourke, PMA, 1964. Emergence of potato blight, 1843-46. *Nature* 203, 805-808
- Fry WE, SB Goodwin, JM Matuszak, LJ Spielman, MG Milgroom and A Drenth, 1992. Population genetics and intercontinental migrations of *Phytophthora infestans*. *Annual Review of Phytopathology* 30: 107-129.
- Hansen, JG, P Lassen, DEL Cooke and AK Lees, 2006. Phytophthora.exe ver. 1.1 PC-program for the storage and upload of *Phytophthora infestans* isolate information to the EUCABLIGHT database – User Manual. Ministry of Agriculture and Fisheries, Danish Institute of Agricultural Sciences. Internal Report: Plant Production No. 2, January 2006, 46 pp.
- Bradshaw NJ and TB Vaughan, 1996. The effect of phenylamide fungicides on the control of potato late blight (*Phytophthora infestans*) in England and Wales from 1978 to 1992. *Plant Pathology* 45, 249-269.
- Lassen, P and JG Hansen, 2005. EUCABLIGHT database: collecting, storing and analysing data related to potato late blight. Proceedings of the Joint 5th Conference of the European Federation for Information Technology in Agriculture, Food and Environment and the 3rd World Congress on Computers in Agriculture and Natural Resources, July 25-28, 2005, Vila Real, Portugal.
- Lees, AK, R Wattier, L Sullivan, NA Williams and DEL Cooke, 2005 Novel microsatellite markers for the analysis of *Phytophthora infestans* populations. *Plant Pathology* (in press)
- Ristaino JB, CT Groves and GR Parra, 2001. PCR amplification of the Irish potato famine pathogen from historic specimens. *Nature* 411, 695–7.

**The evolution of the population of *Phytophthora infestans* in France
(*Epidemiology and phenotypic markers*)**

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Summary

The Monitoring of *Phytophthora infestans* strains in the North of France shows an increase of A2 strains, and metalaxyl resistant strains.

The results are different according to the region : many A2 strains in Alsace, very few in Brittany.

Keywords: Late blight, A2 strains, metalaxyl resistance, population.

The Epidemic

In 2005, the epidemic in most of the regions was usual: severe in Brittany but correctly controlled, early but moderated during the season in South, early and moderate in July in the center of France. Moderate with some problems in July in Champagne Ardenne.

But in Normandy, Picardy, Nord Pas-de-Calais, the epidemic was the most severe since 15 years: with an early pressure during the second part of May and the beginning of June and particularly a very severe pressure in July and beginning of August.

The control was very difficult, even if the epidemic was correctly forecasted by the models and the DSS: MILPV. A lot of fields with very susceptible varieties showed some symptoms at the end of July.

We have some explanations:

- Many sources of inoculum: dumps, volunteers.
- A weather very favorable to the epidemic but very unfavorable to the control (growth of the crop in July, difficulties of sprays, rainfastness).

But there is also a new question: why not the aggressiveness of the *Phytophthora* ?

The monitoring of strains of the Plant Protection Service (A2 tests)

The isolate sexual type is determined by a confrontation test on Vg agar medium.

Mycelium plugs from the strain to be tested are confronted with reference strains A1 and A2 on V8 agar medium.

The oospores formation requires the two opposite mating types.

In Champagne Ardenne, Normandy, Picardy, Nord Pas-de-Calais, between 1993 to 2003, 783 samples are tested ; some A2 strains were detected in 1997: 11 in garden and only 3 in fields.

In 2003, we found 7 samples with A2 strains, 3 in fields and 4 on dumps: 6 % of the strains are A2.

In 2004, 70 samples were tested, 43 from fields, 15 from dumps and 5 from volunteers.

In 2004, in fields 30 % of the samples are A2 strains and 20 % of the fields have A2 strains.

In 2005, 35% of samples from crops are A2 and 38% of the fields have A2 strains (cf table I).

Table I. Results of mating type North of France 2005.

	A1	A2	A1/A2
Field	93 (65 Fields)	34 (28 Fields)	15 (10 fields)
Dumps	33 (23 dumps)	15 (11 dumps)	
Volunteers	2	2 (1 volunteer)	
Garden			
Potato			
Tomatoes	2		
Total	130	51	15

The results in the other regions are different:

- In Brittany: on the 24 samples only one is A2.
- In Alsace: on the 22 samples, 15 are A2 and 12 fields by 15 have A2 strains. Alsace is the French area with the most important quantity of A2 strains.
- In the other regions: Centre of France, South west, from 23 samples (18 fields) only 1 A2 strain was found of tomato.

The monitoring of metalaxyl test

The method to assess the resistance to metalaxyl is that one described by the FRAC (Fungicide Resistance Action Committee) using the floating leaf disc method (Sozzi *et al*, 1992). A range of 6 doses is tested: 0, 001, 0.01, 0.1, 1, 10 and 100 ppm.

The EC_{50} is determined for each tested isolate:

$EC_{50} \leq 0.1$ ppm: sensitive isolate

$0.1 < EC_{50} \leq 10$ ppm: intermediate isolate

$EC_{50} > 10$ ppm: resistant

These tests are set up since 1980 in North of France.

If we look at the results since 1997 to 2004, the average of samples with resistance strains are 17 % but there are differences according to the years (table II).

Table II. Results of metalaxyl tests North of France before 2004.

	Sensitive	Intermediate	Resistant	Total
1997	10	104	13	117
1998	12	112	21	145
1999	6	81	40	127
2000	8	45	15	68
2001	3	14	9	53
2002	10	25	5	40
2003	24	35	8	45
Total	73	443	111	627

≈ 17 % resistant strains

In 2004: 28 % of samples contain resistance metalaxyl strains, 13 % on dumps and 37 % on fields (table III).

Table III. Results of metalaxyl tests North of France 2004.

		Sensitive	Intermediate	Resistant	Total
Field		16	11	16	43
Garden	Tomatoes	2			2
	Potatoes	3		2	5
Dumps		13	0	2	15
Volunteers		5			5
Total		39	11	20	70

In 2005 in North of France, 56 % of strains are resistant, 34 % of dumps (38 % of the dumps have resistant strains, 64 % in fields (64 % of fields have resistant strains) (Table IV)

Table IV. Results of mefenoxam North of France 2005.

	Sensitive	Intermediate	Resistant	Total
Field	32 (25 fields)	4 (4 fields)	64 (52 fields)	100 (81 fields)
Dumps	25 (17 dumps)	2	14 (11 dumps)	41 (29 dumps)
Volunteers			4 (3 volunteers)	4
Garden tomatoes	1		1	2
Total	58	6	83	147

In the others regions, the results are different:

- In Brittany: 26 samples from 22 fields have been tested, 22 samples from 18 fields ($\approx 82\%$) have resistant strains
- In Alsace: 10 samples from 15 fields have been tested, 5 samples from 3 fields have resistant strains (21%)
- In the Centre and south of France: 23 samples from 17 fields have been tested, 6 samples from 4 fields have resistant strains (28 %)

The global conclusion for the North of France is:

There is an increase of A2 strains:

- Before 2003: 0 %
- 2003: 6 %
- 2004: 20 % fields with A2 (North)
- 2005: 38 % fields with A2 (North)

There is increase of metalaxyl resistant samples particularly in fields:

- 2003: 17 %
- 2004: 37 % of fields with resistant strains
- 2005: 64 % of fields with resistant strains

Discussions and conclusions

The results with the phenotic tests show different results according to the regions.

In North of France, there is an evolution of the population:

- many more A2 strains;
- many more mefenoxam resistant strains.

The analyses of the samples show that there is no link between the type of strain and the mefenoxam resistant.

Is this population more aggressive than in The Netherlands? We have to study this aspect.

But it is necessary:

According to A2 strain:

- to be careful at the beginning of the season if the weather conditions are favorable.

According to metalaxyl resistance ; a new strategy to use phenylamid compounds:

- Only 2 times by year on a field.
- Always in preventive conditions
- Always before 5 of July.

We have to continue the study in collaboration with INRA (genotypic tests, aggressiveness studies).

An overview of the situation of the Estonian population of *Phytophthora infestans*

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Keywords: diversity, mating type, metalaxyl resistance, *Phytophthora infestans*, potato late blight, virulence phenotype

Abstract

Phytophthora infestans isolated from potato leaves and tubers were collected from different regions of Estonia during 2001 to 2004. Isolates were assessed for mating type, resistance to metalaxyl and virulence phenotype. 328 isolates were assessed for mating type and 322 isolates for sensitivity to metalaxyl. The frequencies of A1 and A2 were 64,3 and 34,5 % respectively. Metalaxyl resistant, intermediate and sensitive isolates were recorded as 43,5 %, 38,1 % and 18,4 % respectively. Metalaxyl resistant strains were distributed in both mating types. Virulence to all known resistance genes (R1-R11) was found among 449 isolates. The most common race was 1.3.4.7.10.11. Assessed isolates were highly virulent, having 6,6 virulence factors per isolate in average. Nearly all isolates were virulent on differentials with genotypes R1, R3, R4, R7, R10 and R11. Less frequent was virulence against R5 (5,6 %) and R9 (6,9 %). Racial structure of Estonian population of *Phytophthora infestans* is quite similar with population of Nordic countries and Polish population and is differing from Western European and Russian populations.

Introduction

Potato late blight caused by the oomycete *Phytophthora infestans* (Mont.) de Bary may be the best known, longest studied and still among the most destructive of all plant diseases. In

Europe the first late blight epidemic occurred in 1845 and this resulted in the notorious Irish famine (Drenth, *et al.*, 1994). The disease became problematic throughout the rest of the world, usually shortly after potato production was established (Andrivon, 1995). In the past two decades, the frequency and severity of the disease have increased in many parts of the world and have been a serious threat to potato production (Fry & Goodwin, 1997).

Phytophthora infestans is heterothallic with two known mating types, A1 and A2 (Fry *et al.*, 1999). Interaction between hyphae of opposite mating type induces the formation of antheridia and oogonia which may associate and fuse to form an oospore, which means that the pathogen has the potential to reproduce sexually (Drenth *et al.*, 1993). Until the 1980s, worldwide populations of *Phytophthora infestans* outside Mexico (considered to be the centre of origin for *Phytophthora infestans*) were dominated by a single clonal lineage, US-1 (Goodwin *et al.*, 1994). This 'old' clonal lineage was of mating type A1 that limited *Phytophthora infestans* to asexual reproduction (Brurberg *et al.*, 1999). The second mating type, A2, was detected in Europe for the first time in 1981 from Switzerland (Drenth *et al.*, 1993), thereafter from England and Netherlands in the same year, from Scotland and Israel in 1983, from Egypt in 1984, from Sweden, Soviet Union, Japan and West-Germany in 1985, from Poland in 1988 (Drenth *et al.*, 1993), from Finland in 1992 and from Norway in 1993 (Hermansen *et al.*, 2000) and from Estonia 1987 (Koppel, 1996). The appearance of mating type A2 could allow *Phytophthora infestans* to reproduce sexually, with subsequent effects on disease epidemiology and control (Zhang *et al.*, 2001). There is strong evidence that *Phytophthora infestans* is reproducing sexually in the Netherlands (Drenth *et al.*, 1994) and in Poland (Sujkowski *et al.*, 1994). In many cases, there was an increase in complexity of virulence phenotypes and tolerance to the specific fungicide metalaxyl (Hermansen *et al.*, 2000; Bakony *et al.*, 2002).

The main objective of this study was to characterize the population of *Phytophthora infestans* in Estonia with different epidemiologically important markers such as virulence phenotype, metalaxyl resistance and mating type, in order to decide the best control strategies for potato late blight in Estonia. Results of the current study in comparison with results from similar studies made in other countries (Andrivon *et al.*, 1996, Hermansen *et al.*, 2000, Swiezynski *et al.*, 2000, Elansky *et al.*, 2001) enable better planning of strategies for efficient resistance breeding and integrated control of potato late blight.

Materials and methods

Collection and culture of isolates

Potato leaves and tubers naturally infected by *Phytophthora infestans* were collected during 2001-2004 from different regions of Estonia. Samples were originated from commercial fields representing most important potato-growing areas, small farm fields and untreated experimental plots of Jõgeva Plant Breeding Institute and Plant Biotechnological Research Centre EVIKA of Estonian Agricultural University. Blighted leaves were collected starting from the emergence of disease until the end of growing season. The majority of samples was taken from cultivars Anti, Ants, Ando, Asterix, Berber, Bintje, Folva, Latona and Van Gogh. Isolation was carried out from one typical, single lesion per sample. Isolations were attempted by transferring a fragment of infected plant tissue at first to potato slices or tubers of susceptible cultivars (Bintje or Berber) without known R-genes. Isolates of *P. infestans* were stored for longer period in tuber slices of susceptible potato cultivars or on the rye agar.

Mating type determination

Each sample isolate was grown together with known A1 and A2 testers in a Petri dish containing rye agar. Plates were scored for oospore formation at the hyphal interface between the developing colonies after growth for 10-18 days at 16 °C at darkness. If a plate yielded oospores, the test isolate was rated as the opposite mating type of the known isolate. Test isolates producing oospores with both A1 and A2 were scored A1/A2. These could be self-fertile isolates or a mixture of mating types, but this was not determined.

Response to metalaxyl

The resistance to fungicide metalaxyl was determined on leaves of susceptible cultivars Bintje or Berber. Leaves of plants grown in the greenhouse for 4-5 weeks were used. Leaflets were floated in distilled water or in solutions of technical metalaxyl of 10,0 and 100,0 mg L⁻¹ concentrations. Sporangia from pure cultures were inoculated on leaves of cultivars Bintje and Berber to increase the inoculum. Then sporangia were collected into distilled water with a paintbrush and the spore concentration was adjusted to 100 000 sporangia mL⁻¹. Twenty microlitres of sporangial suspension was placed in the centre of each leaflet. Inoculated leaflets were incubated at 15° C for 7 days. After incubation, the leaves were observed using a stereomicroscope to estimate fungal growth and sporulation.

Virulence tests

The specific virulence of isolates was determined by inoculation of detached leaflets of a differential set of potato cultivars carrying the 11 known major (R) genes for resistance. Differentials (Black's) were obtained from Mlochow Research Centre of the Plant Breeding and Acclimatization Institute (Poland) in form of tube plants. The plants were preserved as virus free tissue culture stocks in Estonian Plant Biotechnical Research Centre EVIKA and were subsequently grown in greenhouse or in growth chamber. Fully expanded young leaflets collected from the middle part of each differential cultivar at 6-8 weeks of age were used for inoculation. Leaflets were placed in moistened filter paper tray abaxial surface up and each leaflet was inoculated with two separate droplets of suspension of sporangia ($1.0-4.0 \times 10^4$ sporangia ml^{-1}) prepared from 7-9 day old culture. After seven days incubation at 15°C (under low light), the leaflets were examined with a stereomicroscope for sporulation of *Phytophthora infestans*.

Results and discussion

328 isolates were assessed for mating type. The frequencies of A1 and A2 were 64,3 and 34,5 % respectively (Figure 1). There were considerable differences ($P < 0,001$) in the proportion of A1 and A2 between different years and fields. The frequency of A1 mating type was highest (91 %) in Saku experimental trial. Both mating types were present in all studied regions. The frequency of A2 mating type in separate regions ranged from 18,0 % to 54,3 %. A2 mating type was not found only from trial fields in Saku in 2002. Self fertile A1/A2 isolates were very rare (1,2 %).

294 isolates were assessed for sensitivity to metalaxyl. Metalaxyl resistant (MR), intermediate (MI) and sensitive (MS) isolates were recorded as 41,9 %, 38,8 % and 19,3 % respectively (Figure 2). Metalaxyl resistant strains were distributed in both mating types. The proportion of intermediate isolates was highest in region with the highest frequency of the A1 mating type. Statistically significant differences ($P < 0,01$) in the frequency of resistance to metalaxyl between regions and years were observed. Metalaxyl resistant isolates were predominant in 2004 (58,7 %).

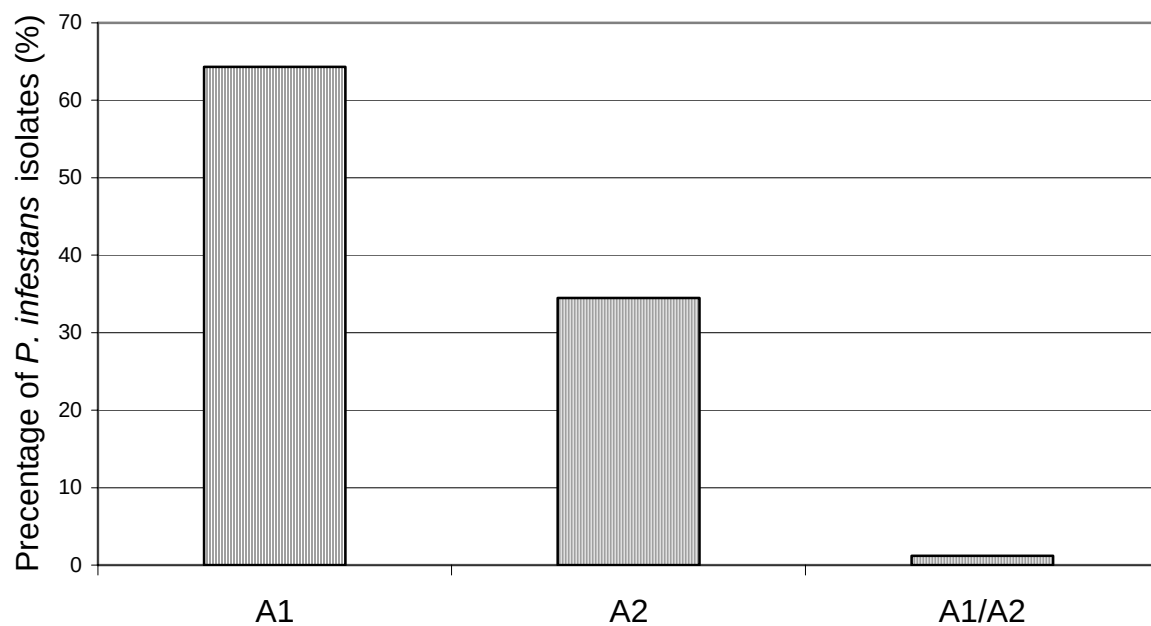


Figure 1. Frequency (%) of A1 and A2 mating type isolates of *Phytophthora infestans*.

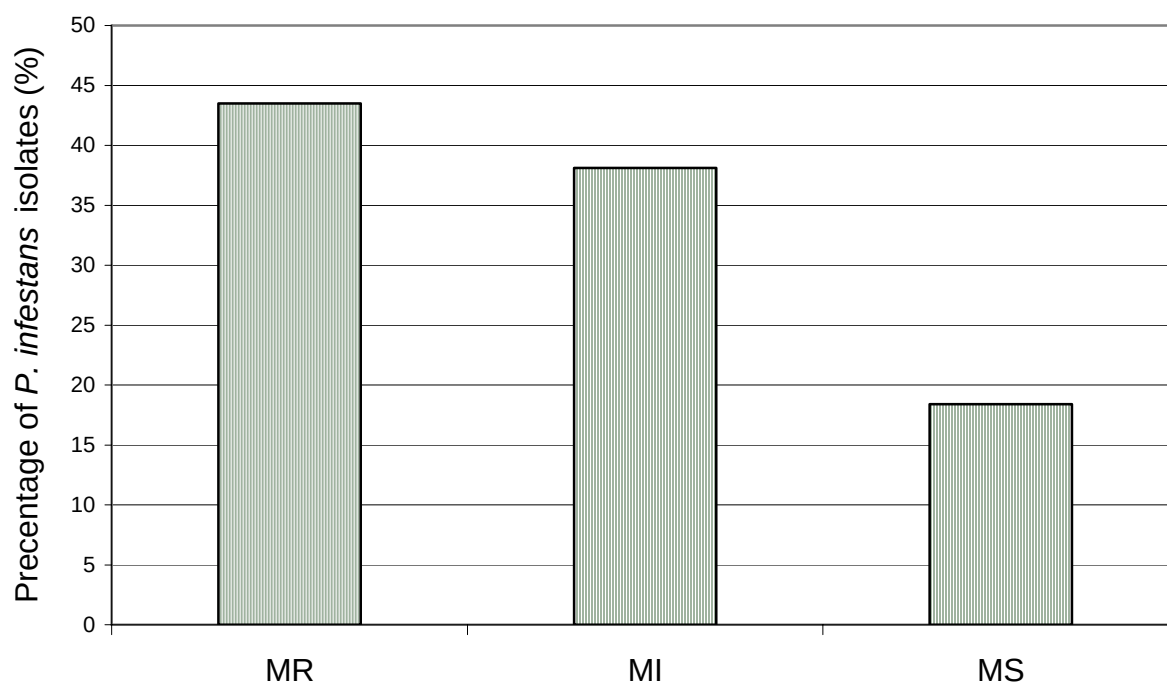


Figure 2. Metalaxyl resistance among isolates of *Phytophthora infestans* during 2001 to 2004.

All known virulence genes (R1-R11) were found among tested 449 isolates. Most of the isolates (94 %) were able to overcome four or more R-genes. 125 different pathotypes were detected. Assessed isolates were highly virulent, having 6,6 virulence factors (average number of R-genes overcome) per isolate in average. Two isolates were virulent on all used R-gene differential potato clones. Nearly all isolates were virulent on differentials with genotypes R1, R3, R4, R7, R10 and R11 (Figure 3). Estonian population has very low frequency of virulence against R5 (5,6 %) and R9 (6,9 %) differential factors. The most common pathotype was 1.3.4.7.10.11 (26,7 %). Pathotype 1.2.3.4.6.7.10.11 (12,5 %) was the second most commonly detected pathotype among whole isolates.

Racial structure of Estonian population of *Phytophthora infestans* is quite similar with population of Nordic countries and Polish population and is differing from Western European and Russian populations. The most common race, in Estonia, was also prevalent in Finland and Norway (Hermansen *et al.*, 2000). The frequency of virulence genes was similar with Norway (Hermansen *et al.*, 2000), and also with Finland, except for virulence genes 2 and 8. The virulence complexity (mean number of virulence genes per isolate) in Estonia (6,6) is somewhat higher than found in Norway (5,78), Finland (5,30) (Hermansen *et al.*, 2000), Netherlands (4,7) (Schöber & Turkensteen, 1992) and France (4,8). Estonian population virulence complexity is also higher than in Polish population (6,4) in 1985-91, but lower than in Eastern Germany in 1985 (7,1) (Sujkowski, *et al.*, 1996).

The results of the study indicate that the Estonian population of *Phytophthora infestans* is highly heterogeneous in all studied phenotypical markers, and the control of potato late blight fungus is complicated.

Acknowledgements

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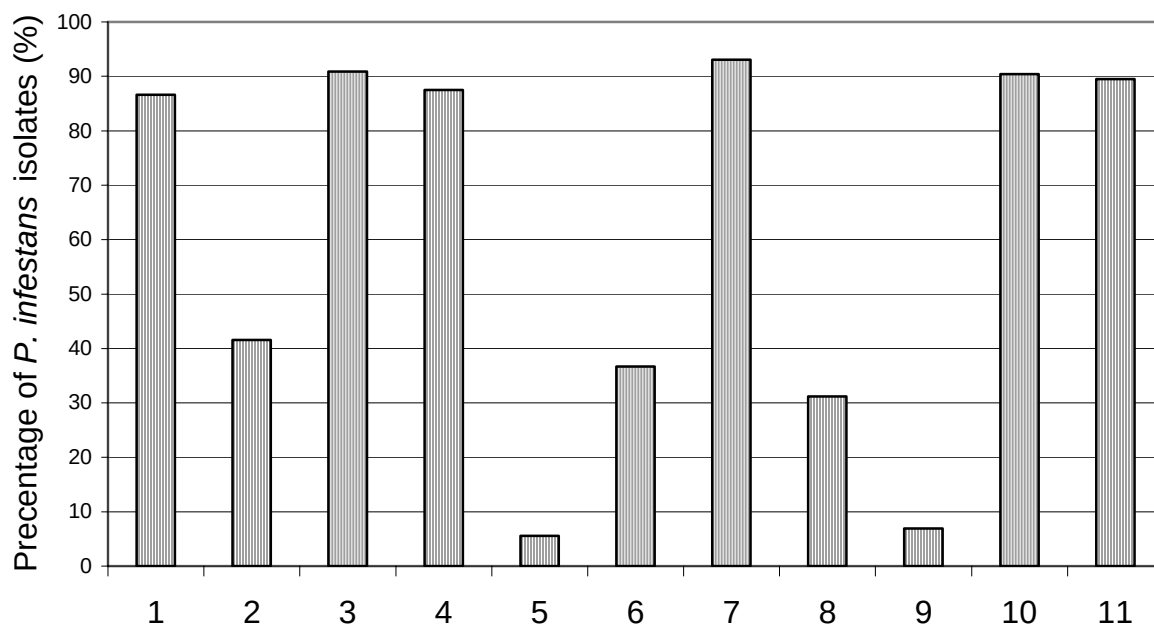


Figure 3. Frequency (%) of virulence to potato R-gene differentials in Estonian population of *Phytophthora infestans*.

References

- Andrison, D, 1996. The origin of *Phytophthora infestans* populations present in Europe in the 1840s: a critical review of historical and scientific evidence. *Plant Pathology* 45: 1027-1035.
- Andrison, D, 1995. Biology, ecology, and epidemiology of the potato late blight pathogen *Phytophthora infestans* in soil. - *The American Phytopathological Society* 85:1053-1056.
- Brurberg, MB, A Hannukkala and A Hermansen, 1999. Genetic variability of *Phytophthora infestans* in Norway and Finland as revealed by mating type and fingerprint probe RG57. *Mycol. Res.* 103 (12): 1616-1620.
- Drenth, A, ICQ Tas and F Govers, 1994. DNA fingerprinting uncovers a new sexually reproducing population of *Phytophthora infestans* in the Netherlands. *European Journal of Plant Pathology* 100, 97-107.
- Drenth, A, LJ Turkensteen, F Govers, 1993. The occurrence of the A2 mating type of *Phytophthora infestans* in the Netherlands: significance and consequences. - *Neth. J. Plant Pathology*, 99:57-67.
- Elansky, S, A Smirnov, Y Dyakov, A Dolgova, A Filippov, B Kozłowski, I Kozłowska, P Russo, C Smart, C and WE Fry, 2001. Genotypic analysis of Russian isolates of *Phytophthora infestans* from the Moscow region, Siberia and Far East. *J. Phytopathology* 149: 605-611.

- Fry, WE and SB Goodwin, 1997. Re-emergence of potato and tomato late blight in the United States. Plant Dis. 81, 1349-1357.
- Fry, WE, SB Goodwin, AT Dyer, JM Matuszak, A Drenth, PW Tooley, LS Sujkowski, YJ Koh, BA Cohen, LJ Spielman, KL Deahl, DA Inglis and KP Sandlan, 1993. Historical and recent migrations of *Phytophthora infestans*: chronology, pathways and implications. Plant Disease 77, 653-61.
- Hermansen, A, A Hannukkala, R Hafskjold Naerstad and M Brurberg, 2000. Variation in populations of *Phytophthora infestans* in Finland and Norway: mating type, metalaxyl resistance and virulence phenotype. Plant Pathology 49: 11-22.
- Koppel, M, 1996. Muutused *Phytophthora infestans* populatsioonis ja kartulisortide lehemädanikukindlus. - Akadeemilise Põllumajanduse Seltsi toimetised nr. 1. Tartu, lk. 30-33.
- Schöber, B and LJ Turkensteen, 1992. Recent and future developments in potato fungal pathology. Netherlands Journal of Plant Pathology 98 (Suppl. 2), 73-83.
- Sujkowski, LS, SB Goodwin and WE Fry, 1996. Changes in specific virulence in Polish populations of *Phytophthora infestans*: 1985-91. European Journal of Plant Pathology 102, 555-61.
- Sujkowski, LS, SB Goodwin, AT Dyer and WE Fry, 1994. Increased genotypic diversity via migration and possible occurrence of sexual reproduction of *Phytophthora infestans* in Poland. Phytopathology 84, 201-7.
- Swiezynski, KM, L Domanski, H Zarzycka and E Ziemnoch-Gusowska, 2000. The reaction of potato differentials to *Phytophthora infestans* isolates collected in nature. Plant Breeding 119: 119-126.
- Zhang, Z, J Zhu, B Song, Y Li, S Titan and H Jiang, 2001. Further investigation on A2 mating type of *Phytophthora infestans* in China. Journal of Agricultural University of Hebei Vol. 24, No. 2.

Early blight: disease control and isolate studies

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Summary

In 2005 several field trials were carried out in order to investigate the importance and dispersal of early blight and to test the efficacy of fungicides against this disease. Azoxystrobin, which is discussed as the best active ingredient against early blight at the moment, was tested at different application times. Through the development of fungicide strategies it shall give a successful disease control. The disease progress was mapped during the whole vegetation period. Good control of leaf lesion was obtained through the use of Azoxystrobin. Yield benefit (through more tubers as well as a higher starch content) confirmed the received rating data.

From all fields leaf symptoms were sampled over the season in order to create single spore isolates.

Keywords: early blight, chemical control, fungicide efficacy, yield loss, field isolate

Introduction

Early blight – an increasing problem

In many German potato growing areas early blight, which is caused by *Alternaria spp.*, has established as a relevant and destructive pathogen. On potatoes *Alternaria* causes big brown and necrotic lesions, which shows typically concentric rings (Rotem 1994). As disease progresses whole leaves can be infected and drop off. Because *Alternaria* produce toxins that diffuse into host tissues, it is not uncommon to see yellow halos around the brown spots (Laemmle 2004).

Within the last years an increase in disease frequency was observed, so that up to now early blight became more and more an important disease in potatoes (Hausladen 2004). Different factors, depending upon environment and plant physiology, have a central influence on the disease progress of *Alternaria*. In addition lower nitrogen fertilisation or varieties with higher leaf susceptibility are leading to a more rapid propagation.

Material and methods

Field trials

In order to examine the effect of different fungicide ingredients against early blight, two identically field trials were carried out in 2005. In each field 40.000 tubers/ha were planted on april 10th and on may 2nd. For the specific fungicide treatments the potato field was divided into smaller plots of 24 square meters. Each trial was replicated four times. The tested fungicide ingredients were Azoxystrobin (125 gr a.i./ha) and mancozeb (1350 gr a.i./ha). Azoxystrobin has a broad spectrum of disease control with eradicant, protectant, translaminar and systemic properties (Bouwman 2004). The control plot stayed untreated against early blight. In comparison Mancozeb only has protectant and antisporelulant properties.

In order to protect against late blight, the fungicide RanMan (80 gr a.i./ha cyazofamid), was applicated in all plots. Because RanMan only prevents late blight infestation, there was no influence on treatments with Azoxystrobin or Mancozeb. The coverspray and the trial fungicides were applicated separately. RanMan was first applicated on June 3rd and then treated every 8 to 10 days. Mancozeb and Azoxystrobin were applicated weekly from the beginning of first symptoms (June 6th).

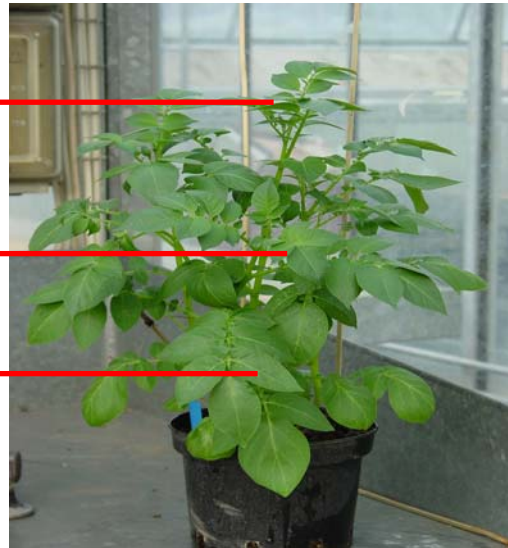
Rating

Over the season the expansion of the necrotic leaf area caused by early blight was observed weekly. In each of the four control plots 10 plants were checked about its disease progress. In the other variants 6 plants were examined. For the ratings the potato plant was divided into three parts (lower leaf level, middle leaf level and upper leaf level). From each of these leaf levels one leaflet was choosen and the height of the necrotic leaf area was determined.

upper leaf level

middel leaf level

lower leaf level



Results

Rating

Already three weeks after crop emergence first early blight symptoms were found in the field on older leafs and lower leaflets. From there the disease spreaded up into higher leaf levels within the following weeks.

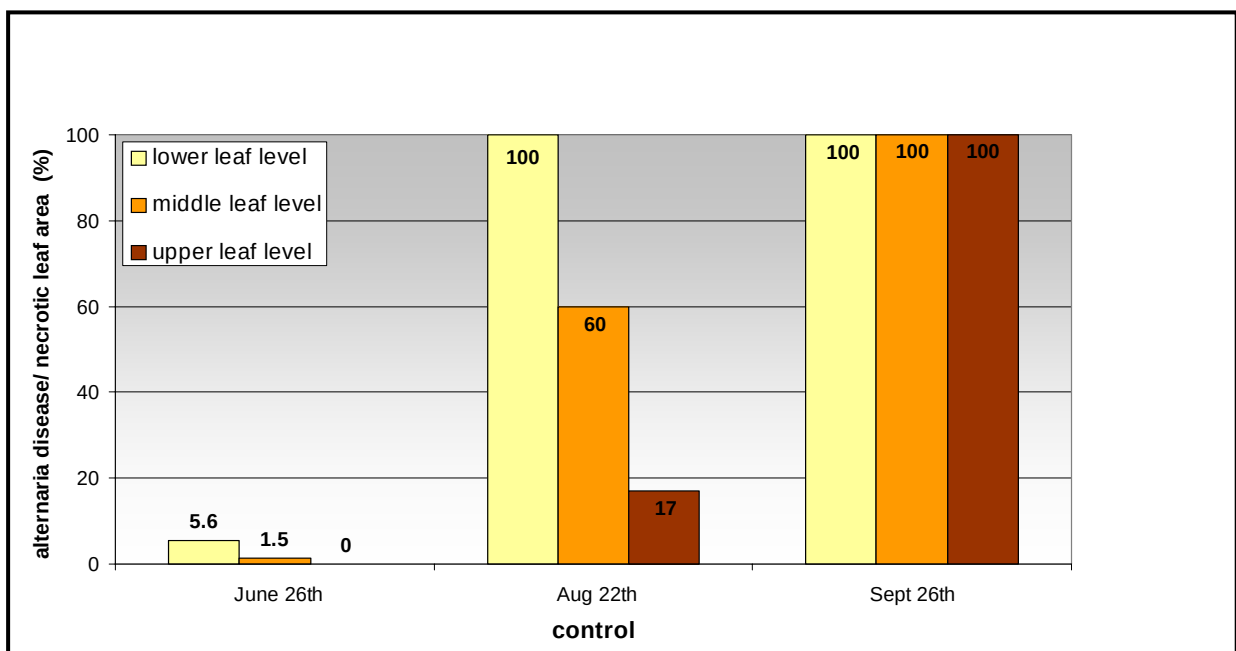


Figure 1. Disease progress in the untreated control plot

The potato plants in the control plot were totally destroyed by early blight until September 26th. Through fungicide treatments the disease progress could be reduced. In the plots treated with Mancozeb the lower and the middle leaf level were destroyed completely until September 26th as well. But in comparison to the untreated plots the Mancozeb treatment showed a less severe disease infestation on the upper leaf level. Here only 40% were destroyed by early blight.

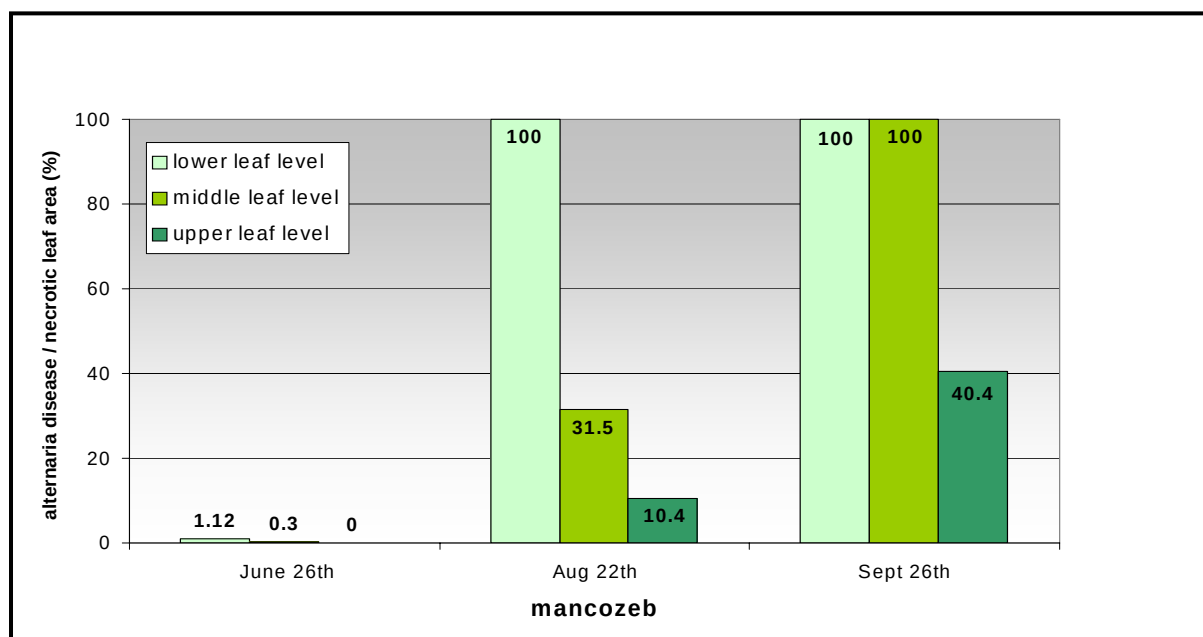


Figure 2. Disease progress in plots weekly treated with mancozeb.

However, the best fungicide results were obtained in the plots treated with Azoxystrobin. From the beginning of the ratings up to harvest time this treatment showed the lowest rates in necrotic leaf area. Even shortly before the harvest time on Oktober 1th there was a relatively low disease infestation on the middle and the upper leaf levels. In this trail Azoxystrobin provided the best protection against early blight.

The comparison of the three figures show, that early blight can be reduced through fungicide application. The different active ingredients provided a more or less good protection, according to their specific mechanism of action. Despite of the good protection of early blight through use of Azoxystrobin, it was not possible to eliminate the disease totally.

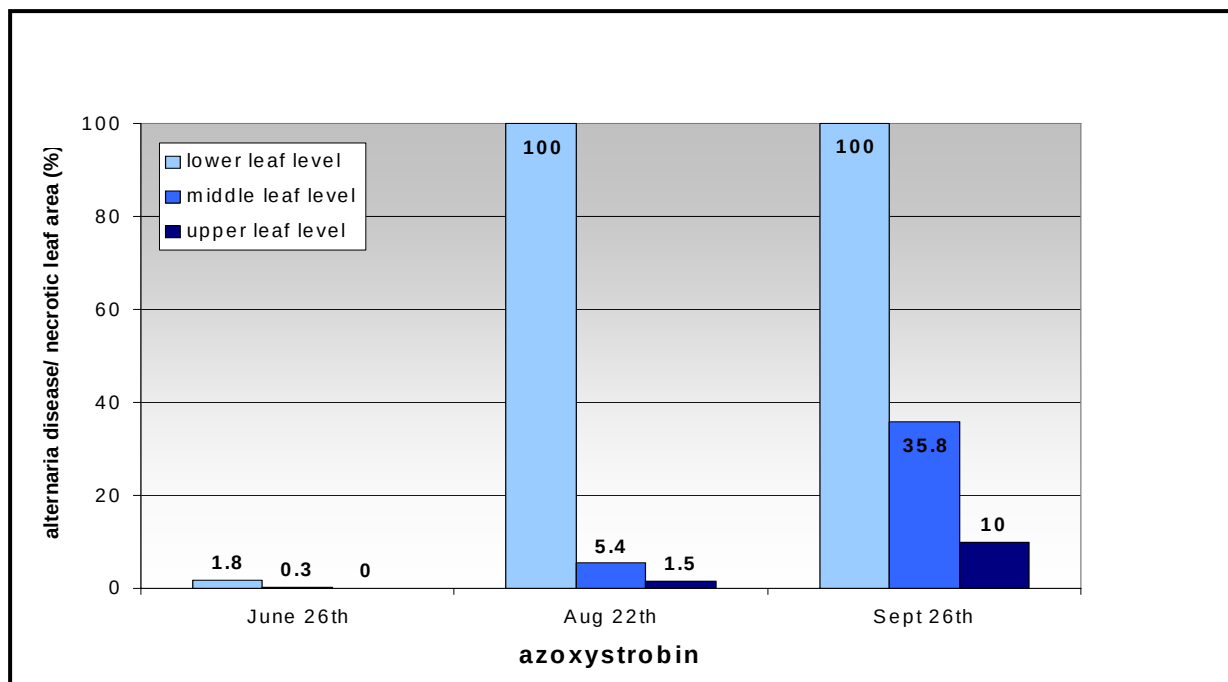


Figure 3. Disease progress in plots weekly treated with Azoxystrobin.

Figure 4 gives an overview about the extend of the necrotic leaf area with or without fungicide treatment. All three leaflets were collected on September 2nd from the upper leaf level.

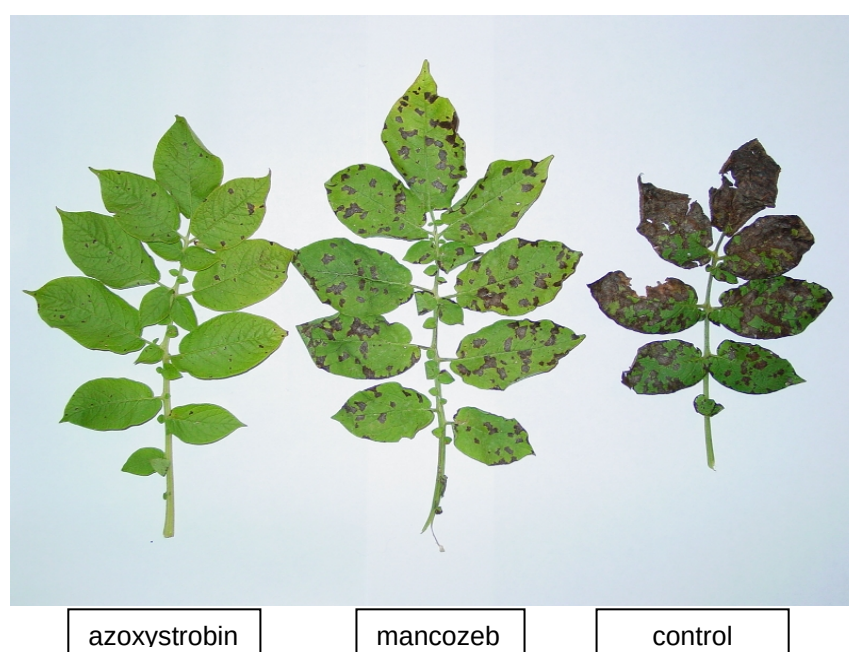


Figure 4. Leaflets infected with early blight, taken from the upper leaf level.

Yield

On Oktober 1th the trial plots were harvested by hand. Tuber yield was determined on side. The starch content was fixed three weeks after harvest. In the untreated control plot 674 dt/ha were harvested, whereas in the treated plots a higher yield could be reached due to a longer assimilation time. The highest yield with 745 dt/ha was harvested in the plot treated with Azoxystrobin, which results in a 10% higher tuber yield level compared to the untreated plot (Figure 5).

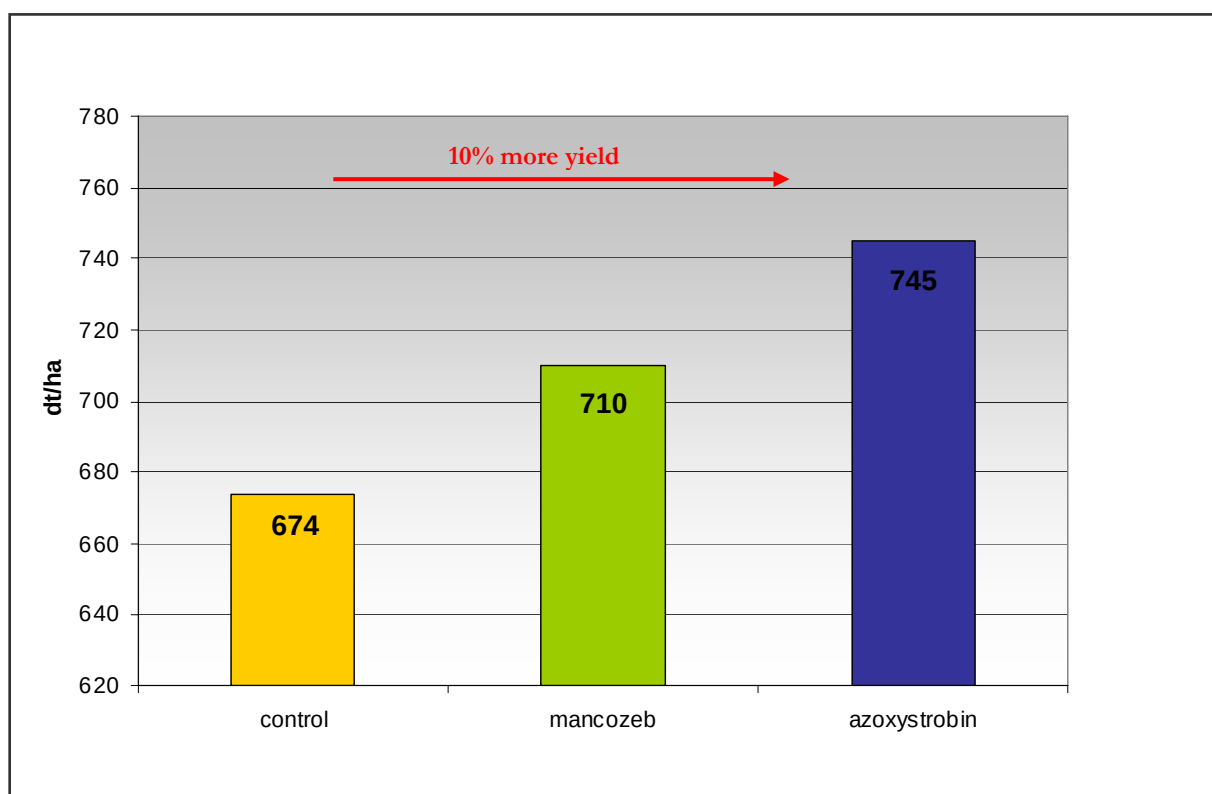


Figure 5. Tuber yield of the control plot compared with the treated trails.

Furthermore, the results of the tuber yield was seen as well in the starch measurement. With both fungicide treatments it was able to obtain an higher tuber yield as well as an increase in starch. In 2005 in the plots treated with Azoxystrobin 9 % more starch was produced than in the untreated plots. In complete the application of Azoxystrobin enhanced the starch yield of 20% (Figure 6).

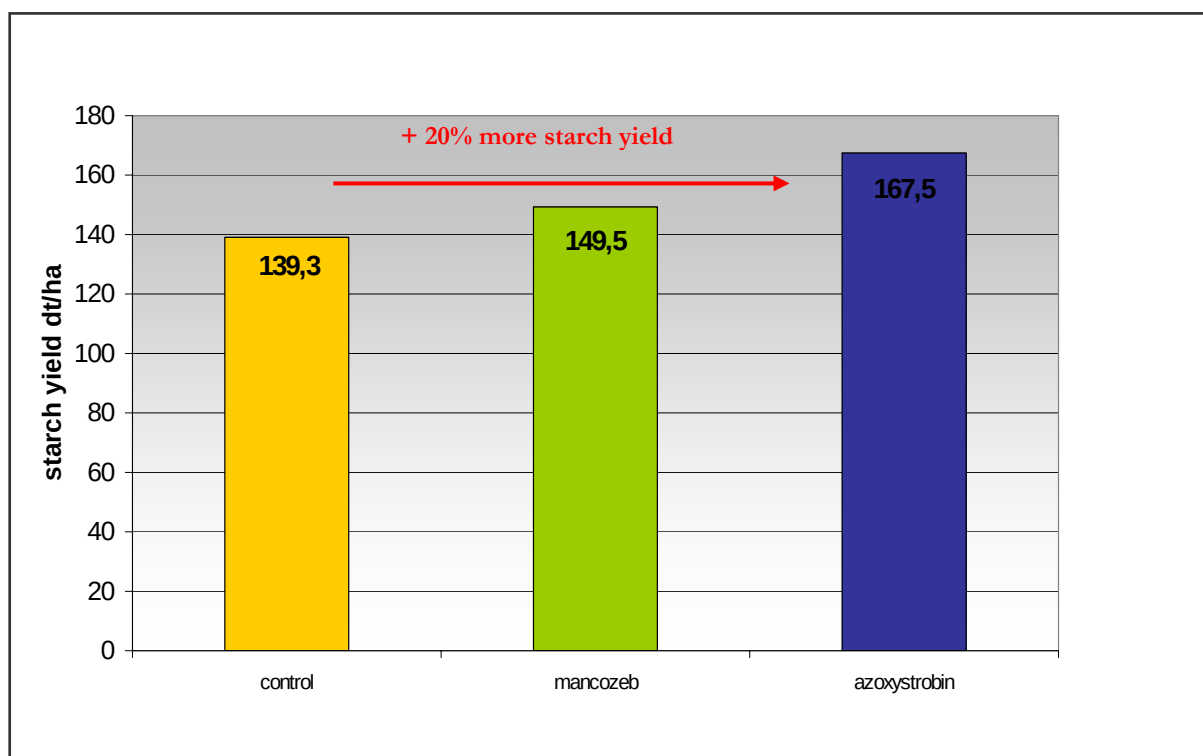


Figure 6. Starch yield of the control plot compared with the treated trials

Isolate studies:

In order to obtain more data about the different pathotypes which leads to early blight, isolate studies were accomplished. Primarily single spore isolates, of both pathotypes (*Alternaria solani* and *Alternaria alternata*) were gained. On the basis of leaves, showing typical early blight symptoms, single spores were isolated and transferred on slightly nutrient agar. Under defined conditions of light (ultraviolet light, day and night rhythm) and temperature (21 °C) sporulation sets in generally between 8 to 10 days. However, spores were only produced on agar which was slightly nutrient. On other agars like PDA (potato dextrose agar) or V8 (vegetable agar) only mycelial growth was determined, but no production of conidia. In this way obtained spores were used for artificial inoculations on plants as well as on tubers.

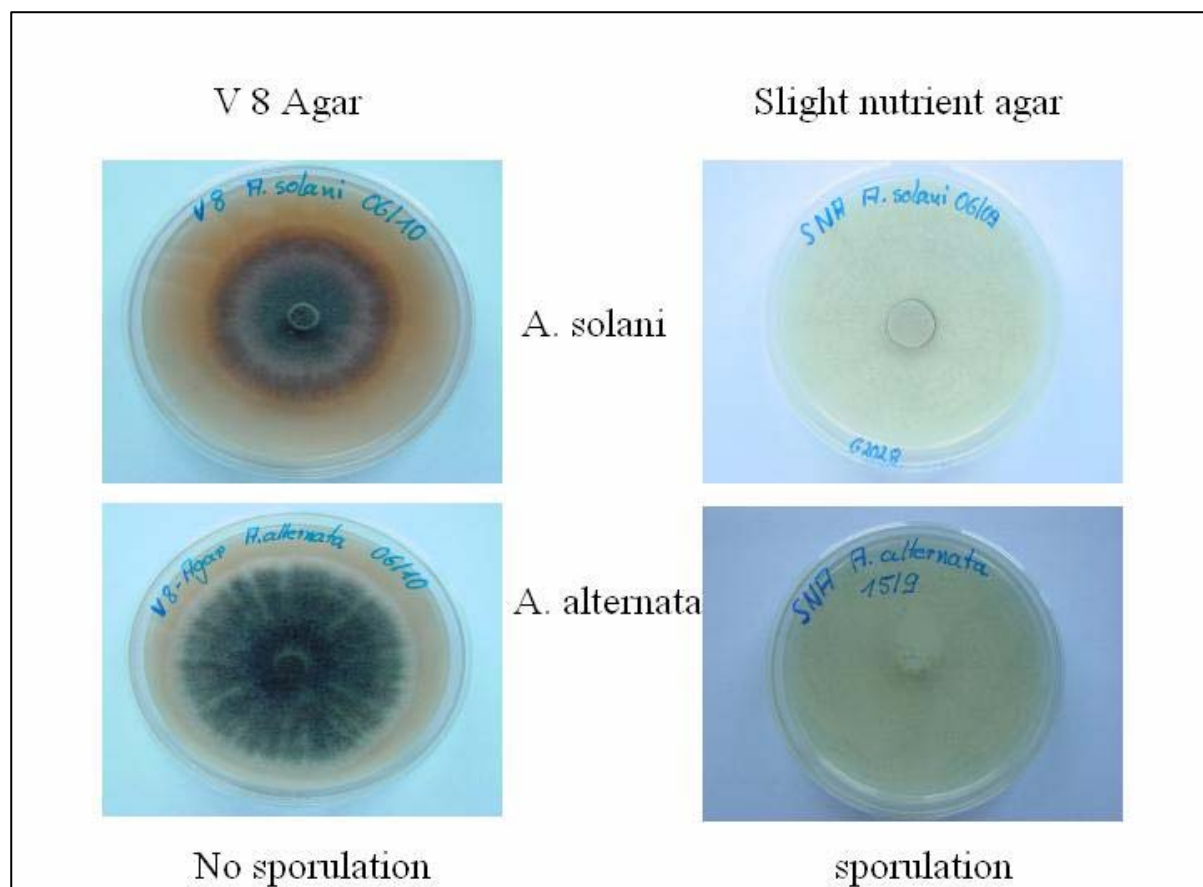


Figure 7. Comparison of different agar and isolate growth.

Conclusion

In Germany early blight becomes more and more a severe disease. Through the use of fungicides the disease progress was able to slow down. Considering the specific fungicide impact differently good results could be obtained.

Field trials in 2005 showed that early blight appeared very early in the season. Already three weeks after crop emergence first symptoms were found on older and lower leaflets (Viskonti, Chelkowski 1992). During the following weeks the disease infestation remained on a relatively low level. Not before August a stronger increase of early blight disease could be determined. Though the use of potent fungicides the disease incidence could be reduced effectively. Tuber yield as well as starch content were increased significantly.

In comparison of the weekly treatments Azoxystrobin showed a better early blight protection than Mancozeb did. Despite the weekly treatments a complete elimination of *Alternaria* was not possible. Although Azoxystrobin offers the best protection against early blight it is not allowed for application in potatoes in Germany at the moment. At the moment for the German market there are fungicides available, which only have side actions against early blight. These fungicides are not able to ensure a complete disease control.

Further investigations about the pathogen complex of early blight shall give more knowledge on the way to an effective disease control strategy.

References

- Bouwman, JJ and G Rijkers, 2004. The control of *Alternaria solani* (early blight) with azoxystrobin in potatoes, PPO Special Report No. 10, pp 179-188.
- Hausladen, J, 2004. Early blight of potato, PPO Special Report No. 10, pp173-177.
- Laemmlen, F, 2004. *Alternaria* diseases, University of California, Agriculture and Natural Resources, 2004, www.anrcatalog.ucdavis.edu/pdf/8040.pdf.
- Rotem J, 1994. The genus *Alternaria*; biology and pathogenicity, APS Press, St. Paul, Minnesota.
- Viskonti, A and I Chelkowski(Hrsg.), 1992. *Alternaria-Biology, plant diseases and metabolites*, Elsevier Verlag, Amsterdam.

Potato late blight control with fluazinam and the current status of phenylamide resistance in Northern Ireland

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Summary

Field trials carried out in Northern Ireland in 2004 and 2005 showed that potato late blight control by programmes based on metalaxyl-M + mancozeb followed by fluazinam (150 g ha⁻¹ at 7-d intervals) could be improved by increasing the amount of fluazinam applied. This was achieved either by applying fluazinam at 5-d intervals during the period of greatest infection pressure or by using 200 g fluazinam ha⁻¹ (the rate approved elsewhere in Europe, but not in the UK) for part of the programme. These options could be useful for Northern Ireland growers under conditions of severe blight risk.

Monitoring the incidence of *Phytophthora infestans* isolates containing phenylamide-resistant strains in Northern Ireland showed that between 1999 and 2001 they increased from 49% to 76%. The existing anti-resistance strategy was modified for the 2002 season and growers were recommended to use no more than two (rather than three) phenylamide applications per crop at the start of the spray programme only. Subsequently, the percentage of isolates containing resistant strains declined to 22% in 2005. Phenylamides continue to have a useful role in blight control in Northern Ireland as long as appropriate strategies are used to reduce the impact of resistance. Monitoring of the incidence of phenylamide-resistant strains is a key component of this.

Keywords: *Phytophthora infestans*, potato late blight, phenylamide resistance, fluazinam.

Introduction

The non-systemic fungicide fluazinam has been approved for the control of potato late blight in the UK since 1994. It is widely used on commercial potato crops in Northern Ireland and has also proved very effective in field trials, particularly when preceded by applications of metalaxyl + mancozeb (Cooke *et al.*, 1999). In the UK, the minimum spray interval approved for fluazinam under severe blight pressure has recently been reduced from 7 to 5 days, but the maximum approved application rate is 150 g fluazinam ha⁻¹, whereas elsewhere in Europe it is at 200 g ha⁻¹. In Northern Ireland, weather very favourable to foliar blight and particularly to tuber infection occurs frequently. It was therefore decided to evaluate the benefits of using fluazinam either at a reduced spray interval and or at an increased dose in field trials in 2004 and 2005 in programmes with applications of metalaxyl-M + mancozeb as the first sprays.

Formulations containing phenylamides + mancozeb have been approved for the control of potato late blight in the UK since 1978. In Northern Ireland, phenylamide-resistant strains of *P. infestans* were first identified in 1981 and annual surveys of their incidence initiated (Cooke, 1981). In the early 1980s, the percentage of isolates containing phenylamide-resistant strains was under 50% in each year, but this increased to *c.* 90% in the late 1980s, which was attributed to selection pressure produced by wide-spread and season-long use of formulations containing phenylamides and a succession of very wet summers (Cooke, 1991). In the early 1990s, an anti-resistance strategy based on the one developed in the Republic of Ireland (Dowley *et al.*, 1995) was adopted in Northern Ireland and growers were advised to use no more than three applications of phenylamides at the start of the spray programme only. Subsequently, the incidence of phenylamide-resistant strains in *P. infestans* in Northern Ireland declined to *c.* 50% and remained relatively stable in the period 1993-2000 (Cooke *et al.*, 2001), but there was an increase in the year 2000. This paper reports on the subsequent modification of the anti-resistance strategy and the results of monitoring in the period 2001-2005.

Materials and Methods

Field trials on use of fluazinam, 2004-2005

Tubers of the blight-susceptible maincrop potato cv. Up-to-date were planted on 11 May 2004 and 13 May 2005 at the Agriculture & Food Science Centre, Newforge, Belfast in fully

randomised blocks with five replicate plots per treatment. Each plot (2.8 x 3.0 m²) contained four rows of ten tubers. Pairs of rows of unsprayed plants adjacent to each treated plot served as an infection source. Plants in these rows were inoculated (7 July 2004, 7 July 2005) with phenylamide-resistant and phenylamide-sensitive isolates of *P. infestans* (50% of leaves inoculated with a mixture of resistant isolates and 50% with sensitive isolates obtained from recent Northern Ireland blight samples). The plots were misted daily after inoculation for 2-3 h at dawn and dusk when required to encourage spread of blight.

In both years, the standard programme comprised two sprays of metalaxyl-M + mancozeb as 'Fubol Gold WG' (Syngenta) followed by eight sprays of fluazinam as 'Shirlan' (Syngenta). In 2004, the comparison programme included three applications of 'Shirlan' at 5-d intervals and in 2005 it included five applications of 'Shirlan' at 400 ml ha⁻¹ (200 g fluazinam ha⁻¹). Details of programmes are shown in Table 1.

Table 1. Fungicide programmes evaluated for control of potato blight, 2004-05.

Number of applications and treatment	Active ingredient rate (g ha ⁻¹)	Spray interval (days)	2004	2005
2 x metalaxyl-M + mancozeb	76 + 1216	7	√	√
8 x fluazinam	150	7		
2 x metalaxyl-M + mancozeb	76 + 1216	7		
4 x fluazinam	150	7	√	x
3 x fluazinam	150	5		
2 x 'fluazinam	150	7		
2 x metalaxyl-M + mancozeb	76 + 1216	7		
5 x fluazinam	200	7	x	√
3 x fluazinam	150	7		

Spray programmes started on 22 June 2004 and 23 June 2005 and ended on 25 August 2004 and 26 August 2005. Foliar late blight was assessed twice weekly during July and August. Plots were desiccated with diquat ('Reglone', Syngenta, 2 September 2004, 1 September 2005) and tubers lifted on 28 September 2004 and 27 September 2005. The yield from each plot was graded and recorded; the number and weight of blighted, soft-rotted tubers was recorded and they were then discarded. The number and weight of firm blighted tubers >35 mm was assessed (and diseased tubers discarded) in November in each year and again in February (data available for 2004 trial only).

Sampling of potato crops and isolation of *Phytophthora infestans*

Samples of infected potato foliar together with data on sample site, potato cultivar, fungicide usage and disease incidence were obtained (mainly from seed crops) by members of the Department of Agriculture and Rural Development (DARD) Quality Assurance Branch, as previously described (Cooke *et al.*, 1997). Isolates were derived by bulking together the sporangia obtained from all foliar samples within a single crop and maintained on detached glasshouse-grown potato leaflets (Cooke, 1986).

Tests for phenylamide resistance

Isolates were tested, using the floating leaf disc technique (Cooke, 1986), on 100 and 2 mg metalaxyl litre⁻¹. Isolates were designated resistant if they sporulated on 100 mg metalaxyl litre⁻¹-treated discs and sensitive if they sporulated on untreated discs, but not on any metalaxyl-treated disc. Isolates which grew on discs floating on 2 mg, but not on 100 mg metalaxyl litre⁻¹ were designated intermediate. Isolates which failed to grow on at least four out of six untreated discs were re-tested.

Results

Field trials on use of fluazinam, 2004-2005

In 2004, for the programme which included three fluazinam applications at 5-d intervals, these were made between 2 and 12 August and only added one additional spray compared with the standard 7-d programme. Nonetheless, this programme achieved significantly better control of foliar blight than the standard programme after 17 August (Figure 1a, Table 2) and, although there were no significant differences in yield, tubers from plots receiving the 5-d fluazinam sprays had a significantly lower percentage of blight (Table 2).

In 2005, the programme including five fluazinam applications at 200 g ha⁻¹ had significantly less foliar blight than the standard programme (Figure 1b, Table 2). There were no significant differences in yield or the percentage of blighted tubers after the first tuber blight assessment in November 2005 (Table 2), although the 200 g fluazinam ha⁻¹ programme had a greater healthy yield and a lower percentage of blighted tubers; a final tuber blight assessment will be made in January-February 2006.

Table 2. Field trials on use of fluazinam, 2004-2005: foliar blight and yield assessments.

Treatment	Foliar blight (%) ^a	Weight (kg/plot) tubers ^b		Blighted tubers (%) by number ^{b,c}
		Total	Healthy ^c	
<u>2004</u>				
metalaxyl-M+mancozeb/fluazinam	36.2	63.7	57.7	4.3
metalaxyl-M+mancozeb/fluazinam 5-d	26.8	63.9	59.2	1.7
L.S.D. (<i>P</i> <0.05)	8.67	n/a	n/a	1.99
<u>2005</u>				
metalaxyl-M+mancozeb/fluazinam	20.5	59.4	55.8	2.1
metalaxyl-M+mancozeb/fluazinam 200 g	8.5	60.8	57.3	1.6
L.S.D. (<i>P</i> <0.05)	9.53	n/a	n/a	n/a

a) *final assessment before haulm destruction*

b) *based on tubers >35 mm*

c) *after final tuber blight assessment in February 2005 for 2004 trial; after first tuber blight assessment in November 2005 for 2005 trial.*

Incidence of phenylamide resistance

The overall proportion of isolates containing phenylamide-resistant strains for the period 1981-2005 is shown in Figure 2. Cooke *et al.* (2001) noted that in 2000, the proportion of isolates containing phenylamide-resistant strains was 57%, an increase on the previous seven years. A more marked increase was noted in 2001 when the corresponding figure was 76%. The reason for this was not clear, since fungicide usage had not changed, but may have been associated with wet weather in the summer months of 1998-2000, which increased the number of generations of *P. infestans* within each season and favoured the build-up of resistant strains. For 2002, DARD and Syngenta agreed revised recommendations for phenylamide usage: growers were advised to use no more than two applications per season and to switch to an alternative product type no later than 15 July. Subsequently, the proportion of isolates containing resistant strains declined from *c.* 60% in 2002 to 22% in 2005. Most growers are now following the recommendation to use no more than two phenylamide applications per crop (Table 3); there has also been a reduction in the area of potato crops treated with formulations containing phenylamides in recent years (Fig. 3).

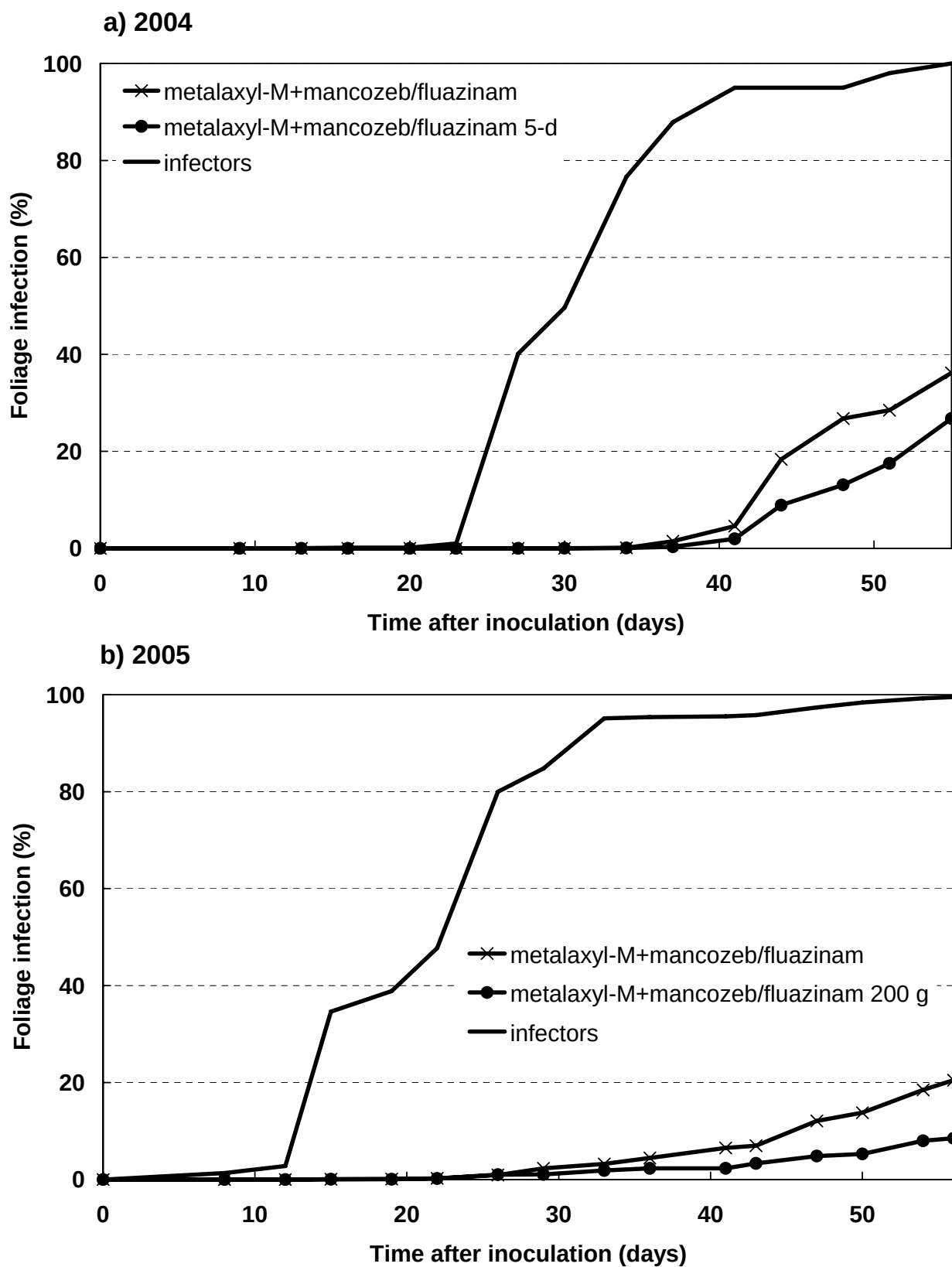


Figure 1. Foliar blight development in field trials on use of fluazinam, 2004-2005.

Table 3. Number of applications used by seed potato growers applying phenylamides, 2000-2004.

Number of phenylamide applications	Of growers using phenylamides (%)				
	2000	2001	2002	2003	2004
one	13	17	11	41	41
two	50	58	30	41	41
three	25	19	48	16	12
four	10	5	9	2	6
five +	2	1	2	0	0
% growers using phenylamides	79	62	44	36	15

Discussion

The field trials in 2004 and 2005 confirmed the effectiveness in controlling late blight of a standard programme of metalaxyl-M + mancozeb followed by 7-d applications of fluazinam at 150 g ha⁻¹. However, they showed that foliar and tuber blight control were improved by using an increased amount of fluazinam either by using fluazinam at a shorter interval during the critical period when foliar infection was building up most rapidly or by applying it at the 200 g ha⁻¹ rate used elsewhere in Europe. For growers in Northern Ireland, these would be useful options, particularly when high rainfall favours tuber infection, although at present, while growers can legally apply fluazinam at 5-d intervals under severe risk conditions, the use of fluazinam at 200 g ha⁻¹ does not have UK approval. Effects of such treatments on the fluazinam sensitivity of *P. infestans* will be investigated and compared with results obtained from previous sensitivity monitoring, which showed that all Northern Ireland isolates collected between 1993 and 1998 were very sensitive to fluazinam (Cooke *et al.*, 1999).

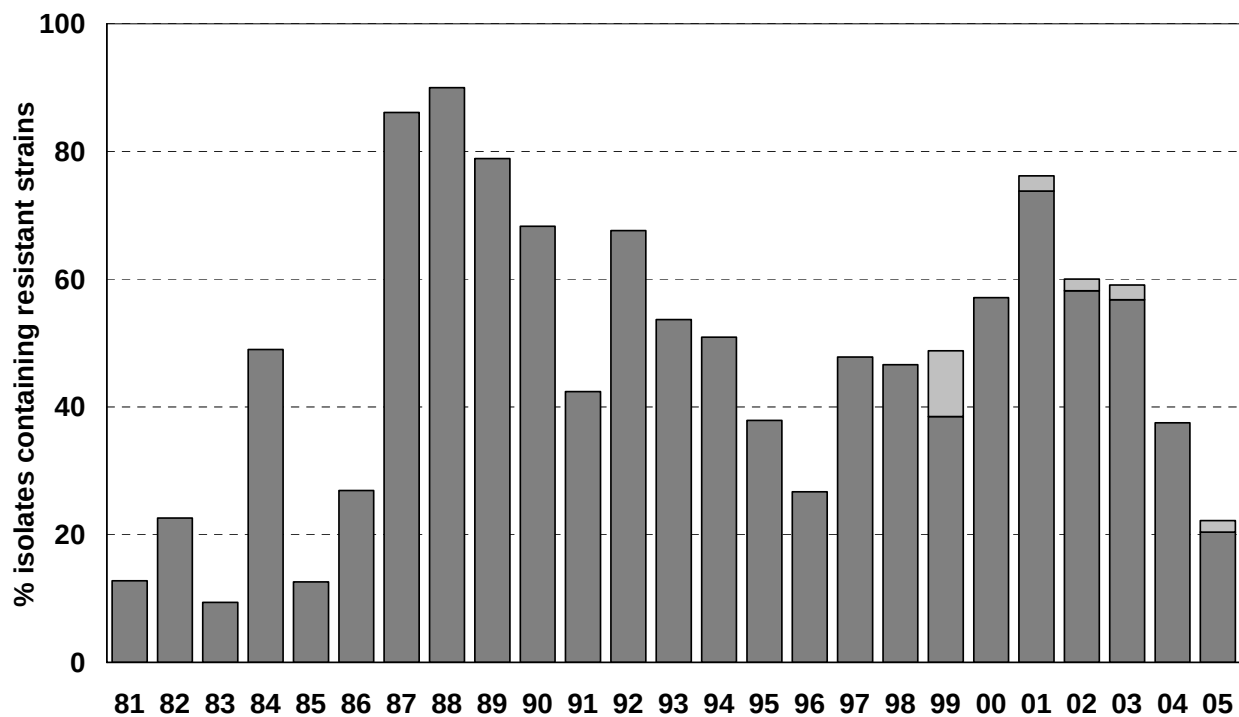


Figure 2. The proportion of Northern Ireland *Phytophthora infestans* isolates containing phenylamide-resistant strains, 1981-2005.

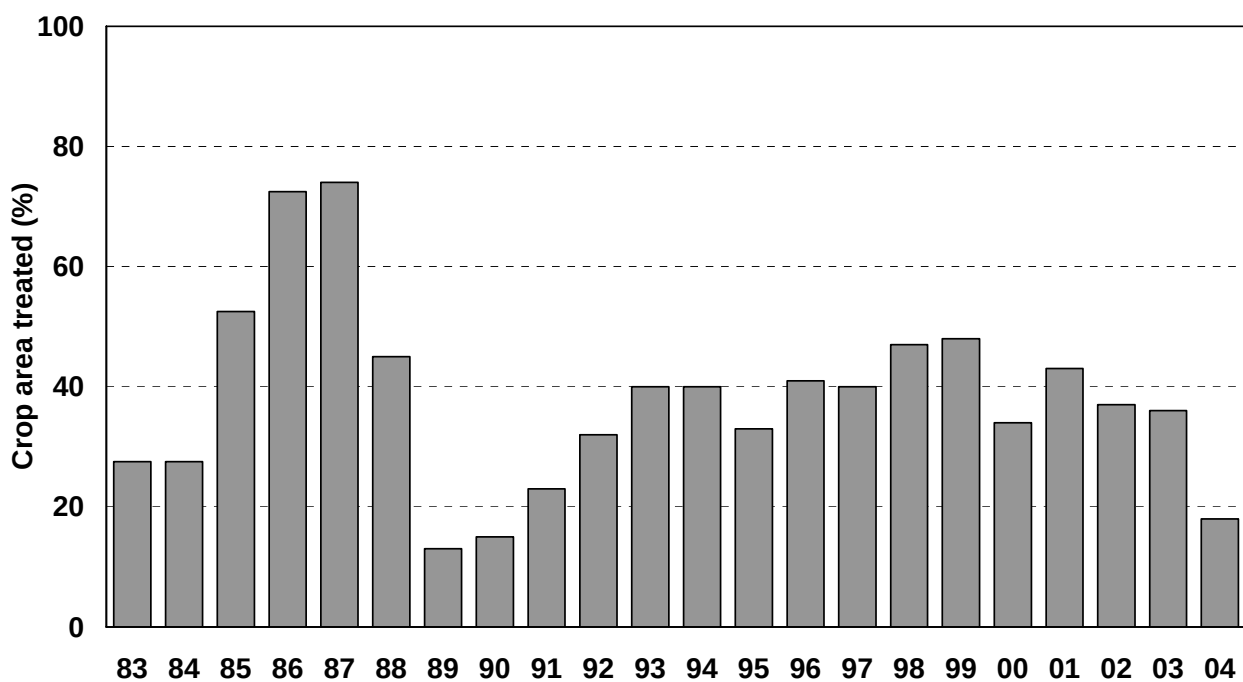


Figure 3. The proportion of Northern Ireland seed potato crops treated with phenylamides, 1983-2004 (data for 1981-82 not available; data for 2005 not yet collected).

In Northern Ireland, formulations containing phenylamide fungicides offer benefits in controlling blight at the start of the season when growth of the potato plant is most rapid and the systemicity of metalaxyl-M of greatest value. However, if the *P. infestans* population is dominated by phenylamide-resistant strains, then this benefit is lost (Cooke and Little, 1989). The incidence of phenylamide resistance increased in the late 1990s and 2000-2001, but after modifying the anti-resistance strategy for the 2002 season, it declined. It is concluded that phenylamides still have a useful role in blight control in Northern Ireland and that the impact of resistance can be reduced by appropriate strategies. The expanding range of fungicides with different modes of action provides many more options for growers and they are increasingly exploiting these, which helps to reduce the selection pressure in favour of resistance to any one mode of action group. However, it is essential to continue to monitor the fungicide sensitivity of the local *P. infestans* population in order to judge the success or otherwise of anti-resistance strategies and to have early warning of potential resistance problems.

Acknowledgements

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References

- Cooke LR, 1981. Resistance to metalaxyl in *Phytophthora infestans* in Northern Ireland. Proceedings 1981 British Crop Protection Conference - Pests and Diseases **2**, 641-649.
- Cooke LR, 1986. Acylalanine resistance in *Phytophthora infestans* in Northern Ireland. *Proceedings of the 1986 British Crop Protection Conference - Pests and Diseases* **2**, 507-514.
- Cooke LR, 1991. Current problems in the chemical control of late blight: the Northern Ireland experience. In *Phytophthora*. Chapter 22. pp. 337-348. Eds. Lucas, J.A., Shattock, R.C., Shaw, D.S. & Cooke, L.R. Cambridge University Press. 447pp.
- Cooke LR and G Little, 1989. The control of a phenylamide-resistant potato blight infection by fungicide formulations. *Tests of Agrochemicals and Cultivars 10. A supplement to Annals of Applied Biology* **114**, 174-175.

- Cooke LR, G Little and DJ Carlisle 1997. The current status of phenylamide resistance in *Phytophthora infestans* in Northern Ireland. Proceedings First Workshop of an European Network for Development of an Integrated Control Strategy of potato late blight. *PAV-Special Report no. 1*, 61-68.
- Cooke LR, G Little, M Quinn and DG Wilson, 2001. Potato blight population studies 1999-2000 and field results on integration of cultivar resistance and fungicide programmes. Proceedings of the Fifth Workshop of an European Network for Development of an Integrated Control Strategy of potato late blight, Munich, Germany, 6-10 September 2000. *PAV-Special Report no. 7*, 245-254.
- Cooke LR, G Little and DG Wilson, 1999. Use of fluazinam in potato late blight control: sensitivity and field performance. Third Workshop of an European Network for Development of an Integrated Control Strategy of potato late blight. Uppsala, Sweden, 9 - 12 September 1998. *PAV-Special Report no. 5*, 237-246.
- Dowley LJ, LR Cooke and E O'Sullivan, 1995. Development and monitoring of an anti-resistance strategy for phenylamide use against *Phytophthora infestans*. In *Phytophthora infestans*. pp. 130-136. Eds. Dowley, L.J., Bannon, E., Cooke, L.R., Keane, T. & O'Sullivan, E. Boole Press, Dublin. 382 pp.

The Maine Approach to Late Blight Prediction and Control

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Summary

Late blight prediction in Maine has moved from a centralized approach to a localized approach. Progressive Maine potato growers use automated weather stations for real-time, weather data collection at the grower level. On-site data analysis and late blight prediction is accomplished with the computer model NoBlight. Late blight is not controlled by predictions but by application of sound disease control principals. Control of initial inoculum, proper application of fungicides and potential early vine killing are part of the consciousness effort of the potato growers to control late blight. Since control of late blight has always been performed locally and it is a natural progression to guide the control of potato late blight at the local level.

Keywords: Late blight, prediction, NoBlight

Introduction

Potato late blight, caused by *Phytophthora infestans*, is one of the most destructive foliar diseases on potatoes and has been around over 150 years. Most potato-growing areas have developed prediction schemes to schedule fungicide application to control this pathogen. Late blight prediction and control in Maine is not new. It has been ongoing for over 30 years with varied levels of participation on the grower's part. Much of the activity has been involved in an active Integrated Pest Management (IPM) Program during that time. Within the IPM

program, scouting has been routinely performed on as many as 125 farms representing as much as 25 percent of the area devoted to potatoes in Maine. Historically, the formal prediction and the formal scouting for potato late blight have not been done by the potato farmer but rather by University of Maine field scouts. First observation or discovery of the disease in the field has been by the University of Maine representatives, the farmers, or other service personnel observing the field. Final management of late blight in the field and related decisions always rests with the farmer.

In Maine, the potential for late blight to appear is predicted with severity values (1). Severity values are based on weather conditions and accumulate when weather conditions are appropriate for the development of the pathogen. Severity values are based on hours of relative humidity above 90 percent and the average temperature during this period and are accumulated in the manner demonstrated in Table 1. The first occurrence of late blight is predicted 7 days after 18 severity values have accumulated. Once 18 severity values have accumulated from emergence, the first spray is recommended. As can be seen from Table 1, three separate six-hour periods of relative humidity greater than 90 percent will not accumulate any severity values. However, an 18-hour period of relative humidity greater than 90 percent will accumulate severity values, depending on the average temperature during that period (3 severity values at 20°C, 2 at 14°C, 1 at 10°C and 0 at 4°F or 30°C). Subsequent protective sprays are recommended based on additional severity value accumulation during the previous seven days (table 2). Fungicide treatment for the prevention of late blight should begin immediately if the disease is developing from seed or has otherwise been sighted in the field or in nearby fields.

Table 1. Calculation of Severity Values

Temperature °C	Hours of 90% or higher relative humidity (RH)				
7 - 12	< 15	16-18	19-21	22-24	25-27
13 - 15	< 12	13-15	16-18	19-21	22-24
16 - 27	< 9	10-12	13-15	16-18	19-21
SV	0	1	2	3	4
At 7-12°C, >27 hrs. 90% RH		At 13-15°C, >24 hrs. 90% RH		At 16-27°C, >21 hrs. 90% RH	
(Total hours - 1)		(Total hours - 1)		(Total hours - 1)	
SV = $\frac{\text{Total hours} - 1}{4} - 4$		SV = $\frac{\text{Total hours} - 1}{3} - 3$		SV = $\frac{\text{Total hours} - 1}{3} - 2$	
4		3		3	

The traditional approach has been centralized late blight prediction using weather data collected from on-site equipment. This approach removes the grower from the process. Frequently, the weather collection equipment was mechanical and unreliable. Local late blight predictions were extrapolated from these on-site data. With centralized late blight prediction, emphasis was placed on local rather than on-site predictions. Attempts at regional data collection and interpretation to provide local predictions have not met with success owing to localized climatic differences within regions.

Table 2. Spray Interval Based on Severity Values

7-Day Severity Value Accumulation	7-Day Severity Value Accumulation	Spray Interval
(< 30 cm of rain)		(≥30 cm of rain)
≥6	≥5	5 day
≥5 <6	≥ 4 < 5	7 day
> 4 < 5	>3 <4	10 day
≤4	≤3	10–14 day

Minimum weather data inputs needed for developing late blight prediction include air temperature, relative humidity and rainfall on an hourly basis. Major concerns of on-site weather data collection are the time required, the complexity of use, the initial and maintenance cost of the equipment. With very reasonably priced, good quality, dependable automated weather stations coupled with user-friendly software, these hurdles were passed.

This has moved the approach to on-site data collection yielding on-site late blight prediction that is extrapolated to local predictions. The initial network consisted of seven weather stations covering 25,000 hectares of potatoes grown on nearly 475 farms. This has now increased to 17 stations covering the same area, and is ever expanding. The weather stations are on site and operated by growers.

The missing component to move from centralized late blight prediction to on-site late blight prediction is on-site data analysis. Major concerns of on-site late blight prediction are the time

required, the complexity of use, and risk. Risk is perceived as the risk of late blight appearance; risk is not related to charges for using a prediction system. Risk is also attached to an unknown or unproven prediction scheme for the Maine potato production areas. There is effectively a zero tolerance for late blight in the Maine potato production system. This gap was bridged with the computer model “NoBlight.” NoBlight was developed specifically to address the concerns of the Maine potato grower. The software interface is simple and extremely fast to use and utilizes the late blight prediction system that has been long used and accepted. NoBlight outputs the Severity Values on a given day, the previous seven days and year to date as well as a spray interval recommendation. NoBlight was developed in Maine and is used to guide the initiation and subsequent applications of fungicides for control of potato late blight in Maine. NoBlight is based on “Blitecast,” which uses Wallin’s model of severity value accumulation. The NoBlight model initiates accumulation of severity values starting at 50 percent plant emergence. NoBlight, like Blitecast, weights relative humidity more heavily than rainfall in predicting the timing of the applications. Close study of Table 2 will reveal that the spray interval becomes shorter with the accumulation 30 cm of rain over the past seven days under the same number of accumulated severity values.

NoBlight differs from Blitecast in the accumulation of severity values based on relative humidity. NoBlight does not stop accumulating conducive conditions where the relative humidity drops below 90 percent. NoBlight uses 76.5 percent relative humidity to discontinue accumulation of infection conditions. Usually, this adds a half hour or more onto the typical Wallin hours. Typically, this is a dewy morning period in Maine summers. More importantly, this does not discontinue the accumulation of conducive conditions when the relative humidity drops to just below 90 percent for a period of time. In effect, the severity values accumulated by NoBlight are more conservative than the Wallin severity values.

The late blight prediction software is on site and operated by growers. Twice weekly during the growing season, weather data are electronically sent to a central location. The information is extrapolated to local predictions and put onto a Late Blight Hotline. The Late Blight Hotline is a voice mail system operating on a toll-free telephone line available on a 24-hour basis.

Other approaches have been investigated in the recent past. Satellite weather data collection with local extrapolation has proven unable to account for localized weather phenomenon typical of the potato production areas. Annual subscription fees for late blight prediction service have not been met with success, nor has a DSS. While other more traditional prediction algorithms have not been exhaustively evaluated, many of these were developed or modified for specific areas and are likely best suited in those areas.

As with any model, NoBlight is no better than the data it analyzes. The value of a predictive model is to provide the user with a reliable estimate of when conditions are conducive for late blight development and when conditions are not conducive for late blight development. The model provides some guidance on when a grower can stretch spray intervals with minimal risk, as well as when the spray interval needs to be reduced because the crop is at risk. The interpretation of the weather data and the skill of the forecaster are still critical factors in late blight prediction. With practice, growers can interpret weather data and become better forecasters. The more information available to the grower, the better the decision becomes. A decentralized weather network and late blight prediction network actively involves the producers in their own decisions. On-site late blight prediction by potato growers is proving a successful approach and is increasing in Maine.

Leadership in late blight prediction and information distribution is by University of Maine personnel but it is only part of the approach to late blight control in Maine. Timely and accurate fungicide applications are performed by the potato grower. Their part of the control lies in initial inoculum control, proper timing and rate of the application, and potentially the partial crop destruction, if conditions warrant.

First and foremost, control of initial inoculum is critical. The organism causing potato late blight overwinters in infected tubers, cull piles, and in infected volunteer plants. Infected tubers sprout and the organism develops and under moist conditions, spore production is initiated. NoBlight, like most late blight prediction schemes operates under the assumption that initial inoculum is present. The key to control is ensuring that the levels of initial inoculum are very low. Most years start with low levels of initial inoculum. High quality seed and conscientious growers see to that. Importing seed from areas where late blight occurred changes the assumption of low initial inoculum. Growers need to pay very close attention to seed imported from a known late blight area. In a normal year, the expectation is that there

would be little or no initial inoculum from Maine seed. Maine has legislation dictating that cull piles be buried or covered by June 10 of each year. This law is aggressively enforced and reduces potential initial inoculum. Under severe late blight pressure, a seed screening program is offered. Samples of seed are collected, incubated, and then evaluated for the visual presence of late blight infection. This is a parallel process to a winter grow out test for viruses. Potato ground keepers, in the unusual year that they do occur, are chemically or mechanically removed.

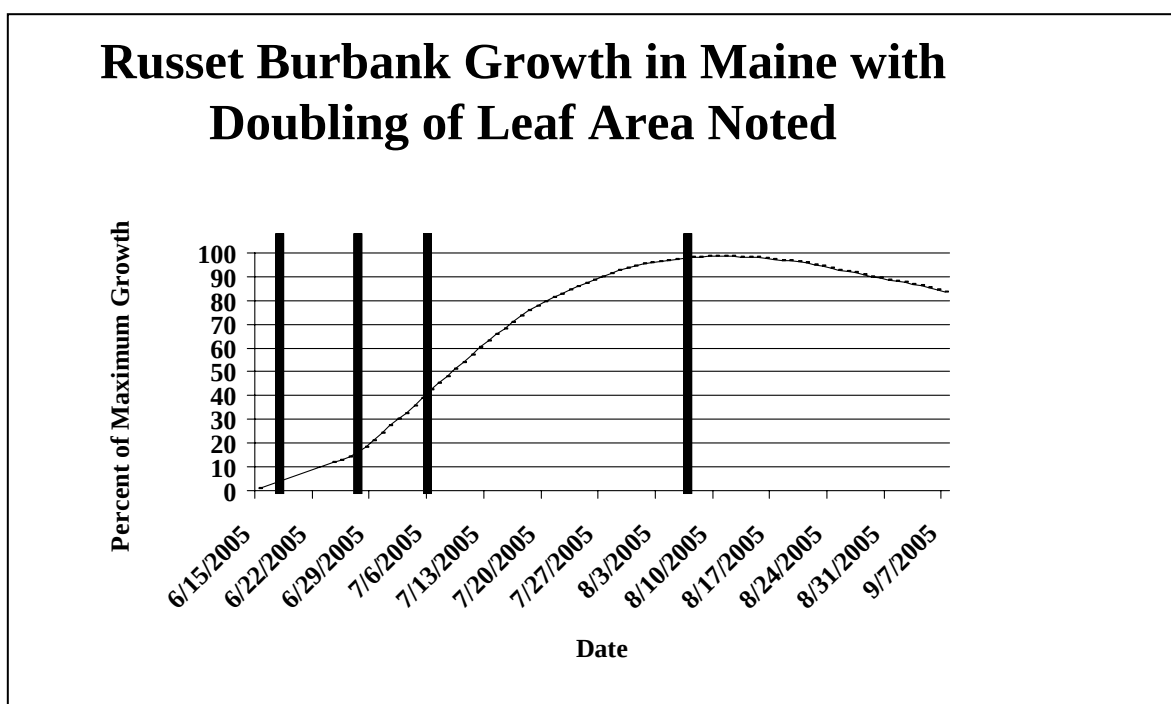


Chart 1. Indication of the periods of rapid growth of potato haulm in Maine.

Basic principals of fungicide application are also an integral part of late blight control tactics. NoBlight provides guidance on timing of initial and subsequent protective measures. The backbone of late blight preventative programs in Maine is the application of protectant chemicals, be they chlorothalonil or EBDC materials. The proper timing of the material is far more important than the choice of material. Success or failure with protectant chemicals is more a matter of timing than choice of material. Bear in mind that poorly timed applications with any chemical will likely result in failure of late blight control under even slight disease pressure. However, there are situations that dictate these protective applications be applied more frequently than in a normal growing season. If the initial application for disease control

is predicted to occur when the plants are actively growing, more frequent applications may be needed to insure protection of the newly emerged foliage. Potato plants can double their leaf area in five days or less when growing rapidly. This could leave half the leaf area unprotected. At this time, the timing of material is more critical than the rate of protectant material used. Chart 1 provides an indication of the periods of rapid growth of potato haulm in Maine. The first 30 days after emergence is a period of rapid leaf area increase. If protective applications for late blight are called for during this period, lower rates but increased frequency are used. The key to coverage with protectant fungicides is putting the material where it is needed and replacing the eroded fungicide. Chart 2 shows the same Russet Burbank growth curve with the overlay of a 5-day spray program. The holes in the protective program are where the plants may have outgrown the protective material or the protective material may have eroded. The lack of protection is not as dramatic as may appear in chart 2. The “holes” in the protection are where 100 percent of the applied material is not present. In actuality, much less than 100 percent of the applied rate is needed to confer effective protection from late blight inoculum to the leaf. But there are still potential holes in the program.

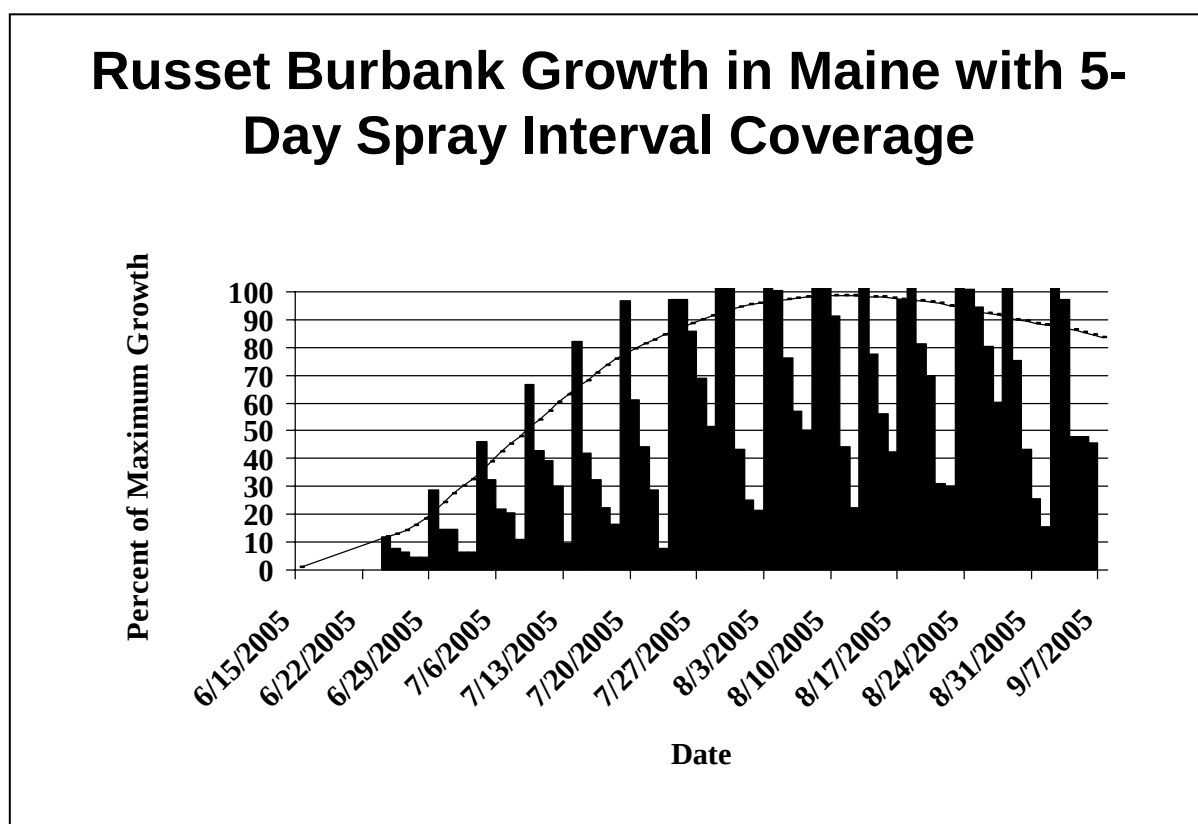


Chart 2. Russet Burbank Growth in Maine with 5-Day Spray Interval Coverage.

Under the best of situations, the crop will remain late blight-free when protectant chemicals are used exclusively and applied judiciously. There are, however, sometimes circumstances beyond our control and late blight may appear in a field. There are times that a suggested schedule can not be kept. These gaps in the control program are often the time the late blight pathogen enters the field. Once late blight is present in a field, the goal switches from keeping the pathogen out to containing the disease to a limited area. Once late blight reaches a high proportion in the field, protectant fungicides will not control it.

If seed-borne late blight is present in the field and is moving up the stems and sporulating on the stems, there is no control. These, plants and possibly the entire field should be destroyed. The destruction will help protect other fields from spread of inoculum; the field most likely would never have produced a marketable or storable crop anyway.

Aside from the seed-borne late blight issue, once late blight is present a field, most of the prediction models become less useful. In fact, late blight at a very close proximity should be treated similarly to late blight in the field. This further stresses the importance of correctly timing the applications to keep the disease from occurring. If late blight is in a field, a seven-day schedule is the bare minimum for that field. There will be many instances when a 5-day schedule will be needed. With late blight in a field, rainfall and showers become more important in the disease cycle. A field without late blight present must have the pathogen enter the field and initiate the infection process. A field with late blight present has the pathogen present and likely sporulating so inoculum is immediately available to start the infection process. Predictions may call for a ten- to fourteen-day schedule for a field without late blight. Stretching the interval that long in a field with late blight is risky.

The first and foremost decision to be made is whether to physically remove, by disking or other means, the portion with late blight. This technique has been highly successful in many situations and should always be a first consideration. Remember, the pathogen is already present and causing disease, so the goal is containment. Applying chemicals and expecting them alone to control the disease usually leads to disaster. Removing the hot spots in the field combined with chemical applications, is far more successful than either one alone.

It appears that we are not finished with late blight in Maine or elsewhere for that matter. The future of late blight control in Maine depends in proper application (timing, rate, coverage) of protectant materials because the future of the Maine potato industry lies in economics. If late

blight control can be accomplished by fewer, more timely chemical applications, this will help control escalating costs.

Better adoption of forecasting spray intervals will be the challenge for potato growers. Potato growers need to be up for this challenge. Real-time forecasts with real-time weather and grower-level data collection are the challenges for the scientific community that serves the potato growers. This is being addressed with current automated weather stations and computer models on site to predict late blight using real time weather collected at the grower level. One key of the Maine late blight control approach are the automated weather stations and the NoBlight computer program being operated by growers on their farms. Another key is the consciousness effort of the potato growers to control late blight with a combination of chemical and nonchemical approaches. Together, these constitute the Maine approach to late blight prediction and control.

References

Krause, RA, LB Massie and RA Hyre, 1975. BLITECAST, a computerized forecast of potato late blight Plant Disease Reporter 59, 95-98.

Possibilities using the Internet Climate Station iMETOS in blight advice systems

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Abstract

With iMETOS Pessl Instruments was launching this spring a cost effective and simple to use internet based climate monitoring system.

iMETOS measures all climate factors needed for blight or evapotranspiration models. It can be equipped with different sensors for soil moisture measurement. The new feature on iMETOS is that it uses GPRS to transmit its data to a web server and its data can be accessed from everywhere without the need of any special software.

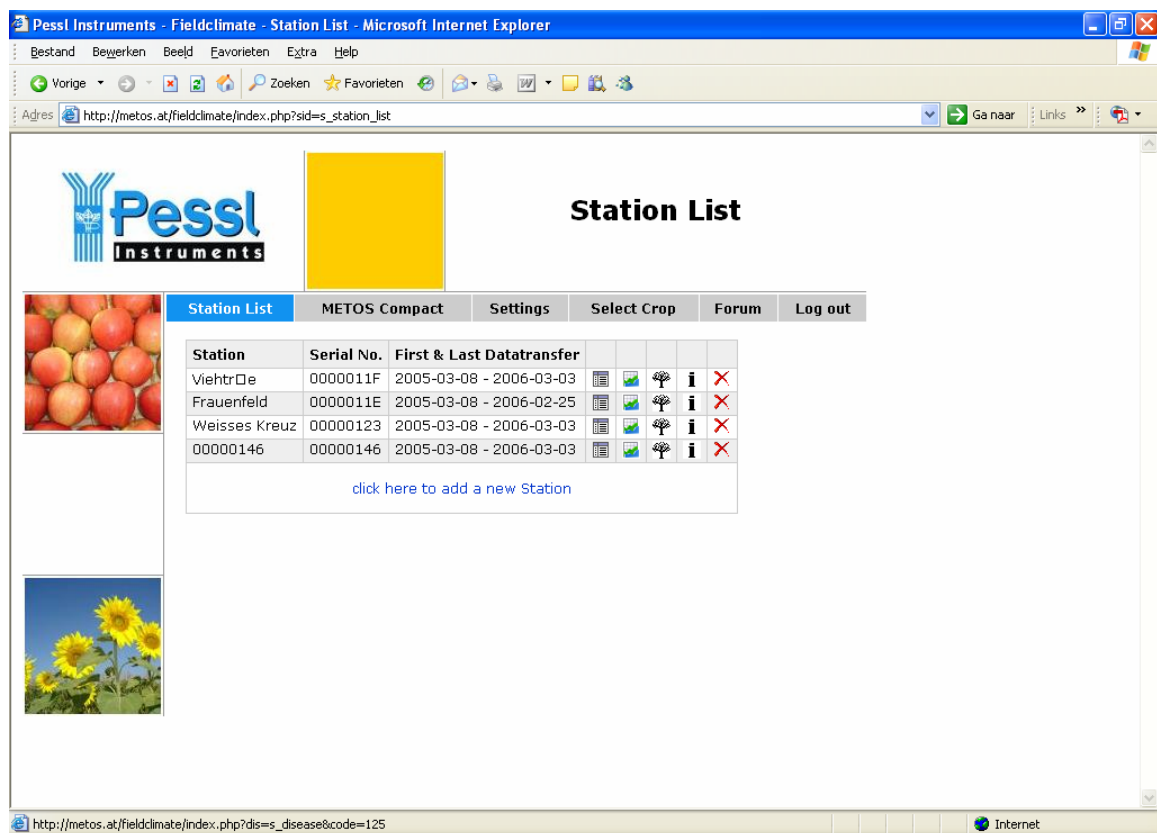
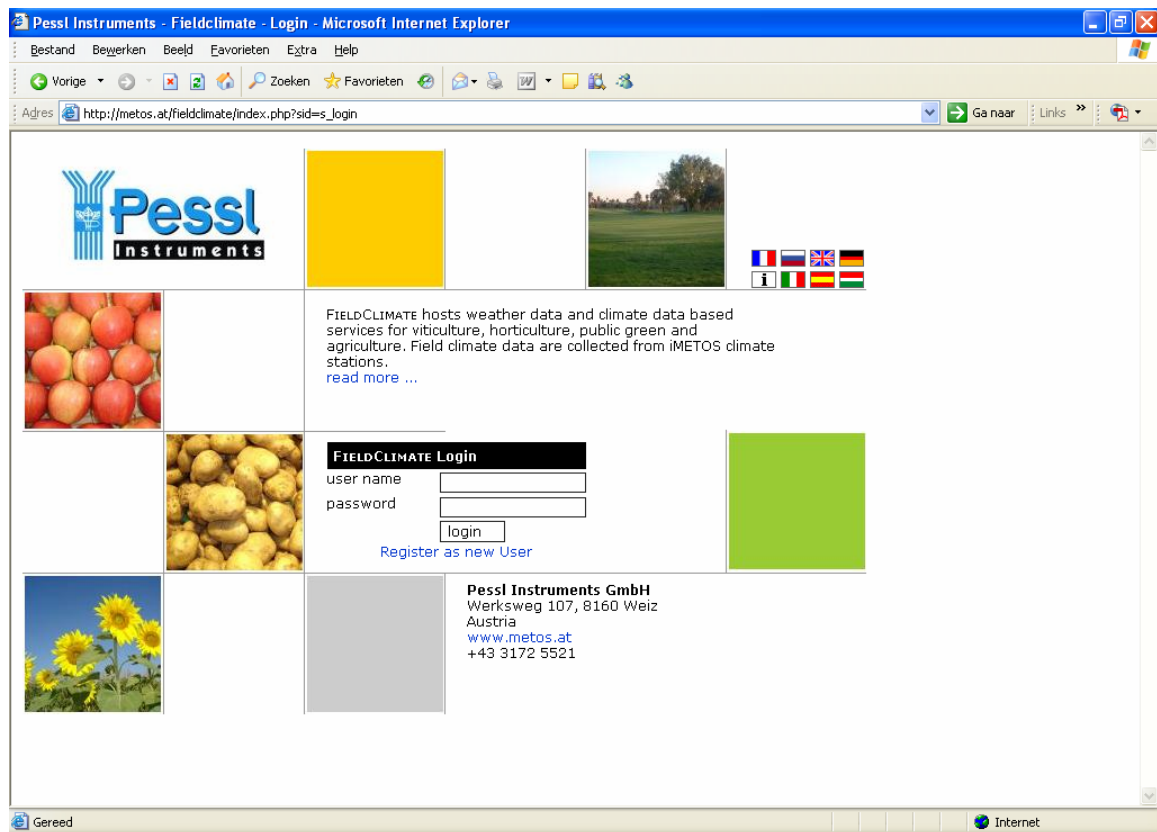
By default iMETOS transfers its data to a web based database serviced by Pessl Instruments. This can be changed by any individual instrument.

Pessl Instruments will deliver the SQL-scripts needed for the service of iMETOS to the interested clients. Data can be used from this database by Pessl Instruments own disease models or by advisory services or private advisory groups running their own disease models. Pessl Instruments clients are accessing the data on <http://www.metos.at/fieldclimate> But do to the fact that data can be used form any other institutional or private service their clients can access the data physically or virtually from their websites.

For people who like to see the actual climate data collected by iMETOS systems please connect to:

<http://www.metos.at/fieldclimate>

Use the username "austria" and the password "guest".



The use of GEWIS as a tool for application of fungicides on the right moment of the day

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Abstract

Weather circumstances before, during and after application of Plant protection products are very important for the efficacy. Knowledge of the behaviour of fungicides in relation to weather circumstances can be an aid to achieve a better efficacy. Formulation type and dynamic buildup of the wax-layer at the upper side of the leaf are important for the adhesion and the speed and way of uptake of systemic active ingredients in the leaves. For farmers it is difficult to combine all the important factors. The knowledge of the relations between crop protecting agents and meteorological conditions are combined in a decision support system with the acronym GEWIS. The system calculates (hourly-based) the physical behaviour of the Plant Protection Products in different stages of the process. With the help of this decision support system the farmer can choose the best moment of the day to apply a product with the optimum dose. Furthermore the users learn when it is possible to apply and when it is better not to apply at all. By using the system, the users of GEWIS will become more aware of the relation between weather conditions and efficacy of crop protecting agents.

Introduction

A number of Decision Support Systems (DSS) can calculate and advise whether applications are necessary to control late blight (*Phytophthora infestans*) and or Alternaria leaf spot (*Alternaria alternata* & *A. solani*). Furthermore most of the DSS's also provide an advice regarding the dose. However, when the circumstances are unfavorable for application and the active ingredient cannot adhere to the leaf and stems or cannot be taken up and transported to the

place where it has to work, the protection will not be optimal.

Application of plant protection products at the moment of highest efficacy is very important to guard against failure of control. Besides the chemical and physical characteristics of the product itself, efficacy is affected by the weather conditions before, during and after application (Bouma, 1995). Therefore a DSS with the acronym GEWIS (Gewasbeschermings En Weer Informatie Systeem) has been developed. It integrates all available information on type of products (insecticides, growth regulators, fungicides, herbicides, haulm killers, etc.) in relation to weather conditions. The output of the model is an hourly-based overview of the efficacy. All stages of uptake, transport and mode of action of the different kind of Plant protection products were modeled, and GEWIS has been developed for these weather-related principles (Bouma, 1998, 2000). It also integrates all available information on all types of formulations in relation to weather conditions and efficacy. On the other hand it is possible to prevent applications at moments with unfavorable conditions.

Application of plant protection products at the moment of highest efficacy is very important to guard against failure of control. The use of on-farm weather stations can improve the efficacy enormously.

Meteorological conditions inside the crop canopy.

Temperature

For an optimal interpretation the meteorological circumstances in the crop have to be studied at the place where the crop protection formulations have to be taken up into the plant or act against the target organism. The meteorological conditions under the canopy can be quite different compared to conditions measured at standard height (2 meters in a Stevenson screen) Differences in temperature of 8-10 °C are not exceptional (Wartena & Bouma, 1998). The interpretation of the leaf temperature can be very interesting for phytopathological purposes. Rising of air temperature is not caused by sun radiation directly, but indirectly by the leaves and the soil, which release their energy while they are heated by sunrays. Therefore, net radiation influences the leaf temperature (Jacobs *et al.*, 1994, 1995). When a lot of radiation is available, the temperature of the leaf is the power unit for increasing the air temperature (Bouma, 1999). At night and at sunset the temperature differences can be opposite and at that moment of the day leaves are colder than the air.

Relative Humidity¹

When the sun is shining and the soil is not covered by plants, the relative humidity near the soil is significant lower compared to the relative humidity at official height (2 meters) caused by the higher temperature near the soil (Bouma, 1995). Under a (closed) canopy however the relative humidity is on average higher compared to measurements on official height. These micrometeorological data are quite important before, during and shortly after application, while it has great influence on the possibilities for uptake, run-off or sticking of crop protecting agents.

In addition, the efficacy of plant protecting products is greatly affected by radiation, temperature (differences), precipitation and relative humidity. On the one side because plants, fungi and insects are affected, on the other side because crop protecting agents (or formulations) will be affected (directly or indirectly) by these meteorological conditions.

Leaf wetness

Leaf wetness can be caused by rainfall, fog, drizzle and dew. Dew can occur by dewfall, a process during the night when water is extracted from the atmosphere; by dewrise, a process by which soil evaporated during the night is intercepted by the canopy; and by guttation, the exudation of plant water (Garatt & Segal, 1988; Beysens, 1995). The distribution of dew is not homogeneous and changes in time (Jacobs & Nieveen, 1995). The longest wetness period is expected to occur in the lower canopy layers. Water dripping from leaves and stems at night can lead to accumulation of liquid water in the lower canopy layers where it may cause long wetness periods (Jacobs *et al*, 2005).

Relation weather and efficacy

For almost all Plant protection products it is quite important to know their mode of action in relation to the optimal weather conditions. Focused on fungicides it is important to divide two groups: contact fungicides and systemic fungicides.

¹ The use of water vapour pressure should be preferable because relative humidity is influenced by temperature. On the other hand relative humidity is easy to measure and in some cases relative humidity is the driving force of shrinking and swelling of the cuticle.

Contact fungicides

Contact fungicides have to work on the outside of the cuticle layer of the leaves. This implies that after application on dry leaves, the water in the (spray) droplets has to evaporate quickly. Low relative humidity, some wind and sunny periods are optimal. Precipitation within a few hours after application can decrease the efficacy by wash-off of fungicides (Scheepers, 1996, Mathiassen *et al*, 1996, 1998; Evenhuis, 1998, Emery *et al*, 1999, Bødker & Nielsen, 2002).

Systemic fungicides

Systemic fungicides have to be taken up through the cutin layer. The conditions before application can affect the uptake of polar formulated crop protecting agents, because of changes in the wax and cutin layer (Caseley & Coupland, 1985, Kalkdijk *et al*, 2004).

Radiation, relative humidity and soil moisture have a primary influence on the thickness of these layers (Cutler *et al*, 1982) and the hardening of plant leaves. Conditions favorable for plant growth, with regular precipitation, lead to a non-hardened leaf surface (Baker & Procopiou, 1980; Lundkvist, 1996). This wax layer can act as a shield against the uptake of crop protecting agents. The interception, retention and penetration of most polar-formulated (hydrophilic) Plant protection products are much more difficult through thicker wax layers. The weather conditions during application determine the requirements for adjuvants needed for optimal uptake. During dry growing situations lipophilic surfactants gave a better performance, while hydrophilic surfactants perform better during humid periods (Hull *et al*, 1975).

Polar-formulated products with a (local) systemic quality have to diffuse through small pores and micro canals in the cuticle and cutin layer. The cutin layer shrinks during dry and sunny weather with a lot of radiation, the cutin layer together with wax in the cuticle forms a sealed cover as a result of those dehydrating circumstances. During damp, moist situations the cutin layer is swollen and the pores are full of water. Diffusion occurs easily over a long period. Uptake of the polar-formulated products is optimal during such dull, damp circumstances, (Baker, 1980; Baker & Hunt, 1986). Furthermore, most leaves stretch somewhat during wet periods and wax production cannot keep up with leaf stretching. Also a part of the wax on the cuticle is washed off. Under these conditions, polar-formulated fungicides are in most cases easily taken up.

However, efficacy can change rapidly during the day when the temperature rises. If the source of air does not change dramatically, the relative humidity decreases. Wax production is induced by lower relative humidity and high radiation. At the same time, the cutin layer shrinks and the pores and canals in the cutin layer become very small. Under these conditions uptake of polar fungicides is much more difficult.

Deficiency of free water by the roots, low relative humidity and high radiation are conditions in which there is a lot of wax excretion and leaf cuticles are hardened very fast. Under these conditions the uptake of polar formulated Plant protection products is very difficult.

The efficacy of non-polar-formulated Plant protection products is not so much related to weather conditions, because the solvent of the formulation penetrates into the leaves very quickly facilitating the uptake of the active substance. Retention and penetration of active ingredients is relatively easy through these solved cuticles.

The weather conditions during and shortly after application are also important. The total uptake of polar-formulated systemic fungicides is stimulated by dull weather with a high relative humidity, but without actual rain.

The major amount of a polar-formulated fungicide will be taken up within one hour after application. After that period the rest of the fungicide will stay on the leaves, but there is almost no uptake due to the bad circumstances caused by the thin cutin layer and the thick wax layer. When the situation for uptake will be changed from bad during the day to optimal during the night (by the dew fall) a part of the fungicides on the leaves ultimately will be taken up (Wander *et al*, 2004). If, and in which amounts this delayed uptake will take place, depends on the formulation of the fungicides.

Leaf wetness

When fungicides are applied on leaves with free water (e.g. dew) on the cuticle, the possibility of sticking or direct uptake is very bad. In some cases the dew droplets will be induced to run off by the droplets (containing water and fungicide) applied by the sprayer. Most of the time, the run off will be induced by the wind after application. Plant protection products applied on a leaf with free water will stick very poorly. Wind will induce fluttering of the leaves. Due to this fluttering the droplets of free water (dew) and the (fungicide)droplets applied by the sprayer will merge and run off together. Also when fungicides are applied on leaves which are

wet (without free water) and soon after the application rain follows, a very large quantity of the fungicide will run off because of the bad sticking situation. When the leaves were dry before application and rain follows soon after the application, the sticking qualities are much better (that depends also on the plant protection product, the formulation, the additives and sometimes on the addition of mineral oil). A good estimation of the length of the interval between the application and the start of the precipitation (rain or irrigation) is quite important. The length of this period depends on the meteorological circumstances and the specific qualities of the applied plant protection product. Furthermore the different fungicides possess variation in rain fastness (Schepers, 1996, Mathiassen *et al*, 1996, 1998, Evenhuis, 1998, Bødker & Nielsen, 2001). So, for a good efficacy (for contact fungicides as well as for systemic fungicides), the leaves must be dry at the moment of application.

Weather circumstances after application

After the active ingredients have dried up on the outside of the cuticle or taken up by the plant and transported to the apoplast and the symplast, the meteorological circumstances in the next 36 hours also play a decisive role on the efficacy.

GEWIS

To tackle most problems with application on the optimal moment of the day, a DSS was developed. All stages of uptake, transport and action mode of Plant protection products (herbicides, insecticides, fungicides, growth regulators, haulm killers etc.) were modeled, and a DSS with the acronym GEWIS (Gewasbeschermings En Weers Informatie Systeem) has been developed for these weather-related principles (Bouma, 1998, 2000, 2003). It also integrates all available information on all types of formulations in relation to weather conditions and efficacy. Opticrop BV, a software company in Wageningen, the Netherlands, markets this DSS.

The models of GEWIS

Within GEWIS, 26 models have been developed, 21 agrochemical weather-related models and 5 meteorological-related models. Each model is the result of the modeling of a certain process in the separate parts of the chain of uptake-transport-modes of action of different Plant protection products in or upon the leaves of a plant or in soil. All models need

meteorological data (temperature at three stages +150 cm, +10 cm and soil temperature at –5 cm, relative humidity at 10 cm, wind, precipitation and radiation) as input. This meteorological data should be measured in on-farm meteo stations, which are also equipped to measure the temperature and relative humidity inside the crop canopy. Also the 72-hour weather forecast is required, see table 1.

Table 1. Agrochemical-weather related models used in the decision support system GEWIS.

Model	Measured weather data + forecast							
	Duration (h)	Soil Humidity	Temperature	Precipitation	Radiation	Relative Humidity	Wind	Weather forecast
Hydration of the cuticle	24	X	X	X		X		X
Leaf dry	5			X		X		X
Cuticle development	60	X	X	X	X	X		X
Stick on leaf	7	X	X	X	X	X	X	X
Photo synthesis inhibitor	72	X	X		X	X		X
Mitosis inhibitor	72	X	X	X	X	X		X
High temp insecticides	4	X	X	X	X			X
Low temp insecticides	4	X	X	X	X			X
Growth	30	X	X	X	X	X		X
Systemic transport	72	X	X	X		X		X
Respiration	72	X	X	X	X	X		X
ALS-herbicide	72	X	X	X	X	X		X
Leaf uptake	8	X				X		X
Soil surface dry	12	X		X		X		X
Transport to roots	72	X		X				X
Wash out	6			X				X
Lipid synthesise inhibit	72	X	X	X		X		X
Affix to	7	X	X	X	X	X	X	X
Crop damage	12		X					X
Direct soil temperature influence	72		X					X
Direct crop temperature influence	72		X					X

All plant protection products registered in The Netherlands are in a database in the DSS. The main source of this database is the plant protection product database of the Dutch Plant Protection Service. The Plant protection products are divided in groups according to their mode of action, e.g. contact fungicides, systemic fungicides, etc.. The application technique and the dose are also important.

For every hour the measured weather data and the weather forecast data are used as input to calculate the called *SCORE*-parameter. All single Plant protection products within the groups are allocated to a certain *INTEREST*-parameter per individual process (table 2 & 3). In the example of Curzate M, there are two efficacy calculations. For every single active substance, there is one efficacy calculation. The efficacy can be calculated by multiplying the *INTEREST*-parameter and *SCORE* –parameter by expert judgment models.

Table 2. Efficacy calculation within GEWIS of mancozeb (Curzate M) on August 17, 2005 at 09.00 hour.

Process	Interest	Score	Efficacy
Drying on the leaf	100	50	1.0
Leaf dry	100	0	0.0
Stick on the leaf	80	40	0.9
Total effect			0

Table 3. Efficacy calculation within GEWIS of cymoxanil (Curzate M) on August 17, 2005 at 09.00 hour.

Process	Interest	Score	Efficacy
Soil temperature	85	50	1.0
Crop temperature	85	55	1.0
Hydration of cuticle	70	100	1.4
Leaf uptake	60	100	1.3
Leaf dry	100	0	0.0
Systemic transport	80	56	1.1
Cuticle development	60	70	1.1
Total effect			0

The highest possible value for the calculated efficacy is 2 (this is a value without a unit). This relative value is necessary for calculating the height of the bars in the figure, see figure 1. Efficacy values from zero to 0.8, are indicated with red bars, from 0.8 to 1.3, the bars are yellow, above efficacy values of 1.3, the bars are green.

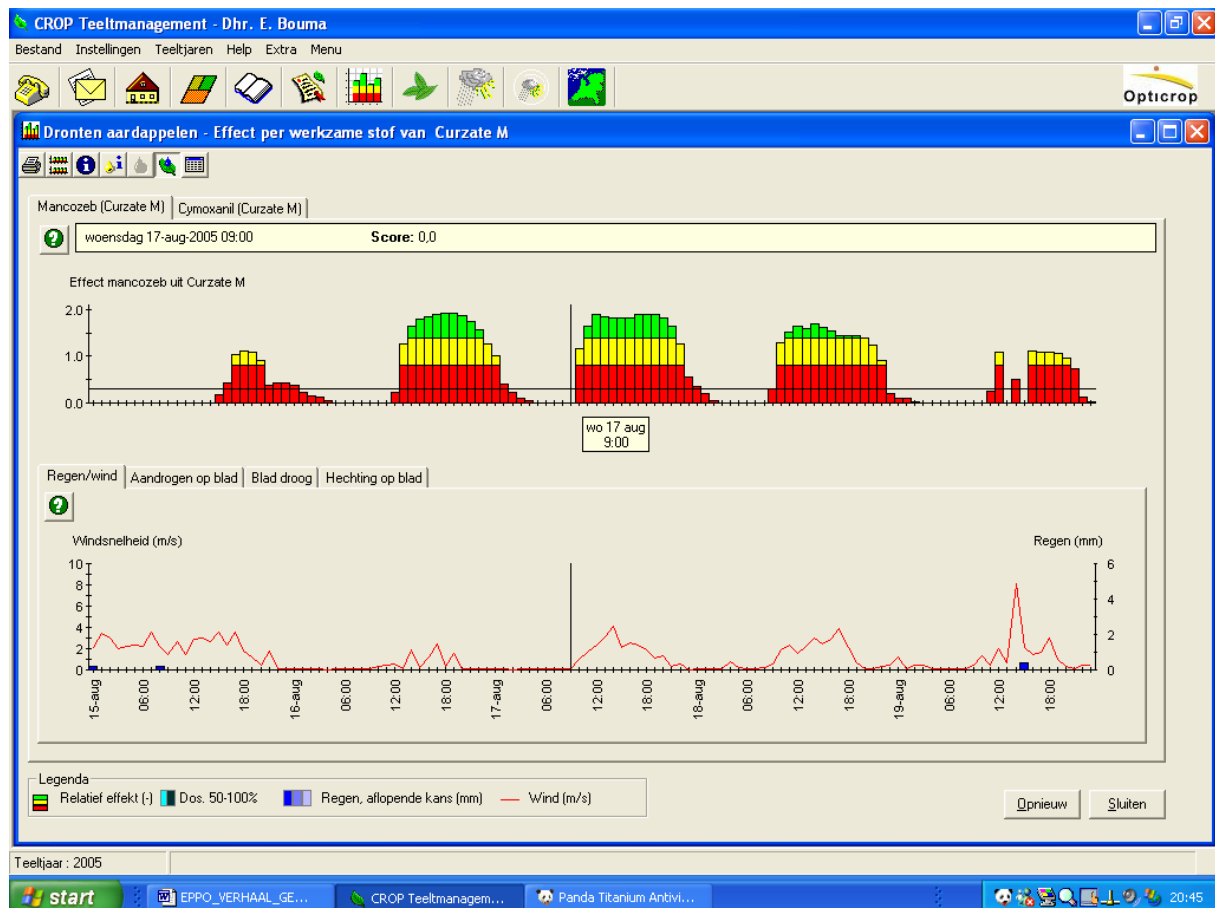


Figure 1. Graphics of the efficacy calculation of cymoxanil on August 17, 2005 at 09.00 hour with GEWIS.

The efficacy graph in the figure is a hourly-based, for a 72 hours, 36 hours measured and 36 hours forecasted weather data. The colors of the bars give an indication of the efficacy. No bars or red (dark grey) bars, mean a low efficacy, yellow (light grey) bars indicate a medium efficacy and green (medium grey) bars, high efficacy.

The second graph in figure 1 is an indication of the possibilities to apply; the line in the graph indicates the wind speed at 2 meters and the dark bars are an indication of the amount of precipitation.

With the help of GEWIS, it is possible to find the moment of the highest efficacy. It is also possible to avoid applications at moments with very bad conditions (e.g. shortly before rainfall or on wet leaves) and it is possible to compare the good and the bad conditions for efficacy between the different fungicides. Those conditions are not always visible in the field.

Users of GEWIS become more aware of the relation between weather circumstances and efficacy of plant protection products.

There are approximately 1200 users in the Netherlands (farmers, extension officers and researchers) who use the system as a planning and application tool. They look one to three times before they apply. Data from user groups show that the moment of application has changed (learning effect) and there are fewer failures in applications. Furthermore the users have learned when it is possible to apply lower dosages without loss of efficacy (in the case of insecticides and herbicides) and when not to apply at all.

Conclusions

Weather circumstances influence efficacy of applications a great deal. In many cases it is difficult to select the best moment of the day for application due to difficulties in the interpretation of the conditions in the crop, the relation between crop and formulation, crop and active ingredient. With the help of the Decision Support System GEWIS using measured and forecasted weather data as input, it is possible to calculate and predict the efficacy of crop protection applications. The model can be used as an aid in application planning in establishing, what hours of the day are the optimum moments with the highest efficacy.

References

- Baker, EA, 1980. Effect of cuticular components on foliar penetration. *Pesticide Science* 11, 367—370.
- Baker, EA and GM Hunt, 1986. Erosion of waxes from leaf surfaces by simulated rain. *New Phytologist* 102, 161—173.
- Baker, EA and J Procopiou, 1980. Effect of soil moisture status on leaf surface wax yield of some drought-resistant species. *Journal of Horticultural Science* 55, 85—87.
- Beysens, D, 1995. The formation of dew. *Atmosphere Research* 39: 215 – 237.
- Bouma, E, 1995. [How weather affects plant protection]. *Pflanzenschutz-Praxis* 3 26-27 (in German).
- Bouma, E, 1998. Gewis, a weather-based DSS for timing the application of agrochemicals. In: *Abstracts of the 7th International Congress of Plant Pathology* 3, 3.1. 19. Edinburgh (GB).
- Bouma, E, 1999. Practical aspects of Epidemiology. *Journal of Plant Pathology* (1999), 81 (3), 219-223.
- Bouma, E, 2000. The Dutch approach: a combination of meteo-based decision support systems. *Bulletin OEPP/EPPO Bulletin* 30, 65-68.
- Bouma, E, 2003. Gewis, a weather-based decision support system for timing the application of plant protection products. *Bulletin OEPP/EPPO Bulletin* 33, 483-487.

- Bødker, L and BJ Nielsen, 2002. Influence of irrigation on the wash-off of fungicides in field grown potato. In: *PAV Special Report* 8, 163—167. PAV, Lelystad (NL).
- Caseley, JC and D Coupland, 1985. Environmental and plant factors affecting glyphosate uptake, movement and activity. In: *The Herbicide Glyphosate*, ed. E. Grossbard & D Atkinson, 92-124. Butterworths, London.
- Cutler, DF, KL Alvin and CE Price, 1982. *The Plant Cuticle*. Academic Press, London (GB).
- Emery, D, L Culie and S Duvauchelle, 2000. Perfecting a biological test assessing the resistance of anti late blight fungicide to rainfastness. In: *PAV Special Report* 6, 235-240. PAV, Lelystad (NL).
- Evenhuis A, HTAM Schepers, CB Bus and WLM Stegeman, 1998. Rainfastness of mancozeb and Curzate M on potato leaves. In: *PAV Special Report* 3, 218—225. PAV, Lelystad (NL).
- Garratt, JR and M Segal, 1988. On the contribution of atmospheric moisture to dew formation. *Boundary-Layer Meteorology* 45: 209-236
- Hull, HM, HL Morton and JR Wharrie, 1975. Environmental influences on cuticle development and resultant foliar penetration. *Botanical Review* 41: 421-452.
- Jacobs, AFG, JH van Boxel and RMM El-Kilani, 1994. Night time free convection characteristics within a plant canopy. *Boundary-Layer Meteorology* 71: 375-391.
- Jacobs, AFG and JP Nieveen, 1995. Formation of dew and the drying process within crop canopies. *Meteorological Applications* 2: 249-256.
- Jacobs, AFG, JH van Boxel and RMM El-Kilani, 1995. Vertical and horizontal distribution of wind speed and air temperature in a dense vegetation canopy. *Journal of Hydrology* 166: 3 13-326.
- Jacobs, AFG, BG Heusinkveld and GJT Kessel, 2005. Stimulating of leaf wetness duration within a potato canopy. *Neth.J.Agric.Sciences (in press)*.
- Lundkvist, A, 1996. Weather effects on herbicide efficacy at reduced doses, *Acta niversitatis Agriculturae Sueciae Agraria* 14.
- Mathiasen, SK, P Kudsk, E Kirknel, & H Schlutz, 1996. Rain fastness and residual activity of some *Phytophthora* fungicides. In: *PAV Special Report* 1, 91—97. PAV, Lelystad (NL).
- Mathiasen, SK, H Schlutz, and P Kudsk, 1998. Influence of rain on the activity of fungicides against potato late blight. In: *PAV Special Report* 3, 209-217. PAV, Lelystad (NL).
- Schepers, HTAM, 1996. Rain fastness of fungicides used to control *Phytophthora infestans*. In: *Abstracts of the 13th European Association of Potato Research Conference*, 374-375.
- Wander JGN, W Nugteren, JR Kalkdijk, LJ Esselink and HTAM Schepers, 2004. Influence of remoistening of leaves on efficacy of fungicides. In: *PPO-Special Report* no 10, 299-302.
- Wartena, L & E Bouma, 1998. *Agrarisch Weerboek*, p. 175. Uitgeverij Roodbont, Zutphen (in Dutch).

Evaluation of the efficacy of different fungicides to control potato and tomato late blight in Italy

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Summary

Several fungicides were tested in field trials on potato and tomato for efficacy on late blight caused by *Phytophthora infestans*. Treatments were carried out at 7 or 10 day-intervals and assessments were conducted both on leaves and fruits for tomato and on leaves for potato. In potato trials the metalaxyl M+copper mixture provided the highest control of blight and good activity was also shown by pyraclostrobin+metiram and fluazinam. On tomato the best activity was provided by metalaxyl M+copper and zoxamide+mancozeb but the other products (pyraclostrobin+metiram, azoxystrobin, fenamidone+copper, cyazofamid) also showed good control. The satisfactory results obtained with recent fungicides also effective against early blight are particular interesting in Italy where many products specific for late blight are normally used in mixture with copper which has a poor activity on *Alternaria* spp..

Keywords: *Phytophthora infestans*, sensitivity to fungicides, field trials, potato, tomato.

Introduction

Late blight is the main threat of potato and tomato crops in North-Eastern area of Italy. Since the late 90's disease pressure has increased (Bugiani *et al.*, 2001): strains appeared more aggressive, higher levels of infection were observed and the life cycle was completed within a shorter period. In the Po Valley the potato growing cycle starts between February and March and finishes during the second week of July, whereas tomato normally grows from May to the end of August/September. During the last ten years disease pressure increased in May and August/September in coincidence with lower temperatures and prolonged rainy days. Late blight control strategy is based mainly on scheduled application of metalaxyl and cymoxanil in mixture with copper along with new active ingredients. A regional project has established and tested *P. infestans* strains that had not acquired resistance to phenylamides (Collina *et al.*, 2004).

The aim of this study was to evaluate the efficacy of old and new fungicides for the control of late blight on tomato and potato in field trials.

Materials & Methods

Two field trials were carried out, each on tomato and potato in the Emilia Romagna region (North East Italy).

The potato trials were carried out at the experimental farm of the Bologna University at Altedo (Bologna province) during the growing seasons of 2001 and 2004. Seed potatoes were planted on the 30th July 2001 and the 1st July 2004, late in the season with the aim of facilitating disease occurrence by favorable weather conditions. Several fungicides (Table 1) were compared in a spray programme based on a 7-day (2004) and a 10-day (2001) interval resulting in three and four applications, respectively. The experiments were set up with the cultivar “Spunta” in 2001 and “Agata” in 2004. Artificial field inoculation was achieved by distributing slices of infected potato tubers inoculated with a mixture of *P. infestans* isolates at the end of the first ten days of September 2001 and during the third ten days of August 2004. The percentage of diseased leaf surface was estimated at regular intervals after the appearance of symptoms.

Tomato trials were carried out at the University of Bologna experimental farm in Altedo during the 2004 and at a commercial farm in Ferrara province in 2005. Tomato seedlings (cultivar Perfect Peel) were transplanted on the 29th July 2004 and the 10th May (cultivar

Precocix) in 2005. Several fungicides (Table 1) were compared in a spray schedule based on 7-10 day intervals resulting in 7 applications for both trials. The percentage of diseased leaf surface was assessed at regular intervals; at harvest the percentage of affected fruits was estimated.

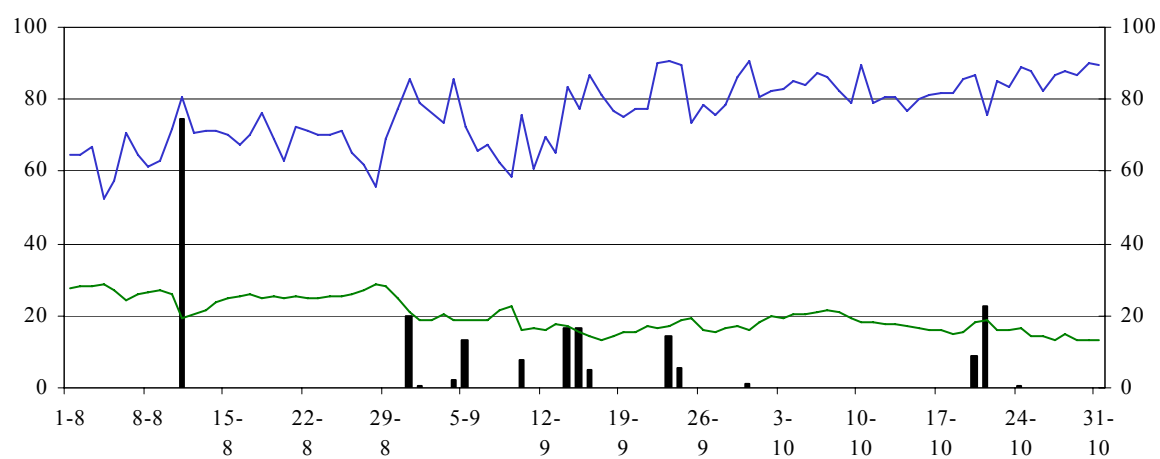
Both potato and tomato treatments were applied to 3 - 4 m wide and 6 m long plots with pressurised knapsack equipment through a spray boom to deliver 10 hl/ha. A randomised block design was used for all trials and treatments were replicated four times. Data were processed with analysis of variance and the treatment means were separated using LSD's multiple range test ($p < 0.05$).

Table 1. Fungicides tested in potato and tomato field trials

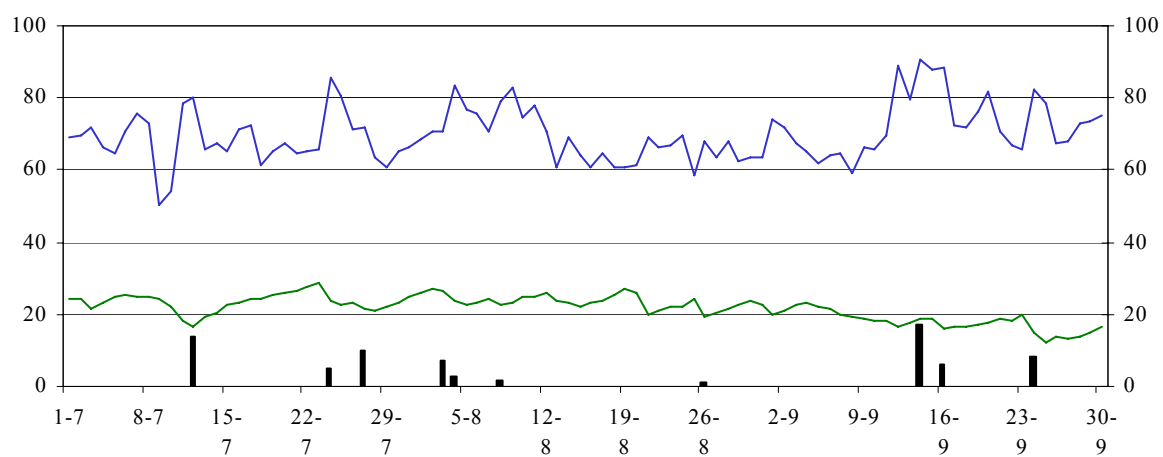
Active ingredient	Formulate	Content	Potato		Tomato	
			'01	'04	'04	'05
Cu oxychloride	Cuprocaffaro	WP	50 %	●	●	
Mancozeb	Dithane DG Neotec	WG	75 %	●		
Chlorothalonil	Daconil	SC	480 g/l		●	
Fluazinam	Ohayo	SC	500 g/l	●	●	
Zoxamide+ mancozeb	Electis	WG	8.3 + 66.7 %		●	●
Iprovalicarb + Cu oxychloride	Melody compact	WG	4.2 + 20.3 %			●
Benthiavdicarb + Cu hydroxysulphate	experimental	WG	1.17 + 25 %			●
Dimethomorph +Cu oxychloride	Forum R	WG	6 + 40 %	●	●	●
Metalaxyl M +Cu oxychloride	Ridomil Gold R	WG	2.5 + 40 %	●	●	●
Cymoxanil +Cu oxychloride	Curzate R	WG	4.2 + 39.75 %	●	●	
Famoxadone +cymoxanil	Equation Pro	WG	22.5 + 30.5 %	●		
Fenamidone +Cu oxychloride	Oracle	WG	4 + 40 %	●		
Azoxystrobin	Ortiva	SC	250 g/l	●		
Pyraclostrobin +metiram	Cabrio Top	WG	5 + 55 %	●	●	●
Cyazofamid	Ranman	SC	400 g/l			●

Next page: Weather conditions: temperature, relative humidity and rainfall during field trials

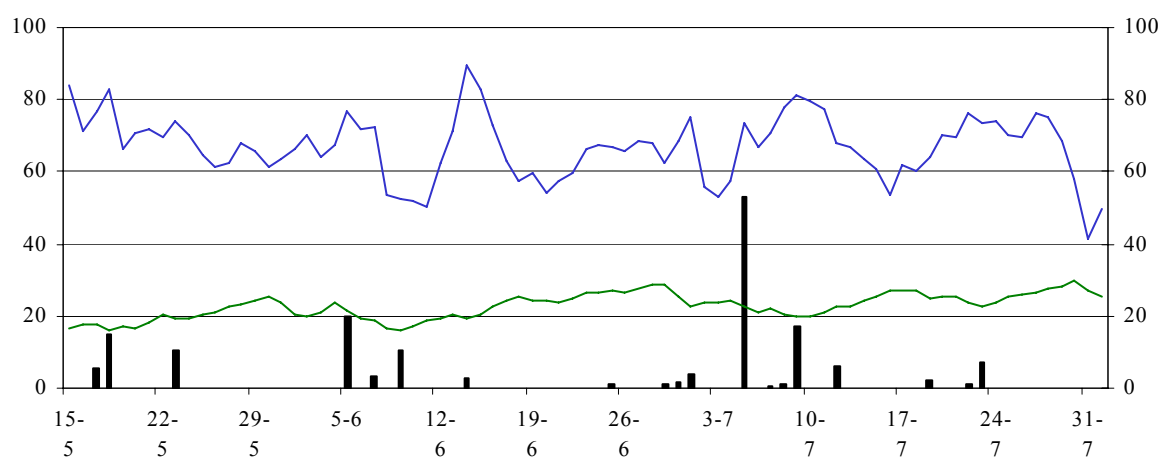
Altedo (Bologna) 2001



Altedo (Bologna) 2004



Ferrara 2005



Results

Potato field trials

Incidence of the disease in the untreated control plots was high for both 2001 and 2004 seasons due to favourable weather conditions and to late crop cycle.

In 2001 the first presence of downy mildew was observed one week after the first application of fungicides (24th September) with a high level of disease at the end of the season (Table 2). Significant differences were observed throughout the growing season between treated and untreated plots starting at the first assessment. The next ratings on leaves showed differences between the tested products: metalaxyl M+copper was the most effective in reducing development of late blight, followed by fluazinam and dimethomorph+copper.

Table 2. Potato 2001 trial: effect of fungicides on *P. infestans*.

Treatment	Rate / hl		% of diseased leaf area		
	Formulate	g a.i.	9/10	19/10	30/10
Untreated		-	38.8 b	81.3 d	93.8 f
Metalaxyl M +Cu oxychloride	400 g	10 + 160	2.0 a	8.1 a	23.8 a
Dimethomorph +Cu oxychloride	350 g	21 + 140	3.8 a	16.3 ab	46.9 c
Cymoxanil + Cu oxychloride	250 g	10.5 + 99.4	6.9 a	40.0 c	78.8 e
Famoxadone + cymoxanil	40 g	9 + 12	5.0 a	26.9 bc	66.3 d
Fluazinam	30 ml	15	2.5 a	12.5 a	33.8 b
Cu oxychloride	400 g	200	8.5 a	46.3 c	81.3 e

Spray timing: 18/9, 27/9, 5/10, 15/10.

At the end of the season famoxadone mixed with cymoxanil did not provide good protection from late blight whereas plots sprayed with copper and copper + cymoxanil were similar to the untreated control (Table 2).

Late blight severity in 2004 was higher after a rainy period at the beginning of September and complete destruction of untreated plots was observed at the end of September (Table 3). The strobilurin pyraclostrobin mixed with metiram and the metalaxyl based compound provided the highest level of protection. Good control was also observed in plots sprayed with fenamidone and dimethomorph, both in mixture with copper oxychloride. Copper activity by

itself or mixed with cymoxanil was low during the first assessment and did not differ statistically from the untreated control at the end of the trial. Furthermore, mancozeb was unsatisfactory in the control of late blight (Table 3).

Table 3. Potato 2004 trial: effect of fungicides on *P. infestans*.

Treatment	Rate / hl		% of diseased leaf area	
	formulate	g a.i.	15/9	24/9
Untreated	-		61.3 e	99.5 e
Metalaxyl M + Cu oxychloride	400 g	10 + 160	4.4 a	23.1 ab
Dimethomorph + Cu oxychloride	350 g	21 + 140	10.0 ab	39.4 c
Cymoxanil + Cu oxychloride	300 g	12.6 + 119.3	29.4 cd	95.0 e
Fenamidone + Cu oxychloride	300 g	12 + 120	12.5 ab	30.0 abc
Pyraclostrobin + metiram	200 g	10 + 110	8.8 ab	21.3 a
Fluazinam	40 ml	20	10.6 ab	33.8 bc
Mancozeb	200 g	150	18.8 bc	68.8 d
Cu oxychloride	400 g	200	33.1 d	96.3 e

Spray timing: 30/8, 6/9,13/9.

Tomato field trials

During the 2004 tomato trial weather conditions were favourable for disease development and the first symptoms were observed as early as the 28th July. The first fungicide application was performed two days later. At the beginning of September the disease affected 45% of the foliage area in the untreated plots (Table 4), which was almost destroyed on the 23rd September. Fruit assessment was carried out just before harvest; more than 50% of the untreated plots were diseased. The best control of late blight was achieved with QoI based compounds such as azoxystrobin, fenamidone +Cu oxychloride and pyraclostrobin +metiram. The lowest control of disease was observed with mancozeb.

The disease in 2005 almost completely destroyed the untreated tomato control plots at the first leaf rating due to extremely favourable weather conditions, although fruits were barely diseased (Table 5). All the compounds tested showed good levels of controlling of the disease, with higher activity observed with metalaxyl M+copper and zoxamide+mancozeb, mainly on leaves.

Table 4. Tomato 2004 trial: effect of fungicides on *P. infestans*.

Treatment	Rate / hl		% of diseased leaf area		% of affected fruits
	formulate	g a.i	8/9	23/9	4-7/10
Untreated	-	-	45.0 d	95.0 e	54.2 e
Metalaxyl M + Cu oxychloride	400 g	10 + 160	2.5 a	5.0 a	12.8 bc
Dimetomorph + Cu oxychloride	350 g	21 + 140	6.9 ab	11.3 bc	15.6 c
Fenamidone + Cu oxychloride	300 g	12 + 120	6.9 ab	12.5 ab	6.6 ab
Pyraclostrobin + metiram	200 g	10 + 110	5.1 ab	8.8 abc	6.7 ab
Azoxystrobin	100 ml	25	6.9 ab	10.0 abc	4.3 a
Zoxamide + mancozeb	200 g	16.6+133.4	1.5 a	4.9 a	14.5 c
Chlorothalonil	300 ml	144	3.1 a	6.3 ab	13.8 bc
Mancozeb	200 g	150	10.0 c	23.1 d	34.3 d

Spray timing: 30/7, 9/8, 17/8, 27/8, 3/9, 10/9,17/9.

Table 5. Tomato 2005 trial: effect of fungicides on *P. infestans*.

Treatment	Rate / hl		% of diseased leaf area		% of affected fruits
	Formulate	g a.i	18/7	26/7	26/7
Untreated			97.6 d	98.2 d	22.2 e
Metalaxyl M + Cu oxychloride	400 g	10 + 160	0.8 a	2.6 a	0 a
Pyraclostrobin + metiram	175 g	8.8 + 96.3	1.8 ab	5.3 abc	1.2 cd
Iprovalicarb + Cu oxychloride	350 g	14.7 + 71	5.6 c	8.4 c	0.9 bcd
Fenamidone + Cu oxychloride	275 g	11 +110	3.1 b	7.8 c	0.4 abc
Cyazofamid	20 ml	8	1.0 a	6.7 bc	0.1 ab
Zoxamide + mancozeb	175 g	14.5+116.7	1.3 a	3.0 ab	0.1 ab
Benthiavalicarb + Cu hydroxysulphate	300 g	3.5 + 75	6.4 c	8.4 c	1.2 cd

Spray timing: 25/5, 03/06, 10/06, 18/06, 28/06, 07/07, 18/07.

Discussion and conclusions

In the potato trials (carried out in particular climatic and agronomic conditions, e.g. late crop cycle and artificial inoculation) metalaxyl M+copper was the most effective product while oxychloride and cymoxanil+copper showed a poor activity both at 7 and 10 day intervals. Satisfactory results were obtained with other more recent fungicides (pyraclostrobin+metiram, fluazinam, fenamidone+copper, dimethomorph+copper).

In the tomato trials all the active ingredients, applied at 7-10 day intervals, showed good efficacy (except mancozeb alone) and overall metalaxyl M+copper and zoxamide+mancozeb were the most effective.

On the whole the trials showed that phenylamide compounds still have very good activity against late blight both on potato and tomato in Italy, probably due to the limited number of sprays needed by the disease pressure, normally not too high. Many recent fungicides also provided satisfactory control of late blight on both crops. The results obtained are very interesting because the new products are also effective against early blight while phenylamides (applied in Italy in mixture with copper) barely control the disease, in some years very dangerous especially on tomato.

References

- Bugiani, R, V Testi and B Chiusa*, 2001. Aumenta l'aggressività della peronospora su pomodoro e patata. *Informatore Agrario* **22**, 55-57.
- Collina, M, E Sala, L Landi and MF Do Nascimento*, 2004. Phenotypic and genetic characterization of *Phytophthora infestans* populations from Northern and Central Italy. PPO-Special Report no. 10, 279-286.

Influence of Host Diversity on Development of Epidemics: an Evaluation and Elaboration of Mixture Theory

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Introduction

The potential of genotype mixtures to slow down or prevent epidemic development has been established through the use of computer simulation and by experimentation. There is evidence for a potentially beneficial effect of host diversity in reducing potato late blight in temperate regions such as France (Andrivon *et al.*, 2003) and the United States (Garrett and Mundt, 2000), where late blight epidemics tend to develop from obvious foci (focal epidemics). However, recent field studies (Garrett *et al.*, 2001) suggest that the results of studies into host-diversity effects on potato late blight from temperate regions cannot be extrapolated to humid, tropical regions where general epidemics are commonly observed and success in the use of genotype mixtures has been variable. The primary objective of this research was to develop a theoretical framework for evaluating effects of host-diversity that encompasses both general and focal epidemics. This would provide theoretical support for future experimental research efforts aimed at developing globally applicable management strategies based on diversified landscapes / mosaics.

Theoretical framework and approach

The rate of progress of focal epidemics in infinitesimally fine-grained mixtures (ideal mixtures) can be characterised by the radial velocity of focus expansion (Van den Bosch *et al.*, 1988):

$$c = a \ln (f R_0) + b$$

where f is the fraction of susceptible host plants in the mixture, R_0 (-) is the net lifetime reproduction (average number of daughter lesions produced per mother lesion) and a and b are parameters. General epidemics can be characterised by the apparent infection rate, r (d⁻¹). This development rate can be approximated using life history theory (e.g. Keyfitz, 1985) whereby r is related to net lifetime reproduction, R_0 , and to generation time T (d), the average age of the mother at birth:

$$r \approx \frac{\ln (R_0)}{T}$$

For ideal mixtures, R_0 is replaced by $f R_0$, similar to the first equation. It therefore follows from these two equations that there must be a linear relationship between the two development rates. We hypothesize that the net lifetime reproduction within any mixture depends on both the fraction of susceptibles and on their spatial configuration and we summarize these two effects in a new parameter q (-), the genotype connectivity. The parameter q expresses the overall probability that a propagule produced in a susceptible genotype unit in the field (or landscape), when dispersed according to a dispersal kernel, will be deposited within (upon) a susceptible genotype unit (whether the same unit or another unit). To investigate these hypothesized relations, a spatio-temporal age-structured integro-difference equation model was developed to run disease scenarios for general and focal epidemics in non-ideal genotype mixtures at different scales and patterns and deduct from these simulations predictive relationships regarding the use of genotype mixtures in non-ideal configurations. The effects of different types of dispersal kernel on model results were also investigated. The model was parameterized for potato late blight. Figure 1 gives a selection of the block and row patterns of host plants that were used in the simulations of both general and focal epidemics.

Results and discussion

The genotype connectivity, q , was used to predict the effects of crop arrangement on the development rates of both types of epidemic. Figure 2 shows that q can be used effectively to predict changes in both r and c across heterogeneous host populations; the linear relationships between $\ln(q)$ and r , and $\ln(q)$ and c , were highly significant, indicating that q is an effective parameter for predicting the disease suppressiveness of a landscape. Figure 3 shows a high level of correlation between r and c for different spatial configurations of host plants and for different dispersal kernels. These results indicate that the spatial arrangement of the host population impacts the development of general epidemics and the spread of focal epidemics by a common mechanism. These findings act as evidence against the conjecture that results from studies of host-diversity effects on potato late blight in temperate regions cannot be extrapolated to more tropical regions and suggest that genotype mixtures that are effective in reducing general epidemics of *Phytophthora infestans* will likewise curtail focal epidemics and *vice versa*.

A full account of this work is given in Skelsey *et al.* (2005). The developed modelling framework can be further developed to explore the durability of resistance in potato against *P. infestans* in spatially heterogeneous environments with mosaic patterns of potato genotypes and dispersal of the spores of different genotypes of the pathogen across the environment.

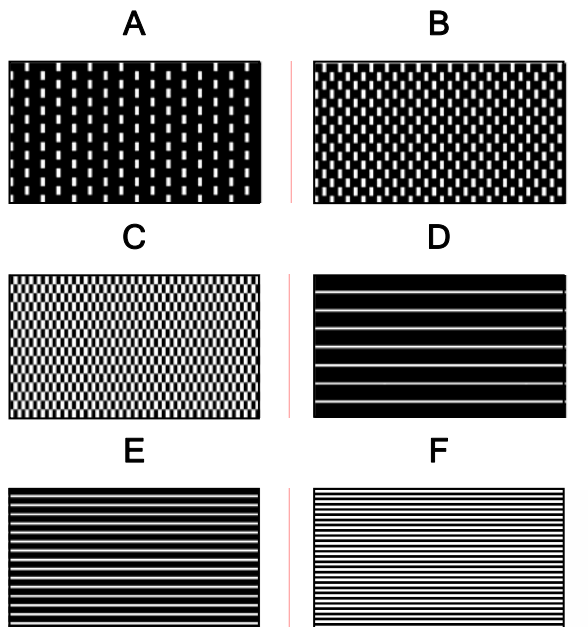


Figure 1. Genotype mixtures used to study the effect of spatial configuration and fraction, f , of susceptible host plants on the behavior of simulated potato late blight epidemics. White blocks represent plants susceptible to *Phytophthora infestans* and black areas represent resistant plants.

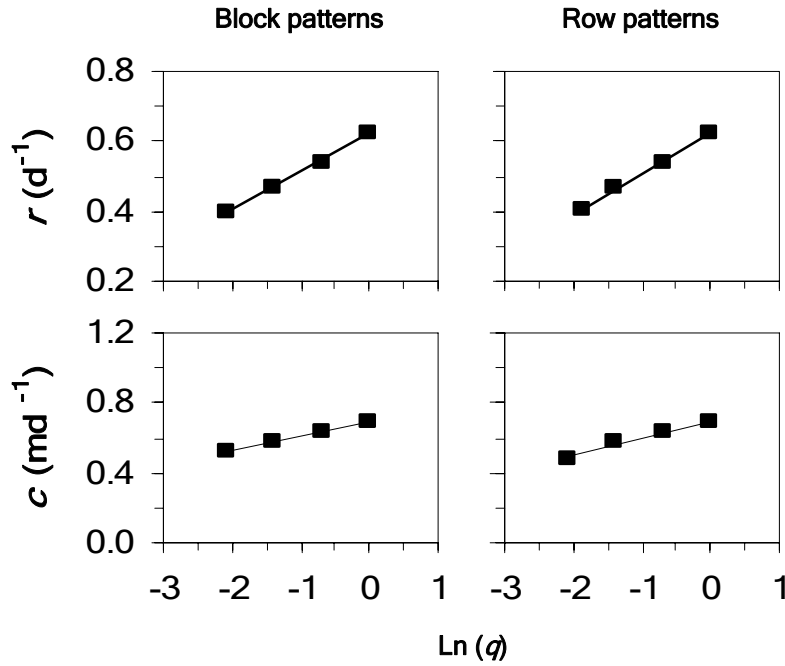


Figure 2. Relationship between the apparent infection rate, r , in general epidemics, the radial velocity of focus expansion, c , in focal epidemics, and the logarithm of the genotype connectivity parameter, q , in simulated potato late blight. The four points in each data set relate to calculations of c at four fractions, f , of susceptible plants in the host population: 0.125, 0.25, 0.5, and 1.

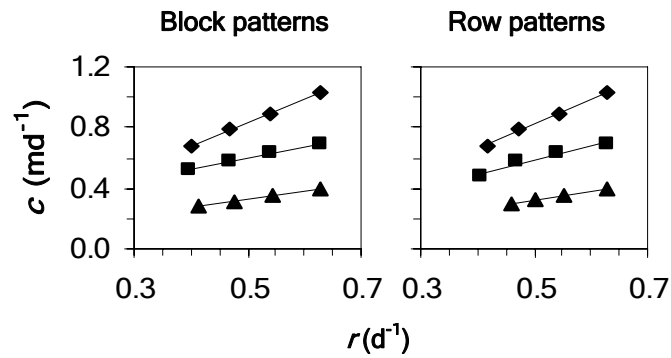


Figure 3. Relationship between apparent infection rate, r , and radial velocity of focus expansion, c in simulated potato late blight epidemics. $\blacklozenge$ = wide Laplace kernel, $\blacktriangle$ = narrow Laplace kernel, $\blacksquare$ = Gaussian kernel, with mean dispersal distances of 2.44, 0.95 and 2.44m respectively. The four points in each data set relate to calculations of r or c at four fractions, f , of susceptible plants in the host population: 0.125, 0.25, 0.5, and 1.

References

- Andrison, D, JM Lucas and D Ellisseebe*, 2003. Development of natural late blight epidemics in pure and mixed plots of potato cultivars with different levels of partial resistance. *Plant Pathology* 52: 586-594.
- Garrett, KA and CC Mundt*, 2000. Host diversity can reduce potato late blight severity for focal and general patterns of primary inoculum. *Phytopathology* 90: 1307-1312.
- Garrett, KA, RJ Nelson, CC Mundt, G Chacon, RE Jaramillo and GA Forbes*, 2001. The effects of host diversity and other management components on epidemics of potato late blight in the humid highland tropics. *Phytopathology* 91: 993-1000.
- Keyfitz, N*, 1985. *Applied Mathematical Demography*, 2nd Edition. Springer Verlag, New York, 441 pp.
- Skelsey, P, WAH Rossing, GJT Kessel, JA Powell & W van der Werf*, 2005. Influence of Host Diversity on Development of Epidemics: An Evaluation and Elaboration of Mixture Theory. *Phytopathology* 95, 328-338.
- Van den Bosch, F, HD Frinking, JAJ Metz and JC Zadoks*, 1988. Focus expansion in plant disease. III. Two experimental examples. *Phytopathology* 78: 919-25.

Epidemiology of *P. infestans* in relation to tuber blight. Survival of *P. infestans* sporangia in field soils

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Summary

Infected tubers are a main source of primary inoculum for potato late blight epidemics. To estimate the risk of occurrence of tuber blight “decision support rules” are being developed. Infection of tubers depends on a number of key factors which have to be identified and quantitated. One of those key factors is survival of sporangia in the ridge. Once sporangia have been washed into the ridge they may immediately infect tubers or survive in the soil until conditions become favourable for tuber infection again. Depending on soil climatic conditions, sporangia of *P. infestans* can survive in potato ridges for up to two months. Long term survival of sporangia under field conditions has to be taken into account when developing a strategy to control tuber blight.

Keywords: potato; *Solanum tuberosum*; control strategy;

Introduction

Infected tubers are a main source of (primary) inoculum for late blight epidemics. Prevention of tuber infection during the growing season could be a major contribution to disease control. Formation of sporangia in the foliage and transport of sporangia to the ridge and tubers is considered a prerequisite for tuber infection to occur. Subsequently tubers can be readily infected by *P. infestans*. Sporangia are washed down with rain upon the ridges and into the soil if sporulating *P. infestans* is present in the foliage during rain showers. Especially

tubers near the soil surface were shown to be vulnerable, indicating transport of sporangia and zoospores into the soil by rain water (Lacey, 1966). Once sporangia have been transported into the ridge they can infect potato tubers. Depending on the variety grown infection might occur frequently or sporadically.

The aim of the project is to develop “decision support rules”. These rules can be used for forecasting, to identify risk situations for tuber infection during the growing season and generate a warning accordingly. Also the rules can be used for back casting, meaning retrospective identification of potato lots with a high risk on tuber infection. Weather data and crop growth data are used to identify such lots. In order to do so we had to quantify key factors involved in tuber infection. This paper describes the survival of sporangia in the potato ridge as one of the steps to develop “decision support rules”

Materials & methods

Soil samples

Soil was sampled from agricultural land at Wageningen, Lelystad, Valthermond and Vredepeel. These locations differ in soil type and the latter three represent the most important potato growing regions in The Netherlands. No potatoes were grown on the sampled fields for at least two years. Soil samples were stored in polythene bags at 4 °C in the dark until use.

Culturing and inoculum preparation.

Isolate IPO98014 was maintained on potato leaves and tuber slices, cultivar Bintje, in an alternating sequence. One week before the start of the experiments detached potato leaves were sprayed with a sporangial suspension of IPO98014. Leaves were placed on water agar in Petri dishes. These were placed in trays and wrapped in transparent polythene bags. Inoculated leaves were incubated at 15 °C in a climate chamber, with a 16 h light period, during one week. Sporangia suspensions were prepared by rinsing the potato leaves with tap water and adjusting the sporangial concentration in such a way, that for each combination of soil type and soil moisture content 5000 sporangia per gram soil was achieved.

Incubation of the inoculated soil samples

Inoculated soil was put into mesh bags. These bags containing sporangia of *P. infestans* were buried in potato ridges. At each location 4 (replicates) x 15 bags were buried at 5, 10 and 20 cm depth in the ridge.

Survival and viability of *P. infestans* in soil samples

Survival of *P. infestans* was established using the tuber slice test developed by Lacey (1965). Viability of *P. infestans* sporangia was assessed more or less weekly. Sampling dates were adjusted to the expected recovery of *P. infestans*. Sampling was stopped when no viable *P. infestans* could be detected for two sampling dates in a row, or when no more of the 15 samples were available.

Slices of Bintje tubers were cut to a thickness of approximately 0.5 cm and placed individually in a Petri dish. From each of the samples ten times 1 g of soil was put on individual tuber slices. 500 µL of tap water was added onto the soil. The wetted soil was then evenly distributed on the potato slice and the Petri dish was closed. Petri dishes were placed in plastic boxes which were wrapped in transparent polythene bags. The boxes were placed in a climate chamber at 15 °C and a day / night period of 16 / 8 hours. Tuber slices were turned and cut in eight equally sized parts (octants) after 1 day of incubation and placed back in the climate chamber. The number of octants infested with *P. infestans* was established visually after 7 days of incubation. To confirm the presence of *P. infestans*, occasionally mycelial growth was checked for the typical sporangiophores under a light microscope.

Data analysis

The experiments were carried out at four locations with four replicates each time. Statistical analyses were carried out using Genstat (Payne et al, 2002).

Results

The recovery of viable sporangia is given in Table 1. The viability lasted longer in 2004 than in 2005. The depth to which the sporangia are buried had little effect upon survival of the sporangia.

Table 1. Final date of recovery of vital *P. infestans* sporangia (days after inoculation) in the ridge at different depths in fields

Location	soil type	Year	Viable sporangia recovered in days after inoculation at different depths		
			5 cm	10 cm	20 cm
Wageningen	clay	2004	64	50	56
Lelystad	clay	2005	35	35	35
Valthermond	peat-like	2005	35	28	42
Vredepeel	sand	2005	35	28	42

Discussion

Survival of *P. infestans* sporangia under field conditions was still found two months after inoculation. Survival of the sporangia is influenced by many factors of which the strain used is one. IPO98014 is one of the most aggressive isolates in the collection of Plant Research International. A preliminary test with 6 different isolates showed that IPO98014 was one of the two isolates which survived the longest (data not published). For building a model to estimate tuber infection risk or “decision support rules”, data should be based on worst case scenarios, i.e. long term survival of sporangia.

Survival of sporangia is influenced by lysis due to colonisation of sporangia by fungi and bacteria and fungistasis (Andrivon, 1994). Survival of sporangia in 2004 was longer than in 2005. The 2004 season can be characterised as dry, whereas 2005 should be characterised as wet. Survival of sporangia under dry conditions lasts longer than under wet conditions (data not published). Probably under wet conditions sporangia germinate and either infect a potato tuber or die, whereas under dry conditions fungistasis may occur until conditions become favourable for germination. Also colonisation of sporangia by bacteria and fungi might be more important under wet than under dry conditions.

Maximum persistence of sporangia in a clay soil was 77 days in the UK (Zan, 1962). Survival of *P. infestans* sporangia up to 45 days was found in France (Andrivon, 1994). These tests were carried out in the laboratory and not under field conditions. Our results were obtained in a field situation showing survival of sporangia in line with other published results (Zan, 1962; Lacey, 1965; Andrivon, 1994).

Long term survival of sporangia might implicate that protection from tuber infection is already needed at flowering. If a potato crop is infested at flowering spores may be washed into the ridge and remain viable until the onset of tuberisation. If conditions are favourable, surviving sporangia might infect newly formed tubers. It is unknown whether this scenario occurs in the actual field situation. Results from our experiments suggest that sporangia at least can survive long enough. The question remains whether the numbers of sporangia surviving are high enough to infect growing potato tubers to some quantity. Nevertheless in agricultural practise it is recommended to protect tubers from as early as the first onset of tuber formation.

Conclusions

Sporangia of *P. infestans* can survive up to 2 months in potato fields.

Data generated in the experiment are incorporated into a tuber blight risk model.

Tuber protection should start as early as the onset of tuber formation if infection risks of late blight occur.

References

- Andrivon, D, 1994. Dynamics of the survival and infectivity to potato tubers of sporangia of *Phytophthora infestans* in three different soils. Soil. Biol. Biochem. 8: 945-952.
- Lacey J, 1965. The infectivity of soils containing *Phytophthora infestans*. Annals of Applied Biology 56: 363-380.
- Lacey J, 1966. The distribution of healthy and blighted tubers in potato ridges. European Potato Journal 9: 86-98.
- Payne RW, DB Baird, M Cherry, AR Gilmour, SA Harding, AF Kane, PW Lane, DA Murray, DA Soutar, R Thompson, AD Todd, G Tunnicliffe-Wilson, R Webster and SJ Welham, 2002. The Guide to Genstat Release 7.1. R.W. Payne, ed. Oxford, UK: VSN International.
- Zan K, 1962. Activity of *Phytophthora infestans* in soil in relation to tuber infection. Transactions of the British Mycological Society 45: 205-221.

How to decrease the input of copper to control the late blight in organic crop with “organic MILPV”

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Introduction

According to years the number of treatments varies from 3 to 7 treatments of copper metal from 2 to 8 kilogrammes. The evolution of the European regulation => to decrease doses of copper. Since 2003, the dose is 8 kg of copper metal per hectare and per year. In 2006, the dose will be 6 kg of copper metal per hectare and per year .

It's necessary:

- to search substitute products;
- to reduce the copper amount.

The plant protection service of the Nord/Pas-de-Calais is partner of European project V.E.T.A.B. it is a program Interreg III North-pas-de-Calais, Wallonia and Flanders, working on the biological production.

The main target of this project is to find substitute products for copper and new techniques to reduce the copper amount.

Materials and Methods

Two axes are worked:

- the research for copper substitutes and reduction of the copper contributions. Various copper products and amounts are tested on a tolerant variety with the late blight (Juliette);
- the research of the thresholds of treatments adapted to the biological production, to determine starting from which level of late blight risk given by the DSS MILPV, it is advisable to carry out a fungicidal intervention.

Within the framework of project V.E.T.AB. the research center of Libramont in Belgium (M R Michelante David) tested in laboratory different substitute products to copper.

From David studies we choose different products which gave an effectiveness against the LATE BLIGHT

Protocol of trial

Various copper products and amounts are tested on a late blight tolerant variety : Juliette.

To determine the first spray against late blight and other dates of treatment, we use the Guntz-Divoux and Milsol models and MILPV DSS, and to chose the type of product according to the level of risks.

To reduce quantities of copper in the trial, treatments are activated by MILPV.

MILPV is a computer tool developed by the Plant Protection Service (in France) for the reasoning of treatments against the late blight of the potato.

MILPV allows of :

- management of the croft: the user can enter the fields of his whole farm and register the state of advice: MILPV generates advices of specific treatments in every field of the farm, according to the sanitary situation of the disease in the environnement and to the sanitary situation of the specific fiels.

For the trial (in 4 replications) we used a variety of intermediate sensibility in the late blight (Juliette).

The control was excluded from the trial. There is no contaminated row. The trial was set up in a contaminated environment (the contaminated tests were located at less than 50 meters).

To decide the treatments, MILPV used the Milsol model. It quantifies the daily risks of late blight with two variables:

- SPOSPO potential sporulation; the number of spores which could be produced if the climatic conditions became favorable;
- SPORUL real sporulation; the number of spores which could contaminate at the first rain.

Various thresholds of risk of the Milsol model were tested according to various products.

Results 2002

Table of products 2002.

Method	Speciality	Actives(s) matter	Proportion Spécialité	Concentr ation.	Proportion Cu/Ha	Give rhythm or threshold
01 BB2Kg	BOUILLIE BORDELAISE RSR DISPERSS	Copper	2 Kg/Ha	20 %	400 G	7 days
02 BB4Kg	BOUILLIE BORDELAISE RSR DISPERSS	Copper	4 Kg/Ha	20 %	800 G	7 days
03 Ferticui	FERTICUIVRE + Fertifeuille	Oxychloride of Cu Fertifeuille	3 L L/Ha 5 kg	Cu 9%	270g	7 days
04 Promild2	PROMILD2	Cu, mn, Zn, Fe	6 L/Ha	Cu5%	300g	7 days
05 BBFER	BOUILLIE BORDELAISE RSR DISPERSS	Copper	2 Kg/Ha	20 %	400 G	If spospo > 5
Threshold 3-2	FERTICUIVRE + fertifeuille	Oxychloride of Cu	3 l/Ha	Cu 9%	270 G	If spospo < 5
06 CUPRS32	CUPRAVIT	Copper oxychloride	1,6 Kg/Ha	Cu 50%	800 G	If spospo > 5
Threshold 3-2	FERTICUIVRE + fertifeuille	Oxychloride of Cu	3 l/Ha and 5 Kg/Ha	Cu 9%	270 G	If spospo < 5
07 BBS32	BOUILLIE BORDELAISEBOUI LLIE BORDELAISE RSR DISPERSS	Copper	2 Kg/Ha	20 %	400 G	Threshold 3-2

The impact of the disease on the foliage is initially given in a number of spots, then when these points of attack become too numerous, the percentage of destruction of the foliage is evaluated. A statistical analysis is carried out on these values.

The first spots of late blight were observed on the test as from July 2002. The pressure of the disease then increased very strongly starting from the beginning of August.

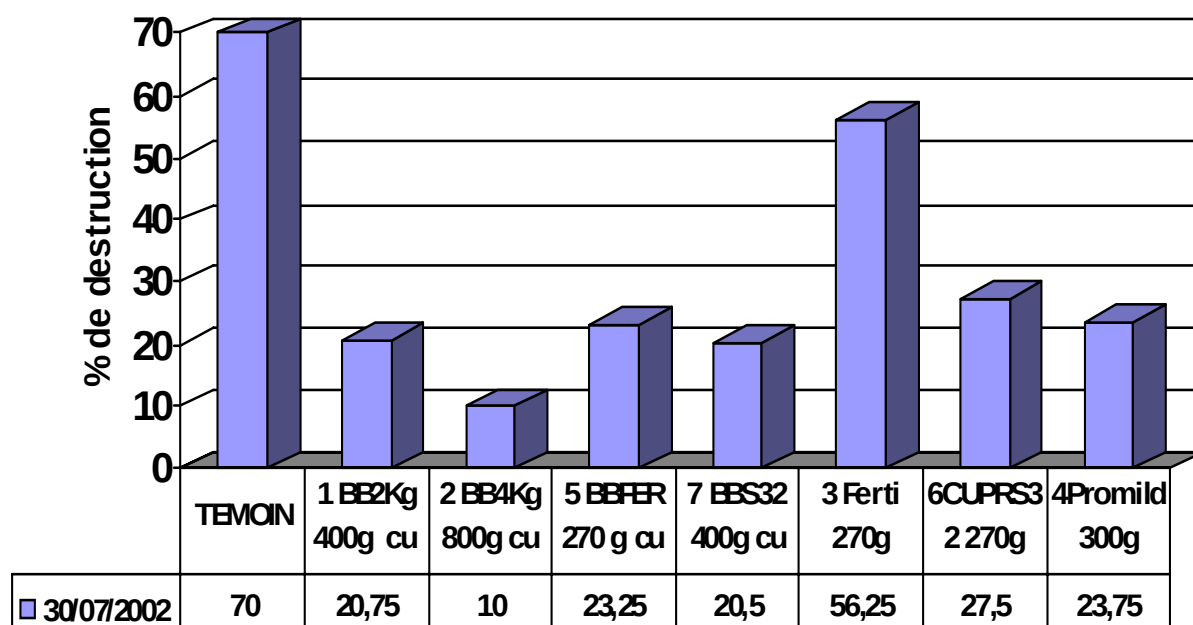
mid-August, the untreated control, was destroyed with more than 96 % by the late blight. To July 30 only method FERTICUIVRE gives a worse effectiveness.

The use of the models gives interesting results. They allowed a satisfactory control of the epidemic with a reduction of the number of treatments and quantity of copper compared to the BOUILLIE BORDELAISE to 4 kg/ha to rate 7 days.

A reduction of 2 treatments was obtained on the pieces with model.

On method 7 (BBS32), where the treatments are started with the models, the control of the disease was at the same level of effectiveness as the systematic method treatment with 2 kg/ha and 4 kg/ha, but with a reduction of more than 60% of the quantity of copper used compared to method 2.

The copper oxychloride condition 6 gave results a little worse on this test. That can be with the regular rains of the year and a persistence of action a little worse of this formulation of copper. On method 5 where we used FERTICUIVRE the development of the disease was more significant. The result can be explained by the smallest quantity of copper applied.



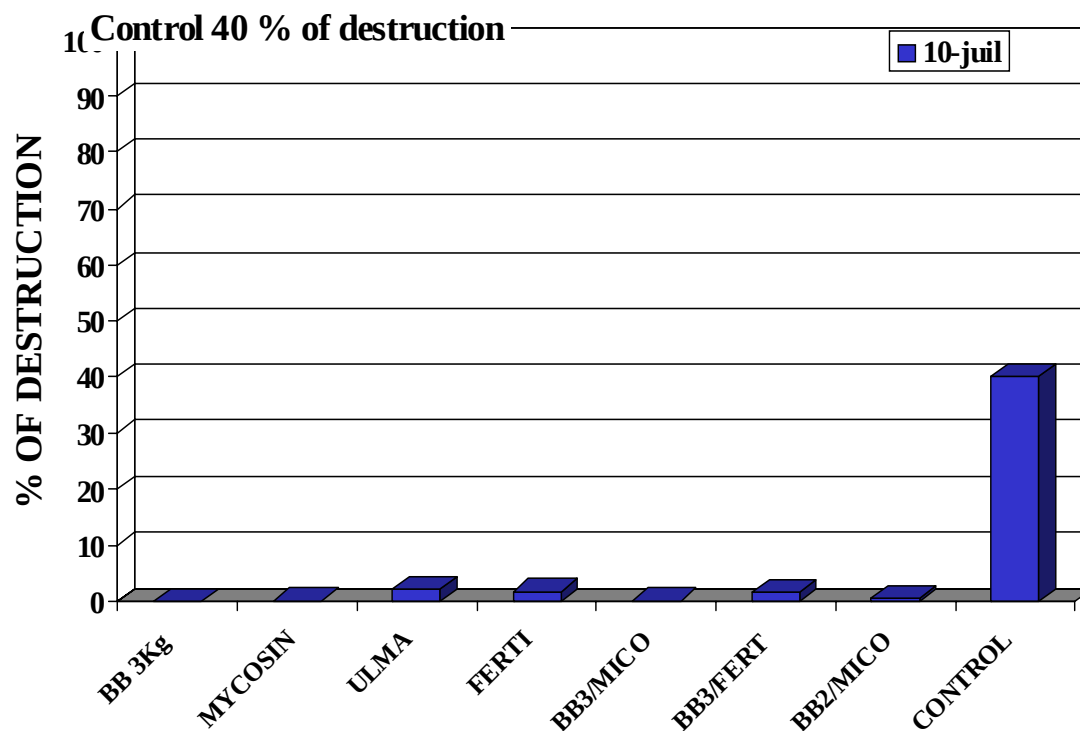
Result 2003

Table of product 2003.

MODALITE	SPECIALITY	MATIERE(S) ACTIVE(S)	PROPO RTION ON SPE	CONCEN T.	PROPO RTION CU/HA	GIVE RHYTHM OR THRESHOLD
01 BBKg	BOUILLIE BORDELAISE RSR DISPERSS	Copper	3 Kg/Ha	20 %	600 G	7 days
02 Myco	MYCOSIN	Powders rocks	8 Kg/Ha	0	0	7 days
03 Ulma	ULMASUB B	Oligo element	6 kg	0	0	7 days
04 Ferti	FERTICUIVRE	Copper + oligo element	6 Kg/Ha	Cu 4 %	240 G	7 days
05 BBMyco	BORDELAISEBO UILLIE BORDELAISE RSR DISPERSS	Copper	3 Kg/Ha	20 %	600 G	According to the Milsol model
In weak risk	MYCOSIN	Powders vegetable rocks, extracts	8 Kg/Ha	0	0	
06 CUFerti	BOUILLIE BORDELAISE RSR DISPERSS	Copper	3Kg/H a	Cu 20 %	600 G	According to the Milsol model
In weak risk	FERTICUIVRE	Copper + Oligo element	6 Kg/Ha	Cu 4 %	240 G	
07 BBMyco	BOUILLIE BORDELAISE RSR DISPERSS	Copper	2 Kg/Ha	20 %	400 G	According to the Milsol model

- The progression of the disease was slow. The control was destroyed only at 35%, at the end of July;
- There was no disease in the treated plots;
- On the level of the treated plots no significant difference in effectiveness was observed between the product containing of copper or without copper.
- A reduction of 50 % of number of treatments was obtained with MILPV DSS compared to the systematic reference.

Trial 2003



Results 2004

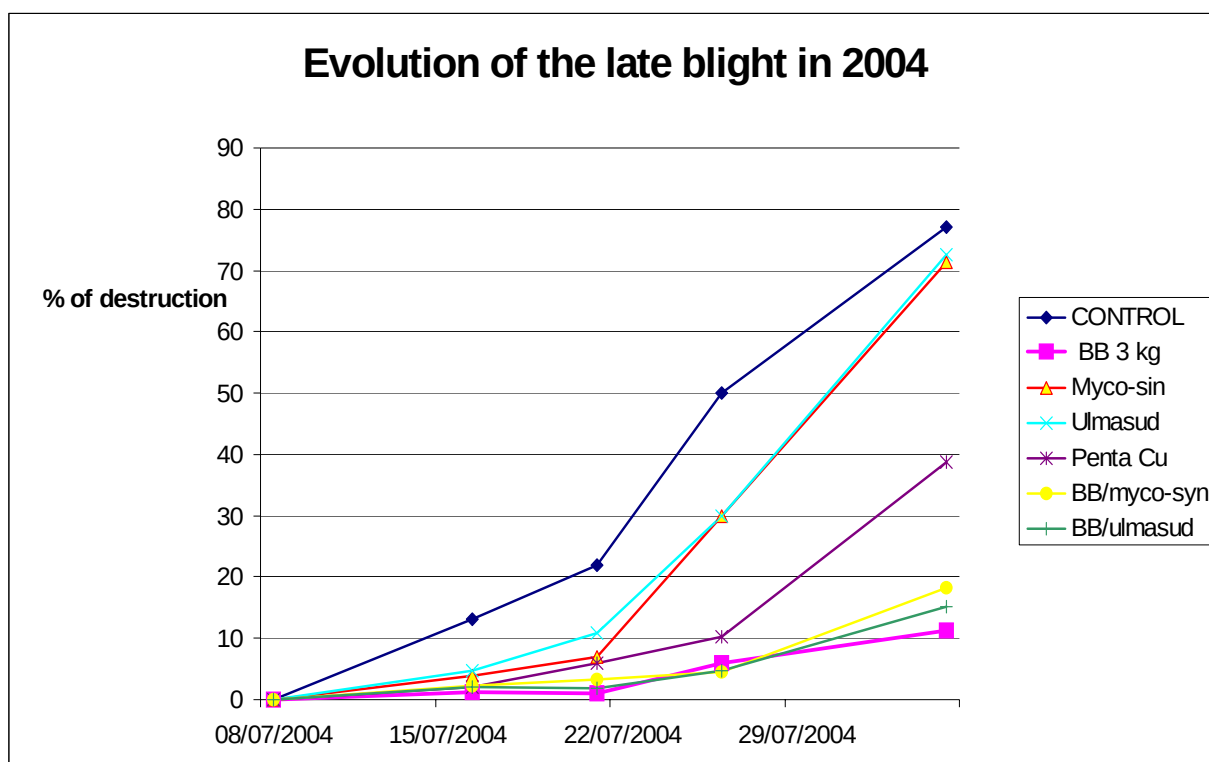
Table of product 2004.

Modalite	Spéciality	Matière(s) Actives(s)	Proportion Spe	Concent.	proportion Cu/Ha	GIVE RHYTHM OR THRESH OLD
01 BB 3 Kg	BOUILLIE BORDELAISE RSR DISPERSS	COPPER	3 Kg/Ha	20 %	600 g	7 jours
02 Myco-sin	MYCO-SIN	Stone Powder	8 Kg/Ha	0	0	7 jours
03 Ulmasud	ULMASUB B	oligo élément	6 Kg	0	0	7 jours
04 Penta Cu	Penta Cu	Copper + oligo element	6 Kg/Ha			7 jours
05 BBMyco	BOUILLIE BORDELAISE RSR DISPERSS	Copper	2 Kg/Ha	20 %	400 g	According to MILPV
In weak risk	Myco-sin	Stone powder	8 Kg/Ha	0	0	
06 BB Ulma	BOUILLIE BORDELAISE RSR DISPERSS	Cuivre	2 Kg/Ha	Cu 20%	400 g/	According to MILPV
In weak risk	Ulmasub B	Oligo element	6 Kg/Ha	0	0	

Modalite	Speciality	Application numbers	Quantity of copper KG/HA
01 BBKg	BOUILLIE BORDELAISE	8	4.8
02 Myco	MYCO-SIN	8	0
03 Ulma	ULMASUB B	8	0
04 Penta	PENTA CU	8	1.9
05 BBMyco Selon les risques	BOUILLIE BORDELAISE	7	2.8
	Myco-sin	1	0
07 BBUlma Selon les risques	BOUILLIE BORDELAISE	7	2.8
	Ulmasud	0	0

- The progression of the disease was quick. The control was destroyed at 80%, at the end of July;
- For the Penta Cu the control of the late blight was correct;
- For the two products without copper Myco-Sin and ULMASUB B, the results were not very good with more than 70 % of destruction of the foliage at the end of July.

Results of synthesis of the Nord/Pas-de-Calais Area test 2004



With the level of risk in 2004 it was not possible to reduce the number of treatments with MILPV DSS compared to the systematic reference, but it was possible to reduce the copper quantities.

Discussion and conclusion

The results of the test set up since 2002 brings interesting information as for the possibility of reduction of copper, but this copper is necessary against severe disease.

On the tests, no difference in effectiveness is noted between the high copper amount (800 g of copper) and the low copper amounts (copper 400 g).

The behavior of the products containing less copper (300 g) was variable according to the pressure (risk, precipitation).

In 2003, the late blight pressure was lower, the results were similar for products with and without copper.

In 2004, the risks are high and the results were different for products with and without copper.

The contribution of the model milsol and now DSS MILPV is interesting in reduction of the number of sprays and the quantity of copper.

It is necessary to review the test carried out into 2005 to validate the effectiveness of the various substitute products. It is preferable to use a “resistant” variety.

The farmers have now new tools to anticipate the periods of risks.

The use of MILPV allows to:

- chose the date of necessary spray (severe thresholds);
- chose the type of product to be used according to the risks:
 - severe: bordeaux mixture (400 g cu);
 - moderate: bordeaux mixture (200g cu) + substitute product or substitute product alone.

SIMBLIGHT1: a new approach to predict first outbreak of Late Blight

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Summary

The new model SIMBLIGHT1 to forecast Late Blight outbreak was developed. As input parameters it requires temperature, rel. humidity and information on soil moisture, crop prevalence and cultivar susceptibility. SIMBLIGHT1 calculates for classified emergence date groups a cumulative risk index with a certain threshold. Model validation and a comparison of SIMBLIGHT1 with the model SIMPHYT1 was done with assessed field data from eleven years was done. Results were promising that SIMBLIGHT1 will replace SIMPHYT1 as a tool for the warning service.

Keywords: potato Late Blight, first outbreak, *Phytophthora infestans*, SIMPHYT1, SIMBLIGHT1, DSS

Introduction

For more than 20 years the forecast model SIMPHYT1 was used to recommend the first fungicide application for the control of Late Blight outbreak (Kluge & Gutsche 1990, Roßberg, *et al.* 2001). Until 1994 SIMPHYT1 was only used in the eastern part of Germany (on the territory of former German Democratic Republic). Four years after their unification of both parts of Germany this forecast model was introduced in all potato growing regions (Kleinhenz, *et al.* 1996). The model gave good results in most of the years but in 1999, 2002 and 2003 a decrease of correct forecasts with SIMPHYT1 was observed (figure 6). Modifications of SIMPHYT1 didn't lead to better results. Analyzing the three years with bad model results it was assumed that the high soil moisture after planting the potato tubers could influence the first outbreak of Late Blight. A new model named SIMBLIGHT1 which takes into account high soil moisture was developed.

Model description

Input

As input parameters the model needs hourly meteorological parameters of temperature and relative humidity. Also the soil moisture as input parameter is needed. But up to now it is not possible to measure this parameter for each potato field. An assessment is necessary to decide if the soil moisture is present. Wet soil is assumed if the predicted potato field was not passable by machines for more than four successive days in the period after planting until seven days after emergence (figure 1).

Additionally crop prevalence is required as an input parameter. It indicates if in the relevant region the percentage of potato fields is more or less than 10 %. The last input parameter is the cultivar susceptibility in two groups (medium and high susceptibility).

Reference input parameters (SIMBLIGHT1)

Name: Met. station:
Harvest (Year):

Potato prevalence
☒ low (< 10 %)
☐ high (>= 10 %)

Cultivar susceptibility
☒ medium
☐ high

Field more than 4 successive days not passable ?
(after planting until 7 days after emergence)
☒ no
☐ yes

Figure 4: SIMBLIGHT1 input

Output

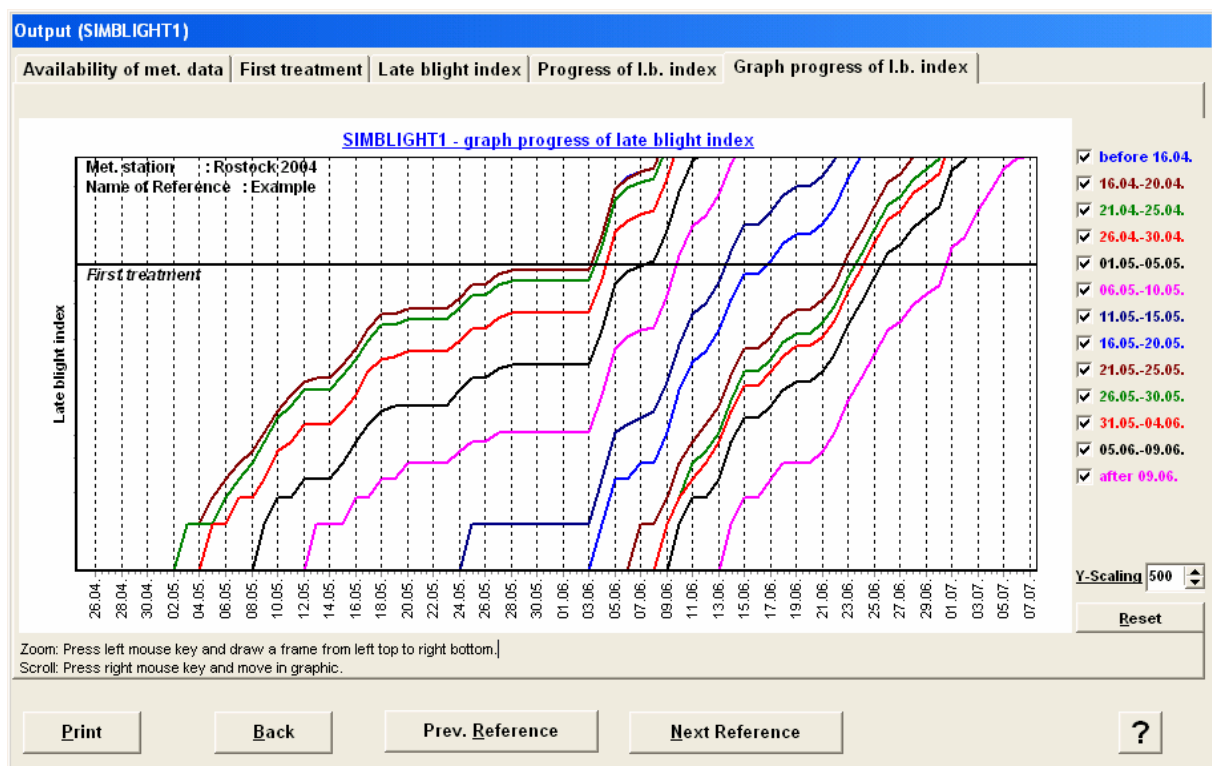


Figure 5: SIMBLIGHT1 output: progress of cumulative risk index

Output (SIMBLIGHT1)		
Availability of met. data		Late blight index
Met. station	: Rostock 2004	
End of Simulation	: 14.09.2004	
Name of Reference	:	
Potato prevalence	: low (< 10 %)	
Cultivar suscept.	: medium	
Extremly high soil humidity:	no	
Emergence date	First treatment at:	
before 16.04.	04.06.	
16.04.-20.04.	04.06.	
21.04.-25.04.	04.06.	
26.04.-30.04.	05.06.	
01.05.-05.05.	08.06.	
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06.05.-10.05.	10.06.	
11.05.-15.05.	14.06.	
16.05.-20.05.	17.06.	
21.05.-25.05.	23.06.	
26.05.-30.05.	24.06.	
31.05.-04.06.	25.06.	
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05.06.-09.06.	26.06.	
after 09.06.	01.07.	

Figure 6: SIMBLIGHT1 output: recommendations of first treatments.

Results and Discussion

First appearance of Late Blight

The first appearance of Late Blight in a crop is generally influenced by many external sources producing spores of *Phytophthora infestans* which are transported by wind into the uninfected potato fields. The most known important sources are infected adjacent fields, infected fields with volunteer potatoes and potato dumps. (Adler 2001) showed that high soil moisture after crop planting increases the number of plants with *P. infestans* symptoms. In this cases the source of infection were latent infested tubers and Late Blight symptoms were recorded very early after crop emergence.

According to this results a national assessment was done. For four years (2001- 2004) the percentage of fields with Late Blight appearance up to 28 days after crop emergence were determined. In 2002 and 2003 the percentage was 15 % and 16 % respectively in contrast to 2001 and 2004 with 6 % and 1% respectively (figure 4).

In figure 5 the sum of field capacity is pointed out for six reference met. stations representing Germany. The month May was chosen because in Germany most potato fields were planted in April and emerge between mid until end of May. In 2002 and 2003 the sum of field

SIMBLIGHT1 calculates the risk of Late Blight outbreak. The result is given as an index between 0 and 100. When the index 100 is reached the first fungicide treatment is recommended. The results are shown in emergence date groups. Each emergence date group comprises five days. The progression of the daily cumulated risk index is shown as a graph (figure 2). The recommendations for the first treatment per emergence date group is also given in a table (figure 3).

capacity at most met. stations was more than 20% higher than in 2001 and 2004.

An expansion of the SIMPHYT1 algorithm to introduce soil moisture was not possible. This was the reason to build the new model SIMBLIGHT1 to predict Late Blight outbreak.

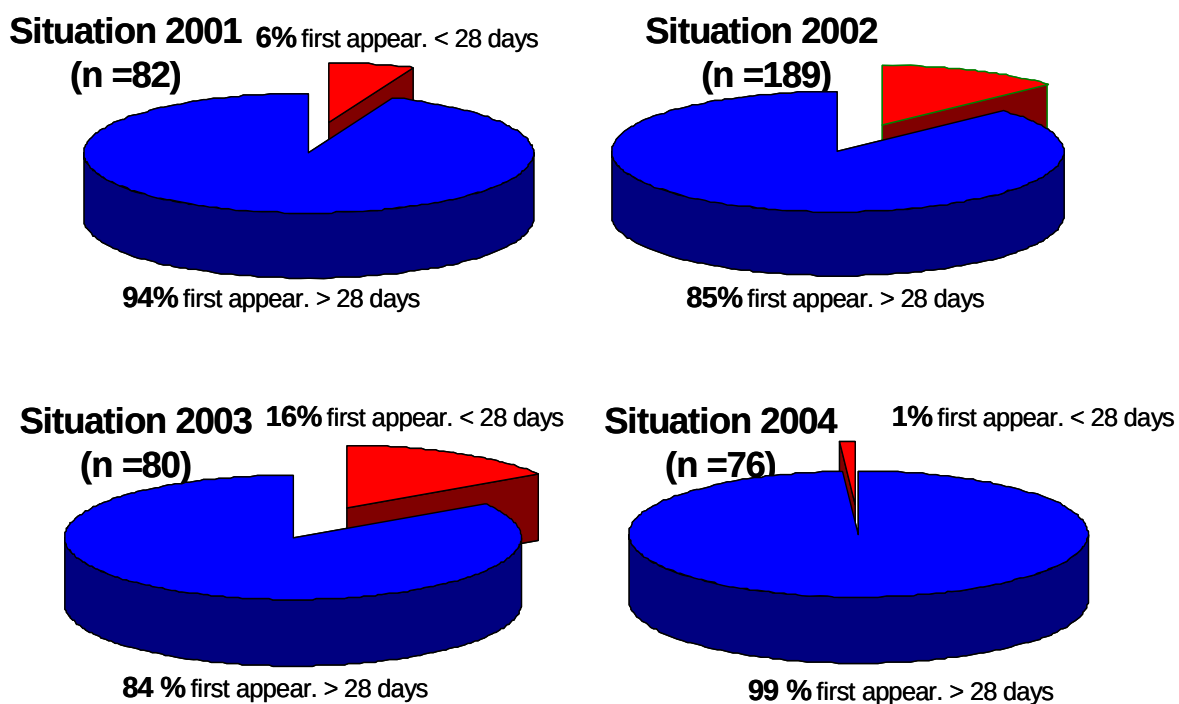


Figure 7: First appearance of Late Blight less and later than 28 days after crop emergence.

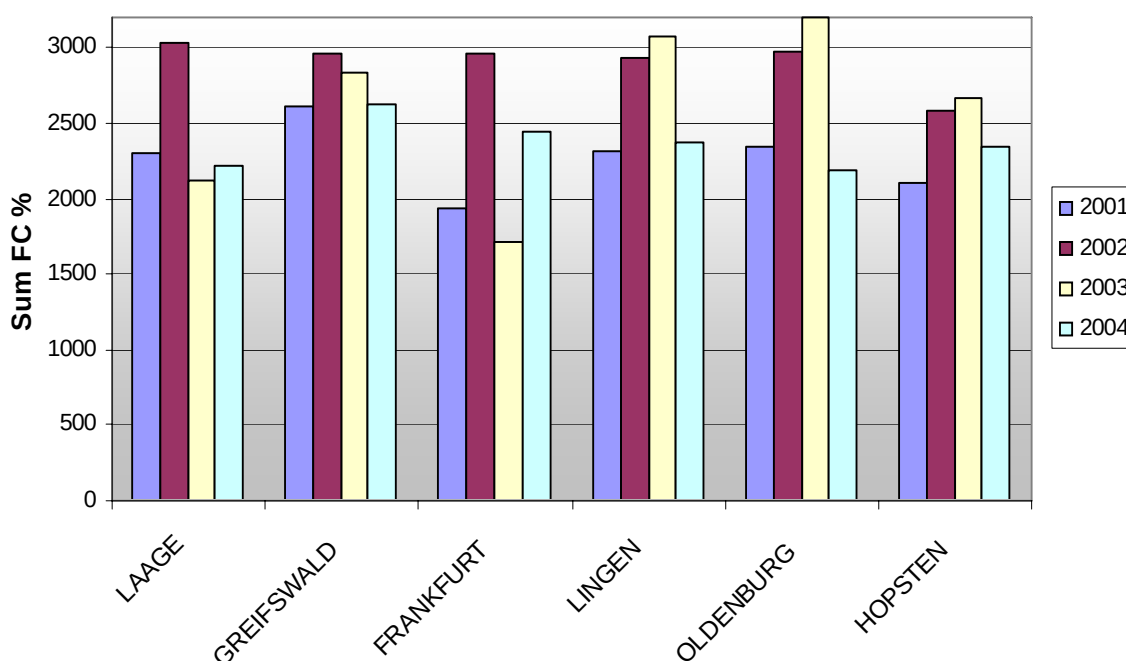


Figure 8: Sum of field capacity in May in Germany between 2001 and 2004.

Model Validation

During the years 1994 -2005 in all potato growing regions of Germany 779 observations of Late Blight outbreak were collected. Each single observation was identified by met. station, year, emergence date and cultivar grouped into medium and high susceptibility. For all observations the SIMPHYT1 and the SIMBLIGHT1 model were run. The model results were compared to the assessed dates of Late Blight outbreak. The result were indicated as correct if the predicted date for the first treatment was earlier than the date of the field observation

In most years the percentage of correct forecasts given by SIMPHYT1 and SIMBLIGHT1 are with more than 90 % similar (figure 6). The results for the problematic years 1999, 2002 and 2003 show that with the new SIMBLIGHT1 model in particular in the years 2002 and 2003 the percentage of correct forecasts could be increased by 22 % and 27 % respectively.

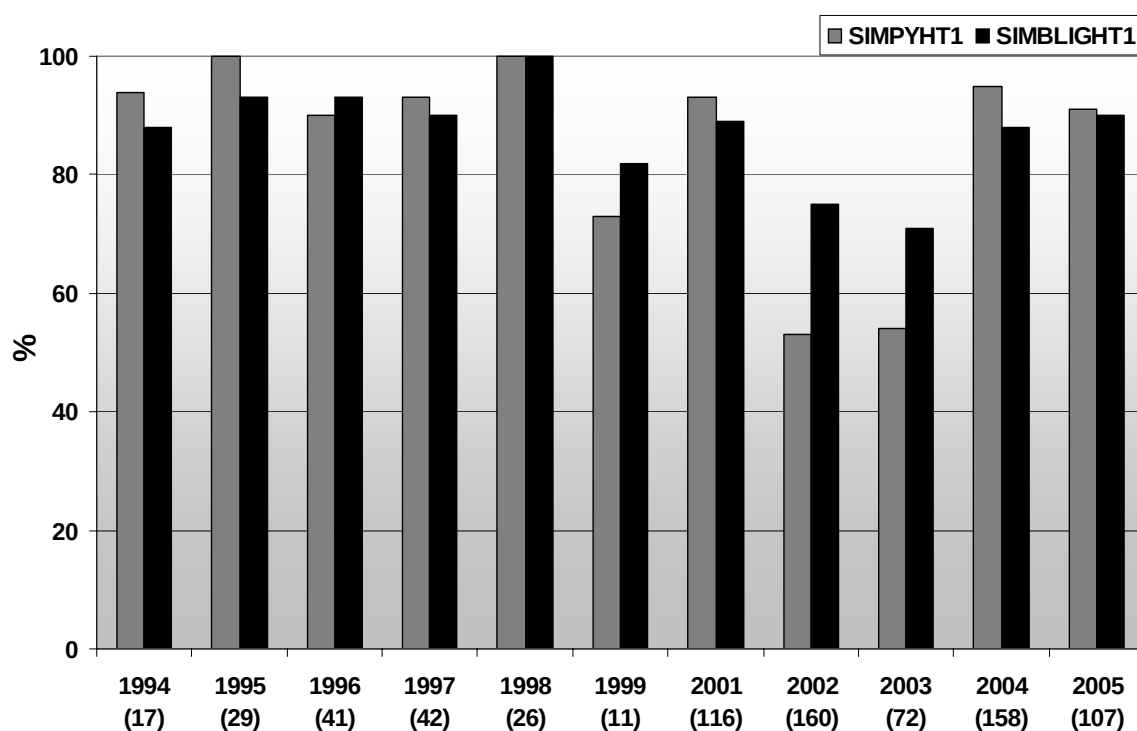


Figure 9: Percentage of correct Late Blight forecasts given by SIMPHYT1 und SIMBLIGHT1.

Conclusions

SIMBLIGHT1 is a new model to predict Late Blight outbreak. It uses meteorological data, cultivar susceptibility, information of soil moisture and crop prevalence as input parameters. The model differs to SIMPHYT1 also in the algorithm for the calculations. The results of SIMBLIGHT1 compared to the old SIMPHYT1 model are much better. More efforts will be performed to derive soil moisture from precipitation. If it is possible to improve results SIMBLIGHT1 will replace SIMPHYT1 as a tool for the warning service.

References

- Adler, N, 2001. Untersuchungen zum Befall von Kartoffeln mit *Phytophthora infestans* (Mont.) de Bary mittels visueller Bonituren und PCR Methoden. DISS..TU Weihenstephan, Freising-Weihenstephan.
- Kleinhenz, B, et al., 1996. "PASO-computer-aided models for decision making in plant protection." OEPP Bulletin/EPPO Bulletin 26: 461-468.
- Kluge, E, and V Gutsche, 1990. "Krautfäuleprognose mittels Simulationsmodell - Ergebnisse der Anwendung 1982 bis 1988." Arch. Phytopathol. Pflanzenschutz, Berlin 26: 265-281.
- Rößberg, D, et al., 2001. "Prognose von *Phytophthora infestans* mit den SIMPHYT Modellen." Gesunde Pflanzen 53: 37-43.

**Scenario studies on strategic control options for *Phytophthora infestans* in
potato**

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Abstract

A model framework is developed to evaluate the effect of different strategic management options on the initiation of *P. infestans* epidemics at target potato crops as a result of the deposition of spores that are produced on sources (e.g. cull piles; infected potato crops) elsewhere in the agro-environment. Model calculations indicate that regional policies that lead to a reduction of spore production at the target or a large separation distance between potential sources and target crops are effective at reducing infection pressure. A reduction of spore production at targets may be achieved by a ban on the use of highly susceptible varieties or by intensive scouting and eradication of sources. The least effective scenario was one that relied on the use of partially resistant varieties at the target but left spore input from distant sources untouched by policy measures. The results indicate that regional measures can make a substantial contribution towards the objective of reducing the requirement for prophylactic sprays against potato late blight. The scenario approach would benefit from further work, especially on the empirical underpinning of the assumptions used in scenario development.

Introduction

The initiation and rate of progress of potato late blight epidemics in farmers fields not only depends on inoculum produced locally in the field, but also on inoculum produced on external sources. Such sources may be effectively prevented from causing epidemics by appropriate management at the strategic level; however, strategic and regional control options are very hard to study experimentally because they require a regional approach. Therefore a modelling approach was taken to study the effectiveness of different possibilities for control at the regional level. Here we present a model that quantifies infection pressure on a receptor crop caused by inoculum from a distant source, i.e. a source outside the target potato field. The model accounts for the production of inoculum on the source, transport of inoculum through the atmosphere (using a Gaussian Plume Model), and deposition on a target crop and the initiation of daughter lesions on this target. Scenario studies were made with the model to study the effectiveness of four control strategies: eradication of heavily infected inoculum sources, use of a partially resistant cultivar at the target, a total ban on the use of the more susceptible cultivars, and spatial separation of potato cultivation into regions where different levels of disease are tolerated.

Materials & methods

The four control scenarios are characterized by four parameters:

- the size of the *Phytophthora* source, i.e. the number of infected potato leaflets at the source;
- the net production of lesions outside a source crop with *P. infestans* as it depends on net reproduction of *P. infestans* and on the fraction of spores that escape the canopy and enter long distance transport [note: net reproduction indicates the production of daughter lesions from mother lesions – part of the daughter lesions is produced close to the mother lesions; another part is produced after long distance transport of spores];
- the infectious period of a *P. infestans* lesion;
- the distance between source of spores and the target field where they land.

The number of lesions at the target field quantifies the effectiveness of a scenario with respect to limiting the spread of disease; the smaller the number of daughter lesions, the more effective the control scenario.

In the reference scenario, a large source of *Phytophthora* spores (200,000 infected leaflets) is present at a short distance (100 m) from the target crop. Both the source of inoculum and the target crop are of a susceptible potato variety. Analysis of net reproduction of *P. infestans* (Spijkerboer, 2004; Chapter 2) in conjunction with information on the escape of spores from an infected potato canopy (Spijkerboer *et al.*, 2002), leads to an estimate of 5.6 daughter lesions that are produced outside a source for each mother lesion at the source. On a susceptible cultivar the infectious period of a lesion is considered to be 7 days (*IP* is defined here as the length of the period of time in the life of a lesion during which it sporulates; cf. Spijkerboer (2004) for details).

The four studied scenarios differ from the reference scenario in one or more of the four above mentioned parameters (Table 1).

Table 1. Characterization of four hypothetical control policies for *Phytophthora infestans*.

Scenario	L (#)	R_0 (-)	IP (d)	x (m)
Reference	200,000	5.6	7	100
1. Eradication of large sources	2,000	5.6	7	100
2. Resistant variety at target	200,000	1.2	7	100
3. Total ban on susceptible potato varieties	20,000	1.02	24	100
4. Spatial separation	200,000	5.6	7	10,000

L is the disease level at the source (#), R_0 the net reproduction (-), IP the infectious period (d) and x the downwind distance (m) between source and target.

- Scenario 1 – Eradication of large sources. In the first scenario, there are no large sources. Here the production of daughter lesions from a small source at 100 m from the target is quantified. This scenario exemplifies a control strategy with a high investment in disease surveillance and prompt eradication of even small sources of infection.
- Scenario 2 – Resistant variety at target. Here, the only parameter that differs from the reference is R_0 , the number of daughter lesions *outside* the source per mother lesion at the source. Lowering this value accounts for the smaller infection chance on resistant potato genotypes, resulting in a reduction in the number of daughter lesions. In this scenario, there is no regional policy against *Phytophthora* in place. The potato farmer is on his own to plant a resistant crop in an environment that may be loaded with spores.

- Scenario 3 – Total ban on susceptible potato varieties. If susceptible potato varieties were banned, both the potato crop at the source and at the target would be resistant. The reduction of spore production on resistant cultivars, compared to susceptible genotypes, results in a further reduction in R_0 compared to scenario 2. Furthermore, the slower lesion growth on resistant cultivars leads to an increase in generation time, and hence longer IP in this scenario (Table 1). Finally, it is considered that the planting of more resistant potato varieties in all fields will reduce the growth rate of late blight epidemics and the regional level of disease, and hence, the size of sources. Source size is chosen intermediate between the reference scenario and scenario 1 (eradication of large sources). Scenario 3 is one which is based on national policy and legislation.
- Scenario 4 – Spatial separation. In this scenario, it is assumed that there are no large sources in a radius of 10 km from the considered target potato crops. This scenario can represent a situation where it is allowable to grow potatoes that have substantial *Phytophthora* severity, but that such crops are confined to “high disease” areas, which are separate from “low disease” areas. The difference with the reference scenario is distance between source and target: 10,000 m. This scenario represents a regional policy choice.

Results

In the reference scenario, potential infection pressure is 3.8 infections per m (380 per 100 m downwind, integrated over the cross wind direction) on a well protected crop on which the fungicide efficacy is 99%. Apparently, the target potato crop under the reference scenario is at risk even with effective fungicide use and strategic management is therefore needed to control disease.

There are large differences in the effect of the four studied control strategies (Table 2). Eradication of sources, a ban on susceptible potato cultivars, and separation of cropping systems are the most effective strategies. They lead to a factor 100 reduction in infection pressure. Under these strategies, fungicide requirements become much lower. The potential infection pressure on unsprayed crops in these scenarios is similar to that on well-sprayed crops in the reference scenario.

Table 2. Infection pressure (number of infections per m downwind distance) under different control strategies and fungicide efficacies (ϵ , %).

	$\epsilon = 0\%$	$\epsilon = 70\%$	$\epsilon = 90\%$	$\epsilon = 99\%$
Reference	381	114	38	3.8
1. Eradication of large sources	3.8	1.1	0.4	0.04
2. Resistant variety at target	82	25	8.2	0.8
3. Total ban on susceptible potato varieties	2.0	0.6	0.2	0.02
4. Spatial separation	3.2	1.0	0.3	0.03

The scenarios 1 and 4 that target, respectively, the size or proximity of sources are more effective than scenarios that rely on resistant cultivars (2 and 3). A total ban on susceptible cultivars (scenario 3) is found to be much more effective than the use of a resistant cultivar on the target crop by the individual farmer (scenario 2). The reason for this effect is that a ban reduces the expected size of sources as well as spore production (per unit disease) at the source and the infection efficiency on the receptor crop, whereas the use of more resistant cultivars at the target only affects infection efficiency. Scenario 2, which is the only scenario that does *not* apply a regional approach, is the least effective of the four defined policy choices.

Discussion

The model developed in this paper is based on established principles in population theory (e.g. Keyfitz, 1985), plant disease epidemiology (e.g. Zadoks & Schein, 1979) and atmospheric dispersion (e.g. Pasquill & Smith, 1983), but it cannot be validated without conducting experiments at the regional level. As such experiments are not practically feasible, the results of this study cannot be quantitatively validated in experiments. Furthermore, some arbitrariness is involved in the creation of scenarios, for instance, the choice of the size of the source (200,000 or 2,000 infected leaflets) represents a wide range of possibilities. However, it has been documented that such large differences in source strength do occur in practice (Anonymous, 1992). Furthermore, no polycyclic epidemics of *P. infestans* at the target location are considered. The cultivation of more resistant varieties at the target would reduce the rate of such epidemics, but this effect of the use of resistant varieties is not considered in the model. The scenarios should therefore be interpreted with caution, and considered by comparison among scenarios, taking into account the noted limitations in the scope of the study.

The results indicate that undetected sources of 2000 diseased leaflets can cause appreciable numbers of infections in neighbouring crops. As sources of 2,000 diseased leaflets may be very difficult to detect, a certain level of infection pressure cannot be fully avoided in practice.

The high importance of source size in the scenario calculations would suggest that heavily infected sources need attention in a disease detection system. It can be calculated that the potential infection pressure at 5.5 km downwind from a source with 100,000 infected leaflets is equal to the potential infection pressure at 50 m downwind from a source with 1000 diseased leaflets. However, this calculation assumes that the spore plume hits the target. The chance of hitting the target, however, diminishes with distance between source and target, due to the narrow shape of plumes. Therefore, smaller but closer sources should not be ignored as they are more likely to deposit spores on the target crop frequently. Unfortunately, for both types of sources, it is very hard in practice to set up a reliable information system that does not overlook any important sources.

The main finding in this study is that the best results are obtained with scenario's that take a regional approach and that target the size or proximity of sources. It is shown that good farming practice by the individual farmer at the target is not enough to prevent fields from becoming infected. Control of the disease can thus not be effective unless an area wide approach is taken to tackle the disease at the source. If all farmers plant more resistant varieties and follow eradication policies, and if strategies for spatial isolation of the more heavily affected crops are developed, infection pressure from distant sources can be reduced significantly. A reduction of infection pressure from outside sources will not completely take away the need for fungicides, because there may also be sources *within* the crop, such as potato planting material or oöspores, but it could greatly contribute to an alleviation of the need for frequent use of prophylactic fungicide sprays against potato late blight.

Acknowledgement

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References

- Anonymus*, 1992. Waarnemen in aardappelen. DACOM & Agrevo (in Dutch).
- Keyfitz, N*, 1985. Applied Mathematical Demography, 2nd Edition. Springer Verlag, New York, 441 pp.
- Pasquill, F and FB Smith*, 1983. Atmospheric diffusion. 3rd ed., Wiley, New York, 430 pp.
- Spijkerboer, H.P.* From lesion to region: epidemiology and management of potato late blight. PhD Thesis, Wageningen University, 112 pp.
- Spijkerboer, HP, JE Beniers, D Jaspers, HJ Schouten, J Goudriaan, R Rabbinge and W van der Werf*, 2002. Ability of the Gaussian plume model to predict and describe spore dispersal over a potato crop. Ecological Modelling 155: 1-18.
- Zadoks, JC and RD Schein*, 1979. Epidemiology & plant disease management. Oxford University Press, New York, 427 pp.

Fungicide dose rates & cultivar resistance: Results and analysis of three years of field experiments in the Netherlands

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Introduction

In 2004, the Dutch Umbrella Plan Phytophthora was launched. Within the Umbrella Plan, the Dutch grower organisation LTO, potato industry, potato trade and Wageningen–UR work together to achieve the common goal of 75% reduction of the environmental pressure due to potato late blight control within 10 years. One of the possibilities to reduce the fungicide input in a preventive control strategy is to use reduced dose rates of protectant fungicides on more resistant potato cultivars (Kessel *et al.*, 2004). This option was explored in a series of field experiments 2002 – 2004 in which 30 potato cultivars were protected with a range of Shirlan dose rates (0%, 20%, 40%, ..., 100% of the recommended dose rate of 0.4 l/ha) under high disease pressure. Spray timing was based on PLANT-Plus recommendations except for the first three sprays which were applied at a weekly interval. Spreader rows (cv Nicola) within the field experiments were artificially inoculated with a mixture of 15 current *P. infestans* isolates. This paper describes the analysis of the resulting data set and some of the results.

Materials and Methods

Severity data on the epidemics occurring in 2002 and 2004 were analysed. The weather in 2003 was hot and dry resulting in non-representative low-level epidemics. Logistic curves were fitted to the severity data for each plot (Oude Voshaar 1995). From the logistic curves the following parameters were derived (Zadoks and Schein, 1979): area under the disease progress curve up to 25 days after inoculation (AUDPC₂₅), apparent infection rate (*r*), the day at which 5% severity was reached (delay₀₅) and the severity 25 days post inoculation (sev₂₅). The resulting parameter values were plotted against their corresponding Shirlan dose rate and linear or exponential curves were fitted yielding dose response curves for each cultivar and each parameter.

Results and discussion

The relationship of AUDPC₂₅ and sev₂₅ against Shirlan dose rate were best described by an exponential function ($Y = A + B(R^{**}X)$). The relationship between delay₀₅ and the Shirlan dose rate was best described by linear regression. An exponential function should, at least theoretically, describe this relationship better but within the range covered by the current data, fitting an exponential function did not give an improvement over linear regression. The apparent infection rate was generally very high and hardly influenced by the Shirlan dose rate. It was therefore decided not to use this parameter for further analysis. As illustrated for cv's Aziza (resistant) and Bintje (susceptible) in the 2004 experiment by figure 1, results show clear differences in the response of the cultivars to increasing Shirlan dose rates. The regression line describing the relationship between the Shirlan dose rate and delay₀₅ for Aziza is well above the line for Bintje (fig. 1A). When Bintje at 0.4 l Shirlan/ha is used as a reference, the same delay can be reached with Aziza at approximately 0.1 l Shirlan/ha. For sev₂₅ and AUDPC₂₅, similar curves indicate that increasing the dose rate above 0.1 – 0.2 l Shirlan/ha for Aziza does not result in a better protection against potato late blight, even under the high disease pressure in the 2004 experiment. Bintje on the other hand does benefit from increasing Shirlan dose rates up to the recommended dose rate of 0.4 l/ha.

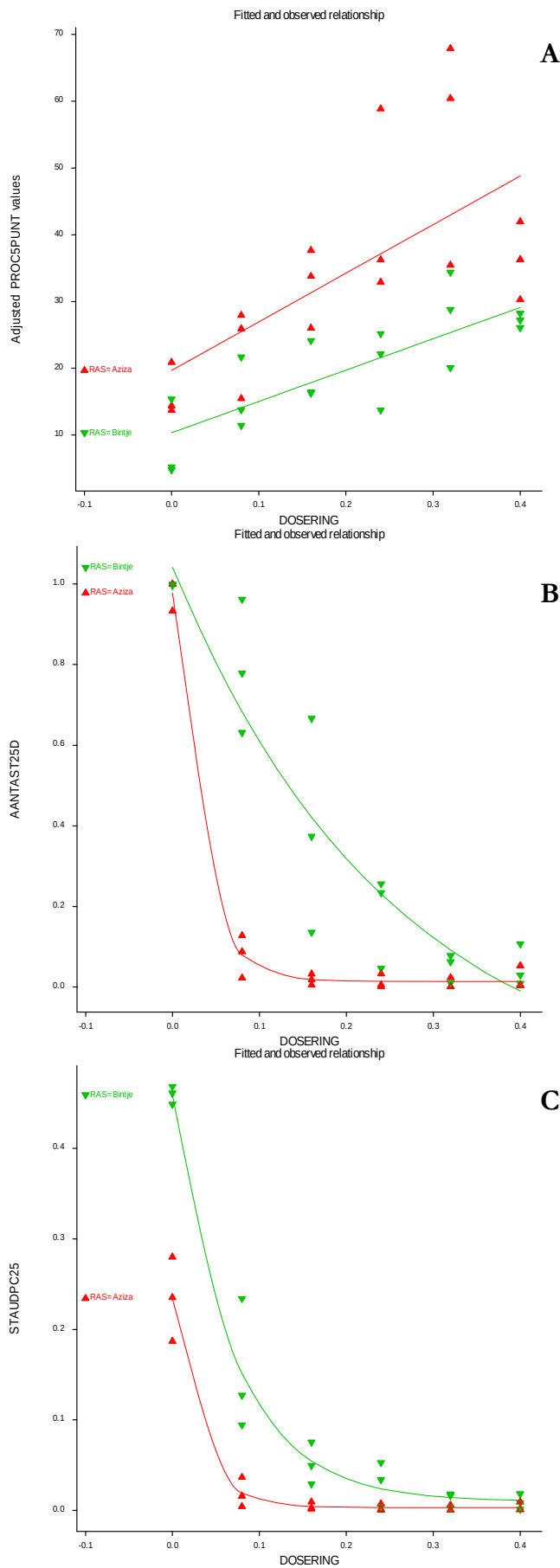


Figure 10. Dose response curves for potato cultivar Aziza representing the effect of a range of Shirlan dose rates on three parameters describing epidemic progress; delay₀₅, the day at which 5% severity is reached (A), sev₂₅, the severity 25 days post inoculation of the spreaders (B) and AUDPC₂₅, the area under the disease progress curve up to 25 days into the epidemic (C).

If the protection level achieved for Bintje at 0.4 l Shirlan/ha is used as a reference point accepted by practice, new recommended reduced dose rates can be derived for each cultivar based on the three parameters mentioned above. For Aziza the resulting recommended reduced Shirlan dose rate would be around 0.15 l Shirlan/ha, only 37% of the official recommended dose rate.

The example above clearly shows that the fungicide input can be drastically reduced on more resistant cultivars. Even more so when the disease pressure is lower than the disease pressure generated in the field experiments which in practice is often the case. A potential problem is posed by the possibility of degradation of cultivar resistance by adaptation of the *P. infestans* population. Reliable and up to date resistance ratings for potato cultivars are therefore essential to implement reduced dose rates of protectant fungicides on more resistant cultivars in practice.

References

- Kessel, GJT, WG Flier, HG Spits, JG Wander and HTAM Schepers*, 2004. Exploitation of cultivar resistance using reduced fungicide dose rates, the Wageningen UR approach. In: PPO-Special report no 10, 211 – 214. C.E. Westerdijk and H.T.A.M Schepers, Editors.
- Oude Voshaar, JH*, 1995. Statistiek voor onderzoekers. Wageningen Press, Wageningen.
- Zadoks, JC and RD Schein*, 1979. Epidemiology and Disease management. Oxford University Press, Inc., New York.

Posters

Epidemiology and Management of Primary *Phytophthora* Infections on Potato

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Keywords: stem blight, soil moisture, seed treatment, tuber infection.

Introduction

Successful management of potato late blight, caused by *Phytophthora infestans*, depends critically on the timing of the first application of control tactics. The decision when to make this application is complicated by the fact that the time of onset of the disease can vary considerably among years, occurring early in some years and late in others. The colonization of above-ground plant parts by *P. infestans* is initiated when the pathogen grows upward from infected tubers through the stems, producing very early symptoms of primary infection on stems or on the foliage.

Materials and Methods

Experiments with infected seed tubers were carried out at two sites, Puch (heavy soil) and Strassmoos (light soil), to determine the effect of precipitation and soil moisture on the incidence of primary *Phytophthora* infections. At both sites, tubers inoculated with 50 zoospores of the pathogen were planted either early (early April) or late (early May). To determine whether primary infections can be reduced by seed treatment or a well-timed early fungicide spray, tubers were treated with the fungicidal seed treatment EPOK (Metalaxyl M + Fluazinam) 50 ml/dt, or stems emerging from untreated tubers were tested for latent *Phytophthora* infections using PCR and the corresponding plots sprayed with RIDOMIL GOLD MZ (Metalaxyl M + Mancozeb) 2 kg/ha after the first positive PCR result.

Results and Discussion

Following crop emergence, the first symptoms of primary *Phytophthora* infection became evident one week after about 20 mm of rain had fallen (Fig. 1). Potatoes planted at Puch in early April subsequently developed 10% incidence of primary stem infection, while those planted in early May had an incidence of primary infection of less than 1%. This difference was most likely due to differences in soil moisture: while the total amount of precipitation prior to symptom appearance was similar for the two planting dates, the temperature sum accumulated between precipitation and symptom appearance was increased by about one-third for the later planting date (Fig. 2).

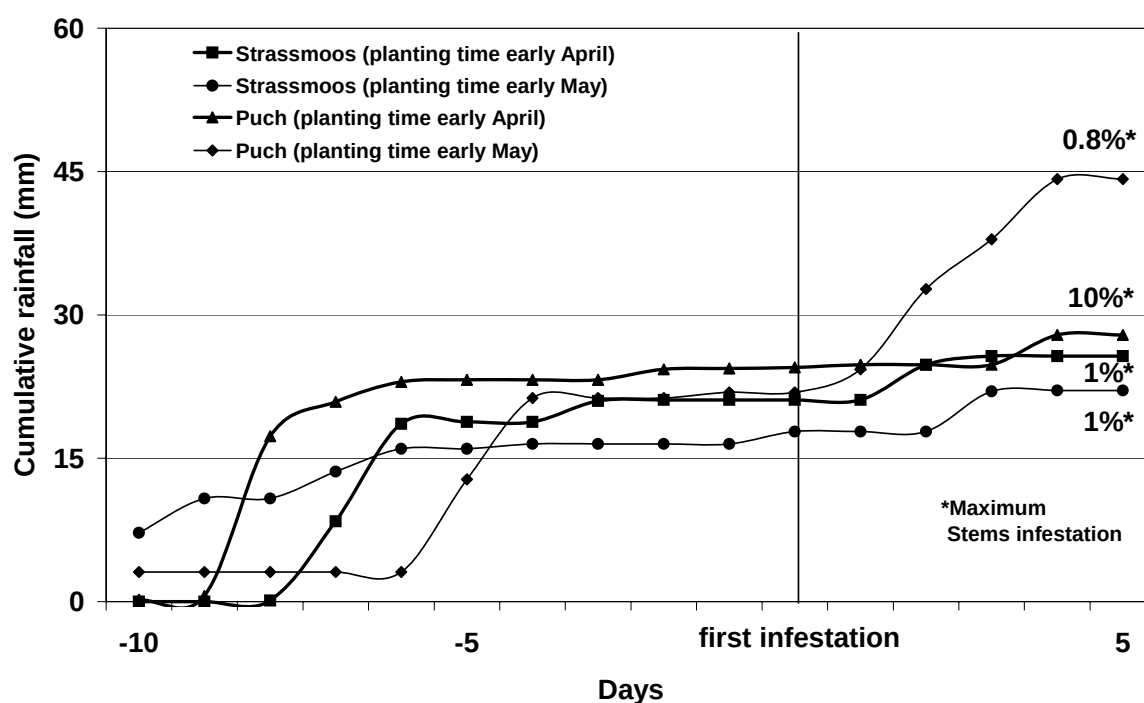


Figure 1. Relationship between cumulative rainfall and time of first symptom appearance.

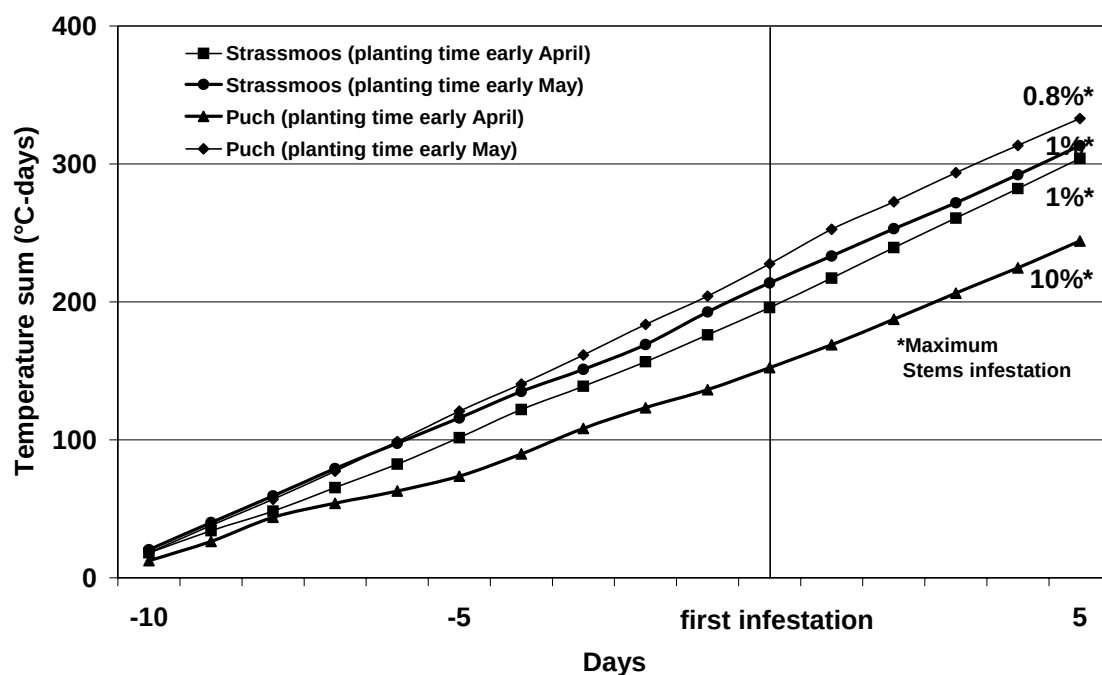


Figure 2. Relationship between temperature sum and time of first symptom appearance.

This resulted in lower soil moisture and, consequently, reduced incidence of primary infection for the later planting date. At the Strassmoos site, soil moisture was generally low because of the light soil, leading to a low incidence of primary infection of less than 1% for both planting dates. These results show that site (including precipitation, temperature, and soil type) and planting date have a major impact on the incidence of primary *Phytophthora* infections.

In plots in which tubers were treated with fungicide prior to planting, the incidence of primary stem infection was reduced by about two-thirds relative to the untreated control. Disease reductions were even greater for plots receiving timely fungicide sprays based on PCR testing for latent infection (Fig. 3).

This study further documented for the first time that *P. infestans* is able to colonize daughter tubers directly from infected mother tubers in the soil.

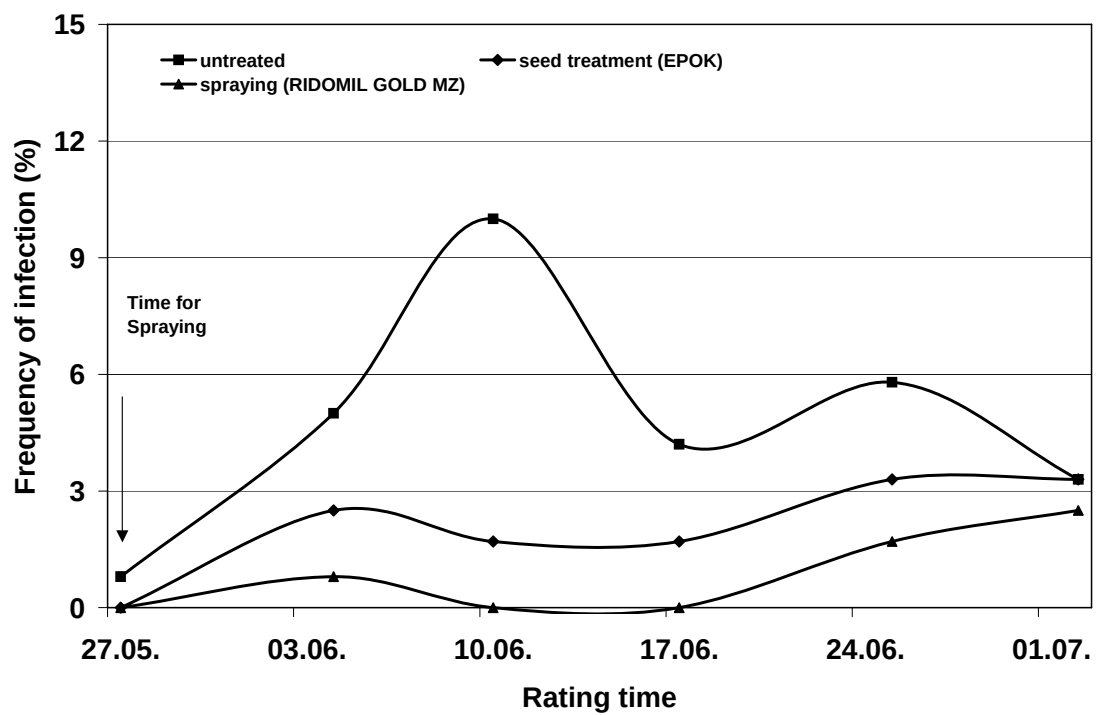


Figure 3. Incidence of stem infection by *Phytophthora infestans* in relation to treatment.

Increased Resistance to Late Blight in Transgenic Potato Expressing Thaumatin II Gene

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Summary

Two Russian potato cultivars transformed by introducing thaumatin II gene into their genomes are more resistant to late blight than non-transgenic plants of these cultivars.

Keywords: Potato cultivars, Thaumatin, Late blight

Introduction

Late Blight caused by oomycete *Phytophthora infestans* (Mont.) de Bary is the most destructive potato disease. The pathogen affects leaves and stems, causing their untimely dying, which results in the decrease of potato yield. *P. infestans* infects potato tubers as well.

Potatoes are grown primarily at home gardens and small private farms in Russia. All potato cultivars planted therein are susceptible to late blight. Only large potato growing enterprises

and some private farms apply fungicides. Taking into consideration such a structure of potato cultivation in Russia the introduction of resistant or less susceptible cultivars will reduce potato yield losses caused by late blight. Genetic transformation is one of effective methods for introducing late blight resistance. It is important to improve resistance without altering key characteristics of the original cultivars.

The goal of this study was to evaluate late blight resistance of transgenic potato clones expressing thaumatin II gene.

Materials and methods

Two Russian potato cultivars Lugovskoi and Charodei were transformed by introducing thaumatin II gene into their genomes. This gene was obtained from tropical plant *Taumatococcus deniellii*. Thaumatin II has almost 65% homology with proteins of the PR-5 group. PR (pathogenesis-related) proteins are known to induce systemic resistance to some plant pathogens. We obtained 98 transgenic clones using *Agrobacterium tumefaciens* strain CBE 121, containing plasmid pBI 121. Various levels of thaumatin gene expression were found in 17 clones of cv. Lugovskoi and 3 clones of cv. Charodei. The transformation and selection of transformed plants were carried out at the Bioengineering Center of Russian Academy of Science. The level of late blight resistance in transgenic and non-transgenic clones was tested at All-Russian Institute of Phytopathology.

Evaluation of the late blight development was based on mathematical simulation model in combination with laboratory testing of detached leaflets inoculated with aggressive strain of *P. infestans*. An incubation period, sporulation capacity as well as the number and size of lesions were estimated. Each host-pathogen association of *Phytophthora* isolate and tested potato clone was compared with a standard host-pathogen association of *Phytophthora* isolate N 161 and standard cultivar Sante. The simulator helped to calculate area under the curve of late blight development and yield loss due to disease when a yield loss of a standard cultivar infected with a standard isolate was equal 35%. The method of evaluation was described by Filippov et al. (2004) earlier. Index of resistance to late blight and yield loss were calculated. Classification of potato clones based on the level of their resistance to late blight and yield losses are shown in Table 1.

Table 1. Classification of potato specimens based on foliage resistance to late blight.

Resistance/susceptibility of cultivars	Degree of Resistance to Late Blight ($ID_{1-9scale}$)*	Calculated yield losses (%)
Resistant (R)	9-8	< 5
Moderately resistant (MR)	7-6	5-15
Moderately susceptible (MS)	5-4	16-35
Susceptible (S)	3-1	> 35

* scores are between 1 and 9, where 1 is highly susceptible and 9 is highly resistant

Calculated yield losses were translated into 9 grades scale as

$$ID_{1-9scale} = -0.17 \times \text{Yield Losses} + 8.85$$

Tubers of eight clones of cv. Lugovskoi and 1 clone of cv. Charodei with high level of thaumatin expression were inoculated with *P. infestans*. Modified Lapwood's method was used for evaluation of tuber resistance to late blight.

Ten tubers of every tested clone were cut into 20 slices (0.7 x 0.5 x 3 cm). Each slice was put into 2-3 mm layer of sporangia suspension in Petri dishes for 3-5 sec. Six days later the blighted zones of slices were measured and index of late blight resistance was determined based on 4-score scale.

The index of tuber resistance was calculated as

$$IR = \frac{\sum(a_i \times b_i)}{n}, \text{ where}$$

IR – index of resistance to late blight, relatively to standard;

a_i – average mean of infection, mm;

b_i – average level of overgrowth with mycelium;

n – number of inoculations.

The tubers of cv. Sante inoculated with *Phytophthora* strain 161 were used as the standard. Mean values of a and b of every tested cultivar were calculated in comparison with the standard (Table 2).

Table 2. Classification of potato specimens based on tuber resistance to late blight.

Resistance/susceptibility of cultivars	Degree of Resistance to Late Blight ($ID_{1-9scale}$)	Calculated index of resistance (IR)
Resistant (R)	9-8	≤ 0.5
Moderately resistant (MR)	7-6	$0.6 - 1.1$
Moderately susceptible (MS)	5-4	$1.2 - 1.7$
Susceptible (S)	3-1	≥ 1.8

IR was translated into 9 grades scale, where 9 = no symptoms of late blight, 1 is highly susceptible to late blight.

$$ID_{1-9scale} = -3.76 \times IR + 9.1$$

The phenotypes and yield as well as kinetics of foliage senescence of all tested plants were evaluated.

Results

We found that foliage resistance to *P. infestans* of 8 transgenic clones of cv. Lugovskoi and 1 clone of cv. Charodei was significantly higher than foliage resistance of non-transgenic plants of both cultivars (Table 3).

We did not find essential differences in other agronomical and morphological traits between transgenic and original clones.

Conclusion

Transgenic potato (cvs. Lugovskoi and Charodei) expressing thaumatin II gene obtained showed increase of partial resistance to *P. infestans*.

Table 3. Foliage resistance to Late blight of thaumatin II clones.

Cultivars	Clones	Level of resistance	
		Foliage	Tubers
Lugovskoi	677302	9.2* (7.3)**	0.35*** (7.8)**
	677369	13.4 (6.6)	0.51 (7.2)
	677314	15 (6.3)	0.3 (8.0)
	677350	11.4 (6.9)	0.72 (6.4)
	677305	9.1 (7.3)	0.38 (7.7)
	677315	11.8 (6.8)	0.81 (6.1)
	677312	13 (6.6)	0.77 (6.2)
	677320	7.8 (7.5)	0.36 (7.7)
	Control	25 (4.6)	0.95 (5.5)
LSD ($\alpha=0.05$)		3.1	0.24
Charodei	103313	10 (7.1)	0.34 (7.8)
	Control	29.6 (3.8)	0.42 (7.5)
LSD ($\alpha=0.05$)		1.9	0.05

* Yield losses, %

**Points (according to 1-9 scale, where 9 = no blight)

*** Index of resistance (IR)

References

Filippov, AV, BI Gurevich, BE Kozlovsky, MA Kuznetsova, AN Rogozhin, SY Spiglasova, TI Smetanina and AN Smirnov, 2004. A rapid method for evaluation of partial potato resistance to Lat Blight and of aggressiveness of *Phytophthora infestans* isolates originating from different regions. Plant Breeding and Seed Science, vol. 50, pp. 29-41.

Production and extraction of oospores of *Phytophthora infestans*

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Summary

Sonication and KMnO₄ treatment were evaluated in aim to facilitate extraction of viable oospores of *P. infestans* and eliminate asexual propagules from the extract. Sonication reduced amount of agar and mycelium residues in the extract. Also oospore concentration was frequently higher in the sonicated extracts. Sonication did not affect significantly on viability of asexual propagules of *P. infestans*. KMnO₄ treatment destroyed asexual propagules, and increased amount of activated oospores.

Keywords: oospore viability, elimination of asexual propagules, sonication, KMnO₄

Introduction

The importance of oospores as a primary inoculum source for potato late blight epidemics has been a topic for speculations since migration of new sexually reproducing *Phytophthora infestans* population into Europe along 1980' s and 1990' s. There is plenty of circumstncial evidence for oospore derived epidemics especially in Nordic countries (Andersson *et al.* 1998, Strömberg *et al.* 2001, Lehtinen & Hannukkala 2004). It is clear that oospores occur in potato fields, are able to survive in soil to the next season, and infect potato plants, at least under controlled environmental conditions (Drenth *et al.* 1995, Medina & Platt 1999, Turkensteen *et al.* 2000, Lehtinen & Hannukkala 2004, Andersson *et al.* 2003, Fernández-Pavía *et al.* 2004). However the commonness and significance of oospore derived epidemics is unclear.

The inadequate knowledge of conditions leading to oospore derived infection has prevented development of decision support systems capable to predict oospore derived epidemics. Partly the lack of knowledge might be a consequence of difficulties in production of viable and readily germinable oospores as it is affected by many external factors (reviewed in Erwin and Ribeiro 1996). The aim of the study was to apply and develop methods to produce and extract sufficient amounts of viable and infective oospores for evaluating oospores as inoculum source of *Phytophthora infestans*.

Materials and methods

Oospore production and extraction

In preliminary work A1 and A2 parent isolates (isolated 2003) were screened for production viable oospores and the best parents were selected for further studies. A1 and A2 isolates were grown together 2-4 weeks in sloppy rye agar plate. Oospores were separated from agar and mycelium in two sets. First set was homogenized 60 s., 9500 rpm (Ultra-Turrax T25, Janke & Kunkel IKA-Labortechnik, Germany), and force filtered with 50- and 20- μ m-pore nylon filters. The second set was homogenized like the first set but before filtering it was sonicated 6×10 s. with 14 W power (Sonopuls HD 2070, probe MS 73, Bandelin-Electronics, Germany). Isolated oospores were tested for viability (described below).

Elimination of asexual spores and mycelium

Sonication and KMnO_4 -treatment (Chang & Ko 1991) were tested for their ability to eliminate asexual inoculum without affecting the viability and infectivity of extracted oospores. Pure cultures with mycelium and sporangia from rye agar were homogenized in sterile water and sonicated for 6×10 s. at 45, 21 and 11 W power. Aliquots of the sonicated suspensions were treated with 0.25 % KMnO_4 -solution according to method described by Chang & Ko (1991). Suspensions were pipetted (20 x 20 μ l) on potato leaflets after sonication and subsequent treatment with KMnO_4 to test presence of viable asexual propagules.

Similar sonication and KMnO_4 treatments were also done on extracted oospores with residual mycelium and sporangia. The oospore samples were mixed with sand (30 g) and

tested for infectivity by bioassay-method described by Drenth et al. (1994). The asexual propagules in the KMnO₄ untreated samples were eliminated in two drying cycles (Fernández-Pavía *et al.* 2004). Oospore samples were also tested for viability (described below).

Oospore viability determination

Viability of oospores was determined by plasmolysis in 2 M NaCl-solution and tetrazolium bromide (MTT) stain (Jiang & Erwin 1990). Autoclaved oospores were used as controls. Plasmolysis tests separates aborted oospores from viable. MTT stain in addition separates dormant and activated oospores.

Results

Oospore production and extraction

Most of the tested A1/A2 isolate pairings produced oospores abundantly, while microscopic examination indicated certain differences in oospore intensity between pairings. The differences in oospore concentrations between the parent isolates were less obvious after extraction. Sonication increased the oospore concentration and the samples contained less agar and mycelium residues than unsonicated samples.

Viability of oospores from different parents

The viabilities were very variable and moderately low in all tested isolate pairings (Figure 1). Only in pairings of A1-isolate 13 with A2-isolates 2 or 40 the oospore viability was constantly over 15 % in plasmolysis test. Pairings of isolate 13 had also higher proportion of dormant oospores than other isolate pairings. Age of the culture or extraction with sonication had no affect to the viability of oospores.

The viabilities were lower measured by plasmolysis test than MTT-staining. In MTT-stain some vacuolated or autoclaved oospores stained blue and were considered as activated. In further tests the blue colored vacuolated oospores were considered unviable.

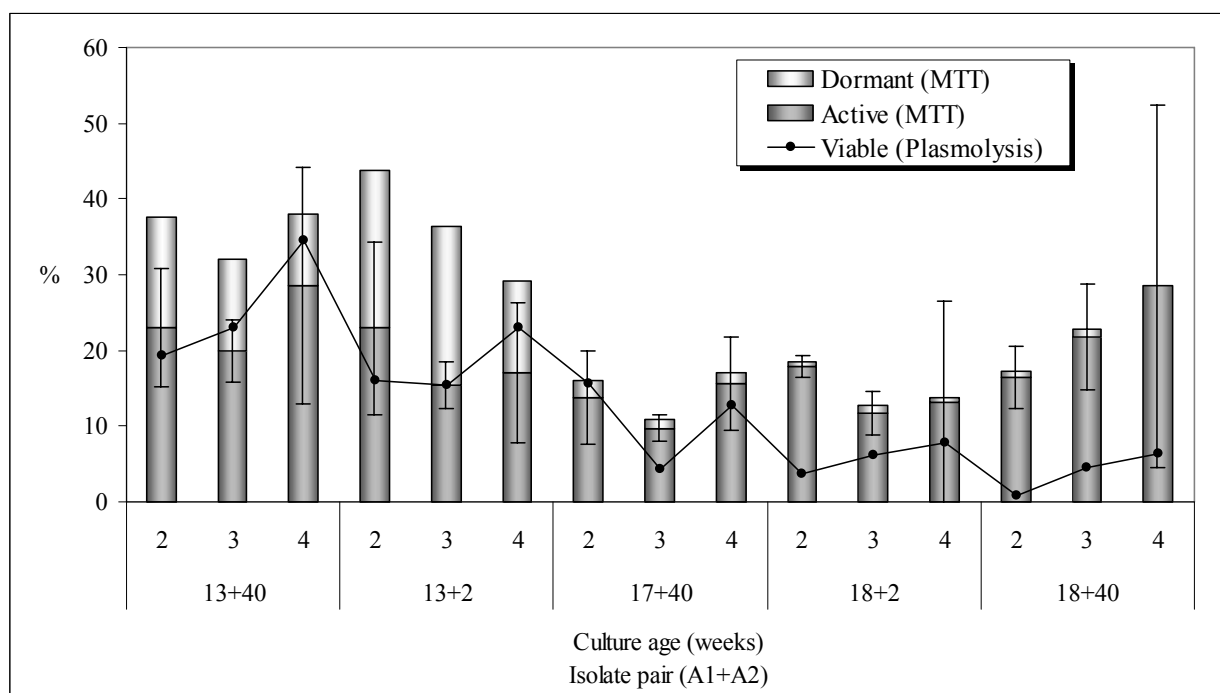


Figure 1. Viability of oospores from different parent isolates extracted after 2-4 weeks. Viability percentages are means of two measurements (sonicated and unsonicated). Standard deviation is only shown for active oospores.

Elimination of asexual spores and mycelium

KMnO₄ treated suspensions containing mycelium fragments and sporangia caused no infections when pipetted on potato leaflets (Table 1). Sonicated suspensions caused as severe infections as the unsonicated control.

Oospore viability remained at the same level in all sonication treatments (Figure 2). KMnO₄ treatment slightly lowered the total proportion of viable oospores compared to untreated samples. KMnO₄ treatment increased the amount of activated oospores measured by MTT stain. In oospore infectivity bioassay dried samples and KMnO₄ treated samples were similar in their ability to cause infections (Table 1).

Table 1. Asexual propagule elimination test. Infectivity is given by number of infected leaflets in both sporangial / mycelium and oospore infectivity.

Sonication power	Sporangial / mycelium infectivity		Oospore infectivity	
	Control (Water)	KMnO ₄	Control (Two drying cycles)	KMnO ₄
45 W	4/4	0/4	2/5	3/5
21 W	4/4	0/4	5/5	5/5
11 W	4/4	0/4	2/5	3/5
0	4/4	0/4	2/5	3/5

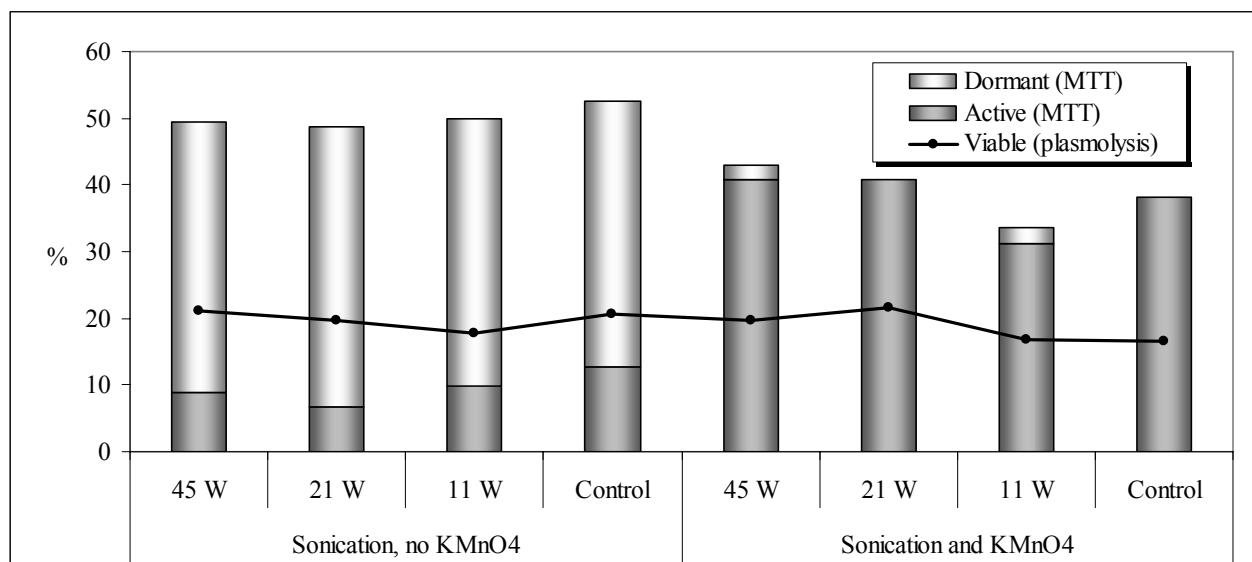


Figure 2. The effect of sonication and KMnO₄ treatment on oospore viability.

Discussion

Selecting compatible parent isolate is important when high quantities oospores are needed. Some isolate pairs, while producing abundant amounts of oospores, may result only small fraction of viable oospores. Extraction procedure also affects the amount and quality of extracted oospores. Sonication provides a useful method separating oospores from agar and mycelium and increasing concentration of extracted oospores without lowering oospore viability. However sonication at 11-45 W power as such is not sufficient method for eliminating asexual propagules. El-Hamalawi and Erwin (1986) showed that mycelium fragments and sporangia of *P. megasperma* f. sp. *medicaginis* were not destroyed until four min sonication at 100 W, indicating that longer and more powerful sonication or other treatments are needed for eliminating asexual propagules. KMnO₄ eliminates viable sporangia and mycelium fragments and has only minor affect in total viability. KMnO₄ treatment also promotes activation of oospores. Chang & Ko (1991) showed that the activation of dormant oospores with KMnO₄ enhances germination markedly. Therefore KMnO₄ treatment could be used in reducing uncontrolled factors affecting infectivity of oospores. KMnO₄ could replace enzymes used in elimination of asexual propagules and activation of oospores e.g. NovoZym 234 (Interspex Products Inc., USA / Novo Biolabs, UK) (Flier et al. 2001), which is no longer commercially available.

References

- Andersson, B, M Sandström and A Strömberg, 1998. Indications of soil borne inoculum of *Phytophthora infestans*. Potato Research 41: 305-310.
- Andersson, B, M Johansson and B Jonsson, 2003. First report of *Solanum physalifolium* as a host plant for *Phytophthora infestans* in Sweden. Plant Disease. 87: 1538.
- Chang, TT and WH Ko, 1991. Factors affecting germination of oospores of *Phytophthora infestans*. J. Phyt. 133 (1): 29-35.
- Cooke, LR and KL Deahl, 2005. Potato blight populations in Ireland and beyond. In: Haverkort, A.J. & Struik, P.C (eds.). Potato in progress: science meets practice. Wageningen Academic Publishers, Wageningen, The Netherlands. 366 s.
- Drenth, A, EM Janssen and F Govers, 1995. Formation and survival of oospores of *Phytophthora infestans* under natural conditions. Plant Pathol. 44 (1): 86-94.

- El-Hamalani, ZA and DC Erwin, 1986. Physical, enzymic, and chemical factors affecting viability and germination of oospores of *Phytophthora megasperma* f.sp. *medicaginis*. *Phytopathology*. 76 (5): 503-507
- Erwin, DC and OK Ribeiro, 1996. *Phytophthora* Diseases Worldwide. Minnesota, The American Phytopathological Society. 562 s.
- Fernández-Paría, SP, NJ Grünwald, M Díaz-Valasis, M Cadena-Hinojosa and WE Fry, 2004. Soilborne oospores of *Phytophthora infestans* in central Mexico survive winter fallow and infect potato plants in the field. *Plant Dis.* 88 (1): 29-33.
- Flier, WG, NJ Grünwald, WE Fry and LJ Turkensteen, 2001. Formation, production and viability of oospores of *Phytophthora infestans* from potato and *Solanum demissum* in the Toluca Valley, central Mexico. *Myc. Res.* 105 (8): 998-1006.
- Lehtinen, A and A Hannukkala, 2004. Oospores of *Phytophthora infestans* in soil provide an important new source of primary inoculum in Finland. *Agricultural and Food Science*. 13 (4): 399-410
- Medina, MV and HW Platt, 1999. Viability of oospores of *Phytophthora infestans* under field conditions in northeastern North America. *Can. J. Plant Pathol.* 21 (2): 137-143.
- Strömberg, A, U Boström and N Hallenberg,. 2001. Oospore germination and formation by the late blight pathogen *Phytophthora infestans* in vitro and under field conditions. *J. Phyt.* 149 (11-12): 659-664.
- Turkensteen, LJ, WG Flier, R Wanningen and A Mulder, 2000. Production, survival and infectivity of oospores of *Phytophthora infestans*. *Plant Pathol.* 49 (6): 688-696.

Susceptibility of varieties to late blight in recent field trials at Lammi in Finland

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Material and methods

Susceptibility of potato varieties to late blight caused by *Phytophthora infestans* is evaluated continuously for the need of official variety testing in Finland. This study was focused on the years 2004 – 2005 at the trial site Lammi in South Finland (61°1'N), where infection pressure of late blight was heavy already early in the summer. Variety maturing score was assessed in official variety trials at several trial sites in Finland (Kangas *et al.* 2005).

Field trials for evaluating late blight susceptibility were carried out as randomised complete block design with four replicates and with a plot size of 4 m². Foliar blight initiating from natural inoculum was assessed once or twice a week. Tubers were harvested when the crop was naturally senesced (except the crop of Kuras). Tuber blight was measured as weight percent of diseased tubers. Evaluation was done 2 – 4 weeks after the harvest.

Results and conclusions

Non-race-specific resistance against *P. infestans* in potato is strongly associated with late foliage maturing (Visker *et al.* 2003). Also in this study maturing type of varieties predicted well their susceptibility to foliage blight (figure 1.). The varieties which diverged in foliar blight susceptibility from the general trend are worth highlighting. The least susceptible variety in the group of early potatoes was Matilda, of the medium late varieties Suvi, Posmo and Rosamunda and of the late varieties Appell and Kuras (figure 2.).

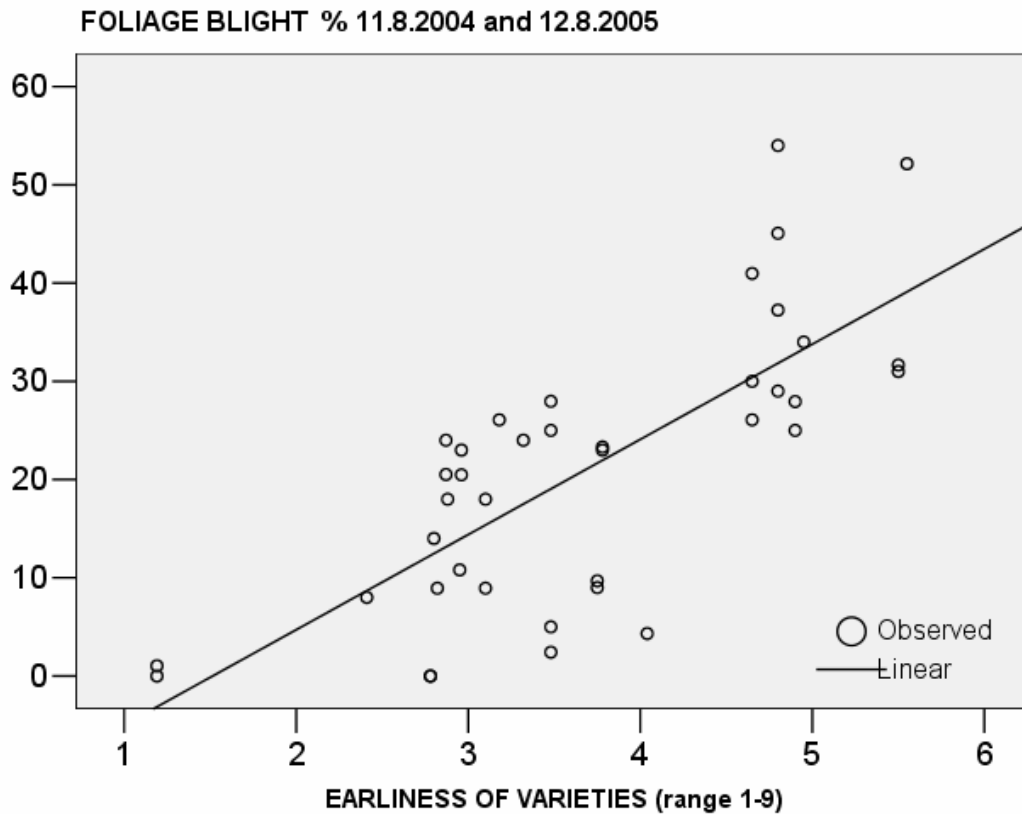


Figure 1. Correlation of foliar blight and maturing type (1 = very late) of varieties ($Y=1.22 \times X + 0.034$, $R^2 = 0.65$, $p<0.01$).

A good foliar blight resistance doesn't necessarily coincide with tuber blight resistance. For example Appell has a good resistance against foliar blight, but it was one of the most susceptible varieties to tuber blight. An early ware potato Premiere proved to be very susceptible and a new Finnish starch variety Tomppa moderately susceptible to tuber blight (figure 3). Concerning quality risks of tuber yield it is good to be aware not only of foliar blight, but also of the tuber blight susceptibility of varieties.

References

- Kangas, A, A Laine, M Niskanen, Y Salo, L Jaubaiainen and H Nikander, 2005. Virallisten lajikekokeiden tulokset 1997-2004. MTT:n selvityksiä 83: 193 s. <http://www.mtt.fi/mtts/pdf/mtts83.pdf>
- Visker, MHPW, HJB Heilersig, HMG van Raaij, LT Colon and PC Struik, 2003. QTLs for late blight resistance and foliage maturity type. Breeding and adaptation of potatoes. EAPR: Section of Breeding and Varietal Assessment EUCARPIA: Potato section 26th – 30th July 2003, Oulu, Finland.

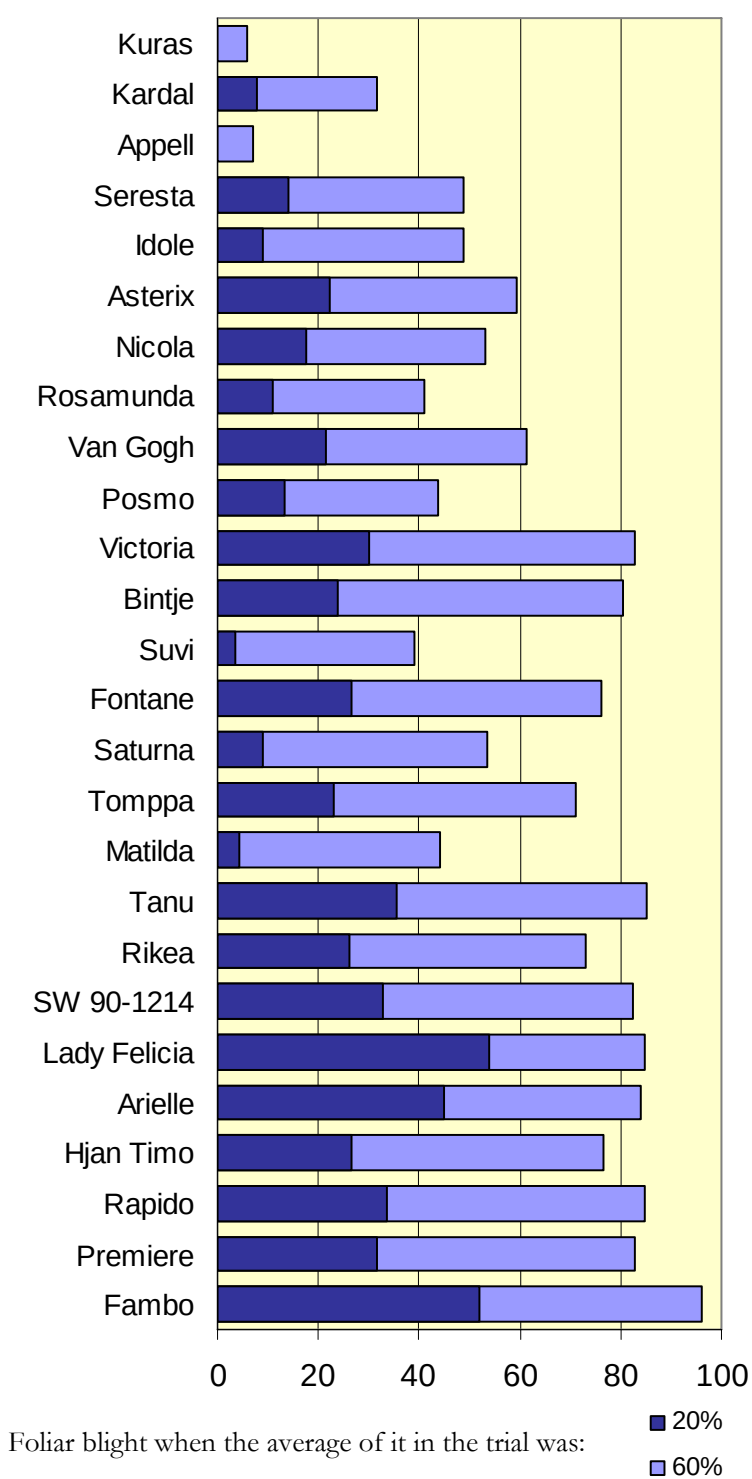


Figure 2. Foliar blight in 2004 – 2005 at Lammi. Varieties in the figure are arranged according to a maturing type from the earliest varieties like Fambo to the latest one Kuras.

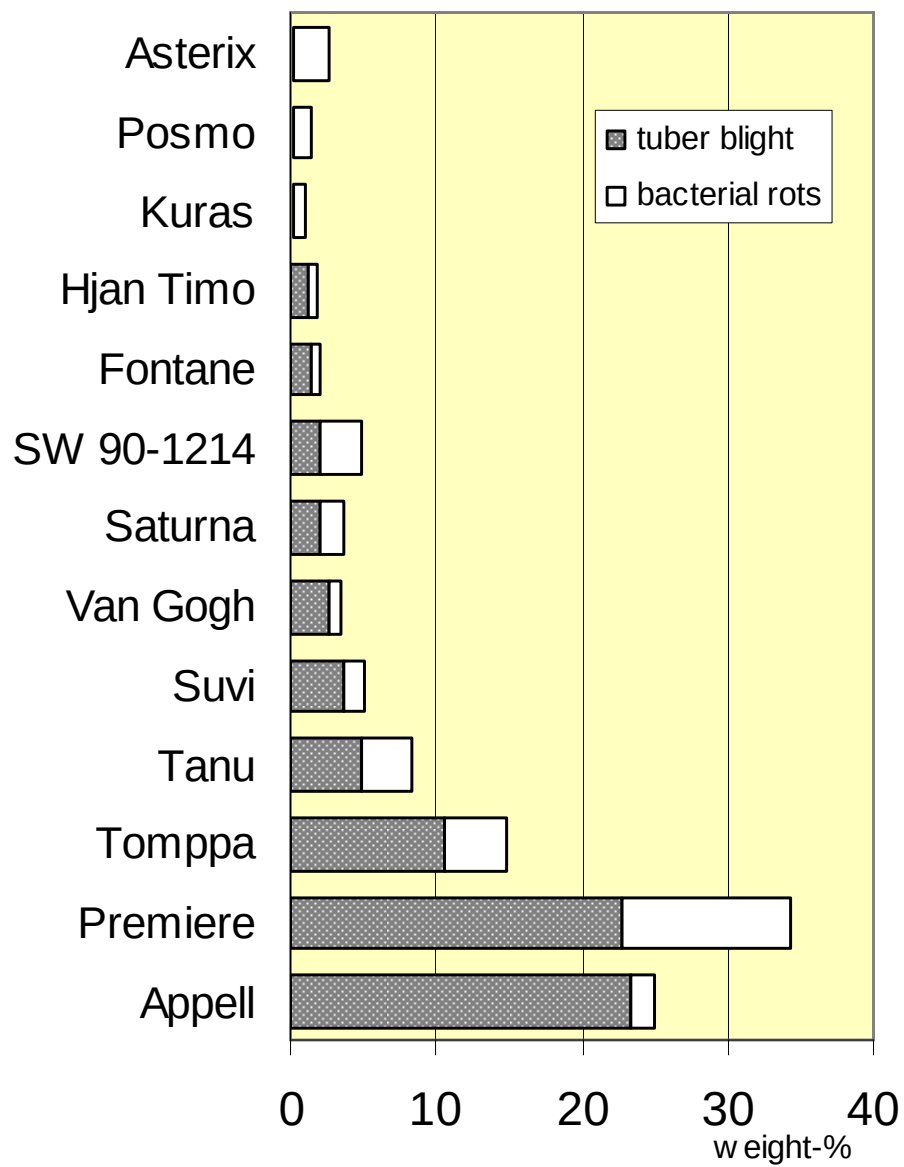


Figure 3. Tuber blight and bacterial soft rots on 2004 – 2005 at Lammi.

Frequency of genotypes with tuber resistance to *Phytophthora infestans* in wild potato species

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Keywords: *Phytophthora infestans*, potato, wild *Solanum* spp., tuber resistance

Introduction

Due to changes in *Phytophthora infestans* population, late blight of potatoes has become a very difficult disease to manage. Economic losses due to late blight are caused by both: foliage and tuber susceptibility of grown cultivars. As foliar and tuber susceptibility to late blight often don't correlate in potato, it is necessary to find out new genetic sources with resistance both in leaves and in tubers (Kirk et al. 2001). An opinion, that foliage resistant cultivars minimize risk of tuber blight, was widely spread not long ago. That is why the research has been focused on leaf resistance evaluation. Treatments with contact fungicides decrease but not completely eliminate the infection. Even weakly blighted foliage during the growing season leads to high percent of infected tubers (Schwinn and Margot, 1991). After tuber infection with *P. infestans* severe storage losses can occur.

The number of resistant varieties being used in potato production is not sufficient to reduce the losses caused by late blight. Besides, aggressive and variable populations of the pathogen are affecting tubers due to their adaptation to grown resistant cultivars. For example tubers of Russian cultivar Romashka found in our 1996 evaluation (artificial inoculation) as highly resistant occurred to be strongly diseased in 2003 field observation. At the time of appearance in Russian fields of cultivar Peterburgskij it was characterized as resistant to late blight. Two last year laboratory tests and field observations showed that the tubers of this cultivar are strongly affected by *P. infestans* (no published data). The monitoring of *P. infestans*

population in this region showed each year presence in its isolates genes of virulence v.1-v.8, v.10, v.11. and both mating types – A1 and A2 (Vedenyapina *et al.*, 2002). In *P. infestans* isolates collected in St. Petersburg Region in 2005 beside mentioned above, gene virulence v.9. was also identified. To improve genetic base of grown cultivars it is necessary to use new resistance sources and consequently screen possible diverse potato germplasm more intensively.

Many wild potato species are highly polymorphic for resistance to *P. infestans*. Polymorphism for leaf resistance to late blight has been found in the majority of 76 species evaluated in field and laboratory studies conducted in early 80th (Zoteyeva 1986).

The objective of this study was to find out wild potato species with high frequency of genotypes with tuber resistance to *P. infestans* and identify the intra specific or intra population polymorphism of this character.

Material and Methods

Plant material. A total of 84 accessions of 19 tuber-bearing *Solanum* L. species from collection of N.I. Vavilov Institute of Plant Industry (VIR) were screened for tuber resistance to *P. infestans* in 1996 – 2001. The tests were conducted in VIR in 1996, 2001 and in IHAR Mlochow Unit (Poland) in 1999 – 2001.

Tubers were collected from plants grown in VIR's experimental station situated in St. Petersburg Region (North-Western Russia) and from plants grown as pot-plants in screen-house of IHAR Mlochow Unit. Plants of wild potato species, obtained from the botanical seeds, had been grown for one month in a glass house and then transplanted in the pots. From 8 to 30 plants from each accession were tested. Number of tubers per plant differed because of low tuber production in several species. Tests were performed in two replications.

Pathogen material. The inoculation was conducted using highly pathogenic isolates of *P. infestans* MP-324 (1.2.3.4.5.7.8.10.11.) from Mlochow's collection of the pathogens and mixture of Russian isolates comprising all known virulence genes except for gene v. 9. The virulence of isolates was examined using potato Black's differentials carrying 1 to 11 R-genes. Inoculation and disease reading

For evaluating the tuber resistance to *P. infestans*, methods of whole tubers and tuber slice inoculation are usually applied (Dorrance and Inglis, 1998; Stewart *et al.*, 1996). To evaluate the tuber resistance to *P. infestans* in wild potatoes characterized by small tuber size, the

method of inoculation of decapitated tubers (fig.1) was developed (Zoteyeva and Zimnoch-Guzowska, 2004). We used two methods of evaluation: inoculation of tuber slices and decapitated tubers. Cut tuber surface was drop inoculated with *P. infestans* inoculum which comprised 50 sporangia/mm³. Tubers were incubated in the dark at 17° C during 6 –14 days depending on testing method. General score criteria in tuber slice tests was combination of lesion size and mycelia development intensity in grade scale 1 – 9, where 9 is the most resistant.

In decapitated tuber tests the lesion size on a longitudinal surface of cut tubers was scored using grade scale 1 – 9, where grade 9 is the lack of symptoms and grade 1 is a totally diseased surface. The mycelium density was scored using grade scale 0 – 3, where grade 3 is the highest density and grade 0 is a lack of sporulation. The cultivars differed by resistance levels: Meduza, Zarevo and breed. line 94/15 (resistant), Irys, Freika and Sante (susceptible) were used as standards.

Results and discussion

All accessions of *S. pinnatisectum* Dun. tested in 1996 – 2001 possess tubers highly resistant to *P. infestans*. This species occurred to be quit monomorphic for tuber resistance to *P. infestans*. The average of mean score grade within the accessions and within species was narrow (Table 2, 3). The lack of *P. infestans* sporulation on a surface of cut tubers was found in all *S. pinnatisectum* accessions tested. High frequency of genotypes with lack of *P. infestans* sporulation was noted within the accessions of *S. acaule* Bitt., *S. cardiophyllum* Lindl., *S. kurtzianum* Bitt. et Wittm., *S. neoantipoviczii* Buk. and *S. parodii* Juz. et Buk. In the majority of *S. pinnatisectum* accessions and in several ones of *S. acaule*, *S. carpiophyllum*, *S. berthaultii* Hawk., *S. parodii*, and *S. spengazzinii* Bitt. the resistance to *P. infestans* was accompanied by necrotic reaction.

High frequency of tuber resistant to *P. infestans* genotypes was observed within the accessions of *S. cardiophyllum* in tests carried out in both: Poland and Russia (Table 1, 2). In evaluation carried out in Russia in 2001 more than half of *S. spengazzinii* genotypes expressed high tuber resistance to *P. infestans* (Table 2). In two accessions of *S. acaule*, four accessions of *S. papita* Rydb. and four accessions of *S. fendleri* Asa Gray tested in Poland high percent of resistant genotypes was found.

With the exception of *S. pinnatisectum*, intra specific polymorphism for tuber resistance to *P. infestans* was found within the majority of species evaluated: *S. berthaultii*, *S. cardiophyllum*, *S. chacoense* Bitt., *S. kurtzianum*, *S. demissum* Lindl., *S. polytrichon* Rydb., *S. spagazzinii* and *S. stoloniferum* Schlecht. et Bché. (Table 1, 2).

The reaction to inoculation in clones, obtained from individual seedlings in tests carried out in Russia (Table 3) and in Poland (Table 4, fig.2) indicates presence of intra population polymorphism. The difference in disease rating between clones obtained from individual seedlings amounted to 4.6 – 6.1 mean grade within the accession *S. antipovichii* Buk. k- 2354, 3.9 – 6.2 mean grade within the accession *S. brachistotrichum* Rydb. k-23198, 4.6 – 6.6 mean grade within the accession *S. bongasii* Corr. k-8818, 5.3 – 6.8 mean grade within the accession *S. neoantipovichii* k-8505, 4.1 – 6.3 mean grade within the accession *S. sparsipilum* Bitt. k-10706 and to 4.1 – 6.6 mean grade within the accession *S. stoloniferum* k-2534. Within the accessions of *S. polytrichon* this values comprised 4.3 – 6.8 mean grade (k-5347), 1 – 5.2 mean grade (k-23558), and 1.1 – 6.0 mean grade (k-23560) (Table 3, 4).

Besides the resistance to *P. infestans* many potato species possess other valuable traits. Some of species were characterized by: relatively large tuber size, regular shape, discoloration of tuber flash, resistance to sprouting etc. (Zoteyeva, 2001 Zoteyeva, 2005). For example, the accessions of *S. cardiophyllum*, *S. pinnatisectum* and *S. polytrichon* produced regular shape tubers in VIR's experimental field (long day condition) which were characterized by relatively large size (*S. cardiophyllum*, *S. polytrichon*) and high tuber number per plant (*S. pinnatisectum*). In our evaluation tubers of several accessions of *S. cardiophyllum* were found as resistant to Silver Scurf, to Potato Moth and to row tuber flash discoloration (Zoteyeva, 2005). One of the most important reasons to involve wild potatoes in breeding programs is existence of a narrow gene background of potato varieties. The strategy of current breeding programs aims at achievement maximum heterozygosity in selected material (Hermesen 1989, Plaisted and Hoopes 1989).

Regarding the evaluation data obtained, wild potato species are considered to be a promising breeding material. The accessions found out by tuber resistance to *P. infestans* should optimize the strategy for the use of new resistance sources. Evident existence of intra population polymorphism for resistance to *P. infestans* indicates the necessity to identify individual resistant genotypes from wild potato accessions to use in interspecific crosses.

Table 1. Range of tuber resistance to *Phytophthora infestans* in several *Solanum* L. species St.Petersburg-Pushkin, Mlochow: 1996 – 2001.

Species	Number of tested accessions / tubers	Range of score grades (min-max)
South-American species		
<i>S. acaule</i>	2/34	5.1 – 9.0
<i>S. berthaultii</i>	2/71	3.4 – 6.9
<i>S. chacoense</i>	10/150	4.0 – 5.7
<i>S. kurtzianum</i>	5/72	3.4 – 6.8
<i>S. spegazzinii</i>	6/72	4.5 – 7.0
Central-American species		
<i>S. cardiophyllum</i>	14/140	2.3 – 9.0
<i>S. demissum</i>	4/48	4.2 – 6.8
<i>S. fendleri</i>	4/36	5.0 – 7.9
<i>S. papita</i>	4/76	5.8 – 6.8
<i>S. pinnatisectum</i>	6/280	6.5 – 9.0
<i>S. polytrichon</i>	5/225	2.5 – 6.5
<i>S. stoloniferum</i>	7/84	3.4 – 6.4

Table 2. Tuber resistance to *Phytophthora infestans* in wild potato species St. Petersburg-Pushkin, 2001.

<i>Solanum</i> species	№ in VIR catalogue	Nr of tested tubers	Disease rating (mean grades) on 4-7 day after inoculation			
			4 day	5 day	6 day	7 day
<i>cardiophyllum</i>	10457	10	9	7	5.4	4.2
“ “	10456	10	9	7	4.4	2.3
“ “	23280	10	9	9	9	7.2
“ “	19986	10	7	7	6.8	6.3
“ “	21300	10	7	7	7	4.5
“ “	21302	10	9	9	9	7.2
“ “	18085	10	7	7	7	6.2
“ “	18224	10	9	9	7	7
“ “	19061	10	7	6.2	4.4	3.2
“ “	16828	10	9	9	9	9
“ “	18086	10	9	9	7	7
“ “	23279	10	9	7	5.8	4.3
“ “	23278	10	7.2	7	5.2	5
“ “	23276	10	7.1	5.3	5.1	4.2
<i>S. spegazzinii</i>	9746	12	9	9	7	6
“ “	21000	12	9	7	5.4	5.2
“ “	12208	12	9	9	7.2	7
“ “	12500	12	9	9	7	7
“ “	12628	12	9	7	7	4.5
“ “	20999	12	9	9	7	7
<i>S. stenophyllidium</i>	18420	6	9	7	5.2	4.6
“ “	15282	6	9	7	5.5	5.4
“ “	18420	6	7	6.9	4.3	3.6
Controls:						
<i>S. pinnatisectum</i>		21955	10	9	9	7
cv. Sante			10	7	5.1	4.5
					2.3	

Table 3. Tuber resistance to *Phytophthora infestans* of wild potato species clones, obtained from different seedlings (tuber slice test) St.Petersburg-Pushkin, 1996.

<i>Solanum</i> species	№ in VIR catalogue	No of clones	Number of tested tubers	Disease rating (mean grade) on 5 – 7 day after inoculation		
				5 day	6 day	7 day
<i>S. brachistotrichum</i>	23198	1	12	7.2	5.4	3.9
“ “	23198	2	12	7	6.2	6.2
<i>S. pinnatisectum</i>	19158	1	15	9	9	8.8
“ “	19158	2	15	9	9	8.7
“ “	19158	3	15	9	9	9
“ “	21955	1	15	9	9	8.4
“ “	21955	2	15	9	9	8.6
“ “	21955	3	15	9	8	7.9
“ “	23569	1	15	9	9	8.8
“ “	23569	2	15	9	9	8.7
“ “	23569	3	15	9	9	8.6
“ “	23570	1	15	9	9	8.4
“ “	23570	2	15	9	9	8.5
“ “	23570	3	15	9	9	8.6
<i>S. polytrichon</i>	23558	1	10	7	6.7	5
“ “	23558	2	10	7	5.4	5.2
“ “	23558	3	10	5	3.2	1
“ “	23559	1	10	5	3	2.8
“ “	23559	2	10	5	5	2.5
“ “	23560	1	10	5	2.9	1.1
“ “	23560	2	10	7	7	6.0
“ “	23561	1	10	5	4.1	3
“ “	23561	2	10	3	1	1
“ “	23561	3	10	6	5.1	4
Controls:						
Zarevo			6	7	7	7
Freika			6	4.7	3	3

Table 4. Tuber resistance to *Phytophthora infestans* of wild potato species clones obtained from individual seedlings (decapitated tuber test) lochow, 2001.

Species	No in VIR catalogue	No of clone	Nr of tested tubers	Mycelium, mean grade	Lesion, mean grade
<i>S. antipovichii</i>	2354	1	14	1	6.1
<i>S. antipovichii</i>	2354	2	16	1.7	4.6
<i>S. bougasii</i>	8818	1	12	0.7	4.6
<i>S. bougasii</i>	8818	2	12	2.2	6.6
<i>S. neoantipovichii</i>	8505	1	23	0.4	5.3
<i>S. neoantipovichii</i>	8505	2	16	0.2	6.8
<i>S. neoantipovichii</i>	8505	3	16	0	6.8
<i>S. neoantipovichii</i>	8505	4	10	0.4	6.2
<i>S. pinnatisectum</i>	4459	1	10	0	7.2
<i>S. pinnatisectum</i>	4459	2	10	0	7.3
<i>S. pinnatisectum</i>	4459	3	10	0	7.5
<i>S. pinnatisectum</i>	4459	4	13	0	7.0
<i>S. pinnatisectum</i>	9174	1	20	0	6.4
<i>S. pinnatisectum</i>	9174	2	20	0	6.8
<i>S. pinnatisectum</i>	9174	3	15	0	6.9
<i>S. pinnatisectum</i>	9174	4	14	0	6.7
<i>S. polytrichon</i>	5347	1	37	0.9	6.0
<i>S. polytrichon</i>	5347	2	18	1.6	6.8
<i>S. polytrichon</i>	5347	3	12	1.7	6.7
<i>S. polytrichon</i>	5347	4	11	1.9	6.2
<i>S. polytrichon</i>	5347	5	17	1.5	5.5
<i>S. polytrichon</i>	5347	6	7	0.8	5.7
<i>S. polytrichon</i>	5347	7	14	1	5.5
<i>S. polytrichon</i>	5347	8	9	0.8	4.3
<i>S. sparsipilum</i>	10706	1	15	2.1	6.1
<i>S. sparsipilum</i>	10706	2	23	2.6	6.3
<i>S. sparsipilum</i>	10706	3	17	1	4.1
<i>S. stoloniferum</i>	2534	1	9	2.8	6.4
<i>S. stoloniferum</i>	2534	2	7	1.1	6.6
<i>S. stoloniferum</i>	2534	3	14	2.1	6.3
<i>S. stoloniferum</i>	2534	4	8	1.1	5.9
<i>S. stoloniferum</i>	2534	5	10	0.3	4.1
Controls:					
Irys			6		2.3
Meduza			6		5.7
Bred.line 94/15			6		8.8



Figure 1. Testing of decapitated tubers for resistance to *Phytophthora infestans*.

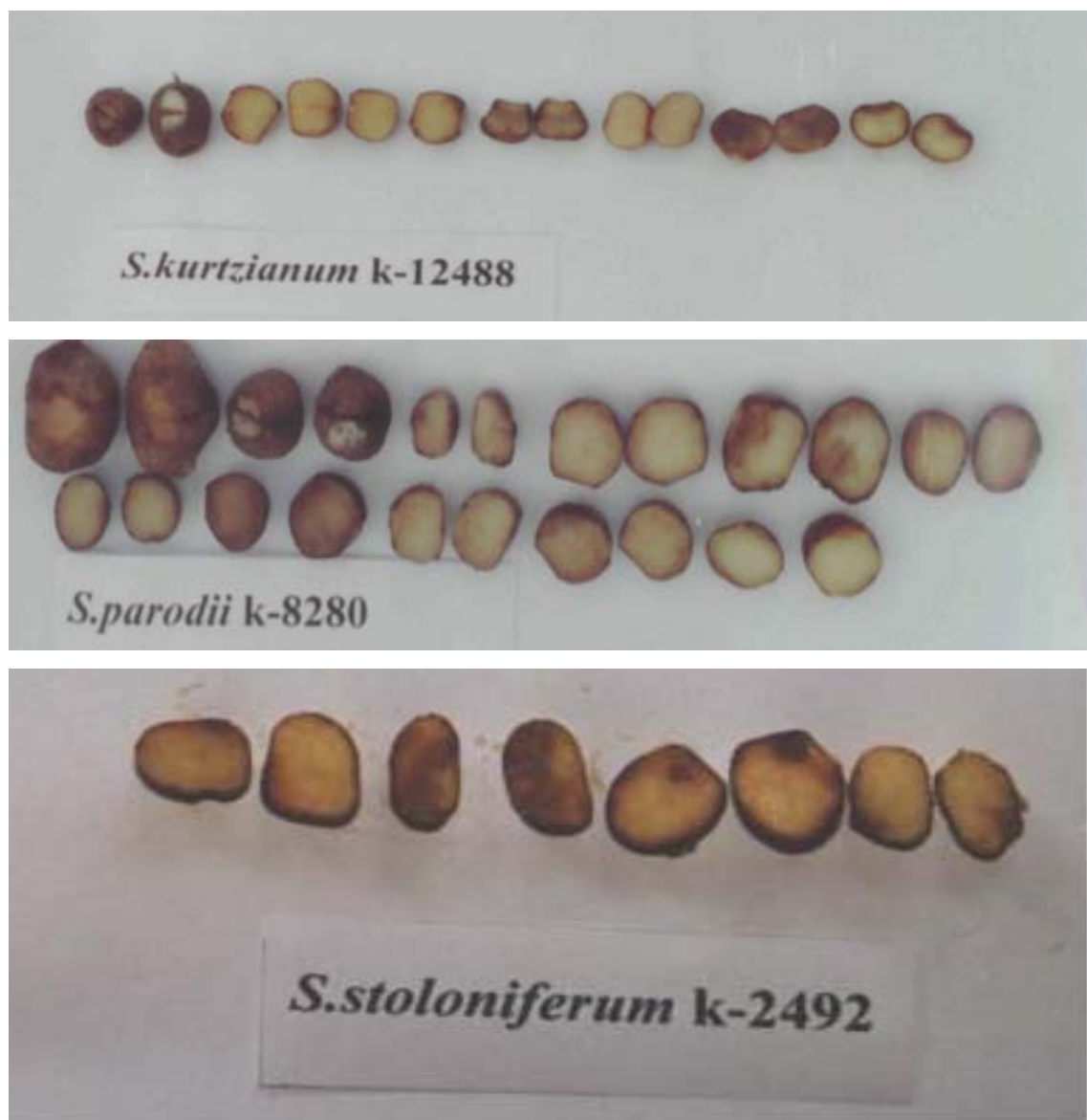


Figure 2. Difference in individual genotype reaction within the accessions of wild potato species to inoculation with *Phytophthora infestans* (two tubers per individual clone).

Literature

- Dorrance, AE and DA Inglis, 1998. Assessment of laboratory methods for evaluating potato tuber for resistance to late blight. Plant Disease. 82:442-446.
- Hermesen JGTh, 1989. Current use of potato collections. In: Brown, A.H. D., O.H. Frankel, D.R. Marshall, and J.T. Williams (eds), The use of plant genetic Resources. Cambridge University press, Melbourn. pp. 68-87.
- Kirk, WW, KJ Felcher, DS Douches, BA Niemira and R Hammerschmidt, 2001. Susceptibility of potato (*Solanum tuberosum* L.) foliage and tubers to the US8 genotype of *Phytophthora infestans*. American Journal of Potato Research, Vol.78, No.4, pp.319-322.
- Plaisted RL and RW Hoopes, 1989. The past record and future prospects for the use of exotic potato germplasm. Am. Potato J. 66:603-627.
- Schwinn FJ and P Margot P, 1991. Control with chemicals // Advances in Plant pathology. / Ed. D.S. Ingram, P.H. Williams. Vol. 7. London: Acad. Press. pp.193-224.
- Stewart H, RL Wastie and JE Bradshaw, 1996. Susceptibility to *Phytophthora infestans* of field – and glass-house-grown potato tubers. Potato Research. 39: 283-288.
- Vedenyapina EG, NM Zoteyeva and MV Patrikeeva, 2002. *Phytophthora infestans* in the Leningrad Region: genes of virulence, mating types and oospore fitness. Micologia i fitopatologia. M., Vol. 36, No 6. pp. 77 – 85 (in Russian).
- Zoteyeva NM, 1986. The sources of resistance to *Phytophthora infestans* (Mont.) de Bary in wild and cultivated potato species. //Ph. D. Thesis, Leningrad. VIR. 16 p. (in Russian).
- Zoteyeva NM, 2001. The characterization of tubers of wild potato species. *Solanaceae* Newsletter. Vol. 4, No3. 2001. pp. 72-73.
- Zoteyeva NM and EM Zimnoch-Guzowska, 2004. New method of evaluation for resistance to *Phytophthora infestans* in potato. Micologia i fitopatologia. M., Vol. 38, No 1. pp. 89 - 93 (in Russian).
- Zoteyeva NM, 2005. *Solanum* L. species of section *Petota* Dumort. as a source of cultivated potato background enrichment. //Dissertation for Dr. of Biology Science. St. Petersburg, VIR. 298 p. (in Russian).

Control of early blight in potatoes in The Netherlands

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Summary

Early blight of potato, caused by *Alternaria solani* and *Alternaria alternata*, can result in premature dying of foliage and yield loss. Early blight is becoming a more serious disease in The Netherlands. An early blight research project was started in 2004 to develop an early blight control strategy which can be implemented in the late blight control strategies.

The emphasis on control of early blight has to be at the end of the growing season. The effect of sprays applied when the crop is flowering is limited.

Keywords: early blight, potato, fungicide strategy, *Alternaria solani*, *Alternaria alternata*

Introduction

Early blight of potato, caused by *Alternaria solani* and *Alternaria alternata*, can result in premature dying of foliage and yield loss. Early blight is becoming a more serious disease in The Netherlands. The decrease of the use of dithiocarbamates and climate change are the most likely contributors to this change.

A good control strategy for early blight in potatoes is missing in The Netherlands. Considering the complexity of the control of late blight in potatoes, it seems sensible to implement the early blight control strategy into the already existing late blight control strategies. The objective was to determine the best time to control early blight in potatoes.

Materials and methods

An experiments (2004 cv Karakter and 2005 cv Agria) were set up in which early blight was controlled in different phases of the growing season (Figure 1).

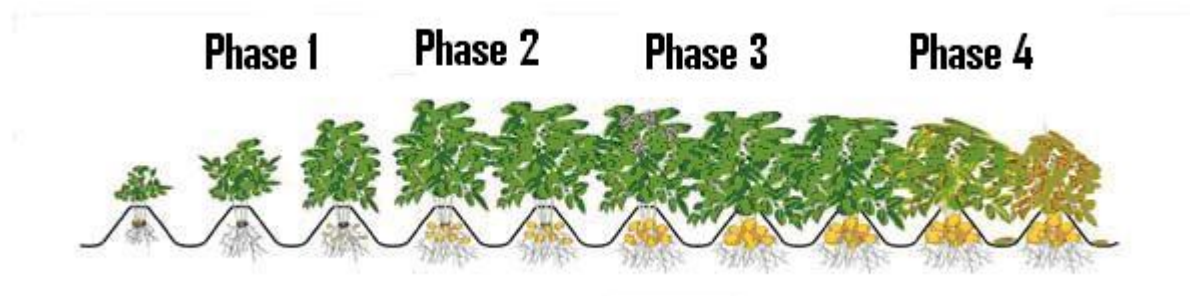


Figure 1. Growing phases of potato during the season in which spray applications were timed.

Curzate M (mancozeb 68%/cymoxanil 4.5%) was used as a representative of the fungicides that control early blight.

Sprays with Curzate M at 2.5 kg ha⁻¹ were carried out weekly to control early blight in each different phase in 2004. Early blight was controlled by spraying Curzate M (2.5 kg ha⁻¹) every 14 days in phase 2, 3 and 4 or 2 and 3 or 2 in 2005. In one treatment early blight was controlled based on a decision support system for early blight (Plant-Plus strategy).

To prevent an infection by late blight during the whole season, Ranman (cyazofamid 500 g/l) at 0.2 l/ ha⁻¹ was sprayed when necessary (Plant-Plus, Dacom). The reference was sprayed with Ranman (0.2 l ha⁻¹) during the whole season. Ranman does not control early blight. The number of spray applications can be found in Table 1.

Disease assessments (Figure 2 and 3) were carried out weekly and did start when infection was found in the reference.

Table 1. Number of sprays (Curzate M) per strategy and year.

Strategy	2004 *)	Strategy	2005 *)
Reference	-	Reference	-
Plant-Plus	14 (1,2,4,7)	Plant-Plus	6 (1,1,4)
Phase 1	3	Phase 2	2 (2,0,0)
Phase 2	3	Phase 2+3	3 (2,1,0)
Phase 3	6	Phase 2+3+4	6 (2,1,3)
Phase 4	7		

*) between brackets number of sprays per phase



Figure 2. Potato leaf infected with *A. solani*.



Figure 3. Potato crop with early blight.

Results and discussion

2004

Disease pressure of early blight was relatively low till the end of August. Infection was visible early September. When Curzate M was sprayed only in phase 1, no control of early blight was observed. When spray applications were carried out later in the season control of early blight increased (Figure 4). The level of control with Plant-Plus was comparable to spray application only in phase 4, in spite additional sprays in previous phases. The number of sprays in the Plant-Plus treatment in phase 4 was equal to the number of sprays in the Phase 4 strategy (Table 1).

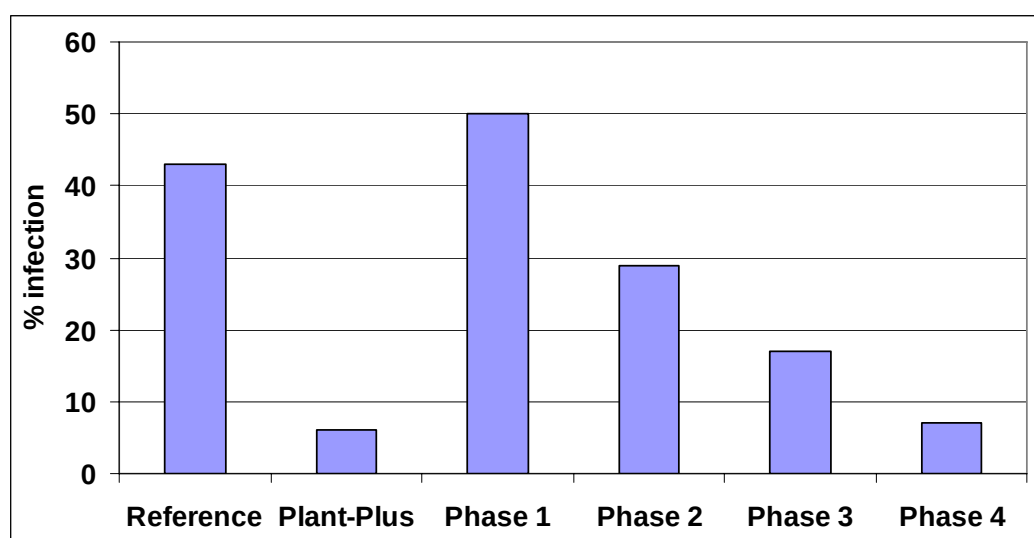


Figure 4. Disease severity of early blight using different control strategies in 2004.

2005

No effect on early blight was found when Curzate M was sprayed (spray-interval 14 days) in phase 2 (Figure 5). Disease control increased when Curzate M was sprayed later in the season (phase 3 and 4). The Plant-Plus treatment resulted in the same level of control as spraying Curzate in phase 2+3+4.

At the end of the season disease severity increased rapidly in the untreated control. The effect on yield was not established. Since the disease was present only late in the season yield loss caused by early blight was probably limited.

Conclusions

Early blight was found late in the season. In uncontrolled plots disease incidence was high leading to premature dying of the foliage. Control of early blight by spraying before tuberization had no effect. Control of early blight was most effective in the second half (after flowering) of the growing season, with emphasis in phase 4. However, when disease pressure is present earlier in the growing season, control in phase 3 could be more important and more useful than shown in these results. In regions where early blight might be a problem a fungicide which both controls early and late blight should be chosen. Alternatively a fungicide which specifically control early blight could be added to a fungicide which control late blight.

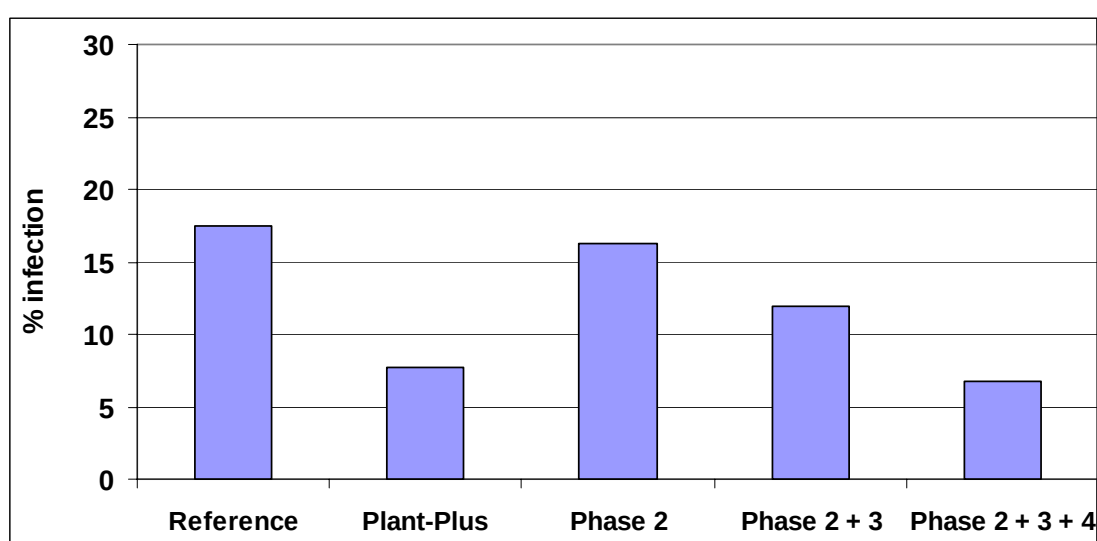


Figure 5. Disease severity of early blight using different control strategies in 2005.

Characterization of late blight isolates from Jersey, UK

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Keywords: *Phytophthora infestans*, potato late blight, Jersey Royal, Channel Islands

The potato variety, International Kidney, also known as 'Jersey Royal' in the UK, was bred by Robert Fenn in Scotland in the 1870s. Jersey Royal is used to produce early eating potatoes on the Island of Jersey, in the English Channel, which are transported to England, where they are highly prized as 'new potatoes'. Jersey Royal is very susceptible to late blight and the risk is intensified on Jersey, where production of potatoes occurs year-round. Information on the current *Phytophthora infestans* population in Jersey is very limited. To investigate this, samples of blighted plant material were collected from infected potato and tomato crops during 2004 and 2005. A total of 44 isolates was obtained, 39 from potato cv. Jersey Royal and five from tomato. These were characterized by mating type, metalaxyl sensitivity, allozyme genotyping, RG57 fingerprinting, mitochondrial DNA (mtDNA) haplotyping and virulence assessment.

With one exception, all isolates from potato had the same multi-locus genotype (A1 mating type, metalaxyl-resistant, *Gpi* 100/100, *Pep* 83/100, mt DNA Ia with a common RG57 fingerprint). The remaining potato isolate was also A1 mating type and metalaxyl-resistant, but was *Gpi* 100/100, *Pep* 100/100, mtDNA IIa with a different RG57 fingerprint. Of the five isolates from tomato, two A1 mating type isolates appeared similar to the majority of the potato isolates, while a third A1 mating type isolate was *Gpi* 100/100, *Pep* 100/100, mtDNA Ia. The other two isolates from tomato were A2 mating type, *Gpi* 100/100, *Pep* 100/100, mtDNA Ia, both had the same RG57 fingerprint which was quite different from those of all other isolates. All five tomato *P. infestans* isolates were metalaxyl-sensitive. The specific virulence patterns of potato and tomato populations of *P. infestans* differed greatly from one another. Isolates were generally highly virulent on their own host differentials, but not on the alternative host differentials. An isolate obtained from infected tomato from Jersey some years ago was found to be A2 mating type (R. Collier, unpublished), but to our knowledge this is the first published report of characterization of isolates of the A2 mating type of *P. infestans* from Jersey. Despite the presence of both mating types on tomato hosts, no evidence of sexual reproduction has yet been found.

Study on the curative and eradicant action of fungicide combinations to control late blight in potato

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Summary

Commercial fungicide combinations were tested in the field for efficacy on foliar late blight caused by *Phytophthora infestans* in substitution of tin. When the first disease symptoms appeared, the tested fungicide treatments for late blight control were applied 3 times at 3-day intervals. The effect of the fungicide treatments on epidemic development, tuber rot and blight incidence and tuber yields were determined. Last summer late blight development was arrested in June due to high temperatures and lasting drought. August was characterized by rather low temperatures and high rainfall. These weather conditions were very favourable for the development of late blight. The foliar protection against *P. infestans* was comparable for all the tested fungicide combinations. The effect of combinations with dimethomorph + mancozeb (AcrobatC, 2.5 kg/ha) was less suppressive for *P. infestans* than the other fungicides tested. Lowest foliar disease severity was recorded in plots treated with fluazinam (Shirlan, 0.4 l/ha) + cymoxanil + chlorothalonil (Mixanil, 2 l/ha). Furthermore, highest tuber yield was noted in plots treated with fluazinam (Shirlan, 0.4 l/ha) + cymoxanil + chlorothalonil (Mixanil, 2 l/ha). The percentage blighted tubers fluctuated between 5 and 11 %. No fungicide combinations completely arrested epidemic development under the environmental conditions of the trial. However, fluazinam (Shirlan, 0.4 l/ha) + cymoxanil + chlorothalonil (Mixanil, 2 l/ha) controlled *P. infestans* most effectively.

Keywords: potato, late blight, *Phytophthora infestans*, fungicide combinations efficacy, curative and eradicator action of fungicides

Introduction

Potato late blight, caused by *P. infestans*, remains one of the most serious constraints to potato production world wide. To control *P. infestans* and to protect the potato crop, potato plants are sprayed preventively with fungicides. Therefore, successful production of healthy potato crops relies on repeated applications of several fungicides during the potato growing season. Due to a restrictive government policy on the use of pesticides, the use of tin based fungicides was prohibited since 2005 in Belgium. These tin based contact fungicides were characterized by a good rainfastness and eradicator activity.

The purpose of this study was to evaluate combinations of fungicides commonly used to control late blight and to investigate the curative and eradicator action of these fungicide combinations for the control of foliar and tuber blight in order to replace tin based fungicides.

Material & Methods

Field trial

A field experiment was carried out on the experimental farm of the 'University College Ghent' at Bottelare during the growing season 2005. Several fungicide combinations (Table 1, table 2) were compared in a spray system based on 3-day intervals to test their curative and eradicator action. Therefore an artificial inoculation was done before the test period was started. The experiment was set up with the variety ' Bintje '. Treatments were carried out with a AKZO sprayer to 3 m wide and 12 m long plots. The spray boom was equipped with TeeJet nozzles (Teejet XR 11003 VK) spaced 50 cm apart. The water volume was always 300 l/ha.

Table 1. Fungicides used in the field trial 2005.

Commercial product	Active matter
Ranman	80 g/ha cyazofamide + 126.9 g/ha heptamethyltrisiloxane
Shirlan	200 g/ha fluazinam
Valbon	28 g/ha benthiavalcarb-isopropyl + 1120 g/ha mancozeb
Acrobat	0.12 kg/ha dimethomorph + 1.07 kg/ha mancozeb
Mixanil	100 g/ha cymoxanil + 750 g/ha chlorothalonil
Tattoo C	0.938 kg/ha propamocarb + 0.938 kg/ha chlorothalonil

Table 2. Fungicide applications.

Treatment	Object 1	Object 2	Object 3	Object 4	Object 5	Object 6	Object 7	Object 8	DSS	Control
1	mancozeb	mancozeb	mancozeb	mancozeb	mancozeb	mancozeb	mancozeb	mancozeb	mancozeb	mancozeb
2	mancozeb	mancozeb	mancozeb	mancozeb	mancozeb	mancozeb	mancozeb	mancozeb	mancozeb	mancozeb
3	Ranman + Valbon	Ranman + Acrobat	Ranman + Mixanil	Ranman + Tattoo C	Shirlan + Valbon	Shirlan + Acrobat	Shirlan + Mixanil	Shirlan + Tattoo C	Tattoo C	untreated
4	Ranman + Valbon	Ranman + Acrobat	Ranman + Mixanil	Ranman + Tattoo C	Shirlan + Valbon	Shirlan + Acrobat	Shirlan + Mixanil	Shirlan + Tattoo C	Acrobat	untreated
5	Ranman + Valbon	Ranman + Acrobat	Ranman + Mixanil	Ranman + Tattoo C	Shirlan + Valbon	Shirlan + Acrobat	Shirlan + Mixanil	Shirlan + Tattoo C	Acrobat	untreated
6	Shirlan	Shirlan	Shirlan	Shirlan	Shirlan	Shirlan	Shirlan	Shirlan	Shirlan	untreated
7	Shirlan	Shirlan	Shirlan	Shirlan	Shirlan	Shirlan	Shirlan	Shirlan	Shirlan	untreated
8	Ranman	Ranman	Ranman	Ranman	Ranman	Ranman	Ranman	Ranman	Ranman	untreated
9	Ranman	Ranman	Ranman	Ranman	Ranman	Ranman	Ranman	Ranman	Ranman	untreated

The experimental design was a fully randomised block design with 4 replicates. The fungicide treatments were randomised within the blocks.

Following crop husbandry measures were taken: planting date of certified seed potatoes: 22 April 2005; row distance: 0.68 m; fertilisation: in autumn 18 ton digested dung, in spring 120 kg/ha N, 100 kg/ha P₂O₅ and 160 kg/ha K₂O and a second fraction of N 148 kg/ha. Herbicide treatment: linuron + pendimethalin + prosulfocarb: 675 g + 800 g + 3.2 kg/ha (Afaon 1.5 l/ha + Stomp 2 l/ha + Defi 4 l/ha); control of chicory volunteer plants: rimsulfuron + isodecyl-alcohol ethoxylaate: 10 g/ha + 90 g/100 ml (Titus 40 g/ha + Trend 100 ml/100 l water).

Inoculum production and foliage inoculation

A mixture of 2 isolates of *P. infestans* was used for artificial infection. Inoculum was produced by the following procedure: sporangia were washed from sporulating lesions on detached leaflets of the susceptible potato cultivar ‘Bintje’ by rinsing the lesions with chilled distilled

water + 0.01 % Tween and adjusted to 10^4 sporangia per ml using a Bürker counting chamber. To release zoospores, the resulting sporangial suspension was chilled for 1.5 h at 6 °C prior to inoculation. Plants of the mid rows (4 plant/row) of each experimental plot were inoculated by spraying ~ 26 sporangia/plant on 28 June in the late afternoon. In total 80 plants were infected with *P. infestans*. Before inoculation and 15 h after inoculation, the plants were sprayed with water to create optimal humidity conditions for infection. Due to high temperatures with daily average temperatures above 20 °C and low humidity the *P. infestans* infection was not successful. The plants were inoculated again on 13 July. Between 13 July and 23 July the mean temperature fluctuated between 15.5 and 20.4 °C and 10 mm of rain was fallen. Those weather conditions favoured the development of *Phytophthora* infections all over the plots.

Fungicides and concentration

The fungicides used in this field experiment were commercial formulations of systemic and protectant fungicides. Eight fungicide combinations were studied and the Flemish decision support system advised to spray the potato crops with 0.938 kg + 0.938 kg/ha propamocarb + chlorothalonil (Tattoo C) and twice with 0.12 kg + 1.07 kg/ha dimethomorph + mancozeb (Acrobat) according to the predominating weather conditions (Table 2). Fungicide applications began 2 weeks after emergence and are summarized in table 2. The first treatments were the same for all objects: all plots were sprayed with mancozeb: 1 kg/ha (Mancomix 3 kg/ha) on a weekly basis to protect foliage from natural infection by *P. infestans*. With the appearance of the first disease symptoms, the plots were 3 times treated with the different fungicide combinations at 3-day intervals (Table 2). After the last application the experimental fields were sprayed twice on a 7-day basis with 200 g/ha fluazinam (Shirlan 0.4 l/ha) and twice with 80 g/ha + 126.9 g/ha cyazofamide + heptamethyltrisiloxaan Ranman A 0.20 l/ha + B 0.15 l/ha).

Diquat 600 g/ha (3 l/ha Reglone, Zeneca) was used to dessicate leaves and stems. During the growing season foliage destructions were also carried out in plots which were infected for 50 % and more to limit the epidemic pressure.

Disease estimates

To measure the intensity of foliage blight caused by *P. infestans* the assessment key of Cox & Large (1960) was used: 0.0 % blight: no disease observed; 0.1 %: a few scattered plants blighted, no more than 1 or 2 spots in 10-m radius; 1 %: up to 10 spots per plant, or general light infection; 5 %: about 50 spots per plant, up to 1 in 10 leaflets infected; 25 %: nearly every leaflet infected, but plants retain normal form, plants may smell of blight, field looks green although every plant is affected; 50 %: every plant affected and about 50 % of leaf area destroyed, field appears green, flecked with brown; 75 %: about 75 % of leaf area destroyed, field appears neither predominantly brown nor green; 95 %: only a few leaves on plants, but stems green; 100 %: all leaves dead, stems dead or dying.

The overall amount of percentage blight was assessed at regular intervals for the middle and outer rows of plot separately.

Data were analysed by performing analysis of variance (SPSS11.0). The One-sample Kolmogorov-Smirnov test was used to analyse the normal distribution of the obtained results. The Duncan test was used to compare treatment means.

Harvest

Tubers were harvested mechanically. Two rows over a distance of 10 m were harvested from the centre of each plot. All tubers were washed, weighed after grading and assessed for blight within 8 days after harvest. Washed tubers were examined visually for the presence or absence of lesions symptomatic of late blight. Furthermore, infected tubers were cut longitudinally to confirm the presence of dry brown corky rot in the tuber beneath the lesion, a symptom typical of late blight tuber infection. The diagnosis of tuber blight was further confirmed by observing sporangia production after incubating tubers with characteristic lesions in plastic containers containing moist paper towels. The amount of blighted tubers was defined as the rotten tubers (but due to the bacterial rot no characteristic blight symptoms could be observed) plus the tubers visually clearly infected by *P. infestans*.

Results & Discussion

The incidence of foliage blight was scored on 1, 8, 12, 23 and 29 August and on 5 September (Fig. 1). The field experiment in 2005 indicated that all the tested fungicide combinations had

a significant suppressive effect on established epidemics compared to untreated plots. The differences in control efficiency for the fungicides tested were rather small and statistically not significant. No treatment was able to stop the infection and even in the sprayed plots the infection level increased above the 50 %. Just for the first treatment with the fungicide combinations the grade of foliar blight was comparable for all the plots: meanly 128 leaf lesions were observed per plot. The first disease symptoms appeared in the middle rows and the development of leaf blight was investigated in the middle and the outer rows. The combinations with dimethomorph + mancozeb (Acrobat) and the combination fluazinam (Shirlan) + benthiavalicarb-isopropyl + mancozeb (Valbon) gave a lower foliage protection. For fluazinam (Shirlan) + cymoxanil + chlorothalonil (Mixanil) the degree of *Phytophthora*-infection was lower in the middle rows than for the other tested combination. And for fluazinam (Shirlan) + cymoxanil + chlorothalonil (Mixanil) late blight developed slower in the outer rows compared to the other treatments.

No significant differences in total yield were observed for the different treatments applied (Table 3). A lower tuber yield was observed for the untreated plots: 50.5 ton/ha. The average tuber yield fluctuated between 54.8 and 61.4 ton/ha and the mean yield of all treatments was 56.1 ton/ha. The combination fluazinam (Shirlan) + cymoxanil + chlorothalonil (Mixanil) had the highest yield: 61.4 ton/ha. The control had a significant lower graded (+35 mm) yield: 41.2 ton/ha (Table 3). A significant higher graded yield was observed for the fungicide combination fluazinam (Shirlan) + cymoxanil + chlorothalonil (Mixanil): 53.1 ton/ha.

Table 3. Influence of the fungicide combinations applied on tuber yield and tuber blight in 'Bintje' during the growing season 2005.

Treatment	total yield ton/ha	yield +35 ton/ha	% diseased tubers
Ranman + Valbon	52,9 ^a	45,3 ^{ab}	8,5 ^a
Ranman + Acrobat	55,5 ^a	47,3 ^{ab}	5,0 ^a
Ranman + Mixanil	55,5 ^a	44,8 ^{ab}	7,3 ^a
Ranman + Tattoo C	59,6 ^a	50,0 ^{ab}	6,5 ^a
Shirlan + Valbon	57,3 ^a	49,1 ^{ab}	5,3 ^a
Shirlan + Acrobat	54,8 ^a	46,6 ^{ab}	7,0 ^a
Shirlan + Mixanil	61,4 ^a	53,1 ^a	7,5 ^a
Shirlan + Tattoo C	57,1 ^a	48,4 ^{ab}	10,8 ^{ab}
Tattoo C - Acrobat - Acrobat	56,6 ^a	47,0 ^{ab}	8,1 ^a
Onbehandeld	50,5 ^a	41,2 ^b	17,0 ^b

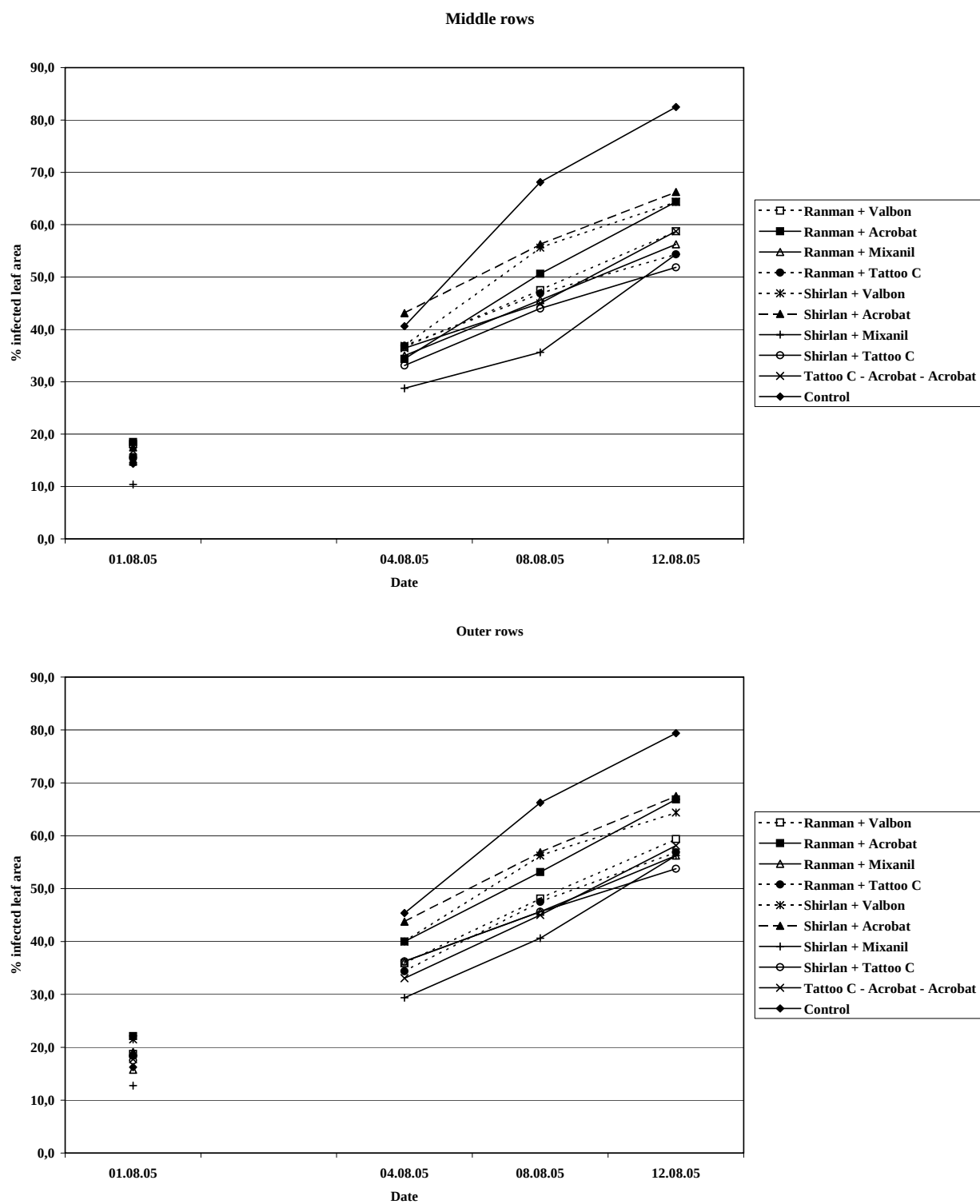


Figure 1. Influence of the fungicide combinations applied on the infection level of late blight of 'Bintje'

The graded yield of the different treatments fluctuated between 53.1 en 44.8 ton/ha en the mean yield of all treatments was 48.1 ton/ha compared to 47.0 ton/ha for the plot sprayed according to the advice of the decision support system (0.938 kg + 0.938 kg/ha propamocarb + chlorothalonil (Tattoo C) and twice with 0.12 kg + 1.07 kg/ha dimethomorph + mancozeb (Acrobat)). The combination fluazinam (Shirlan) + cymoxanil + chlorothalonil (Mixanil) had a good foliage protection as well as the highest yield.

The percent tuber rot was significantly higher for the control and fluazinam (Shirlan) + propamocarb + chlorothalonil (Tattoo C), respectively 17 and 11 % (Table 3). The amount of diseased tubers was significantly lower for the other fungicide treatment tested: the amount of infected tubers fluctuated between 5.0 and 10.8 %. The mean percent tuber blight was 7.2 % compared to 8.1 % for the plots sprayed according to the advice of the decision support system (0.938 kg + 0.938 kg/ha propamocarb + chlorothalonil (Tattoo C) and twice with 0.12 kg + 1.07 kg/ha dimethomorph + mancozeb (Acrobat)).

Conclusions

The growing season 2005 was characterized by high temperatures in the second part of June (daily average temperature above 20 °C) and severall rain showers from the end of June till the first week of July (in ten days 117 mm rain). In Augustus the weather was cloudy, rather cold and a lot of rain: the mean temperature was 16.5 °C and 85.4 mm rain. These weather conditions were very favourable for late blight.

Taking into account all the parameters evaluated (disease incidence, tuber yield, tuber blight) fluazinam (Shirlan) + cymoxanil + chlorothalonil (Mixanil) protected the potato crop slightly better then the other fungicide combinations tested under the environmental conditions of the trial in 2005. But the differences were small and statistically not different.

Acknowledgements

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References

Cox, AE and EC Large, 1960. Potato blight epidemics throughout the world. U.S. Dep. Agric. Agric. Handb. 174 pp.

Observations on tuber infection in relation to Scottish weather parameters

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Summary

The aim of the work in this paper was to determine the combination of weather criteria that increases the risk of tuber infection by *P. infestans* during the growing season. A preliminary model was established to explain tuber infection. It took account of the production of sporangia and zoospores on foliage and the transfer of zoospores into the soil. High-risk periods for tuber infection were first defined in terms of temperature (an optimal air temperature of 11 °C for zoospore production) and relative humidity for sporangia and zoospore production (90% for at least 11 consecutive hours and 2 hours respectively). These periods were refined to take account of the amount and timing of rainfall, i.e. rainfall greater than 13 mm within 12 or 24 hours of zoospore production, to transport zoospores through the soil to the progeny tubers. The preliminary model had six levels of risk for tuber infection.

Keywords: Potato late blight, tuber infection, tuber blight, *Phytophthora infestans*, model and forecasting high-risk periods

Introduction

Potato late blight, caused by *Phytophthora infestans* (Mont.) de Bary, is one of the most devastating pathogens of potato worldwide. The most reliable control against this disease is the use of fungicides but, under pressure to justify crop protection inputs, growers are

encouraged to use forecasting methods to schedule fungicide applications. At the present time in Europe many forecasting methods for blight control do not take account of the tuber phase of the disease but concentrate only on foliar blight. However, tuber blight is an economically important phase of the disease cycle of potato late blight.

The aims of the work in this paper were to investigate the combination of criteria that increases the risk of potato tuber infection by *Phytophthora infestans* during the growing season and also to develop a preliminary model as an aid to explain tuber blight infection.

Materials and methods

A field experiment in each year from 2002 to 2005 examined the effect of foliar blight severity combined with meteorological conditions on tuber blight incidence. King Edward seed tubers were planted in six replicate plots. Infector blocks at each end of the plots were inoculated artificially with sporangia of a mixture of recent UK isolates. The treatment plots were regularly sprayed with mancozeb. Blight in the foliage and on the progeny tubers was assessed weekly starting as soon as there was foliar blight visible in the plots. Met data were provided by the Met Office from an automatic weather station at Auchincruive.

A preliminary model was devised to explain weekly tuber blight incidence. The model had three main components, i.e. sporangia production and zoospore production on the foliage and the transport of zoospores into the ridge. The probability of a tuber being infected was considered a function of the amount of inoculum from the foliar epidemic (I) and the probability of transfer from the foliage to the tuber (T). Factor (I) was evaluated using the optimal conditions for indirect germination of sporangia, i.e. minimum air temperatures of 10-12 °C (Crosier, 1934; Shaw, unpublished) and high relative humidity. Factor (T) was estimated on the basis of the short longevity of zoospores: transfer of a sufficiently large number of viable zoospores will be more likely when rainfall occurs shortly, within 12 hours, after periods of zoospore production, and less after a longer period, within 24 hours. The threshold amount of rainfall chosen was equal or greater than 13 mm (Hirst *et al.*, 1965). There were six levels of risk based on the timing and amount of rainfall and whether air temperature was optimal for zoospore production (Fig. 1).

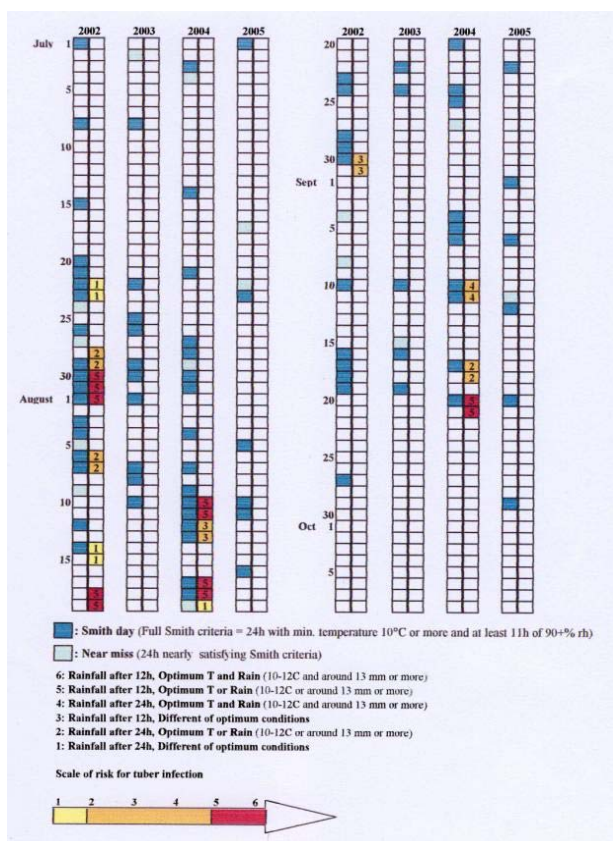


Figure 1. Tuber blight risk in 2002 to 2005.

Results and discussion

The growing seasons of 2003 and 2005 were not favourable for foliar blight development. In addition the criteria for high risk of tuber infection were not met. Consequently the incidences of tuber blight were low (data not presented). In contrast in 2002 and 2004 disease severities in the foliage and the incidences of tuber blight were high (Figs. 2a & b).

The foliar blight progress curves in 2002 and 2004 were very similar and yet the incidence of tuber blight was approximately twice as high in 2002 as 2004. The difference in tuber blight was not accounted for by the number of days on which the

Fig. 2a 2002: tuber blight in relation to foliar blight

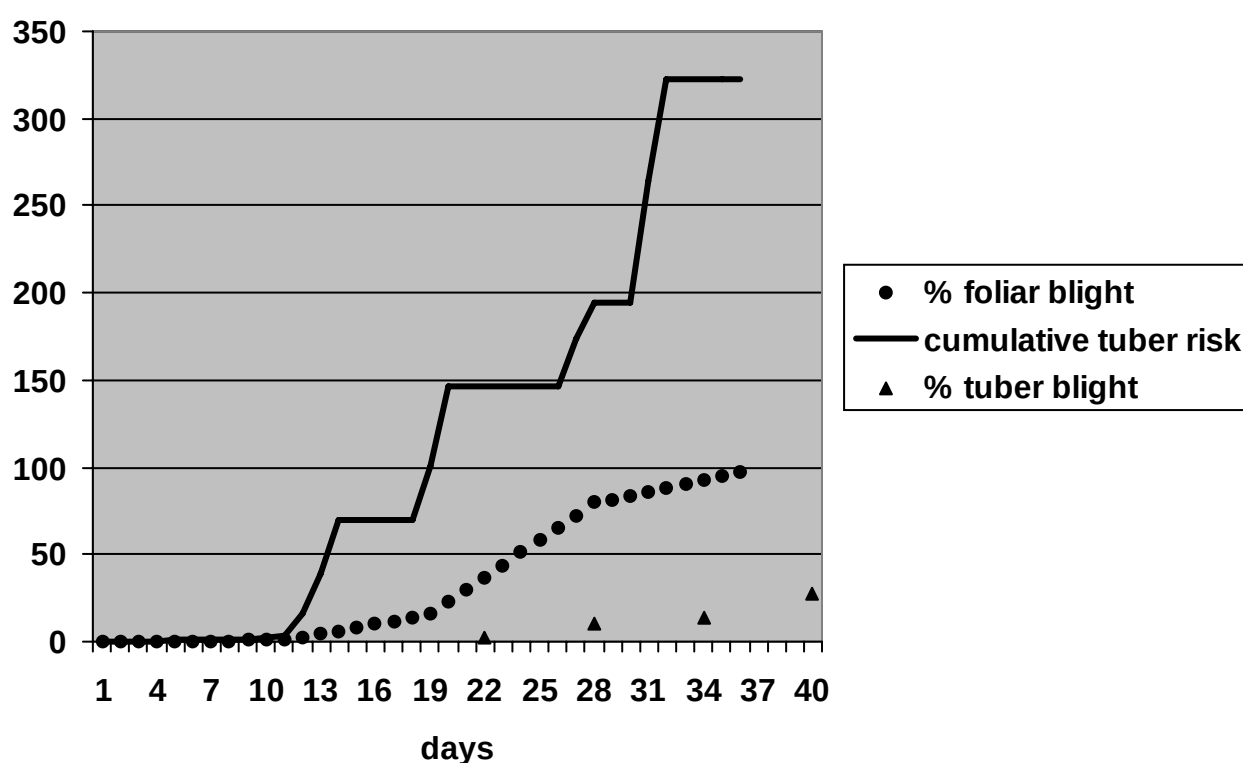
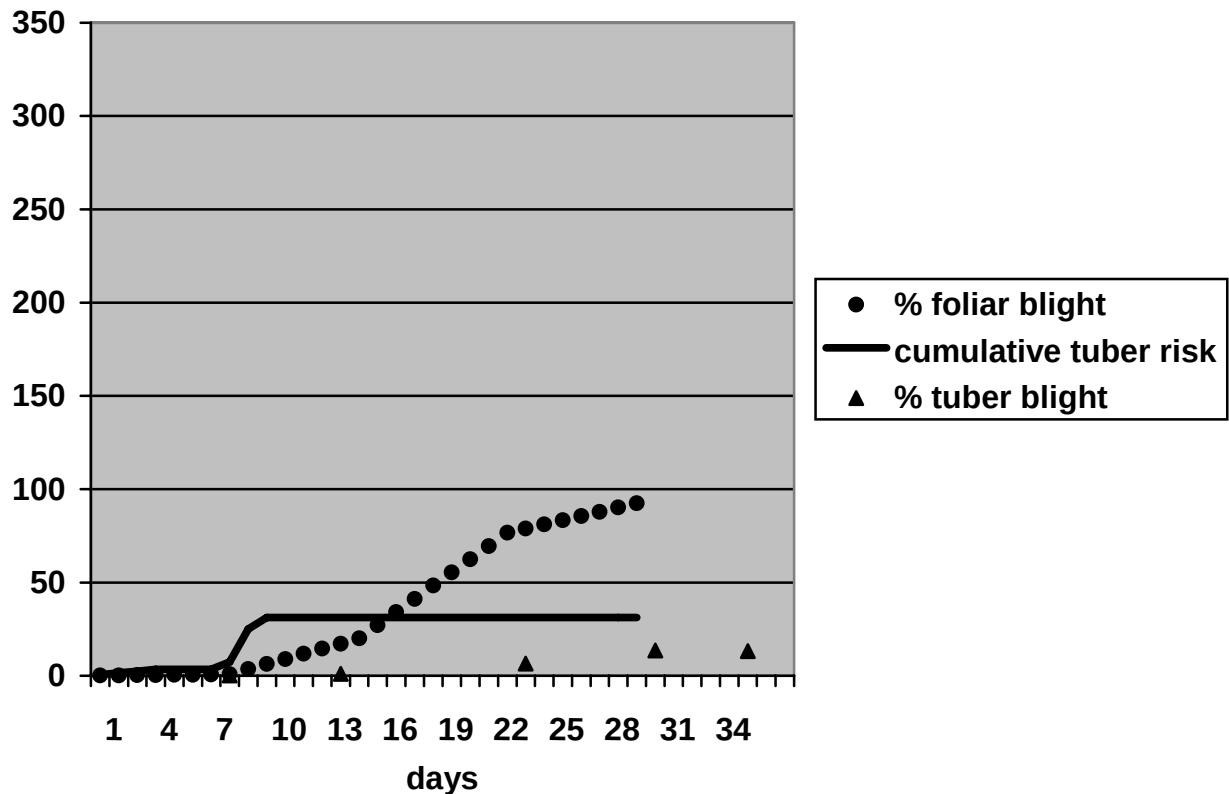


Fig. 2b 2004: tuber blight in relation to foliar blight



Smith criteria were met. For the two years tuber blight was more closely related to the cumulative tuber risk value. This was calculated by multiplying % foliar blight by the level of risk for tuber infection, i.e. 0 to 6 (see Fig. 1). When foliar blight was greater than 50% the value 100 minus % foliar blight was used in the multiplication.

The two experiments were in adjacent fields with very similar soil types.

The increase in incidence of tuber blight during 2004 was not closely related to the cumulative tuber blight risk. There were no tuber risk periods after day 11 and yet the incidence of tuber blight continued to increase for another c. 30 days after the tuber risk had reached its peak. Either the preliminary model needs a major modification or progeny tubers are becoming infected by inoculum not recently transferred from the blighted haulm. Lacey (1962; 1967a) and Lapwood (1962) demonstrated that healthy progeny tubers could become infected by inoculum released from blighted neighbouring tubers. Fairclough *et al.* (1993) also observed such spread and noted that it was much greater at higher soil moisture contents. An

alternative explanation is that tuber infection is initiated when sporangia that have survived in the ridge for many days or weeks initiate tuber infection after indirect germination to produce zoospores.

In 2002 there were multiple tuber risk periods and some of them coincided with foliar blight severities that had the potential to produce a very large number of zoospores. By contrast, in 2004 the main tuber risk period occurred when the severity of foliar blight was very low. There is substantial evidence from other trials (Bain, unpublished) that for King Edward tuber infection can occur when foliar infection is at a very low percentage, i.e. less than 1%. However, tuber infection will be greatest when weather conditions favouring tuber infection coincide with foliar blight severities with the optimum potential to produce very large numbers of zoospores.

This preliminary model should be improved by considering the inclusion of additional factors, e.g. the survival of sporangia and zoospores in the aerial environment and also in the soil. Survival of inoculum in the atmosphere is especially affected by relative humidity, temperature and the presence, or not, of free water. Optimum conditions for zoospore motility are free water and cool temperatures and under these conditions they are able to swim up to 24 hours (Crosier, 1934). Transport of zoospores could be defined better if the type and the moisture content of the soil were known. Murphy (1922) and Lacey (1965, 1967b) reported that zoospores passed more freely through sandy soil than clay and loam soils because of a larger pore size. They also reported that moderate moisture of 20-25% favoured more tuber infection than water-saturated or dry soils. The role of blighted progeny tubers as a source of inoculum for the infection of healthy tubers, and factors determining the extent of this transmission of disease, need to be determined.

The preliminary model should be validated in a much wider set of conditions, particularly soil type and climate. The four experiments were all carried out within a few kilometres of each other using one cultivar.

Acknowledgements

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References

- Crosier, W, (1934). Studies in the biology of *Phytophthora infestans* (Mont.) de Bary. Cornell University Agricultural Experiment Station, Memoir 155, 40 pp.
- Fairclough, R, RA Bain and SJH Holmes, 1993. The effect of soil moisture content on the infection of daughter tubers by *Phytophthora infestans* and subsequent disease transmission. Proceedings Crop Protection in Northern Britain, 1993, 325-330.
- Hirst, JM, OJ Stedman, J Lacey and GA Hide, 1965. The epidemiology of *Phytophthora infestans*. IV. Spraying trails, 1959 to 1963, and the infection of tubers. Annals of Applied Biology 55:373-395.
- Lacey, J, 1962. The activity of *Phytophthora infestans* (Mont.) de Bary in soils. PhD Thesis. University of Reading.
- Lacey, J, 1965. The infectivity of soils containing *Phytophthora infestans*. Annals of Applied Biology 59:363-380.
- Lacey, J, 1967a. The role of water in the spread of *Phytophthora infestans* in the potato crop. Annals of Applied Biology 59:257-264.
- Lacey, J, 1967b. Susceptibility of potato tubers to infection to *Phytophthora infestans*. Annals of Applied Biology 59:245-255.
- Lapwood, DH, 1962. Soil activity of *Phytophthora infestans* and haulm and tuber resistance to blight. In: Rothamsted Experimental Station Report for 1961. Harpenden: Rothamsted Experimental Station, 115-117.
- Murphy, PA, 1922. The bionomics of the conidia of *Phytophthora infestans* (Mont.) de Bary. Scientific Proceedings, Royal Dublin Society 16:442-466.

Potato early blight (*Alternaria ssp.*) in Germany

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Summary

Early blight of potato, caused by the fungi *Alternaria solani* and *Alternaria alternata*, can be found in all German potato growing areas. The disease is a risk to crop productivity in the field and results in significant yield losses. During the last years both pathogens became more and more important in the German potato production areas. An early blight research project at the Technische Universität München conduct a German wide survey accompanied by field trials concerning epidemics and fungicide strategies for the disease control. During the last six years we monitored the early blight epidemic in fungicide treated fields. The disease was found in all potato production areas at the beginning of July. In all years severe attacks were observed mainly in the eastern and southern parts of Germany. Fungicide treatments with mancozeb and azoxystrobin resulted in a delay of the disease progress.

Keywords: *Alternaria solani*, *Alternaria alternata*, early blight, yield reduction, fungicide strategy, chemical control

Symptoms

Two to four weeks after crop emergence the first symptoms can be found in the field. Initial infections are most frequent on older leaflets. Lesions begin as dark brown to black spots,

about 1 mm in diameter. The spots develop in a somewhat irregular shape and usually show concentric rings (“target spot”). Tissue surrounding the spots can turn yellow. When the disease progresses the infected leaflets may turn yellow and either dry up or fall off. In some years stem infections can occur with symptoms similar to those on the leaves.

The fungi *Alternaria solani* and *Alternaria alternata* are able to produce host specific and non-host specific toxins (e.g. alternaric acid, AAL-toxin, tenuazon acid).

Disease development in field trials

The figures 1 to 3 show the development of the early blight disease in an untreated plot in the years 2003 to 2005. At the moment it is not possible to distinguish between necrotic spots caused by *A. solani* or caused by *A. alternata* without PCR-technique. For this reason in field trials early blight is attributed to *Alternaria ssp.*.

In all years three weeks after crop emergence the first symptoms can be found in the field. The next four to eight weeks there is no further development of the disease (1% necrotic leaf area).

In 2003 and 2004 at the end of July, during a period of high temperature, a disease progress of early blight can be observed.

In 2003 the epidemic started at the end of July. Only three weeks later more than 80% of the leaves were destroyed by the fungi *Alternaria ssp.*.

In 2004 the epidemic started at the beginning of August. 20 Days later the crop was completely destroyed by *Alternaria*.

In 2005 the first symptoms were found in the beginning of June. The epidemic started at the end of August. In comparison to the years 2003 and 2004 the start of the epidemic was 3 to 4 weeks later (fig. 3). Like in the two previous years, in 2005 the canopy was fully destroyed by *Alternaria ssp.* within 3 weeks.

Early blight: disease development 2003

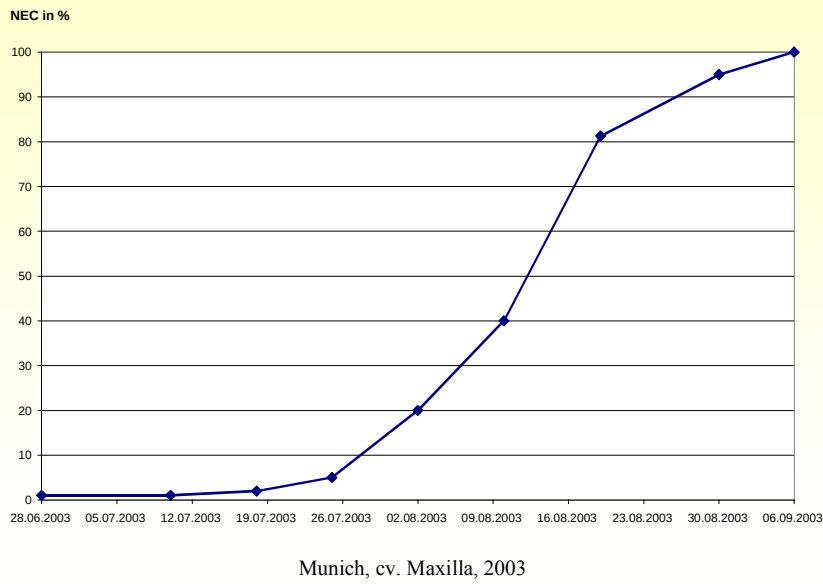


Figure 1. Disease progress of early blight disease in 2003.

Early blight: disease development 2004

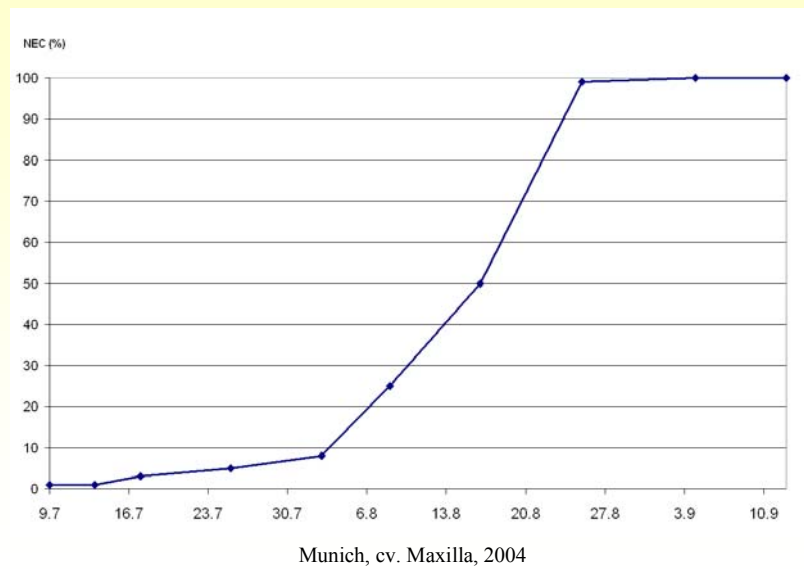


Figure 2. Disease progress of early blight disease in 2004.

Early blight: disease development 2005

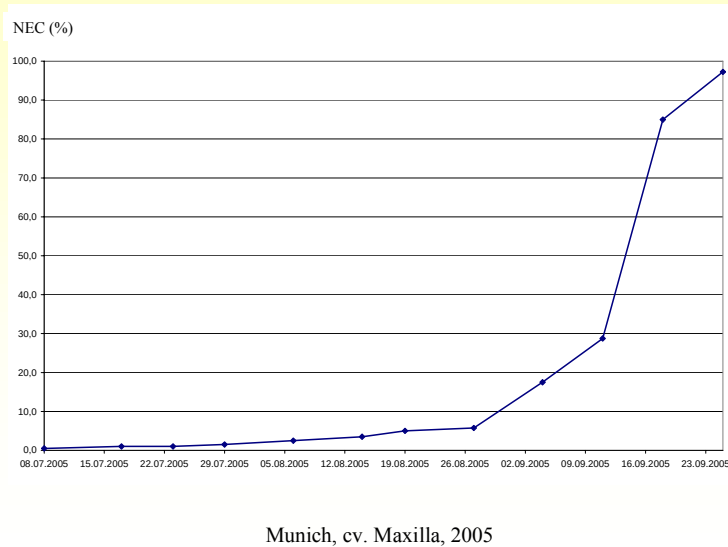


Figure 3. Disease progress of early blight disease in 2005.

Early blight in Germany

During the last six years we observed the early blight epidemic in fungicide treated fields. The disease could be found in all potato production areas at the beginning of July. We detected more early blight one month later. This can be attributed to the higher temperatures in July.

In all years moderate and severe attacks were observed in the eastern and southern part of Germany. Especially in 2004 severe attacks were also registered in the north and western parts of Germany.

In 2005 epidemic of early blight started late (middle/end of August). Therefore we found a moderate disease level predominantly in the starch potato growing areas.

Chemical control

Many factors contribute to the effective control of early blight. The disease is still primarily managed by the use of foliar fungicides. An increased early blight severity in Germany prompted us to study the efficacy of different fungicides with different mode of actions in the field.

To prevent the occurrence of late blight (*Phytophthora infestans*) the complete trial was sprayed with RanMan (a.i.: cyazofamid). This cover spray was carried out weekly.

Figure 4 shows the results of the field trial carried out in 2004. In the middle of August in the cover spray plot 50% of the canopy was destroyed by *Alternaria ssp.*. The disease severity in the treated plots (mancozeb, azoxystrobin) was less than 5%. At the end of August differences between the treatments were visible. Azoxystrobin gave a better control of early blight than mancozeb did at that moment. Fungicide treatments delay significantly the disease progress. In comparison to the mancozeb treated plot the azoxystrobin treatment showed less disease till the end of the season.

The chemical control of early blight resulted in an increased yield. The azoxystrobin treatments increased significantly the starch yield (fig 5).

In our field trials carried out in the last couple of years 10 to 30% yield losses are due to early blight.

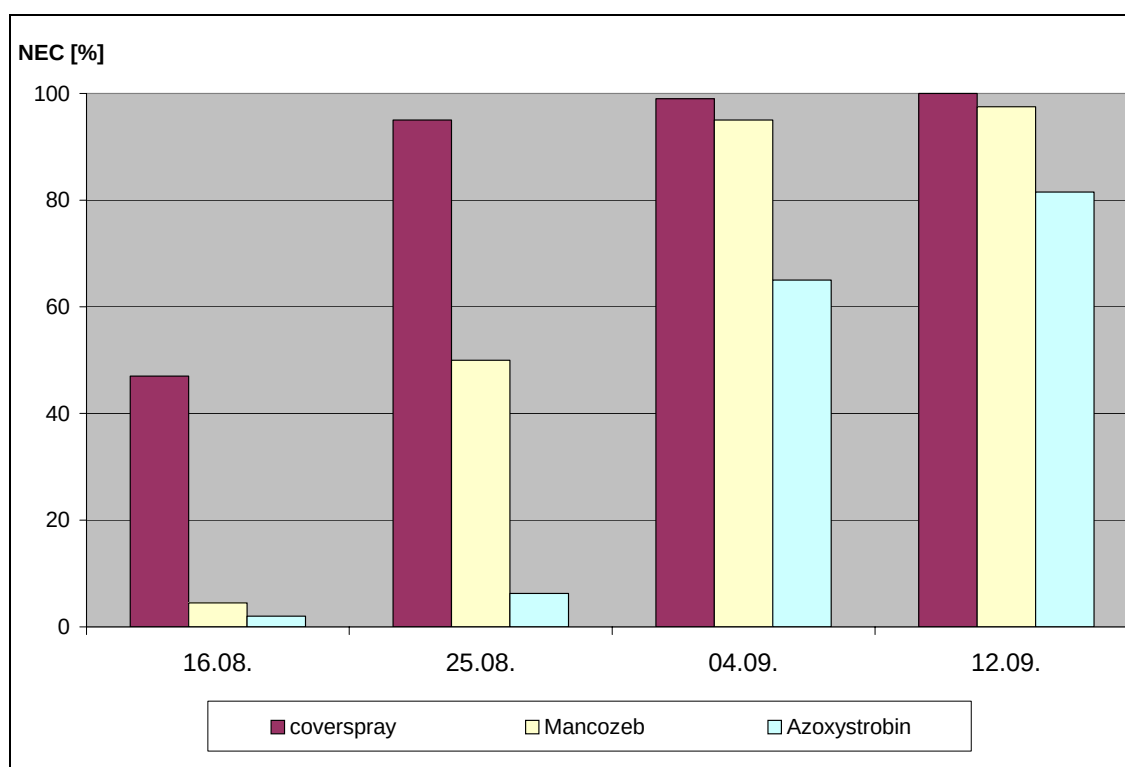


Figure 4. Fungicide treatments delay significantly the disease progress, 2004.

Conclusions

- The results of the field observation over a period of six years show that early blight is an increasing problem in some German potato production regions. We found *Alternaria* in all German growing areas.

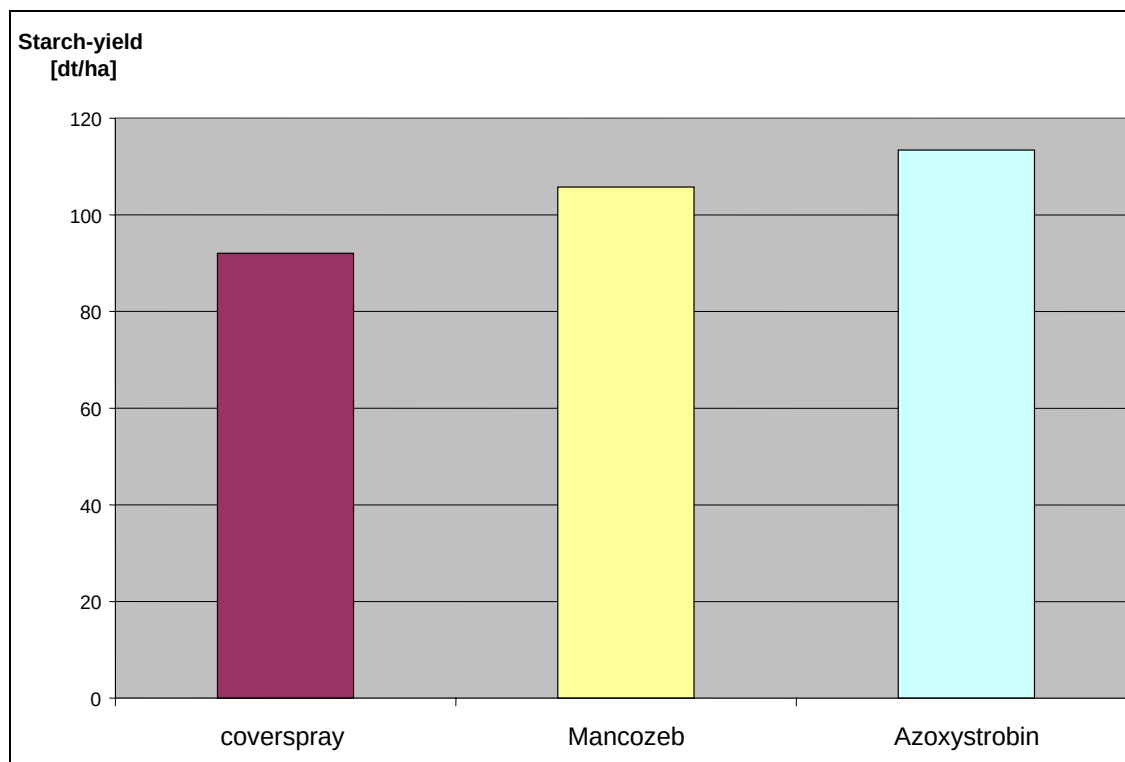


Figure 5. Results of the field trial [Starch yield (dt/ha)], 2004.

- The disease development and the start of the early blight epidemic depend on climatic conditions.
- Fungicide treatment delayed significantly disease progress compared to untreated.
- Chemical control of *Alternaria ssp.* resulted in increased potato yield. The starch yield showed differences between the untreated and the treated plots.
- According to our experience from the past six years 10 to 30% yield losses are due to early blight.

References

- Droby, S, A Dindoor, D Prusky and R Barkai-Golan*, 1984. Pathogenicity of *Alternaria alternata* on potato in Isreal. *Phytopathology* 74: 537-542.
- Rotem, J*, 2004. The genus *Alternaria*. Biology, Epidemiology and Pathogenicity. American Phytopathological Society, St. Paul, MN.
- Shtienberg, D, D Blachinsky, G Ben-Hador and A Dindoor*, 1996. Effects of growing season and fungicide type on the development of *Alternaria solani* and potato yield. *Plant Disease* 80, 994-998.
- Viskonti, A and I Chelkowski*, 1992. *Alternaria*-Biology, plant disease and metabolites. Elsevier Verlag, Amsterdam.

**Registration of products for the control of potato late blight in The
Netherlands:**

How Linge Agroconsultancy can help

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In the Netherlands, potato late blight (*Phytophthora infestans*) is a very important and widespread disease. Not only infestation of the foliage (leaves and stems), resulting in a reduction of the quantitative yield, is of importance but also infestation of the tubers, resulting in a reduction of the qualitative yield. The reasons why late blight is so important in the Netherlands are numerous:

- The area of the Netherlands is relatively small and the crop rotation is quite narrow. As a consequence, the intensity of the growing of potatoes is high which influences the infection pressure of *Phytophthora infestans*.
- The potato varieties used have, in general, a high susceptibility to potato late blight on foliage and tubers. Those varieties are still being used because they possess other, favourable characteristics which make the production of potatoes profitable.
- Weather conditions favourable for *Phytophthora infestans* – sultry and moist – are frequently present in the Netherlands.
- The major part of the potatoes are grown on loam and clay soils. Those soils are very fertile. A lot of leaves and stems are formed resulting in a heavy crop which is infested easily.

As a consequence of all this, the requirements for products which control late blight are very high in the Netherlands. Those requirements are for the most part higher in the Netherlands than in other countries. In addition, a specific control strategy is often needed.

When a company wants to apply for a registration for potato late blight control in the Netherlands, it is necessary that the research trials are largely or entirely carried out in the Netherlands. Often, specific experimental designs are needed to assess the efficacy of a product in an optimal way under Dutch circumstances. This is for instance the case when a product acts in a specific way *e.g.* control of tuber blight. Professional guidance and advice by Linge Agroconsultancy can be of service prior to and during the registration process.

Linge Agroconsultancy is an independent consulting company specialised in supporting the registration of both chemical and biological crop protection products.

We provide advices in how to conduct efficacy research in the most optimal way. By putting an optimal use of extrapolation possibilities, we see to that the product can be claimed as broad as possible.

Linge Agroconsultancy checks the biological dossier for completeness according to the current guidelines. Research data of the biological dossier (*e.g.* effectiveness and crop safety) are summarised and evaluated according to the official guidelines. This also involves the evaluation of a draft product label.

Crop protection products need to be safe for the consumer and the operator and ecologically sound. The GAP-table is the basis for the calculations which are made during the toxicological assessment of the dossier. Linge Agroconsultancy prepares this GAP-table according to the current requirements.

We incorporate research reports in the required European format. A thorough Biological Assessment Dossier is essential for submission in the EU and the various member states.

Linge Agroconsultancy conducts literature studies concerning issues related to crop protection and crop production. We also help with the writing of project proposals and project descriptions.