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Applied Plant Research
AGV Research Unit

Address	:	Edelhertweg 1, 8219 PH Lelystad, The Netherlands
	:	P.O. Box 430, 8200 AK Lelystad, The Netherlands
Tel.	:	+31 320 29 11 11
Fax	:	+31 320 23 04 79
E-mail	:	info.ppo@wur.nl
Internet	:	www.ppo.dlo.nl

Preface

Integrated control of potato late 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 and 2002 the fifth, sixth and seventh Workshop were organised in Munich (Germany), Edinburgh (Scotland) and Poznan (Poland). The Proceedings of these Workshops are published in PPO-Special Reports (7, 8 and 9). The Proceedings are now also available on the internet www.lateblight.nl .

The Ministry of Agriculture and Fisheries of the States of Jersey together with Germicopa and the Regional Plant Protection Service in St. Malo organised the eighth Workshop in Jersey (Channel Islands) from 31 March to 4 April 2004.

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

The Workshop was attended by 69 persons from 14 European countries and the United States of America. Representatives from all countries presented the late blight epidemic in 2003 and recent research results regarding integrated control and decision support systems of late blight in potatoes. Since early blight seems to be an increasing problem in Europe, it was decided to include reports on this disease in the Workshop also. The papers and posters presented at the Workshop and discussions in the subgroups are published in these Proceedings, PPO-Special Report no. 10.

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

Secretariat:

PPO-AGV Lelystad
Att. H. Schepers
PO Box 430
NL-8200 AK Lelystad
The Netherlands

Telephone: + 31 320 291111
Telefax: + 31 320 230479
E-mail: huub.schepers@wur.nl
Internet: www.ppo.dlo.nl

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The development and control of *Phytophthora infestans* in Europe in 2003

H.T.A.M. SCHEPERS

Applied Plant Research, P.O. Box 430, 8200 AK Lelystad, The Netherlands

Introduction

From 31 March-4 April 2004 a Workshop was held in St Helier, Jersey (Channel Islands) on control of *Phytophthora infestans*. Representatives from 16 European countries presented the development and control of late blight in their country in 2003. In this paper these presentations are summarised. The weather conditions of 2003, 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 in **Italy**, a dry and warm growing season was very unfavourable for late blight in potatoes. Just a few late blight lesions (without sporulation) were observed in an organic potato crop that did not lead to further epidemics. Just one MISP event has been recorded in the first week of May. After that no MISP event was registered throughout the growing season.

During the potato growing season very special weather conditions prevailed in **Switzerland**. At many places potatoes were planted early. April was very dry and favourable weather conditions for late blight (MISP) were not registered until May (especially at the end of the month). First late blight was observed on 27 May in an early potato field, previously covered with plastic. The epidemic spread in the beginning of June, particularly in the central part of Switzerland. Due to the very hot and dry weather in the second part of June with daily average temperatures above 33°C, the development of the disease was almost stopped in most of the potato growing areas. Even when MISPs were registered again in July, the late blight epidemic did increase anymore. The total number of registered late blight incidences in the DSS PhytoPRE was much smaller (49) than in 2002 (184).

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In **Germany**, an extensive network of governmental crop protection services monitored fields for the occurrence of late blight. The first blight was detected in a plastic covered crop on 8 May. 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. The infection pressure calculated by the DSS SIMPHYT3 was (very) low for most of the country, only in some coastal regions in the north and some isolated regions in Bavaria and Rhineland-Palatinate reached a higher level of infection pressure in July-August.

From 20 May onwards a lot of late blight was found on dumps in **France**. The third generation threshold was reached between 17-24 May. Violent rain storms in some areas created difficult situations for the protection of crops (rainfastness, new growth). It was not possible to reduce the number of sprays on susceptible varieties. In June most of the dumps were covered with black plastic and this inoculum source became less important. In some fields some isolated plants were completely destroyed by blight (oospores, infected seed?). The disease pressure in maritime Flanders was low, in Artois, Picardy and Champagne the weather situation was stable and crops could be protected effectively. In northern France strong rain showers occurred in July, however blight did not appear in the fields. Later in July and August temperature increased (>30°C) and blight was only observed on some dumps and edges of fields without protection. Until 31 August, MILSOL recorded 14 generations of late blight. Tuber blight was not observed.

In Wallonia (**Belgium**) the season was very early. Despite winter frost, volunteers did appear. Because of the very good harvesting conditions in 2002 a low number of seed tubers was (visibly) infected with blight. Long periods of hot and dry weather made conditions very unfavourable for blight. In Flanders (**Belgium**) potato were planted early (< 25 April) while weather conditions were very unfavourable for blight. The first blight was detected plastic covered crop on 5 May, no other infected fields were observed until 30 May. In June there was little rainfall and record temperatures followed by a tropical July and August. Crops senesced early, from half of July onwards.

In **The Netherlands**, approximately 10,000 growers grew 158.700 ha of potatoes. Weather was dry from 20 February to 10 April. Planting was very early (end of March). The first late blight was observed early May, in commercial fields 15 May. In the second half of May the disease pressure was high caused by oospores (from sandy soils in the Northeast) and infected seed potatoes. The summer broke all records; it was very warm and dry resulting in a low disease pressure in June-August (except first week of July).

In **Ireland** approximately 800 growers grew 13,000 ha of potatoes. The main varieties are Rooster (30%), Kerrs Pink (25%) and B. Queen (10%). The disease appeared very early in May compared to June-July in other years. The disease spread rapidly in June-July but slowed down in July-August. The accumulated risk value (ARV) for 2003 was higher compared to the ARV of 2001 and 2002. The control of foliage blight was excellent; the grower's satisfaction was high.

On **Jersey** blight was first observed in glasshouse grown crops as early as 22 January. In outdoor crops blight was reported 22 April. The number of outbreaks recorded in 2003 (52) was considerably lower than in the years 1997-2002 (number of outbreaks ranged from 287-667).

In **England, Scotland & Wales** the 2003 season was a low blight year. Samples of suspected late blight outbreaks were analysed during the growing season. The first confirmed outbreak came from Lincolnshire on 23 May. The first confirmed case in Scotland was on 4 June. The breakdown of the positive samples at the end of the growing season was as follows: 67 from conventional crops, 18 from dumps, 7 from volunteers, 7 from organic crops and 2 from allotments and gardens.

In **Northern Ireland** the first recorded outbreak of blight in a field was on 5 June. The first infection (Smith Period) was recorded from 26-29 May, with 2 further periods occurring in June, 5 in July and 2 in August. Mid May onwards was wet, June and July were slightly drier but cloudy humid weather did occur; August and September were dry months. The infection pressure was high during June, moderate during July and low in August. A total of 44 field outbreaks from all potato growing areas had been recorded by mid-August.

In **Poland**, the first blight was observed in a plastic covered crop on 23 May in the province Lódzkie. The first blight in a field was seen on 11 June in the province Dolnoslaskie. In Bonin, June and August were relatively dry, with only 38 and 49 mm rain recorded, compared to an average of 104 and 92, respectively. The unfavourable weather for blight was reflected in the low disease incidence in trials in the cultivars Irga, Ibis and Bryza that was lower compared to 1998-2002.

In **Latvia**, blight was first observed in susceptible varieties on 27 June, whereas in resistant varieties the first outbreaks were recorded on 18 July. More rain was recorded and less sunshine compared to 2002. On average 10% of the fields were infected by blight with foci of 1-5 m^2.

In **Estonia**, 15,000 ha of potatoes are grown which is 30% lower than in 2001. The first blight was recorded on 8 July in the south-eastern part of Estonia. In that region higher rainfall was recorded in June, July and August compared to other regions. Blight spread into the north-western part where it was observed from 4 August onwards. The accumulated risk values according to NegFry in Jõgeva reached a level of 100 in the beginning of July and during the rest of the season showed a level that was comparable to 2001 and higher than 1999, 2000 and 2002.

In **Denmark** crops emerged from 15-20 May. NegFry send out a regional warning for risk of primary attacks on 8 June. Two primary attacks were recorded from 3-6 June, there were indications that the infections originated from oospores. Five primary attacks were recorded from 11-13 June (also indications of oospores). From 16-20 June 17 primary attacks were recorded. The risk for infections was low during the whole growing season, especially in August.

In **Norway** the most favourable blight weather was in June and July, later in the season it was less favourable. In two important growing areas, the days with a late blight forecast based on Førsund rules ranged from 6-7 in 2003 whereas in 2001 and 2002 the number of critical days was 1-3 and 4, respectively. More infected fields were recorded than normal, but at low levels. Compared to other years, the time the first outbreaks were recorded in plastic covered crops was normal. In the main crop, outbreaks were in some areas, recorded 2 weeks earlier than normal. Also blight was observed in the northern part of Norway.

In **Sweden** the first attacks were recorded mid May in the early potato district in the Southwest. In ware and processing potatoes, blight was first found in mid June in the south. In this area the weather was very favourable for blight most of the season and in some periods the normal spraying intervals of 7 days were too long. The situation was similar in Midwest Sweden, but in eastern Sweden the blight could be controlled without any "extraordinary" measures.

In **Finland** 2003 was not a severe blight year. The first outbreaks were recorded in the South of Finland on 13 June and in the North on 15 July. Due to heavy rains some fields were not always fully protected against blight. In some sprayed fields some blight lesions occurred. The end of the season was very dry.

Fungicide input

In the Po valley in **Italy**, 4-5 sprays were applied on potato and 6-8 on tomato to control late blight. It is interesting to note that besides a number of widely used fungicides, also dodine, copper and iprovalicarb are registered for control of late blight.

In **Switzerland** 5 fungicide treatments were carried out (mean value of 125 PhytoPRE participants). On average they used 2 sprays with a contact fungicide and 2-3 sprays with a translaminar fungicide. Systemic fungicides are rarely recommended; therefore hardly any sprays with a systemic fungicide are recorded (0.37).

In **Germany**, the number of treatments varied from 2-3 in regions with a low infection pressure to 8-11 in regions with a high pressure (Rheinland).

In **France**, the DSS MILPV recommended 8 sprays on susceptible cvs (e.g. Bintje), 5 on intermediately resistant cvs (eg. Samba, Saturna) and 4 on resistant cvs (Bondeville, Santana). On average growers applied 10-14 sprays.

In Wallonia (**Belgium**) 11-13 sprays were applied. Mancozeb and maneb are generally used. The organotin products were registered for the last year. These applications (after flowering) are replaced by fluazinam. Recently introduced products are Ranman (cyazofamid, Unikat Pro (zoxium, mancozeb), Tanos (famoxate, cymoxanil) and Epok (fluazinam, metalaxyl-M).

In Flanders (**Belgium**) the average number of sprays was 11.2 with an average interval of 10.3 days.

In **The Netherlands**, the average number of sprays applied was 12-13 with an average interval of 8-9 days. Shirlan (80-85%), cymoxanil-containing products (10-15%), Tattoo C (<5%) and Ranman (<5%) were the most important fungicides used. Compared to other years, 2-3 sprays less were applied.

In **Ireland**, control of blight was good using the following products (mentioned in decreasing % of use): mancozeb, fluazinam, phenylamide and cymoxamil.

The recorded fungicide applications for blight control in **Jersey** included 19 different products of which Curzate, Shirlan, Electis and Ripost were most frequently used.

In the **UK** the majority of blight treatment numbers ranged from 8-12 sprays. The most frequently used products were cymoxanil, fluazinam, mancozeb and systemics.

In **Northern Ireland** the number fungicide applications ranged from 4-12, the maximum number being lower than previous years due to drier weather during August/September. Early season fungicides, especially in seed potatoes, included Merlin (Tattoo C) and phenylamide-based products (Fubol Gold), others chose Shirlan or mancozeb when plants were just emerging. Mid season products include Invader, Curzate and Shirlan. End of season products were either Shirlan or tin-based.

In **Poland**, the estimated number of fungicide sprays ranged from 1-6. Chlorothalonil and fluazinam were the most frequently used contact fungicides. The translaminar products that were most used were cymoxanil and dimethomorph. Propamocarb and metalaxyl-M were the most important systemic fungicides.

In **Latvia**, the growers spray on average 1-2 times to control blight, whereas the NegFry model recommends 2-3 sprays. The most frequently used strategy consists of 2 sprays with a systemic fungicide (Tattoo, Ridomil) followed by 2 sprays with a contact fungicide (Dithane, Shirlan).

In **Estonia**, the use of fungicides was higher than in 1999-2002. The most important fungicides are mancozeb, Shirlan, Acrobat, Ridomil Gold and Tattoo. On average, farmers spray 2-3 times to control blight whereas advanced farmers spray 4-6 times and trials fields were sprayed 6-8 times.

In **Denmark** seed potatoes were sprayed 4-5 times, ware potatoes 6-7 times and starch potatoes 7-10 times. In average late blight was controlled with 7 sprays. The fungicides used were Dithane, Shirlan, Tattoo, Acrobat and Ranman.

In **Norway** the number of sprays used to control blight ranged from 5-10 in the most important potato growing areas with an average of 6-7 sprays. The fungicides used were mainly Shirlan and Tattoo.

In the south of **Sweden** there was a tendency to time the first spray earlier compared to other years. In some regions it was very difficult to keep the crop free from blight, which resulted in an increase of the number of sprays. The number of sprays used to control blight in the South was 8-10, in Mid Sweden 6-8, and in the North 2-4. The standard fungicide used is Shirlan. Epok is mainly recommended for the second and/or third/fourth spray but is also used eradicantly. The use of Tattoo is increasing.

In **Finland** Shirlan is the most widely used product followed by mancozeb products. Tattoo C and Acrobat are usually used 1-2 times in the beginning of the spray programme. Epok was not imported to Finland in 2003; old stocks when available were sprayed as the first treatment in some fields. The estimated number of treatments was 3-7 depending on the region, weather and type of production.

Tuber blight

No tuber blight was recorded in the Po valley (**Italy**), **Switzerland**, **France, Sweden** and **Finland**.

In **Belgium** (Wallonia, Flanders) heavy rains in August caused more problems with tuber blight than expected. However, storage problems were not recorded. Hardly any tuber infections were reported in **The Netherlands, Ireland**. In a tuber blight trial in **Jersey** the programme that contained Trustan (2x), Curzate, Dithane, Curzate and Supertin resulted in 3.6% infected tubers 2 weeks after harvest compared to 21.2% in the untreated. In **Northern Ireland** very few cases of tuber blight were found. Only 3 seed stocks out of 75 examined, showed a low level of tuber blight.

In **Poland** the average loss of tuber yield in 1999-2003 caused by late blight is estimated to range from 22.6-54.2%. In **Latvia**, the amount of tuber blight that was observed at harvest was <0.2%. In **Denmark**, tuber blight was recorded in Saturna.

In **Norway** tuber blight was observed in several crops (more than normal) but at low levels.

Organic crops

In Wallonia (**Belgium**) only a small area of organic potatoes are grown (100 ha). Some blight was observed in these crops, but because of the hot and dry conditions during the summer no epidemic developed. Some fields with susceptible cvs (Bintje, Charlotte) did show blight from the beginning of June onwards. On average 4 sprays with copper are applied.

In **The Netherlands** less than 1000 ha potatoes are grown organically. Because of the low disease pressure it was a very good year for organic potato crops.

In **Northern Ireland** 50-60 ha potatoes are grown organically, the main cultivar grown was Santé with growers using copper-based products for protection. Dry weather during August and September gave excellent conditions that led to very few problems with foliage or tuber blight.

In **Latvia**, 50% of the organic fields were infected with late blight.

In **Denmark**, the epidemic developed early-mid July in organic crops. The expected yields are medium to high.

Despite the dry and very hot weather blight was a problem in organic crops in **Sweden**. As far north as Dalarna some organic crops were completely killed by blight in July. Many organic crops are left standing with late blight for long periods.

In **Finland** organic crops were severely attacked at the end of July beginning of August. Especially when crops were very dense due to excess of nitrogen in green manure, the crops were destroyed before tuber formation. Heavy attacks were also recorded in fields where potatoes are grown in two consecutive years.

Alternaria

In the Po valley in **Italy**, Alternaria is a problem on tomato for industrial processing. The disease is favoured by a warm and humid climate. Early cultivars are more affected by the disease than later cvs. Copper, azoxystrobin, famoxadone and difenoconazole are recommended for control of Alternaria.

In **The Netherlands**, Alternaria is becoming a more important disease in potatoes. The dry and warm weather in 2003 favoured the development of Alternaria.

In **Poland**, the first outbreak of early blight was recorded on 27 May. In 2003, 85% of the fields were affected with early blight. On average early blight appeared 64 days after planting. The average loss of tuber yield in 1999-2003 caused by early blight is estimated to range from 22.9-26.9%.

In **Latvia**, 100% of the potato fields were infected with Alternaria.

In **Estonia**, Alternaria is an important disease only in specific cultivars and under specific conditions (soil, climate). Mancozeb provides good control.

In **Norway** the symptoms that are normally ascribed to early blight are normally not caused by pathogens but are mainly caused by stress. The problem will be further investigated.

In **Sweden** some problems were recorded in starch potatoes in the Southeast.

In **Finland,** Alternaria is commonly observed late in the growing season. Up till now only small effects on yield are observed. The problem will be monitored in the coming years.

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Table 1. The estimated use[1] of fungicides to control *P. infestans* on potato in 1997-2003.

	Average number sprays/season						
	1997	1998	1999	2000	2001	2002	2003
Austria	5-6	4-6	4-12	4	4-7	3-12	
Belgium							
* Flanders	14	13	14	16	15	14	11
* Wallonia	10-11	10	11-15	13-16	11-13	12-16	
Denmark	5.5	8	7.5	7-8	8-9	8-9	7
Estonia					3-5	3-5	2-6
Finland	4-5	3-8	2-6	5-9	4-8	4-8	3-7
France							
*Nord-Pas-de-Calais	11-14	?	15	16-17	10-19	12-13	10-14
Germany	7-9	3-10	4-5	2-14	2-16	3-14	3-11
Italy	6-8	4-5	8-10	6-8	4-7	5-8	4-5
Latvia	?	?	?	2	4	2	1-2
Netherlands	7-15	7-15	7-16	15-20	10-18	8-16	12-13
Norway	4	5	5-6	6-7	5.5	6-8	6-7
Poland	1.7	1.7	2	2	1-8	1-5	1-6
Spain (Basque Country)	5-6	3	4-5	2-6	2-3	3-4	
Sweden	4-7	4-12	4-11	?	?	2-8	2-10
Switzerland	7-9	5-7	6-10	7	6.3	5-6	5
United Kingdom							
*Northern Ireland	3-15	4-16	4-14	3-12	3-14	3-14	4-12
*England,Wales,Scotland	7,4	8,9	8,2	8,0	8-12	8-14	9.9[2]
*Jersey	4-5	4-5	4-5	4-5	3-5		

[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 2003 in relation to other years.

	May	June	July	Aug.	Sept.	First outbreak				
						2003	2002	2001	2000	1999
Austria							18 May[1]	19 June	14 July	8 May
Belgium										
* Flanders	*	**	*	**	*	5 May[1]	29 April[2]	2 May[2]	30 April[2]	29 April[1,2]
* Wallonia	**	***	*	*	**	16 May[1,2,3]	2 May	15 May	15 May	15 May
Denmark		**	**	*	*	3 June[4]	10 June[4]	18 June[4]	20 June	18 June
Estonia		**	**	***	*	8 July	3 July	20 June		
Finland	*	**	**	*	*	13 June	18 June	2 July[1]	4 July[1]	2 June[1]
France										
*Nord-Pas-de-Calais	**	**	*	*	*	20 May[2]	15 May[2]	Early April[2]	End April[1,2]	Early April[2]
*Brittany	**	**				21 April[1]	10 April[1]			
Germany	*	*	**	*		8 May[1]	2 May[1]	2 May[1]	11 May[1]	28 April[1]
Italy	*	*	*	*		14 May	16 May	14 May	11 May	10 May
Ireland		**	***	**	*	6 May	June	June	4 July	20 July
Latvia		*	**	**	*	27 June	12 July	6 July	24 July	19 July
Netherlands	**	*	**	*	*	Early May[4]	Early May[3]	17 May[1]	April[2]	26 April[2]
Norway	*	***	***	*	*	2 June[1]	29 May[1]	6 June[1]	16 June[1]	2 June[1]
Poland	*	*	**	*	*	23 May[1]	21 May	6 June	23 June[2]	27 May
Spain (Basq Country)							6 August	2 August	15 June	21 June
Sweden	**	***	***	**	**	14 May	25 May[1,4]	17 May[1,4]	5 June[1]	20 May[1]
Switzerland	*(*)	*	*(*)	*	*	27 May[1]	22 May	11 May[1]	3 May[1]	8 May[1]
United Kingdom										
*Northern Ireland		***	**	*	*	21 May[1]	6 June[2]	2 July	22 June	16 June
*England/ Wales	*	**	**	*	*	23 May	24 April[2]	End May	10 May[2]	mid-May[1]
*Jersey	**	*				22 Jan.[1]	11 March[1]	20 March[1]	20 March	10 March
*Scotland	*	**	**	*	*	4 June	27 June	6 July	22 June[1]	12 May[3]

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

[1] *polythene covered crop;* [2] *waste piles;* [3] *volunteers;* [4] *oospores possibly involved*

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

Blight Forecasting in Jersey – comparison of a high risk year 2002 with a low risk year 2003

HOWARD HINDS[1], ROSEMARY COLLIER[2]

[1] Plantsystems Ltd, 3 Old Dairy Buildings Winkburn, Notts, UK
[2] States of Jersey, Howard Davis Farm, Trinity, Jersey

Summary

Over 300 more late blight outbreaks were reported in 2002 from Jersey potato crops than in 2003. Blight risk as calculated by the Plant-Plus model, based on the cultivar Jersey Royal, was compared from weather data generated by four stations in Jersey for 2002 and 2003. The results from accumulated daily risk values showed blight infection pressure was around 45% higher in 2002 than in 2003 for the period January to May. During the period when the majority of crop was under polythene a large infection period was recorded in March, prior to polythene removal, in 2002 whereas in 2003 no significant risk was recorded in this period. In each year risk in the North of the island was lower than in the South & West by 25-35%. As a consequence of lower blight pressure in 2003 on average 3.7 fewer sprays were applied compared to 2002 which reduced costs by around £43/ha.

Introduction

The maritime climate of the small island of Jersey presents ideal conditions for development of late blight. With a land area only 15km x 8km wide, potatoes grown on the island are never far from the sea. The main potato crop is the blight susceptible variety Jersey Royal which is grown for the early market and mostly exported to the UK. In order to achieve earliness crops are planted from January to March and covered in polythene for 7 to 8 weeks. Crops are left to grow under the polythene for several weeks after emergence, a period when they cannot be treated with fungicides. Seed is grown on the island.

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The combination of weather conditions, polythene covering, variety, and island grown seed makes blight control on the island a very challenging practice. Blight control programmes start as soon as the polythene is removed. Once polythene is removed scouts walk each row. If infected plants are found they are marked with sticks and plants then desiccated (Image 1). All outbreaks should be officially reported to the States of Jersey Agricultural Department.

In 2002, the number of official outbreaks of blight were reported was 374 whereas in 2003 the number of outbreaks were reported was just 51 (source States of Jersey 2004) throughout the season. During this period the Plant-Plus late blight model (*Hadders 1996*) was introduced into Jersey by Plantsystems for use by the States of Jersey Agricultural Department and also commercially by Top Produce (now Jersey Royal Potato Marketing). Blight pressure during these two years was monitored from several sites on the island as calculated by the Plant-Plus system and a comparison of blight risk and resulting spray programmes was made between 2002 and 2003. A comparison was also made of risk from the different monitoring sites on the island. The results of the comparisons are presented in this report.

Image 1 - Desiccated area of infected plants following polythene removal March 30th 2004.

Plant-Plus on Jersey

The States of Jersey use the information from the Plant-Plus model to generate weekly faxed reports (Mon/Wed/Fri) to all growers. Risk is based on 2 weather stations one in the West (St Ouen) and one in the North East (St Martin) of the island.

Top Produce has used the model commercially for 3 years to time spray applications on 700ha of potatoes. This is implemented by setting up several crops references for each main growing area for both late and early crops. The model and data input is then managed by Top Produce's agronomist (Mike Renourard) who centrally coordinates spray recommendations for each the crop references. Weather data for the model is provided by 4 stations owned by Top Produce. Stations are sited in the main growing areas, the North (Rozel), South (St. Clements), West (St Ouen) and Centre (Trinity – Image 2) of the Island.

St Ouen station (west) Rozel station (north)

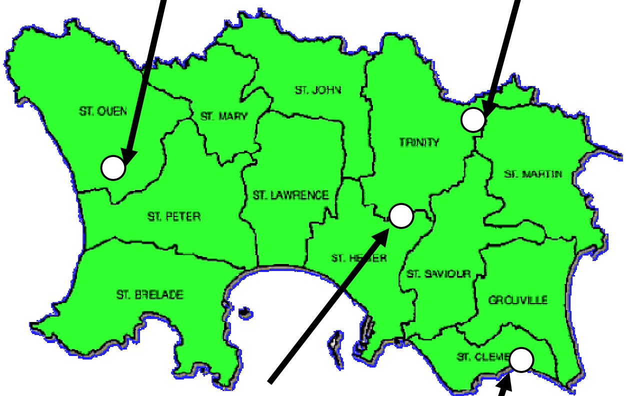

Image 2 Trinity weather station (centre)

St Clements station (south)

Blight risk comparisons

Table 1. Plant-Plus accumulated daily risk values on Jersey for 2002 and 2003

Year	Site	Jan	Feb	Mar	Apr	May	Total
2002	North (Rozel)	699	1092	2783	1651	4012	10237
	West (St Ouen)	1471	1354	2149	3996	6484	15454
	Centre (Trinity)	1544	1081	2296	2852	5378	13151
	South (St Clement)	1661	1822	2855	3709	6008	16055
2003	North (Rozel)	0	0	925	867	4157	5949
	West (St Ouen)	nd	nd	854	1542	5234	7630
	Centre (Trinity)	nd	nd	740	2411	5447	8598
	South (St Clement)	nd	nd	1326	1803	4711	7840

Risk between years

Table 1 shows that the accumulated risk values for the period January to May for 2002 are 45 % higher in 2002 than 2003. Most regions showed this trend as the higher risk in 2002 was experienced all over the island. Charts 1 & 2 illustrate that blight risk in 2002 started earlier with significant periods being recorded in late January, early February and late March, whereas in 2003 risk was low. During March, the period when the majority of polythene crops have emerged, a significant infection period was recorded from 15-20 March in 2002 (Chart 1), whereas in 2003 no significant period was recorded until late March. In both years very high pressure was seen from May.

Regional risk.

In Table 1 blight risk in both years showed regional variations on the island. In 2002 & 2003 the north of the island produced the lowest accumulated risk which in 2002 was 36% lower than the South West, and in 2003 was 31% lower than the South-Centre. The difference in risk between the South and the North was largest in April for both 2002 & 2003

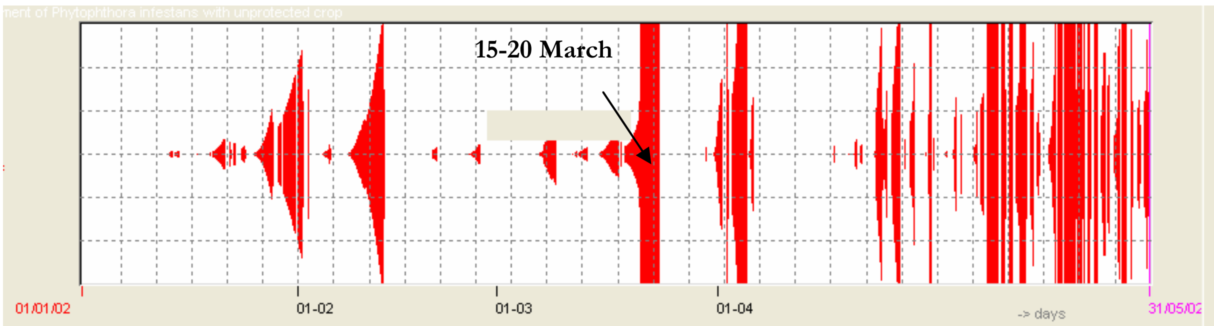

Chart 1. Blight infection chance periods in the North (Rozel) in 2002 from 1st Jan to 31st May

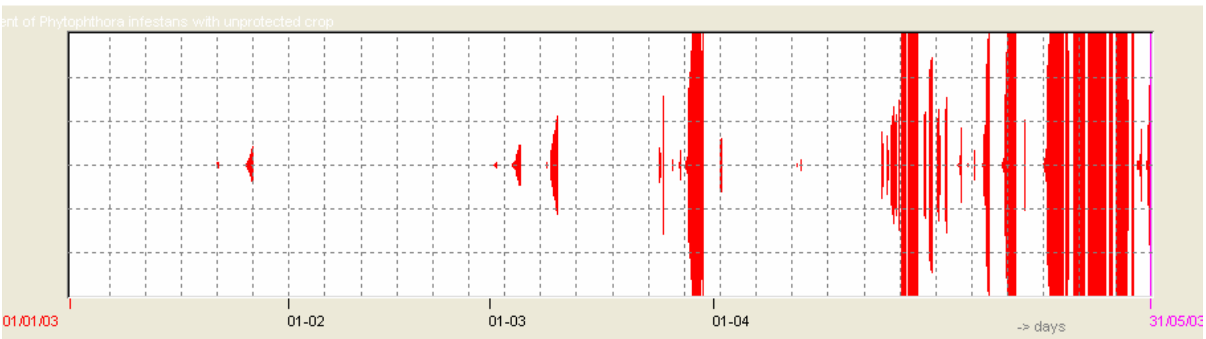

Chart 2. Blight infection chance periods in the North (Rozel) in 2003 from 1st Jan to 31st May

Spray comparison

Table 2 shows that on average 3.7 less sprays were applied according to the Plant-Plus model in 2003 than in 2002. There was no trend for differences in spray number between regions. Charts 3 & 4 show that polythene removal was one week later in 2003, this factor accounted for some of the difference between the years. In Table 3 spray cost between 2002 & 2003 was £43/ha higher. Compared to routine application from Top Produce records in 1999 (pre-Plant-Plus introduction) spray costs were similar to 2002 but higher than 2003. The cost of the standard programme as advised by the States of Jersey was equivalent to the low risk year when using Plant-Plus.

Table 2. Fungicide sprays applied as recommended by the Plant-plus model for early and late crop references for regions in 2002 & 2003.

Year	Site	Early Crop	Late Crop	Average
2002	North (Rozel)	nd	10	9.3
	West (St Ouen)	9	8	
	Centre (Trinity)	10	9	
	South (St Clement)	9	11	
2003	North (Rozel)	9	7	5.6
	West (St Ouen)	5	nd	
	Centre (Trinity)	3	nd	
	South (St Clement)	9	6	

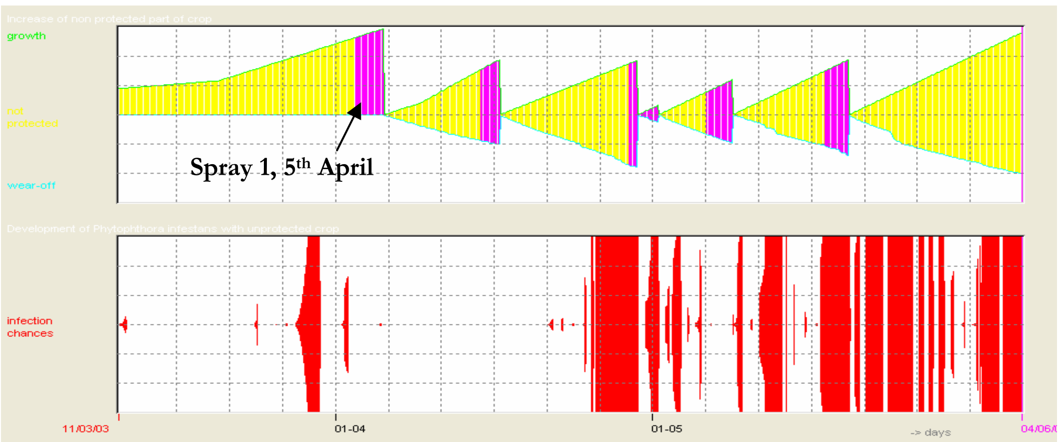

Chart 3. St Clements (late crop) sprays in 2003 following polythene removal on 5 April

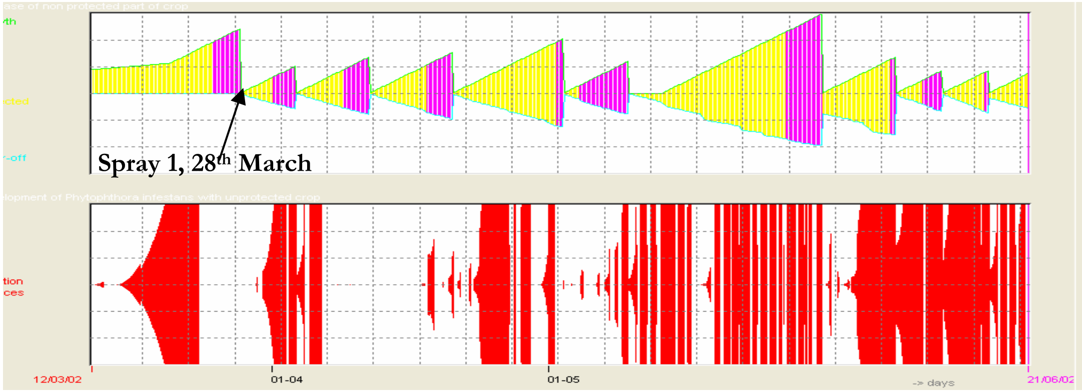

Chart 4. St Clements (late crop) sprays in 2002 following polythene removal on 28 March

Table 3. Fungicide cost comparison of sprays applied in accordance with States advice, routine (1999), Plant-Plus (2002 & 2003).

System	Programme	Cost €/ha
States routine advice	2 x Trustan, 2 x Curzate, Mancozeb, Tin	85
Actual routine 1999	Tattoo, Merlin, Curzate, Shirlan, Trustan, Invader, 2 x Tin	127
PPlus 2002	Fubol/Shirlan, Curzate, Invader, Electis, Curzate, Invader/Shirlan, Electis, Shirlan/Curzate , Invader	125
PPlus 2003	Fubol/Shirlan, Merlin, Curzate, Curzate/Shirlan, Electis	82

Discussion

The comparison of a relatively low blight risk year (2003) with a high risk year (2002) on Jersey shows that, despite the increased disease pressure caused by growing potatoes under polythene on a small island, it is possible to use a blight modelling system practically. As was shown in the spray records of Top Produce a model such as Plant-Plus can be used to adjust spray programmes (*Raatjes 2003*) and product choice following polythene removal. Critical, however to the success of running a DSS on large areas of potatoes (*Hinds 2000*), in this case 700ha, is that the system is managed and monitored centrally for example by the Top Produce agronomist. Recommendations from the model need to communicated effectively to the sprayer team for applications to be implemented at the correct time

Modelling systems can also give an indication as to the possible risk of blight infection occurring under the polythene. Evidence from 2004 & 2002 when early outbreaks were reported suggests that when a large infection period occurs within 2 weeks of polythene removal there is an increased chance of blight infection at an early stage. In 2003 a significant period was recorded from 15-20 March with the main period of polythene removal 8 days later and in 2004 a significant period was recorded from 18-21st March with the main polythene removal period 10 days later. In 2003 no significant infection period was recorded until the end of March as polythene was being uncovered. When these infection periods occur perforations in the polythene mean that infection can occur from external sources such as polythene tunnel crops or dumps, however another likely source will be from seed borne infection. In 2004 this was shown to be the case when seed from primary infectors was tested for latent infection (by SCRI) from a JRPM field near St Helier soon after polythene removal on 30th March. Although 2003 was relatively low risk up to May, high pressure was then experienced later in the summer when seed crops were growing. An alternative infection source under polythene would be from oospore infection, but to date oospores have not been detected on Jersey.

Comparison of blight risk from year to year can show large differences in pressure as this report has highlighted, however another interesting factor was the variation in risk in different parts of the island. The main difference in Jersey was lower risk in the north of the island compared to other areas as little as 5km away. At present site variations have not influenced spray programmes in Jersey as there tends to an element caution when spraying according to the DSS. The issue of such variations in disease risk over small areas does raise the question of the use of interpolated of risk when wider data points are used (*Taylor 2002*). In the future interpolation of data is likely to play a role in DSS's but the Jersey case study has highlighted some possible drawbacks.

Analysis of two very different years on Jersey has raised some interesting areas of further investigation. There would appear to be a relationship between infection periods while the crop is growing under polythene with the risk of infection occurring before polythene is removed. It is not possible to effectively spray through polythene (*Spits 2002*) but it may be possible to remove polythene early to time sprays to coincide with these infection events. By doing this the reduction in potential early yield may be outweighed by the potential increase in quality (blight free tubers) and more importantly the reduction in early infection sources on the island

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ProPhy advice in The Netherlands: what's new?

W. NUGTEREN

Opticrop B.V., P.O. box 34, NL-2140 AA Vijfhuizen, The Netherlands
Tel. +31 – 23 5583041, Fax +31 – 23 5581963, Email: wim@opticrop.nl

Introduction

The ProPhy advice system is in use in The Netherlands since around 1990. By means of different media (pc programs, online, by fax) some 2250 potato growers benefit directly from the information and advices. ProPhy has a well-established position in Dutch agriculture and has set a good example for similar advice systems in other crops. Even for a program started 15 years ago, still there are innovations and improvements. This article covers recent developments regarding the ProPhy system: hardware, software, trial results, use in practice etcetera.

Weather stations

Opticrop operates and maintains a private network of 75 weather stations in The Netherlands. These stations are spread over the country, with emphasis on the areas specialised in arable crops like potatoes, onions and flower bulbs. In recent years, most older weather stations have been replaced by new ones. Since 1998 we use mobile weather stations with solar panel/battery for power supply and GSM modems for communication. These 2nd generation weather stations are far more flexible in installation and moving them from one site to another. This is especially important because we strongly prefer to install the stations right next to or inside the field, in order to place the sensors inside the crop for exact micro-climate measurements.

Hourly measurements are collected in a central database, checked and validated and forwarded to our FTP server and web server. From there the weather data can be accessed by

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the advice applications. Weather stations are owned mostly by commercial companies, cooperatives and groups of farmers. If a farmer is a co-owner of a weather station, he/she pays a share of the maintenance and communication costs. If a company or Opticrop owns the station, there is a general fee for using the weather data. This ranges between € 25 / yr for fax and internet applications and € 80 / yr for pc-programs.

Based on experience and measurements, our guideline is that a weather station can provide reliable data for an area with a radius of about 10-15 km. around its location. Of course this can only be true if the station is placed on a good location and in a representative crop. Furthermore, special circumstances like coastal areas or altitudes have to be taken in account. The number of farmers using one weather station (for different applications/crops) ranges between 10 and 100. This means that in some cases it is difficult to generate enough income to properly cover all maintenance costs.

Weather forecast

Especially *Phytophthora* is a disease that should be treated preventively as much as possible. This means that besides measurement data, there is a definite need for a reliable local weather forecast. Compared to most other countries, we can probably consider ourselves lucky having a low-priced, detailed forecast (5 days ahead, 3-hourly periods) for 35-40 areas in our small country. Depending on the type of advice application, farmers pay € 25 - € 70 per year for having the forecast data. In combination with pc-programs the farmer has full access to the weather forecast (text, numbers and rainfall radar) for € 70 per year.

In The Netherlands there are 3 commercial companies supplying weather forecasts. This has helped to get a low-cost forecast available for anyone. Unfortunately, our experience is that the competition has not (yet) resulted in better, more reliable predictions. Another difficult aspect is how to translate the "general" forecast into conditions in and around the crop, for example by taking in account soil type and soil moisture and their effect on the microclimate. In an ongoing process we spend a lot of time in "tuning" the different advice models on this point. Depending on the aggressiveness of the disease and the availability of curative chemicals, each advice system should have its own balance between being overcautious and missing dangerous days.

Use of ProPhy

There are 3 main ways of using ProPhy:

PC program on the farm desktop computer	500 users
Advice by fax or e-mail	1500 users
Online advice (internet)	250 users

The ProPhy pc-program offers the most detailed advice and background information and recommendations are based on the farmers own specific field data. ProPhy provides a complete recommendation on timing of treatments, product choice and dosage rate. Besides weather conditions, a lot of factors are taken into account: variety resistance, disease pressure, wash off by rain and irrigation, crop growth, crop density, type of chemical, dosage rate, personal strategy (economy, safety, environment) etc..

Advice by fax / e-mail is a very easy, low-cost alternative. Clients automatically receive 3-6 fax messages per week, giving them an overview of weather data, disease situation and spraying advice. In the advice table they can look for specific advices depending on the two main variables: variety resistance and time since last treatment. This way one can have quite detailed advice, though it remains a non-interactive advice system. More and more we cooperate with regional companies/cooperatives providing textual tips about the disease situation in their area. There is an internet application where they enter their texts, and from there our fax application downloads them and puts the text on the fax the next morning.

ProPhy online is an interactive advice program on the internet. In the level of detail and the amount of information, the online advice is somewhere in between the pc-program and the advice fax. For farmers the benefits are the lower price and not having to install software on their own computer. Compared to a daily fax the major advantage of the online advice is in the fact that all data and advices are updated hourly.

Spraying technique

In spraying equipment we have seen a rapid increase in capacity: wide sprayers (up to 48 meters), spraying tracks, low volume, drift reduction techniques etc.. Legislation on mandatory spraying licences (both for farmers themselves and for their equipment), use of drift-reducing nozzles and crop- and spray free zones close to water, has been a strong stimulation for modern, professional equipment.

These technical developments also have an interesting link to advice programs. If you want to have full benefit of the advice and really reach for an optimal treatment schedule, you need high capacity and professional equipment. Earlier research showed that in most years 20-30% of the days were unsuitable for spraying, due to rainfall (50%), wind speed (25%) or leaf wetness (25%). The use of special spraying tracks (leaving out two complete rows of potatoes) has been a major improvement. Except from situations with real large amounts of rain, it is possible to drive the field whenever the program indicates it's necessary.

ProPhy trial results

Over the period 1994-2003 there have been more than 40 official field trials in which spraying according to ProPhy was compared with a standard routine. The standard routine used to be a 7-day schedule, whereas in recent years advice programs are often compared to an "optimal routine" as determined by the manager of the research farm, who has also access to the advice programs.

The overall average outcome of the comparison:

	Standard	ProPhy
Disease control (0-10 scale)	8.7	8.9
Number of treatments	14.1	11.6

This shows that following the ProPhy advice leads to similar or even better *Phytophthora* control, and at the same time reduces the number of sprayings by 2.5 on average.
These conclusions are supported by the results of individual trials:

Disease control (0-10 scale):

3 trials	Standard > ProPhy	8.1 vs. 7.8
19 trials	Standard = ProPhy	9.3
20 trials	Standard < ProPhy	8.0 vs. 8.7

Number of sprayings:

1 trial	Standard < ProPhy	13 vs. 15
6 trials	Standard = ProPhy	14.7
35 trials	Standard > ProPhy	14.0 vs. 10.9

With only few exceptions, ProPhy results in at least the same level of disease control while saving considerably on the number of treatments.

For further example, the average of the 4 official trials in 2003:

	Standard	ProPhy
Disease control (0-10 scale)	10.0	10.0
Number of treatments	11.3	8.8
Active ingredient (kg/ha)	7.5	6.0
Fungicide costs (€/ha)	245	185

In a warm, dry year like 2003 there was hardly any disease in the trials. ProPhy resulted in 2.5 sprayings less and saved € 60 per ha.

The difference with spray routines in practice (on average 12-13 sprayings in 2003) is even bigger. This is the general conclusion for years with low disease pressure: for various reasons farmers tend to be on the safe side and put on more sprays then necessary. In high-risk periods especially the farmers without any advice system sometimes show the opposite behaviour: they tend to stick to their 7 day routine, whereas sometimes a 4-5 day interval proves really essential.

Other experiences in 2003

As in most countries in Western-Europe, 2003 was a warm and dry season without major *Phytophthora* problems. In disease control almost every schedule or strategy performed well, in most cases even "untreated". In such a season some other aspects become of interest:

Some trials and practical experiences showed a significant effect of fungicide choice on the yield. The cause of this was either the (side) effect of chemicals on Alternaria or the "greening effect" of Manganese (Mn) in some products.

In some other trials with healthy crops (no other diseases, well-fertilised) there was a significant and statistically reliable yield-reduction in the sprayed routines vs. the unsprayed control. Seeing that the unsprayed routine had up to 5% higher yields, one could say that every individual spraying can result in a yield reduction between 0 and 0.5%. Besides the influence on the type of chemical (some prove more "aggressive" on the crop than others), the weather conditions on the spraying dates play a major role. Should a spray be necessary on a warm, sunny day then it can best be done late in the evening.

There were many examples of how temperature-resistant the current *Phytophthora* strains are. It takes really high temperatures and low humidity to dry off lesions. And even if so, the lesions tend to recover very quickly when conditions change. If *Phytophthora* is present in a crop, it can survive a long period of hot weather, keep on a low level but reappear when conditions become favourable again.

On the other hand, if the crop is "clean" then there is hardly any danger of getting new infections under warm, dry conditions. Even if there is active sporulation in the area, spores can not survive and infect neighbouring crops under these conditions. This supports the strategy of aiming at 100% disease control, since only with a clean crop you can really benefit from prolonged periods of warm, dry weather.

Legislation on chemicals

In The Netherlands we have had a number of years when the range of available products was getting smaller and smaller. Over the years we lost a series of chemicals: tin-based products, metalaxyl, dimethomorph and chlorothalonil. This left us momentarily with only very limited choice: Shirlan (fluazinam), Aviso (metiram/cymoxanil), Tanos (famoxadone/cymoxanil) and Ranman (cyazofamid). Luckily, there has been a turnaround in this development. All mentioned products are now back in legislation, and restrictions on the use of maneb/mancozeb are gone. Although there is still strong opposition by some organisations, the government seems to have realised that durable and environmental-friendly potato growing in The Netherlands is only possible if there is enough backup in products for high-risk situations.

Technical developments

Right now there are some interesting technical developments:

Pocket pc's

Precision farming

Communication board computers – desktop computers

Opticrop has developed "Pocket CROP": software to be used on pocket pc's (pda/handheld) in combination with the regular CROP program on the desktop computer. Many farmers are very interested in using pocket pc's, because now they can do all the mandatory registration work immediately on the field while spraying, fertilising etc.. They strongly prefer this as opposed to making notes first and then sit down at the desktop computer and retype all their recordings. Besides field-registration, Pocket CROP can be used for downloading the current weather forecast including rain radar pictures onto the pocket pc, by use of the GSM phone. Having the local forecast and information how rain showers move, can be essential while being at the field and (for example) having to decide whether to continue spraying or not.

The use of handheld computers in general, can be regarded a new step also in decision support systems. Most farmers tend to make their decisions "outside" and are not really used to first check the computer for information and advices. So in the near future it is well possible that "portable advice programs" open up a new market.

Although development was quite late compared to some other countries, precision farming now seems to break through. There are lots of initiatives (projects and individual farmers) towards using GIS-GPS systems for precise and site-specific operation. This gives new opportunities for further optimisation of disease control.

There is a newly developed standard protocol for communication between on-board computers (on tractor and/or sprayer) and desktop computers ("IsoBus"), which we have incorporated in our software. Especially in combination with GPS, this brings the possibility of having even more detailed field recordings. Having site-specific instead of field-specific data, could mean more precise use of advice systems. Also the other way around: specific recommendations on chemical choice, dosage rate and application technique can automatically be downloaded to and used by the spraying equipment.

Overview and conclusions

On first look, decision support systems on potato blight might seem to have become a well-known, established and not so fashionable topic. The reality proves different. Still there is lot to learn about the disease and how to optimise control. Different technical developments in hardware (weather stations, handheld computers, GPS etc.) bring new potential for more and other decision support.

Weather and forecasts of late blight from your local weather station: is it worth doing fancy interpolations or can you just use the nearest one for guidance on your spray decisions?

MORAY C. TAYLOR

Environmental Entomology & Plant Pathology, Central Science Laboratory, Sand Hutton, York, YO41 1LZ, UK.

Summary

Forecasts of infection by late blight are often based on weather station readings which are remote from actual potato fields. Whether the meteorological conditions in the fields are similar enough to those at the nearest weather station remains an open question (and will depend on locality) but many researchers attempt to interpolate weather factors. Various methods exist for spatial interpolation but this study simply demonstrates what affect these processes may have on spray decisions rather than just using the report from the nearest weather station. The date of the first Smith Period and the accumulated units of infection warnings under the BLITECAST forecasting scheme at about 220 weather stations were used to measure how spatial interpolation may change the date or magnitude of blight warnings. The effect on the date of the first Smith Period over a five year period was inconsistent although it tended to make them later and therefore riskier. The total of BLITECAST severity units increased, up to a point, when interpolation was used which indicated a greater sensitivity to possible infection.

Keywords: Spatial interpolation, splines, Thiessen polygons

Introduction

Many potato growers are encouraged to use decision support (DS) tools when scheduling fungicide applications to control late blight. Such tools may save unnecessary sprays in some

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seasons and they can help to justify fungicide inputs to show adherence to a production protocol. As late blight infection is strongly dependant on the weather so DS tools need a source of meteorological data on which to base their advice. Farm based weather stations have become widely available in recent years but there is never going to be one in every potato field. Alternatively, observations from an existing, professionally maintained, network could be used for blight warnings but these will be at varying distances from potato crops. This study aimed to compare how blight warnings based on the latter type of network might change if the DS results were spatially interpolated as opposed to simply taking the DS result from the nearest weather station.

Materials & Methods

Hourly weather data from over 300 observing stations was obtained from the UK Meteorological Office (UKMO) as part of a large project working on the spatial interpolation of various weather factors. Only those stations which had a near complete set of hourly readings between 1998 and 2002 were used (Figure 1) resulting in 220 sites. The temperature and relative humidity (RH) data from these locations were used to find the date of the first Smith Period (Smith, 1956) in each of the five years.

An additional data set detailing the date and location of initial observations of late blight infection in fields across England & Wales was obtained for each of the five years. This was used to produce five maps of apparent infection date using a spline based spatial interpolation method (Hutchinson, 1995), as an example Figure 2 is the map for 2002.

Using the date of the first Smith Period results from the weather station data two further maps can be produced, each of the forecasted outbreak date. One is produced using a similar method of spatial interpolation as the actual outbreak map. The spline method was preferred as it makes no assumptions about the distribution of the input data which was usually skewed. The second map was produced by allocating every point the same value as the nearest weather station. This was effectively a simple method of interpolation known as Thiessen Polygons where every location within each polygon has the same value (Figure 3). In both cases final maps were constrained by the potato cropping area (Figure 4). Each of these maps can be subtracted from the actual outbreak map to give a third map which in each case shows the size of the warning, in days, that the Smith Period forecasting scheme gave for that year. As a final step each warning map was reclassified into three categories; warning too late (<10 days), an ideal warning (10 – 21 days) and a warning which was too early (>21 days) Figure 5. Using the potato hectarage map (Figure 4) the area of potatoes within each warning category can be calculated and compared with that produced by the opposite method over the five year period (Figure 6).

To investigate the influence of interpolation over a longer period the weather station data was used to calculate a season long (1 June to 30 September) total of severity units defined by the BLITECAST forecasting scheme (Krause, et al., 1975). The average temperature during a period when the relative humidity rises above 90% defines five classes (0 – 4) of increasing favour for late blight infection (Table 1). Once again a pair of maps for each year were generated, one based on polygons and the other using spline interpolation. The area of potatoes within five severity total size groups (<25, 25 – 50, 50 – 75, 75 – 100, 100 – 125) was calculated and compared for years 1998 - 2002 (Figure 7).

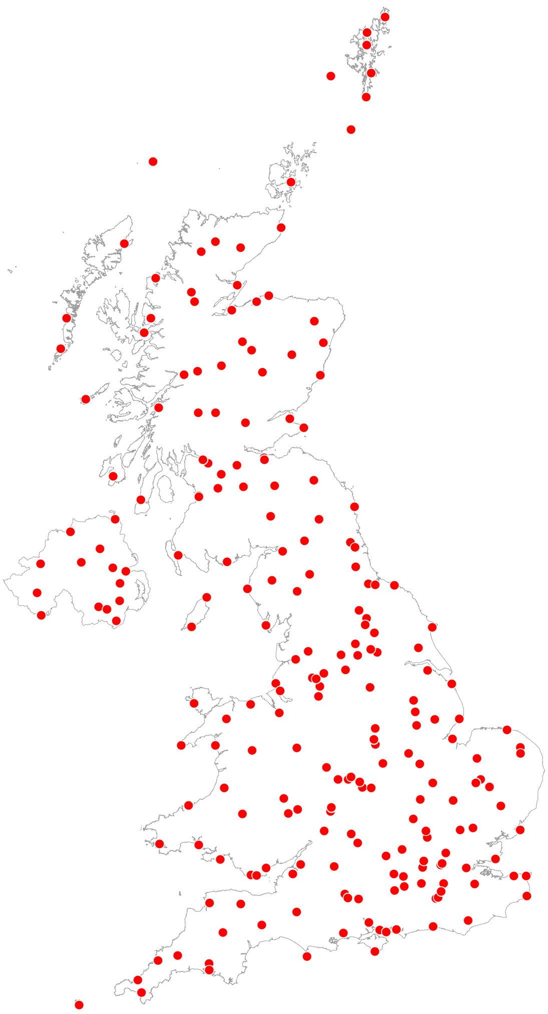

Figure 1. Location of UKMO weather stations with near complete hourly records between 1998 and 2002.

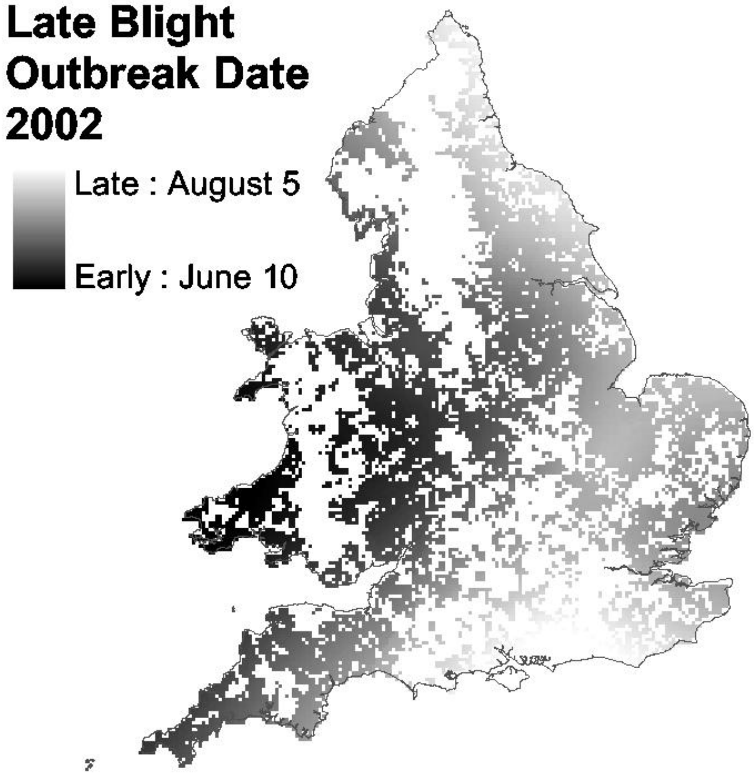

Figure 2. Example of late blight infection date generated from about 20 field reports and smoothed with the thin plate spline spatial interpolation technique.

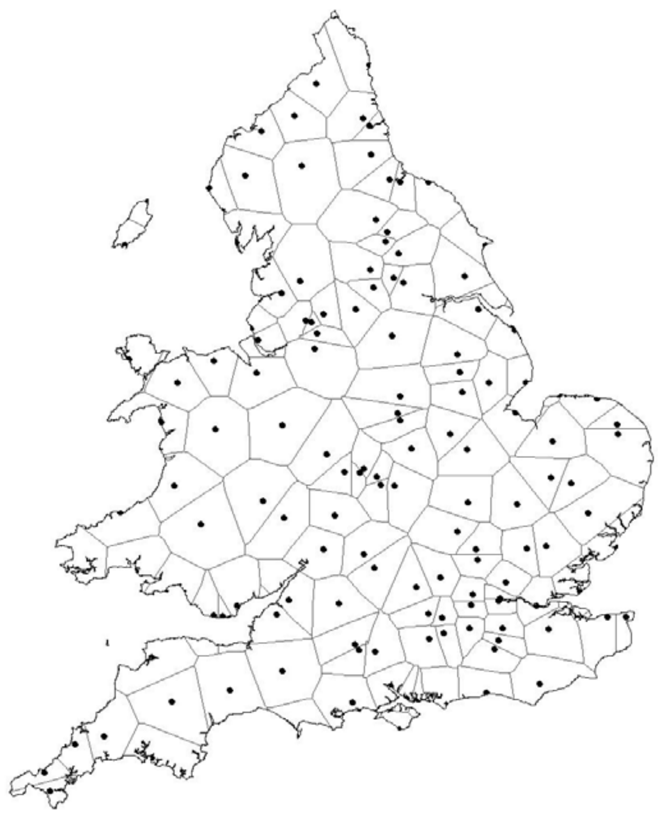

Figure 3. Allocation polygons of all areas to the value of the nearest weather station.

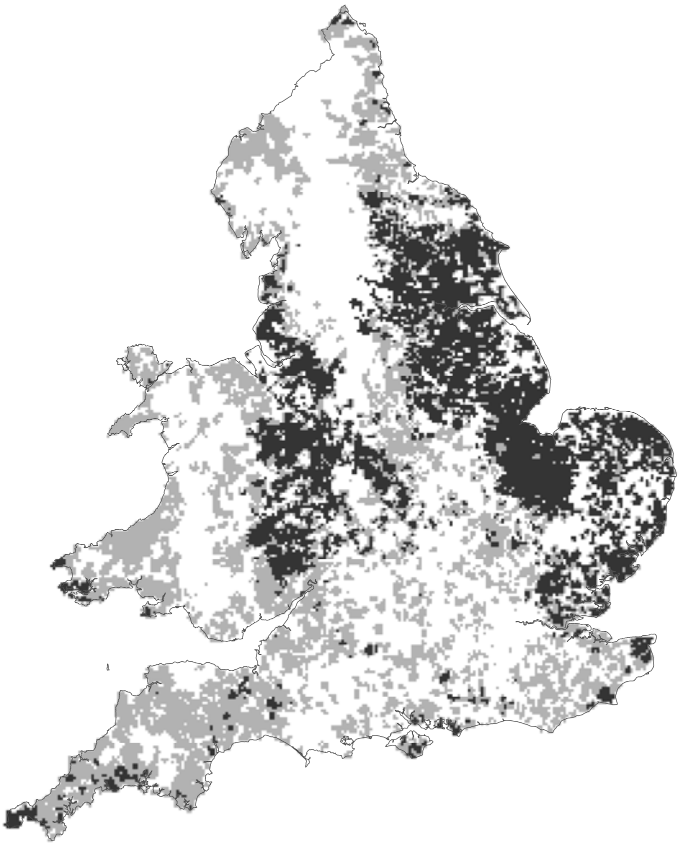

Figure 4. Potato growing areas in England & Wales, 1997. Grid is defined by 2km x 2km squares, light shaded areas have <5 hectares of potatoes in 4 square km, dark areas have >5 hectares in 4 square km.

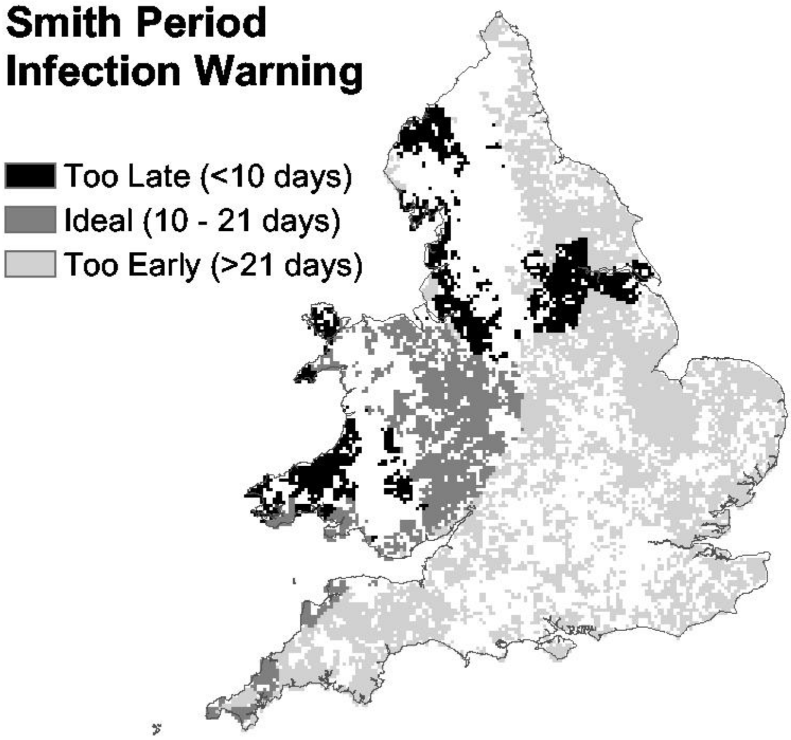

Figure 5. Infection warning categories based on actual outbreak date minus forecast outbreak date and reclassified.

Results

Date of First Smith Period

There were no statistically significant changes in the area of potatoes within each warning category when spatial interpolation was used (Figure 6). However, the year to year variation was large resulting in a wide standard error range; the tendency was for spatial interpolation to give fewer early warnings but more later warnings.

Season Total of BLITECAST Severity Units

Spatial interpolation caused a statistically significant shift from the first severity total category (<25 or lowest risk) into the second category (25 – 50). This meant that the interpolation resulted in more infection warnings under the BLITECAST scheme and therefore probably more recommendations to apply fungicides (Figure 7).

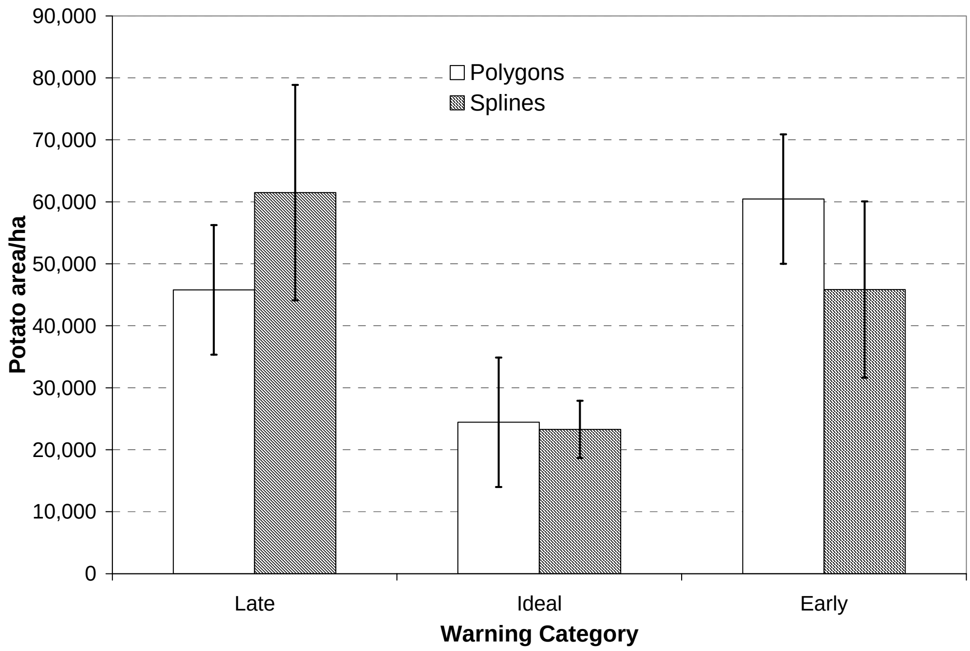

Figure 6. Effect of spatial interpolation on the areas of potatoes falling within three warning categories based on the Smith Period forecasting scheme, 1998 – 2002.

Table 1. BLITECAST severity units (0 – 4) defined by mean temperature during high humidity periods.

	Severity values, hours of ≥ 90% relative humidity				
Average temperature range	0	1	2	3	4
7.2 – 11.6	15	16 – 18	19 – 21	22 – 24	25+
11.7 – 15.0	12	13 – 15	16 – 18	19 – 21	22+
15.1 – 26.6	9	10 – 12	13 – 15	16 – 18	19+

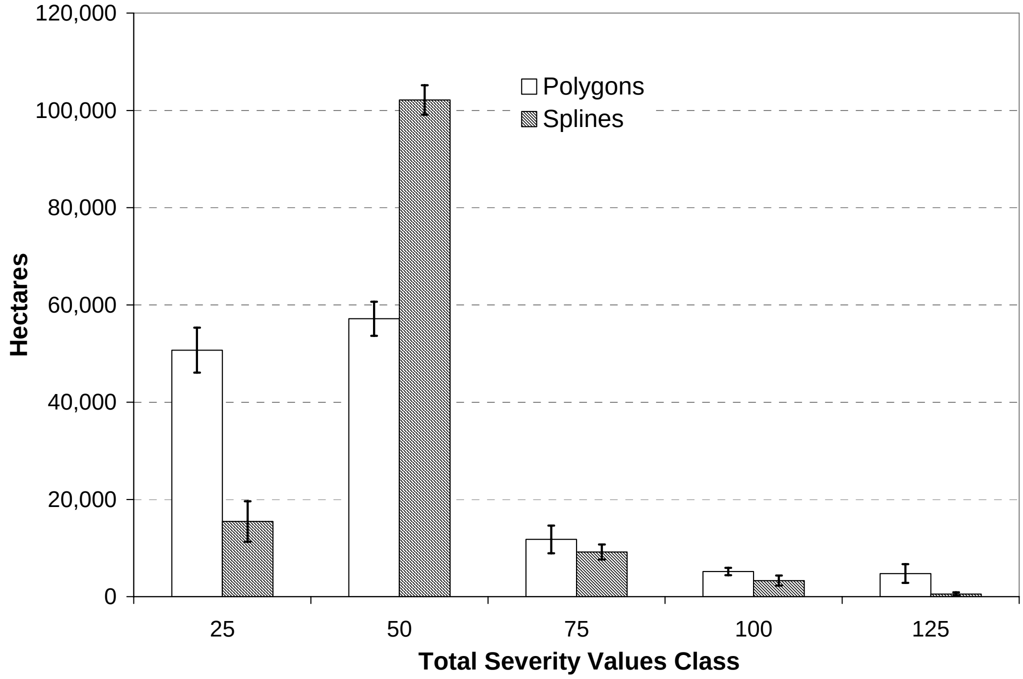

Figure 7. Effect of interpolation on the seasonal total of BLITECAST severity units, 1998 – 2002.

Discussion

The result for the comparison on the date of the initial Smith Period was confounded by a poorly performing spatial interpolation in the majority of the five years. Although the average differences between the 'Too Early' and 'Too Late' warning categories was large, so was the annual variation. The BLITECAST severity unit data was more amenable to interpolation. This was probably because it was derived from a longer series of readings (122 days) at each weather station rather than the initial Smith Period date which was a single event. However, it was more instructive to compare these two different types of derived variable.

The result for the seasonal total of BLITECAST severity units had a much lower amount of annual variability and the spline method of spatial interpolation worked more consistently. The interpolation will honour the input data values at the known locations but acts like stretching a rubber sheet between points so producing a smoother output than the simple polygons. The net result is a move towards the average value of the input data, in Figure 7 this is seen as the greater normality in the distribution of the spline interpolated data in comparison to the polygon data.

Spatial interpolation is a complex field in terms of the mathematics that can be employed on the problem and absolute accuracy can be hard to define. The weather data available to this project was used to derive two abstract variables related to late blight infection risk. In both cases the non-normal distribution of the input data restricted the choice of interpolation method, in particular it would have been inappropriate to use the geostatistical technique of Kriging (Webster, 1996). However, the raw weather data could be analysed by geostatistical methods even though it would considerably lengthen the processing time required. A mean temperature and an 'hours above 90% RH' surface at 4 km^2 resolution would need to be generated for each day of each season and the two forecasting schemes run for every pixel of the potato growing area – 20,244 cells each day. Such an approach may lead to a more consistent interpolation performance and a clearer answer to what difference spatial interpolation rather than simple allocation could make but it would take time to find out.

The low frequency of confirmed reports on the location of late blight infection during the five years for which weather data was available was a weak spot for these analyses. There was no network in place to collect rigorous information on the appearance of the disease across England and Wales. The estimates of pathogen infection date were based on 20 – 25 reports each year some of which were quite vaguely located. In contrast a scouting network instigated by the British Potato Council for the season in 2003 resulted in 104 positive identifications of late blight with excellent location information. Unfortunately, the weather data available to the project does not stretch far enough into 2003 to be able to use the disease outbreak data.

Conclusions

Interpolation shows tendency towards riskier decisions with Smith Periods.

Seasonal potential disease severity as defined by BLITECAST was significantly raised by interpolation.

The accuracy of spatial interpolation may be inconsistent with some types of input data, e.g., the date of a single event. Without good reports on the location of blight infection and development it's difficult to say whether the interpolation provides an estimate, of whatever variable, which is closer to the truth than the polygon method.

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Field validation of four decision support systems for the control of potato late blight in Ireland

LESLIE J. DOWLEY AND JOHN J. BURKE

Summary

Field experiments were carried out in Ireland between 2001 and 2003 to determine the efficacy of the NegFry, Simphyt, ProPhy and Plant Plus decision support systems (DSS) in controlling late blight of potatoes compared with routine fungicide treatments. The experiments were also used to determine the potential of the systems to reduce fungicide inputs.

Over the three year period of the experiment the 7-day routine programme received an average of 13.7 fungicide applications while the DSS programmes varied between 5.7 and 12.3 applications. All decision support systems resulted in a reduction in the number of fungicide application (Fig. 2). Compared with the routine control, the NegFry and SimPhyt programmes resulted in a 58-44% reduction in application frequency. The ProPhy and Plant Plus programmes resulted in more modest savings of between 10 and 25% (Tables 1 & 2).

All fungicide treatments significantly delayed the date of disease onset compared with the untreated control. Compared with the routine control treatment, the NegFry and Plant Plus significantly delayed disease onset in King Edward in 2001 as did NegFry and ProPhy in Rooster. In 2002 there were no differences between treatments in terms of delaying disease onset, while in 2003, disease developed significantly earlier the Plant Plus programme compared with the routine control. In general, the date of disease onset was not significantly different between routine programmes and DSS programmes, irrespective of the cultivar.

In each of the three years, all fungicide treatments significantly reduced the incidence of foliage blight at the end of the season compared with the untreated control. When compared with the routine control, no decision support system resulted in significantly more foliage blight at the end of the season, irrespective of the cultivar or year. Similar results were

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achieved when the treatments were compared using the area under the disease progress curve (AUDPC). These results would confirm that none of the DSS's resulted in inferior disease control when compared with the 7-day routine application of fluazinam.
All fungicide treatments resulted in significantly higher marketable yields compared with the untreated control in all years, irrespective of the variety. Within the fungicide treatments the DSS programmes generally out-yielded the routine fungicide treatment. However, these differences were only significant for Plant-Plus in King Edward in 2001. Within the DSS treatments there were no significant differences in marketable yield in any of the years or either of the varieties.
Within the fungicide treatments there were no significant differences between treatments in terms of tuber blight control for the resistant variety Rooster. In the case of the more susceptible variety, King Edward, all the DSS programmes resulted in significantly lower levels of tuber blight than the routine Shirlan control in 2001 except for Simphyt. More importantly, the routine Shirlan did not result in significantly better tuber blight control in any of the years when compared with any of the DSS programmes. This confirms that all DSS programmes give equivalent tuber blight control to the routine Shirlan application at 7-day intervals even with a very tuber blight susceptible variety.

Key words: NegFry, Simphyt, ProPhy, Plant Plus, *Phytophthora infestans*

Introduction

Potato late blight, caused by the oomycete fungus *Phytophthora infestans* (Mont.) de Bary is the most destructive disease affecting the potato worldwide. Annual losses in Ireland have been estimated at €10.2 m per annum (Copeland *et al.*, 1993). Disease control requires regular application of fungicides at high rates and short intervals throughout the growing season.

There is increasing consumer demand to improve the health status of our foods and to reduce any pollution effects on our environment. This has resulted in a growing international demand to reduce the use of pesticides in food production. Some countries have already introduced legislation to reduce the use of pesticides in crop production while in others, the legislation is still pending. In countries where no such legislation exists, the larger food outlets may insist that their food be produced according to a protocol that includes reduced fungicide inputs. This may involve the scientific justification of each fungicide applied and can only be achieved by the use of a decision support system.

The epidemiology of late blight is very dependent on temperature, relative humidity and rainfall. Due to the large influence of weather on the development and spread of this disease, it is not surprising that forecasting systems have been in use in a number of countries for many years.

One of the first forecasting schemes for potato blight, based on cloudiness, dew, rainfall and temperature was developed in the Netherlands (van Everdingen, 1926). Others were developed in the UK (Beaumont & Staniland, 1933) and the USA (Crosier & Reddick, 1935). Subsequently, Beaumont formulated the Beaumont Period (Beaumont, 1947) which was later superseded by the Smith Period (Smith, 1956). An attempt to refine the system by Sparks (1980) was not successful and the Smith Period continues in use in the UK to the present day.

In the Republic of Ireland, Bourke developed a set of rules for forecasting late blight which were first used in 1952 and are known as the 'Irish Rules'. These rules were based on experimental laboratory work carried out by Crosier in the USA (Bourke, 1955). The rules were used for the development of a late blight warning service that is run by Met. Éireann (the Irish Meteorological Service).

Recent developments in information technology have made it possible to log weather data continuously for individual sites and to use this information in computer-based decision support systems (DSS) to predict the date of disease outbreak and to determine the most suitable intervals between sprays. The objective of any DSS programme is to achieve the most effective timing of each fungicide application while optimising disease control and minimising pesticide use. As part of an EU Concerted Action Programme, four DSS programmes were compared with routine fungicide application at 7-day intervals and an untreated control. The trials were conducted at Oak Park Research Centre, Carlow, Ireland over a three year period between 2001 and 2003. The four DSS programmes were NegFry, SimPhyt, ProPhy and Plant Plus.

The ProPhy and Plant Plus models are restricted to fee paying customers only while NegFry and SimPhyt are both available free of charge. All models require accurate local weather data, especially rainfall, temperature and relative humidity. Other requirements include irradiation, wind speed, cultivar susceptibility, crop growth, disease proximity and future weather prediction for the area. NegFry was developed in Denmark (Hansen *et al.*, 1995) and SimPhyt in Germany (Gutsche & Kluge, 1995). Both ProPhy (Nugtern, 1997) and Plant Plus (Hadders, 1997) were developed in The Netherlands.

The objective of this project was to establish if differences existed between these decision support systems in terms of fungicide use, disease control or yield.

Materials and Methods

Weather data recording

The Oak Park weather station was used to record humidity, temperature, rainfall, radiation, wind speed, soil temperature and soil moisture. The data was recorded every 10 minutes and the average of 3 readings was transferred to a computer where it was stored for final analysis using the different decision support software.

Field experiments

Trials were conducted at Oak Park Research Centre, Carlow, from 2001 to 2003, using certified seed of the main crop potato cultivars Rooster and King Edward. Both cultivars have similar ratings (4) for foliage blight resistance but differ considerably in terms of tuber blight resistance with Rooster (7) being much more resistant than King Edward (3). The preceding crop was winter barley and the soil was a free draining medium loam with a low clay and organic matter content and a pH of 6.6 (+/- 0.2). The trials were planted into destoned beds using a Randsom two-row automatic planter. The drill width was 84.66 cm and the distance between tuber centres was 29.21 cm. Paraquat (600 g. a.i. ha^1) and simazine (600 g. a.i. ha^1) was applied as pre emergence herbicides.

The trial design was a randomised complete block (RCB) with 4 replications per treatment. Each plot consisted of 6 drills 7.69 m long. The total plot size was 37.5 m^2, from which 12.5 m^2 were harvested across the centre 2 drills. A 3 m divider strip was left between plots to facilitate mechanical harvesting. An unsprayed inoculator plot was planted at each end of the trial. A mancozeb treated non-experimental buffer-plot was planted between the unsprayed plot and the experimental area. Artificial inoculum of *P. infestans* (5,000 sporangia/ml) was applied to the under-surface of 5 leaflets/plant in the inoculator strips at either end of the trial area if no disease was apparent within 10 days after disease onset was predicted by the NegFry DSS.

Spraying was carried out with an ATV drawn Hardi sprayer mounted on a Logic chassis with an independent power source. Machinery access was by rotovated spray paths to prevent crop damage. Spraying commenced when the plants were beginning to meet along the drill or as determined by the decision support systems. The spray volume was equivalent to 250 l ha^{-1} and the spray pressure was 3 bars using Hardi flat spray nozzle number 370694/4110-20 delivering 1.59 l min^{-1} at 7.6 km h^{-1} (4.72 mph). During the growing season, disease levels were assessed at weekly intervals up to desiccation using the B.M.S. foliage blight assessment key (Cox & Large, 1960).

The experiments were desiccated with full rate diquat in September and harvesting took place in September-November using a Randsom two-row elevator digger. The produce was stored at a temperature above 10^{0}C for at least two weeks to allow tuber blight symptoms to develop. The tubers were then graded into the following grades:- < 45 mm, 45-65 mm, 65-85 mm, > 85 mm, blighted tubers and other diseases. After grading the produce was weighed and the yield expressed in tonnes ha^{-1}.

Fungicide Treatments

Routine fluazinam application at 7-day intervals was compared with fungicide applications as dictated by the four DSS programmes and an untreated control. The different fungicides applied and the dates of application are given in Appendix 1.

Results

Variation in disease severity between years

The accumulated risk value as measured by the NegFry decision support system is a good measure of the conditions suitable for the spread of foliage blight during the course of each season. It also provides a consistent and scientific comparison between years. High values indicate a year where conditions were most suitable for the spread of foliage blight.

The accumulated risk values for the years 2001 to 2003 are given in Fig. 1. The highest accumulated risk value was recorded for 2003 and the lowest was recorded for 2001. The accumulated risk value for 2002 was normal while 2001 was below normal and 2003 above normal.

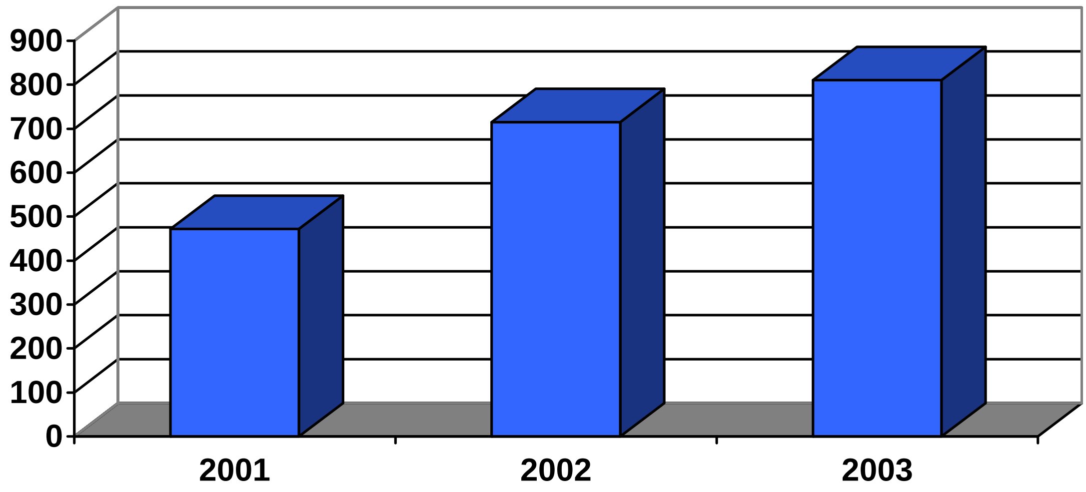

Figure 1. Variation in the accumulated risk value 2001-2003 (Blight units from June 1 to September 30)

Number of fungicide applications

Routine fungicide application started in mid-June and continued at 7-day intervals up to the date of desiccation. The number of routine fungicide applications was dictated mainly by the date of desiccation. The number of fungicide applications for the decision support systems was determined by either the NegFry, SimPhyt, ProPhy or Plant Plus programmes. The number of fungicide applications for each programme in each of the three years is given in Tables 1 & 2.

Table 1. The number of fungicide applications following different application programmes 2001-2003 (cv. King Edward).

Programme	2001	2002	2003	Mean	% Reduction on routine control
7-day routine control	14	14	13	13.7	
NegFry	6	6	7	6.3	54.0
SimPhyt	5	9	9	7.7	43.8
Plant Plus	9	12	10	10.3	24.8
ProPhy	12	15	10	12.3	10.2

Table 2. The number of fungicide applications following different application programmes 2001-2003 (cv. Rooster).

Programme	2001	2002	2003	Mean	% Reduction on routine control
7-day routine control	14	14	13	13.7	
NegFry	6	6	5	5.7	58.4
SimPhyt	5	9	8	7.3	46.7
Plant Plus	-	13	11	12.0	12.4
ProPhy	12	15	10	12.3	10.2

Over the three year period of the experiment, the 7-day routine programme received an average of 13.7 fungicide applications while the DSS programmes varied between 5.7 and 12.3 applications. All decision support systems resulted in a reduction in the number of fungicide applications. Compared with the routine control the NegFry and SimPhyt programmes resulted in a 58-44% reduction in application frequency. The ProPhy and Plant Plus programmes resulted in more modest savings of between 10 and 25% (Tables 1 & 2). All decision support systems represent a considerable saving in fungicide use (Fig. 2) but an acceptable level of disease control must accompany the reduced fungicide inputs.

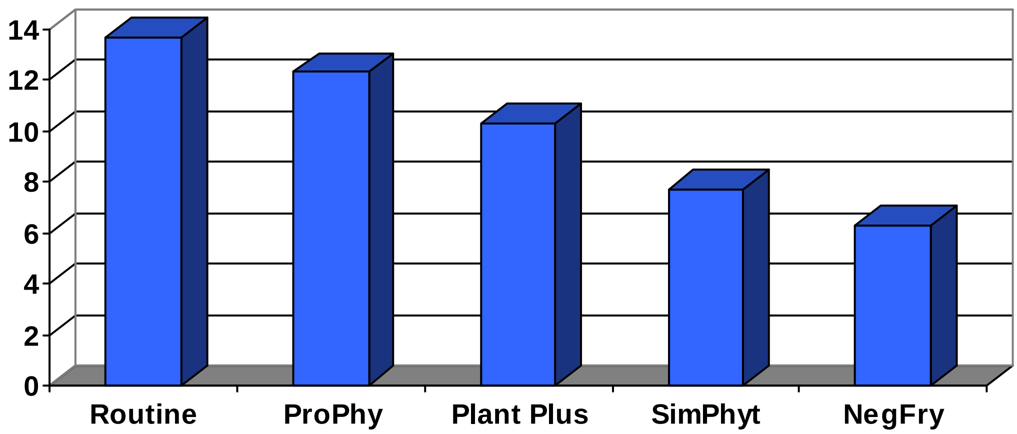

Figure 2. Effect of spray programme on the mean number of fungicide applications 2001-2003 (cv. King Edward)

Effect on foliar blight

The effect of different fungicide programmes on the incidence of foliar blight can be compared by using the delay in disease onset, the level of foliar blight at the end of the season or by using the area under the disease progress curve (AUDPC) which measures the rate of disease development during the course of the whole epidemic.

Delay in disease onset

The delay in disease onset is the length in days between the first record of disease in the untreated control and the first record in the experimental treatment. The delay in disease onset for the different treatments is given in Tables 3 and 4. All fungicide treatments significantly delayed the date of disease onset compared with the untreated control. Compared with the routine control treatment, the NegFry and Plant Plus significantly delayed disease onset in King Edward in 2001, as did NegFry and ProPhy in Rooster. In 2002 there were no significant differences between treatments in terms of delaying disease onset, while in 2003, disease developed significantly earlier in King Edward following the Plant Plus programme compared with the routine control. In general, the date of disease onset was not significantly different between routine programmes and DSS programmes irrespective of the cultivar (Tables 3 & 4).

Table 3. Effect of different decision support based fungicide programmes and routine fungicide application on the delay in disease onset (in days) compared with an untreated control (cv. K. Edward).

Programme	2001	2002	2003	Mean
Shirlan Routine 7-day Control	6.50	20.25	28.00	18.25
NegFry	11.25	20.25	21.00	17.50
ProPhy	9.50	14.50	23.33	15.77
SimPhyt	8.00	25.00	25.67	19.55
Plant Plus	11.00	20.00	14.00	15.00
LSD (5%)	4.25	14.75	11.71	

Table 4. Effect of different decision support based fungicide programmes and routine fungicide application on the delay in disease onset (in days) compared with an untreated control (cv. Rooster).

Programme	2001	2002	2003	Mean
Shirlan Routine 7-day Control	8.00	23.00	10.50	13.83
NegFry	14.75	16.25	15.75	15.58
ProPhy	14.50	28.25	26.25	23.00
SimPhyt	6.50	19.75	21.00	15.75
Plant Plus		24.75	12.25	18.50
LSD (5%)	5.95	10.03	21.55	

Foliar blight at end of season

The % foliar blight for the different treatments at the end of the growing season is given in Tables 5 and 6. In each of the three years, all fungicide treatments significantly reduced the incidence of foliar blight at the end of the season compared with the untreated control. When compared with the routine control, no decision support system resulted in significantly more foliar blight at the end of the season, irrespective of the cultivar or year. In the case of King Edward in 2001, the NegFry, ProPhy and Plant Plus DSS resulted in significantly less foliar blight that the routine control. These results would confirm that none of the DSS's resulted in inferior disease control when compared with the 7-day routine application of fluazinam.

Table 5. Effect of different decision support based fungicide programmes on the % foliar blight at the end of the season compared with routine fungicide application and an untreated control (cv. King Edward).

Programme	2001	2002	2003
Untreated control	100.00	80.00	100.00
Shirlan Routine 7-day Control	50.00	0.78	3.67
NegFry	15.00	0.78	3.67
ProPhy	10.00	0.10	5.00
SimPhyt	31.25	0.55	5.00
Plant Plus	15.00	0.10	5.00
LSD (5%)	19.36	6.15	2.02
LSD (5% excl. untreated control)	21.86	0.58	2.45

Table 6. Effect of different decision support based fungicide programmes on the % foliar blight at the end of the season compared with routine fungicide application and an untreated control (cv. Rooster).

Programme	2001	2002	2003
Untreated control	100.00	100.00	100.00
Shirlan Routine 7-day Control	10.00	8.78	1.00
NegFry	10.00	3.00	1.00
ProPhy	15.00	1.78	1.00
SimPhyt	27.50	2.00	1.00
Plant Plus		1.00	1.00
LSD (5%)	26.66	7.32	1.12
LSD (5% excl. untreated control)	31.25	8.06	1.22

Area under the disease progress curve

The area under the disease progress curve (AUDPC) measures the development of disease over the whole season and is a more accurate assessment of differences between treatments over the course of the epidemic. All fungicide treatments significantly reduced the area under the disease progress curve compared with the untreated control (Tables 7 & 8).

When the programmes applied as per the decision support systems are compared with the fluazinam 7-day routine programme, it can be seen that there was no significant difference between the programmes in any of the years or in either of the cultivars. This again would confirm that the decision support systems resulted in the same level of blight control as the routine application of fluazinam at 7-day intervals.

Table 7. Effect of different decision support based fungicide programmes on the Area Under the Disease Progress Curve (AUDPC) compared with routine fungicide application and an untreated control (cv. K. Edward).

	2001	2002	2003
Untreated Control	2,327	1,427	2,346
Shirlan Routine 7-day Control	442	11	35
NegFry	95	14	26
ProPhy	67	2	33
SimPhyt	211	5	32
Plant Plus	94	5	29
LSD (5%)	245	129	74
LSD (5%) excl. untreated control	235	9	17

Table 8. Effect of different decision support based fungicide programmes on the Area Under the Disease Progress Curve (AUDPC) compared with routine fungicide application and an untreated control (cv. Rooster).

	2001	2002	2003
Untreated Control	2,212	2,363	2,470
Shirlan Routine 7-day Control	78	39	9
NegFry	67	22	17
ProPhy	85	10	7
SimPhyt	246	27	26
Plant Plus		11	12
LSD (5%)	191	145	170
LSD (5%) excl. untreated control	214	33	13

Effect on yield

The marketable yields for the different treatments in the two varieties in each year are given in Tables 9 and 10. The yield varied considerably between years, with the highest yields recorded in 2001 and the lowest in 2002. All fungicide treatments resulted in significantly higher marketable yields compared with the untreated control in all years irrespective of the variety. Within the fungicide treatments, the DSS programmes generally out-yielded the routine fungicide treatment. However, these differences were only significant for Plant-Plus in King Edward in 2001. Within the DSS treatments there were no significant differences in marketable yield in any of the years or either of the varieties.

Table 9. Effect of different decision support based fungicide programmes on the marketable yield (t ha^{-1}) compared with routine fungicide application and an untreated control (cv. K. Edward).

	2001	2002	2003	Mean
Untreated Control	30.90	28.16	14.59	24.55
Shirlan Routine 7-day Control	38.92	34.36	26.40	33.23
NegFry	40.20	35.26	26.11	33.86
ProPhy	40.92	35.00	29.17	35.03
SimPhyt	38.98	40.12	24.35	34.48
Plant Plus	48.08	35.12	28.00	37.06
LSD (5%)	11.74	6.16	8.02	
LSD (5%) excl. untreated control	10.01	6.38	8.94	

Table 10. Effect of different decision support based fungicide programmes on the marketable yield (t ha^{-1}) compared with routine fungicide application and an untreated control (cv. Rooster).

	2001	2002	2003	Mean
Untreated Control	39.28	28.34	28.77	32.13
Shirlan Routine 7-day Control	47.74	39.80	41.00	42.76
NegFry	50.02	41.20	43.44	44.89
ProPhy	51.10	41.64	43.00	45.25
SimPhyt	51.60	40.36	42.06	44.67
Plant Plus		43.28	44.46	43.87
LSD (5%)	9.24	8.30	4.57	
LSD (5%) excl. untreated control	10.25	8.84	4.25	

The total yields for the different treatments in the two varieties in each year are given in Tables 11 and 12. All fungicide treatments resulted in higher total yields compared with the untreated control in all years, irrespective of the variety. In most cases this difference was significant. Within the fungicide treatments the DSS programmes generally out-yielded the routine fungicide treatment. However, these differences were only significant for Plant-Plus in Rooster in 2003. Within the DSS treatments, there were no significant differences in total yield in any of the years or either of the varieties.

Table 11. Effect of different decision support based fungicide programmes on the total yield (t ha^{-1}) compared with routine fungicide application and an untreated control (cv. K. Edward)

	2001	2002	2003	Mean
Untreated Control	40.62	35.84	21.92	32.79
Shirlan Routine 7-day Control	49.74	42.96	35.71	42.80
NegFry	49.74	43.16	35.23	42.71
ProPhy	52.02	43.36	37.84	44.41
SimPhyt	48.90	48.96	33.71	43.86
Plant Plus	57.92	43.70	36.96	46.19
LSD (5%)	10.08	6.84	9.01	
LSD (5%) excl. untreated control	8.84	7.41	9.74	

Table 12. Effect of different decision support based fungicide programmes on the total yield (t ha^{-1}) compared with routine fungicide application and an untreated control (cv. Rooster).

	2001	2002	2003	Mean
Untreated Control	46.53	39.54	39.07	41.71
Shirlan Routine 7-day Control	54.16	48.56	50.08	50.93
NegFry	56.72	50.60	51.87	53.06
ProPhy	57.38	51.18	51.28	53.28
SimPhyt	57.57	49.78	52.88	53.40
Plant Plus	-	51.96	54.38	53.17
LSD (5%)	8.28	8.27	3.73	
LSD (5%) excl. untreated control	9.42	8.67	3.78	

Effect on tuber blight

Despite the existence of good conditions for tuber infection in some years, the overall level of disease during the course of this experiment was low. As expected, there were higher levels of tuber blight in the susceptible variety King Edward compared with the resistant variety

Rooster. The incidence of tuber blight in both varieties following the different fungicide programmes is given in Tables 13 and 14. In the case of the susceptible variety King Edward, all fungicide treatments significantly reduced the incidence of tuber blight compared with the untreated control except in the case of the routine Shirlan control in 2001 (Table 14). In the more tuber resistant variety Rooster, fungicide application significantly reduced tuber blight only in 50% of cases (Table 13).

Within the fungicide treatments there were no significant differences between treatments for the resistant variety Rooster. In the case of the more susceptible variety King Edward all the DSS programmes resulted in significantly lower levels of tuber blight than the routine Shirlan control in 2001 except for Simphyt. More importantly, the routine Shirlan did not result in significantly better tuber blight control in any of the years or for any of the DSS programmes. This confirms that all DSS programmes give equivalent tuber blight control to the routine Shirlan application at 7-day intervals, even with a very tuber blight susceptible variety.

Table 13. Effect of different decision support based fungicide programmes on the yield of blighted tubers (t ha^{-1}) compared with routine fungicide application and an untreated control (cv. K. Edward).

	2001	2002	2003	Mean
Untreated Control	0.20	0.26	0.40	0.29
Shirlan Routine 7-day Control	0.12	0.00	0.00	0.04
NegFry	0.04	0.02	0.08	0.05
ProPhy	0.02	0.00	0.00	0.01
SimPhyt	0.06	0.04	0.01	0.04
Plant Plus	0.02	0.00	0.03	0.02
LSD (5%)	0.14	0.14	0.21	
LSD (5%) excl. untreated control	0.08	0.05	0.04	

Table 14. Effect of different decision support based fungicide programmes on the yield of blighted tubers (t ha^{-1}) compared with routine fungicide application and an untreated control (cv. Rooster).

	2001	2002	2003	Mean
Untreated Control	0.13	0.16	0.00	0.10
Shirlan Routine 7-day Control	0.02	0.04	0.00	0.02
NegFry	0.04	0.08	0.00	0.04
ProPhy	0.00	0.02	0.00	0.07
SimPhyt	0.00	0.06	0.00	0.02
Plant Plus		0.10	0.00	0.05
LSD (5%)	0.08	0.11	0.00	
LSD (5%) excl. untreated control	0.05	0.11	0.00	

Discussion

With reduced fungicide use it would be important to use the most effective fungicide and this could be particularly important in relation to tuber blight control. Shirlan has been shown to be an effective and robust fungicide for the control of both foliar and tuber blight in potatoes when used at 7-day intervals (Dowley & O'Sullivan, 1995). Any fungicide application programme, which resulted in equivalent disease control to a 7-day Shirlan routine programme, could be considered to be robust and reliable. During the course of this experiment, the foliar blight control achieved with the different DSS programmes showed no significant difference from the routine application of Shirlan at 7-day intervals. This would confirm that there was no loss in foliar blight control following the use of decision support systems.

Earlier experiments at Oak Park confirmed that the NegFry decision support system gave excellent control of both foliar and tuber blight in the tuber blight resistant variety, Rooster (Leonard *et al*., 2002). This raised the question of the ability of decision support systems to give adequate control of tuber blight in tuber blight susceptible varieties. The current experiments confirmed that all DSS programmes examined gave equivalent tuber blight control to the routine Shirlan application at 7-day intervals even with a very tuber blight susceptible variety.

During the three years of this experiment, the decision support systems reduced fungicide use by between 10% and 58%. The NegFry and Simphyt DSS resulted in much greater fungicide savings compared with ProPhy and Plant-Plus. As a result the most appropriate DSS for Irish growers and consumers would be either NegFry or Simphyt. However, the cost of fungicide application in potatoes is relatively inexpensive and therefore growers will need another incentive to introduce a DSS system into their production programmes. This could come in the form of consumer demand, a statutory order to reduce fungicide input or more likely as a requirement to justify fungicide use by the large food retailers. Whatever the driving force, decision support systems will play a significant part in future potato production.

Potato production in Ireland tends to be carried out on rented land which may be located far from the grower's base. This would give rise to problems of information transfer from in-crop weather stations. It may also require a number of weather stations to cover different fields for the same grower. This problem would be eliminated if we had a national or regional weather station grid that would be centrally controlled and could be assessed through the Internet.

Conclusions

- No significant loss in foliar blight control was recorded following the use of the DSS programmes.
- No significant loss in tuber blight control was recorded following the use of the DSS programmes, even in a tuber blight susceptible variety.
- The DSS programmes resulted in a 10 to 58% saving in fungicide use when compared with a 7-day routine Shirlan treatment.
- The greatest savings were recorded following the NegFry and Simphyt programmes.

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APPENDIX

Fungicides used and the dates of application for the King Edward trial 2001.

Programme	Fungicide	Rate of Product ha^{-1}	Dates of application
Untreated	None	None	None
Routine	Fluazinam	0.40 l	13/6, 20/6, 27/6, 3/7, 11/7, 19/7, 25/7, 1/8, 8/8, 15/8, 22/8, 29/8, 5/9, 12/9
NegFry	Fluazinam	0.40 l	25/6, 3/7, 13/7, 12/8, 20/8, 3/9
SimPhyt	Fluazinam	0.40 l	25/6
	Metalaxyl/Mancozeb	2.50 kg	4/7, 19/7
	Fluazinam + Mancozeb/Cymoxanil	0.20 l 1.88 kg	20/6, 15/8
ProPhy	Fluazinam	0.40 l	29/5, 7/6, 27/6, 3/7, 3/8, 9/8, 15/8, 22/8, 5/9
	Propamocarb/Mancozeb	4.00 l	19/6
	Mancozeb/Cymoxanil	2.50 kg	12/7, 30/8
Plant Plus	Fluazinam+ Mancozeb/Cymoxanil	0.40 l 2.50 kg	27/6, 3/7, 1/8, 8/8, 13/8, 20/8, 31/8 9/7, 6/9

Fungicides used and the dates of application for the Rooster trial 2001.

Programme	Fungicide	Rate of Product ha^{-1}	Dates of application
Untreated	None	None	None
Routine	Fluazinam	0.40 l	13/6, 20/6, 27/6, 3/7, 11/7, 19/7, 25/7, 1/8, 8/8, 15/8, 22/8, 29/8, 5/9, 12/9
NegFry	Fluazinam	0.40 l	27/6, 9/7, 27/7, 13/8, 22/8, 3/9
SimPhyt	Fluazinam	0.40 l	25/6
	Metalaxyl/Mancozeb	2.50 kg	4/7, 19/7
	Fluazinam + Mancozeb/Cymoxanil	0.20 l 1.88 kg	20/6, 15/8
ProPhy	Fluazinam	0.40 l	29/5, 7/6, 27/6, 3/7, 3/8, 9/8, 15/8,
	Propamocarb/Mancozeb	4.00 l	19/6, 22/8, 5/9
	Mancozeb/Cymoxanil	2.50 kg	12/7, 30/8

Fungicides used and the dates of application for the King Edward trial 2002.

Programme	Fungicide	Rate of Product ha^{-1}	Dates of application
Untreated	None	None	None
Routine	Fluazinam	0.40 l	12/6, 19/6, 26/6, 3/7, 10/7, 19/7, 24/7, 31/7, 7/8, 14/8, 21/8, 28/8, 4/9, 11/9
NegFry	Fluazinam	0.40 l	14/6, 9/7, 24/7, 7/8, 19/8, 29/8
SimPhyt	Fluazinam	0.40 l	14/6, 12/7, 4/9
	Metalaxyl/Mancozeb	2.50 kg	1/7
	Fluazinam + Mancozeb/Cymoxanil	0.20 l 1.88 kg	19/7, 23/7
	Propamocarb/Mancozeb	4.00 l	21/8
	Mancozeb/Cymoxanil	2.50 kg	7/8, 14/8
ProPhy	Fluazinam	0.40 l	29/5, 10/6, 17/6, 4/7, 11/7, 23/7, 29/7, 29/8, 4/9, 10/9
	Propamocarb/Mancozeb	4.00 l	15/7, 7/8
	Mancozeb/Cymoxanil	2.50 kg	1/7, 14/8, 22/8
Plant Plus	Dimethomorph/Mancozeb	2.40 kg	10/6
	Fluazinam	0.40 l	13/6, 21/6, 1/7, 9/7, 17/7, 29/7, 14/8, 21/8, 29/8, 10/9
	Propamocarb/Mancozeb	2.50 kg	7/8

Fungicides used and the dates of application for the Rooster trial 2002

Programme	Fungicide	Rate of Product ha^{-1}	Dates of application
Untreated	None	None	None
Routine	Fluazinam	0.40 l	12/6, 19/6, 26/6, 3/7, 10/7, 19/7, 24/7, 31/7, 7/8, 14/8, 21/8, 28/8, 4/9, 11/9
NegFry	Fluazinam	0.40 l	1/7, 17/7, 30/7, 7/8, 19/8, 29/8
SimPhyt	Fluazinam	0.40 l	14/6, 12/7, 4/9
	Metalaxyl/Mancozeb	2.50 kg	1/7
	Fluazinam + Mancozeb/Cymoxanil	0.20 l 1.88 kg	19/7, 23/7
	Propamocarb/Mancozeb	4.00 l	21/8
	Mancozeb/Cymoxanil	2.50 kg	7/8, 14/8
Programme	Fungicide	Rate of Product ha^{-1}	Dates of application
ProPhy	Fluazinam	0.40 l	29/5, 10/6, 4/7, 11/7, 23/7, 30/7, 19/8, 9/9
	Propamocarb/Mancozeb	4.00 l	17/6, 1/7, 7/8, 14/8, 27/8
	Mancozeb/Cymoxanil	2.50 kg	15/7, 4/9
Plant Plus	Propamocarb/Mancozeb	2.40 kg	10/6
	Fluazinam	0.40 l	13/6, 21/6, 1/7, 9/7, 17/7, 29/7, 14/8, 19/8, 21/8, 27/8, 10/9
	Propamocarb/Mancozeb	4.00 l	7/8

Fungicides used and the dates of application for the King Edward trial 2003.

Programme	Fungicide	Rate of Product ha^{-1}	Dates of application
Untreated	None	None	None
Routine	Fluazinam	0.40 l	11/6, 17/6, 25/6, 2/7, 9/7, 16/7, 23/7, 30/7, 6/8, 13/8, 20/8, 27/8, 3/9
NegFry	Fluazinam	0.40 l	13/6, 1/7, 11/7, 21/7, 30/7, 18/8, 28/8
SimPhyt	Metalaxyl/Mancozeb	2.50 kg	13/6,
	Dimethomorph/Mancozeb +Fluazinam	1.80 kg 0.20 l	23/6, 27/6,
	Fluazinam	0.40 l	8/7, 21/7, 28/8
	Propamocarb/Mancozeb	4.00 l	30/7, 7/8, 18/8,
ProPhy	Fluazinam	0.40 l	10/6, 8/7,
	Mancozeb/Cymoxanil	2.50 kg	20/6, 16/7,
	Propamocarb/Mancozeb	4.0 l	1/7, 21/7, 25/7, 5/8, 11/8, 1/9
Plant Plus	Fluazinam	0.40 l	10/6, 18/6, 1/7, 8/7, 16/7, 21/7, 25/7, 5/8, 11/8
	Mancozeb/Cymoxanil	2.40 kg	30/7,

Fungicides used and the dates of application for the Rooster trial 2003

Programme	Fungicide	Rate of Product ha^{-1}	Dates of application
Untreated	None	None	None
Routine	Fluazinam	0.40 l	11/6, 17/6, 25/6, 2/7, 9/7, 16/7, 23/7, 30/7, 6/8, 13/8, 20/8, 27/8, 3/9
NegFry	Fluazinam	0.40 l	13/6, 1/7, 16/7, 25/7, 27/8
SimPhyt	Metalaxyl/Mancozeb	2.50 kg	13/6, 21/7,
	Fluazinam	0.40 l	24/6, 8/7, 18/8, 30/8
	Mancozeb/Cymoxanil	2.50 kg	30/7,
	Propamocarb/Mancozeb	4.00 l	8/8,
ProPhy	Fluazinam	0.40 l	10/6, 20/6, 8/7, 21/7,
	Propamocarb/Mancozeb	4.00 l	1/7, 5/8, 11/8, 1/9
	Mancozeb/Cymoxanil	2.50 kg	16/7, 30/7,
Plant Plus	Fluazinam	0.40 l	11/6,18/6, 1/7, 8/7, 16/7, 21/7, 25/7, 5/8, 11/8, 1/9
	Mancozeb/Cymoxanil	2.50 kg	30/7,

The development of first appearance of *Phytophthora infestans* in production areas

B. KLEINHENZ, U. PREISS

ZEPP - Central Institution for Decision Support Systems and Programmes in Crop Protection, Rüdesheimer Strasse 60-68, 55545 Bad Kreuznach, Germany
www.zepp.info , email: kleinhenz@zepp.info , preiss@zepp.info

Summary

The epidemiology of late blight on potatoes was investigated in the years 2001 until 2003. For 663 plots in five different production areas the important field and epidemiological data were recorded. The development of potato late blight was observed during the complete growing season. The influences of the meteorological conditions on the epidemics were calculated by the SIMPHYT3 model. The output of the SIMPHYT3 was accumulated as infection pressure index. (ipi). The "ipi" is high correlated to the percentage of infected fields per area. This method is used to describe the risk of new late blight infections caused by the influence of the weather.

Keywords: epidemiology, potato late blight, Phytophthora infestans, SIMPHYT, DSS, infection pressure index

Introduction

Within a framework of an project the epidemiology of late blight on potatoes was investigated in the years 2001 until 2003. The studies were focused on the recordings of the first appearance of *Phytophthora infestans* on each single plot. Goal of the work was the improvement of the forecast model SIMPHYT1 recommending first fungicide application (KLEINHENZ und JÖRG 1999; ROßBERG *et al.* 2001; HANSEN *et al.* 2002). The results of this model are used for recommendations of the first application of late blight fungicides.

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Partners of this project are the Landwirtschaftskammer Weser-Ems, the Dienstleistungszentrum ländlicher Raum Rheinhessen-Nahe-Hunsrück and the Pflanzschutzamt Mecklenburg-Vorpommern. The project is funded by the „Deutsche Bundesstiftung Umwelt".

Material and methods

The investigations where done in five different production areas. The regions vary on a high level in climatic conditions, orography and agricultural practice. The areas are located in the German states a) Niedersachsen (northwest part of Germany) b) Rheinland-Pfalz southwest part of Germany) and c) Mecklenburg-Vorpommern (northeast part of Germany). Also the size of the production areas where very diverse. In Rheinland-Pfalz two areas, each with an diameter of about 6 km, were observed. The size of the plots are in a range between one and four ha. In Niedersachsen one area with an diameter of about 10 km was observed. The size of the plots were between five and 30 ha. In Mecklenburg–Vorpommern two areas with an diameter of about 20 km were inspected. The field size is normally between five and 30 ha. Additionally dumps and volunteer potatoes growing on last year fields where recorded because they carry a high potential risk as sources for infections.

For each plot the important data were recorded. These were for example geographical coordinates, next weather station, soil type, last year crops, variety, planting date, the emergence date, row closing , irrigation, fungicide applications, production with polyethylene cover and so on.

The assessments were started with the emergence of the potatoes and ended with the maturity. The field visits were done two times per week. At each assessment on the potato fields the same path was used. The path started on an tractor track from the edge of the field 50 m inside, then a change in rectangle of 90° to the next tractor track and back to the edge. Large fields where visited a few paths. Each path was corresponded with about 500 plants. In each visited row the number of infected plants, the growth stage of the plants and the growth stage of the crop was assessed. Infected plants outside of marked path were noticed in a special column.

The evaluation of the data was done by an geographical information system (ARC-View 8.3., ESRI)(figure. 1).

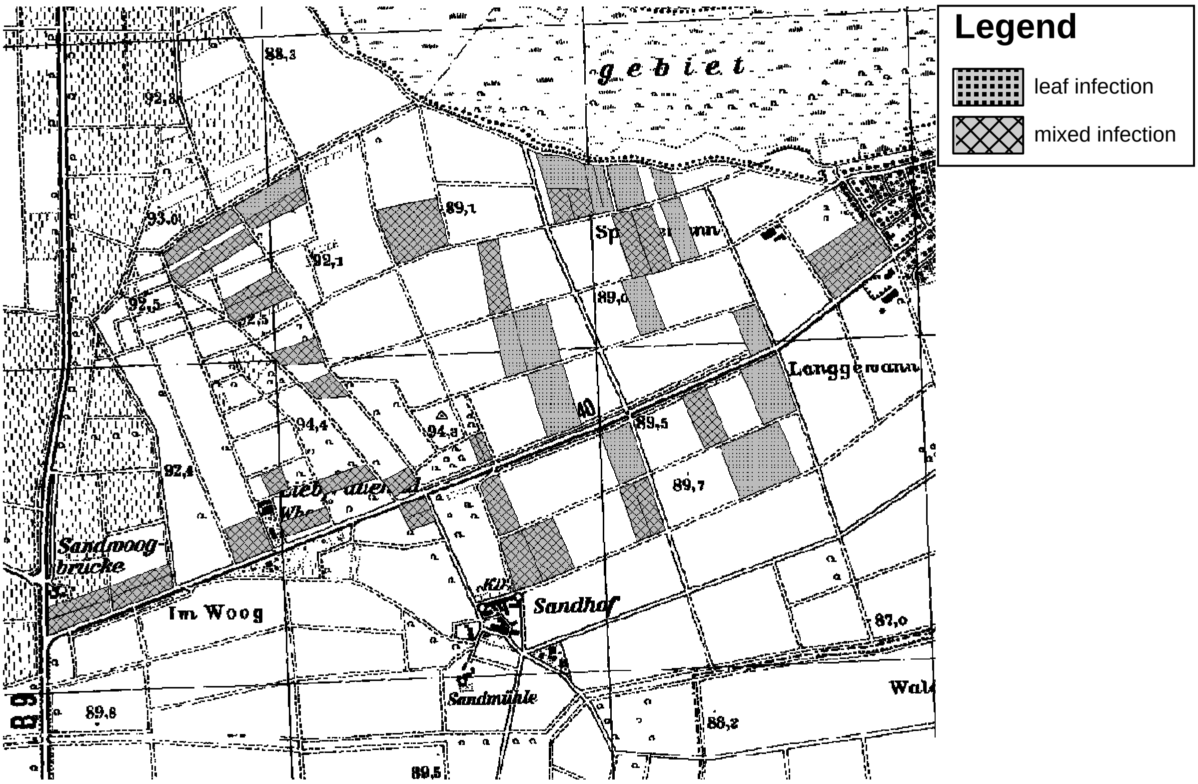

Figure 1. Registration of the potato fields into production area Eich Rheinland-Pfalz in 2001

Results

A) Assessment of the first appearance of *P. infestans*

The assessments in the areas where done from the beginning of May until the end of August. In table 1 the number of the field visits are shown. The total number of all observed plots is 663. Fields with more then one variety were divided in single plots. This also was done in the case that the production methods was different in fields ore the size was higher than 20 ha.

Table 1. Number of observed fields

Year	Production areas	Fields	Plots
2001	7	150	237
2002	5	138	213
2003	5	133	213
total	17	421	663

The epidemiology differs on a high level in the three years and also in the five observation areas which are wide spread it over Germany. The two assessed areas Eich (Rheinland-Pfalz) and Dötlingen (north-west Niedersachsen) are presented in this paper in an exemplary way. Eich is characterised by structures with small plots. Some fields are irrigated and covered with polyethylene. In Dötlingen potatoes were grown under "normal conditions". The normal field size is about five times larger than in Eich. The planting dates were also about two or three weeks later.

In table one is indicated that in both growing regions the first infections appeared on leaves and stems at the same time or the first infection was visible on leaves only. Exceptional from this observations in 2002 in Eich no mixed infection on leaves and stems was recorded. Appreciable infections singular on stems were observed in 2002 in Eich and in Dötlingen. An explanation for this stem infections may be periods with high rainfall after planting. In 2003 the number of infected fields was very low. This was given by the extreme dry period in springtime.

Table 2. Percentage of first infections on plants.

Year/Area	Stem infections (%)		Leaf infections (%)		Stem and Leaf infections (%)	
	Eich	Dötlingen	Eich	Dötlingen	Eich	Dötlingen
2001	0	46	38	23	62	31
2002	36	3	64	58	0	39
2003	0	0	58	0	44	100

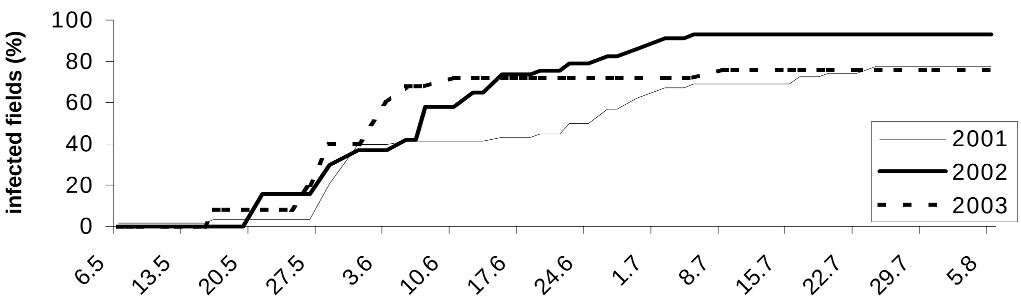

Figure 2 Spread of first appearance in Eich 2001-2003

The comparison of the *P. infestans* -epidemics in all assessed areas showed that the first infections in the plants did not appear in the same time or as an uniform increase. The appearance of the infections occur in temporal restricted intervals. As an example of this observation the results of area Eich are presented in figure 2.

The diagram indicates that later than the 27th of May 2001 the number of new infected plots increased on a high level. On a level of more than 70 % infected plots the disease outbreak came to an end. In the years 2002 and 2003 the increase of infected fields was continued continuously over a lot of weeks. In the three investigated years at Eich the first appearance of late blight happened in the third week of May. The first observed late blight in Dötlingen in 2001 occurred at the 26th of June. In 2002 this event happened three weeks earlier at the 4th of June (figure. 3). In 2003 the infection level was very low. It reached only 10 %.

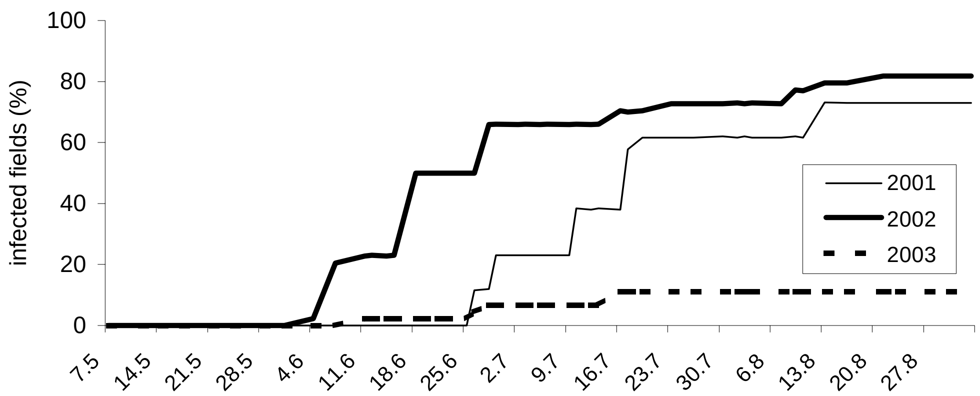

Figure 3. Spread of first appearance in Dötlingen 2001-2003.

B) Development of late light

By using the model SIMPHYT 3 (GUTSCHE 1999) which is driven by hourly data of temperature and air humidity the development of late blight disease in the areas was described. The model calculates daily the “Phytophthora efficacy value (pew)”. This “pew” you was accumulated t to an infection pressure index.(ipi). The correlation between „ipi“ and the percentage of infected fields was calculated with the function of an linear regression. Figure 4 and 5 indicate that the correlations in these six cases succeed in an certainty measure higher than 70%.

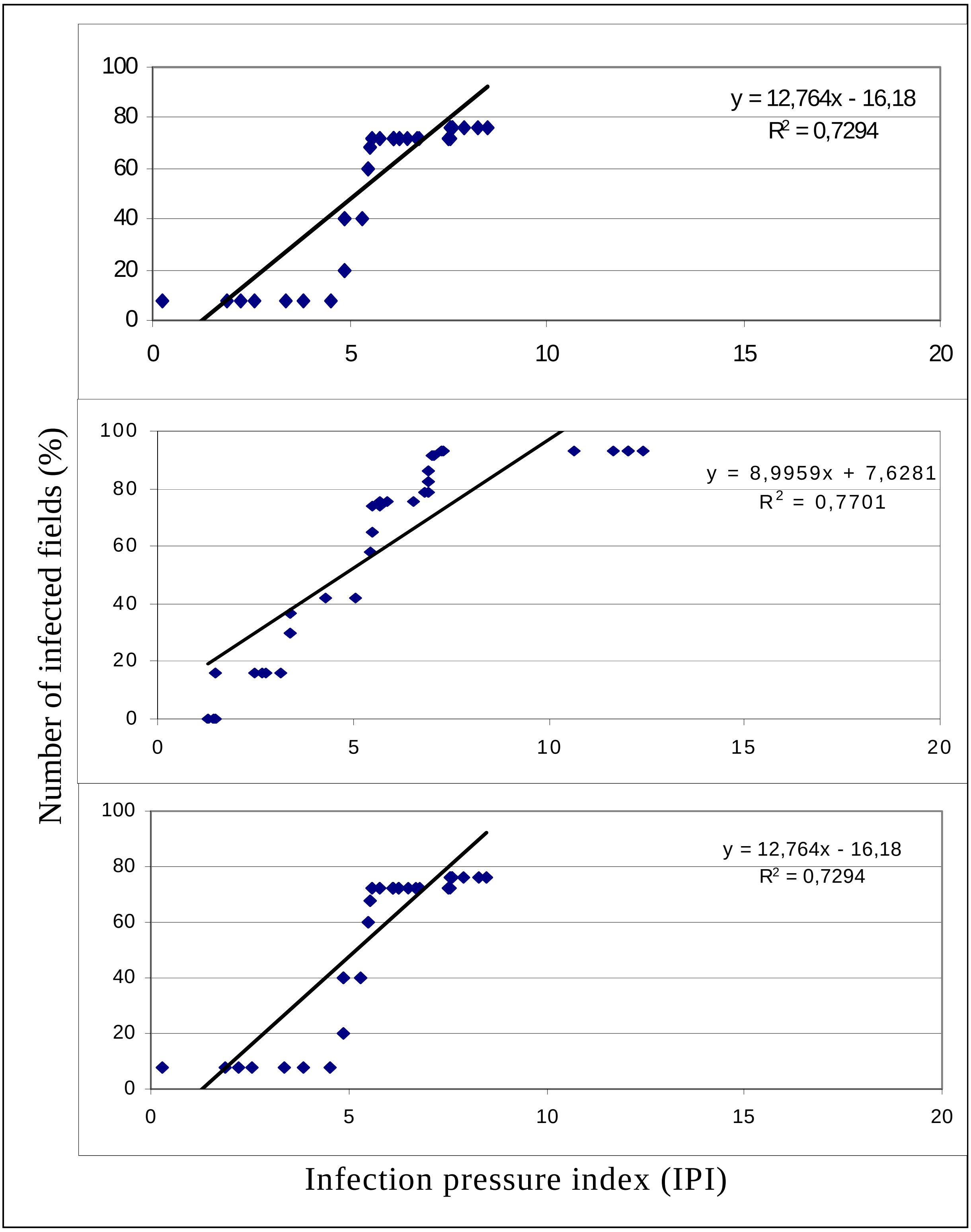

Figure 4. Regression between the number of infected fields and the infection pressure index in the Eich region

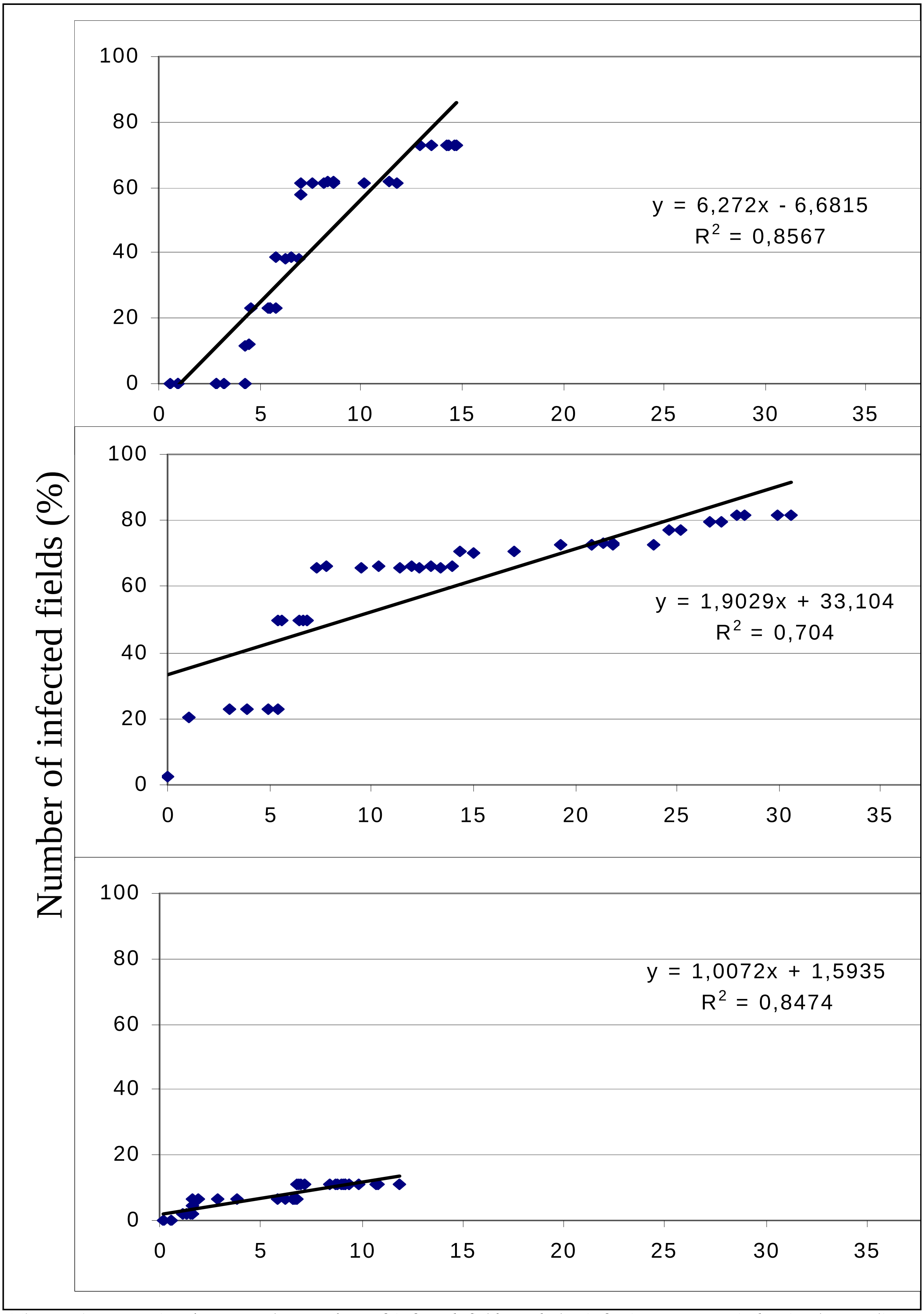

Figure 5. Regression between the number of infected fields and the infection pressure index in the Dötlingen region.

Conclusions

The evaluation of the development of late blight disease outbreak was enabled by complete datasets for five potato growing areas. The results of the investigations allow assessing al factors which affect the first appearance of *P. infestans*. The epidemics of late blight didn't reach each plot of an area in a short time span. It was pointed out that the infection increases in intervals. This is high correlated by the meteorological conditions. The development of Phytophthora within an potato growing area can be compared to the development of the disease in a single plot. With this result it is possible to calculate the risks of the spread of Phytophthora after the first appearance by mathematic model simulation model SIMPHYT3.

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Evaluation of potato cultivars for organic or reduced input production

L R. COOKE AND G. LITTLE

Applied Plant Science Division, Department of Agriculture and Rural Development,
Newforge Lane, Belfast, BT9 5PX, UK

Summary

Small-scale field trials carried out in Northern Ireland between 2001 and 2003 under high infection pressure showed that some potato cultivars had sufficient resistance to late blight to be grown with minimal inputs even under these conditions. Tuber infection is the most problematic phase of the disease for Northern Ireland growers. The trials confirmed the known lack of correlation between foliar and tuber resistance and showed the importance of evaluating tuber susceptibility. Of the 12 cultivars evaluated over the three years, Sárpo Axona, Mira and Tominia proved the most resistant, but may not appeal to the local market due to their red skin colour. The cultivar which performed best overall in terms of blight resistance and agronomic factors was Orla, a first early, which although only moderately resistant to foliar infection proved more resistant to tuber infection. Milagro also showed potential and stored well. Santé, which is currently the widely grown organic cultivar in the UK, also performed acceptably.

Keywords: *Phytophthora infestans*, potato late blight, potato cultivar.

Introduction

During the 1980s and 1990s, research on the control of potato late blight in Northern Ireland focused on highly blight-susceptible cultivars such as Up-to-date (e.g. Cooke and Little, 1998). However, trials elsewhere in the UK showed the potential for integration of fungicide use with more field-resistant cultivars (Gans *et al.*, 1995; Gans, 2003) and laboratory studies of the aggressiveness of Northern Ireland *P. infestans* isolates on detached potato leaflets demonstrated that isolates have lower infection frequency, longer latent periods, slower lesion growth and reduced sporulation capacity on more field-resistant cultivars (Carlisle *et al.*, 2002). In 2000, a small-scale Northern Ireland field trial using fungicide programmes designed to give different levels of protection showed that with a cultivar as susceptible as Bintje, only the 'low risk' programme provided acceptable control, but that on the more resistant cultivars, Santé and Navan, a longer spray interval gave acceptable foliar blight control (Cooke *et al.*, 2001). Due to exceptionally wet weather in autumn 2000, it was not possible to assess effects of treatments on tuber blight.

This paper reports results of field trials carried out in the period 2001-2003 in which 12 potato cultivars with differing levels of field resistance to late blight were evaluated for their potential use in Northern Ireland for organic or reduced input production.

Materials and Methods

All trials were carried out at the Agriculture and Food Science Centre, Belfast.

2001 Field trial

The trial was planted on 11 May 2001 in a split-plot design with three fungicide programmes as main plots, four cultivars as sub-plots and four replicate blocks. Each sub-plot comprised two drills x ten tubers of each cultivar (3 x 1.5.m). Main plots were separated by pairs of unsprayed drills of cv. Désirée, which were inoculated (25 July) with phenylamide-resistant and -sensitive Northern Ireland isolates of *P. infestans* and served as an infection source. Irrigation was provided by a rain-gun when required. The four test cultivars, selected on the basis of their blight resistance, are shown in Table 1. The fungicide programmes were applied high volume by knapsack sprayer. Treatments were:

- 'Fubol Gold' (1.9 kg ha-1; 76 g metalaxyl-M + 1216 g mancozeb ha-1 at 14-d intervals (25 June, 9 July) followed by 'Shirlan' (300 ml ha-1; 150 g fluazinam ha-1) at 14-d intervals (23 July, 7, 20 August, 3 September).
- 'Cuprokylt' (2.5 kg ha-1; 1.25 kg copper ha-1 as copper oxychloride) depending on infection pressure (23 July, 7, 20 August).
- No fungicide application.

Foliar blight was assessed weekly on all drills from 8 August. The trial was desiccated on 11 September and lifted on 3 October. 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 (17 October). The number and weight of firm blighted tubers >35 mm was assessed (and diseased tubers discarded) on 8-14 November and again 18-25 March 2002.

Table 1. Cultivars used in Northern Ireland field trials, 2001-2003.

Cultivar	Blight resistance [a]	Breeder	Trials in which used		
			2001	2002	2003
Santé	7, 6	J.Vegter, Netherlands	√	√	√
Milagro	8, 6	DARD, N.Ireland, UK	√	√	√
Navan	5, 4	DARD, N.Ireland, UK	√	√	
Pomeroy	7, 5 b	DARD, N.Ireland, UK	√		
Orla	6, 7 b	Teagasc, Carlow, Ireland		√	√
Remarka	6, 8 b	E.Kramer, Netherlands		√	√
Valor	medium-high b	Caithness, Scotland, UK		√	
Axona	high b	Sárpo, Hungary		√	√
Tominia	high b	Sárpo, Hungary		√	√
Mira	9, 9	Sárpo, Hungary			√
Lady Balfour	5, 7	SCRI, Scotland, UK			√
Milva	high b	S.J. Berding, Germany			√

[a] *Where available, NIAB ratings for blight resistance are given on a 1-9 scale for foliar and tuber blight resistance respectively, where 9 is maximum resistance. Other ratings (indicated by b) are taken from the literature or estimates from breeders/researchers.*

2002 Field trial

The trial was planted on 10 May 2002 in a split-plot design similar to that used in 2001 except that two fungicide programmes and eight cultivars (Table 1) were evaluated. The cultivars were all reputed to have good field resistance to late blight and were from a range of sources including two Hungarian ones (Axona and Tominia) bred by Sárpo Kft. Single unsprayed drills of cv. Désirée were planted between every four sub-plots and inoculated (16 July) to act as an infection source. The two treatments were:

- 'Headland Copper' (5 l ha-1; 1.25 kg copper ha-1 as copper oxychloride) depending on infection pressure (4 July, 18 July, 1 August, 15 August and 29 August).
- No fungicide application.

Foliar blight was assessed twice weekly from 25 July. The trial was desiccated on 4 September and lifted on 2 October. 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 (31 October – 6 November). The number and weight of outgrades (greened, cracked, misshapen, etc.) and of firm blighted tubers >35 mm was assessed and the unmarketable tubers discarded (22-26 November). The remaining 'healthy' tubers were re-assessed in March 2003, however, as dry rot had developed, but no further blight, these data are not presented.

2003 Field trial

No fungicide programmes were included in the 2003 trial; cultivar was the only factor. It was planted on 9 May 2003 in a complete randomised block design with four blocks of plots (3 drills x 10 tubers) of nine cultivars (Table 1). Single unsprayed drills of cv. Désirée were planted between every three plots and inoculated (16 July) to act as an infection source. Foliar blight was assessed twice weekly from 29 July. The trial was desiccated on 10 September and lifted on 24-25 September. 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 (17-20 November). The number and weight of outgrades and of firm blighted tubers >35 mm was assessed and the marketable yield determined (December 2003 – January 2004). No more blight developed during further storage.

In addition, to evaluate tuber blight resistance directly, plots of the same cultivars used for the main 2003 trial, plus the susceptible standards Home Guard and Up-to-date, were grown and maintained free of foliage blight by application of non-systemic fungicides. Tubers were lifted on 25 August, placed rose-end up in trays lined with moist capillary matting (two replicate trays of 20 tubers per cv.) and immediately inoculated by spraying with a sporangial/zoospore suspension (5 x 104 sporangia ml-1) of a mixture of Northern Ireland *P. infestans* isolates. After three weeks' incubation (high humidity, 15°C), they were assessed and the percentage infected tubers calculated.

Results

2001 Field trial

Foliar blight was first observed on some of the untreated and copper oxychloride-treated sub-plots on 8 August. With the 'Fubol Gold'/'Shirlan' programme, foliage lesions were first seen on 15 August and very little disease developed subsequently except on cv. Pomeroy (Table 2). In the untreated plots, more foliar blight developed on Navan than on Santé, in contrast to the year 2000 trial (Cooke *et al.*, 2001), while Pomeroy proved slightly more resistant than Santé, but produced a large amount of foliage and was very late maturing. Milagro had the least foliar blight and yielded well. It was concluded that future trials should concentrate on cultivars for organic production and therefore programmes based on conventional fungicides applied at extended intervals were omitted.

Table 2. Foliar blight, tuber blight and yield of four potato cultivars, 2001 field trial.

Cultivar/ treatment	Foliar blight (%)[a]	AUDPC	Tuber blight and rots (kg/drill)	Marketable yield (kg/drill)
'Fubol Gold'/'Shirlan'				
Santé	0.3	3	0.16	12.03
Milagro	0.0	6	2.11	15.62
Navan	1.3	13	0.58	14.21
Pomeroy	3.8	27	2.47	12.56
'Cuprokylt'				
Santé	18.9	100	0.75	11.49
Milagro	0.3	2	2.80	14.27
Navan	18.8	123	1.79	9.02
Pomeroy	21.5	171	2.80	10.85
Untreated				
Santé	82.5	822	0.77	11.54
Milagro	18.9	164	3.06	11.62
Navan	91.9	1338	0.64	11.86
Pomeroy	65.6	721	1.32	10.13
L.S.D. ($P<0.05$)	17.96	249.0	1.500	4.777

[a] *final assessment 5 September 2001*

2002 Field trial

Very high rainfall before planting and during the growing season caused water-logging. Foliar blight was first seen in untreated Navan and Orla at the end of July and increased throughout

August reaching c. 90-100% in the untreated Navan, Orla, Valor and Santé by 4 September (Table 3). The untreated Remarka and Milagro developed significantly less foliage infection and none was seen in the two Sárpo cultivars. The ranking order was similar for the copper oxychloride-treated plots. The cool, wet conditions resulted in low yields and much soft rot; while this may have originated in tuber blight, its severity made it impossible to ascertain the primary cause. The yields of cvs. Milagro, Axona and Tominia were lower than the others; these cultivars were late maturing and were probably still bulking up when the haulm was destroyed. Valor and Orla produced the greatest yield of healthy tubers with very few blighted or soft rotted tubers, despite being among those with the most foliage infection.

Table 3. Foliar blight, tuber blight and yield of eight potato cultivars, 2002 field trial.

Cultivar/ treatment	Foliage blight (%)[a]	AUDPC	Tuber blight and rots (kg/drill)	Outgrades (kg/drill)	Marketable yield (kg/drill)
'Headland Copper'					
Santé	50.0	313	0.28	2.17	5.37
Milagro	4.7	34	0.81	3.55	2.98
Navan	50.0	451	0.57	1.80	5.08
Orla	61.2	468	0.10	1.67	6.65
Remarka	18.1	78	0.13	3.50	4.80
Valor	50.0	396	0.14	1.12	8.99
Axona	0.0	0	0.82	0.93	4.62
Tominia	0.0	0	0.89	1.99	5.40
Untreated					
Santé	88.1	988	0.30	1.62	5.48
Milagro	62.5	389	0.97	2.34	2.61
Navan	99.4	2037	0.20	1.13	3.99
Orla	97.5	1679	0.24	1.21	6.67
Remarka	75.0	536	0.21	2.49	6.36
Valor	92.5	1308	0.06	0.72	7.55
Axona	0.0	0	0.85	0.78	4.24
Tominia	0.0	0	0.99	2.20	5.34
L.S.D. ($P<0.05$)	17.06	221.2	0.429	0.841	1.815

[a] *final assessment 4 September 2002*

2003 Field trial

Since in 2002, the ranking orders of cultivars from the copper-treated and untreated plots were similar, it was decided to use untreated plots only in 2003. However, tuber susceptibility was evaluated in a separate trial as the 2002 results had indicated a need for this. Cv. Navan was not used in 2003 because it had proved too susceptible and Valor was excluded due to commercial considerations, but three additional cultivars were included.

Foliar blight began to spread into the cultivar plots at the end of July and by the end of August was >95% in Orla, Santé, Milva, Remarka (Table 4). Infection was noticeably delayed in Milagro and, to a greater extent, in Lady Balfour. No confirmed foliar blight symptoms were observed on the Sárpo cultivars, Axona, Tominia or Mira. Orla produced the greatest yield of healthy marketable tubers, followed by Milva, then Milagro and Lady Balfour. The Orla tubers were very attractive with a good skin finish.

Table 4. Foliar blight, tuber blight and yield of eight potato cultivars, 2003 field trial.

Cultivar	Foliage blight (%)[a]	AUDPC	Tuber blight and rots (kg/drill)	Outgrades (kg/drill)	Marketable yield (kg/drill)
Santé	99.6	2168	0.08	1.64	8.94
Milagro	93.8	1540	0.00	1.98	9.34
Orla	99.6	2252	0.33	1.63	10.39
Remarka	99.2	1949	0.56	3.38	6.16
Axona	0.0	0	1.21	2.84	6.39
Tominia	0.0	0	0.19	5.86	6.54
Mira	0.0	0	0.43	5.30	7.72
Lady Balfour	82.9	1423	0.25	3.17	9.34
Milva	100.0	2011	0.45	2.52	9.70
L.S.D. (P<0.05)	5.73	140.0	n.s.	1.585	2.268

[a] *final assessment 9 September 2003*

In the evaluation of tuber blight resistance, all tubers of the susceptible standard cultivars Home Guard and Up-to-date developed blight (Table 5). Of the test cultivars, 75% of Lady Balfour tubers were infected, but only 10% of Orla, while only a single tuber of each of Sárpo Mira and Tominia was infected and all Axona tubers remained healthy.

Table 5. Tuber blight in directly inoculated tubers, 2003 field trial.

Cultivar/treatment	Tuber blight (%)
Santé	40.0
Milagro	32.5
Orla	10.0
Remarka	50.0
Axona	0.0
Tominia	2.5
Mira	2.5
Lady Balfour	75.0
Milva	52.5
Home Guard	100.0
Up-to-date	100.0
L.S.D. (P<0.05)	12.48

Discussion

The field trials were all exposed to a high infection pressure provided by typical Northern Ireland *P. infestans* isolates, which belong to the aggressive new population (Carlisle *et al.* 2001), and disease development was encouraged by weather conducive to late blight supplemented with irrigation when required. Despite this, the trials demonstrated that several of the cultivars evaluated had sufficient field resistance to allow them to be grown with minimal inputs and still produce an acceptable yield. The need to evaluate cultivars over several seasons was shown by the behaviour of cvs. Navan and Santé. In the trial in 2000, Santé proved considerably more susceptible to foliage infection than cv. Navan despite its higher NIAB ratings (Cooke *et al.*, 2001) and it was also the most severely infected cultivar in a larger-scale trial carried out at another DARD site in 2001 (data not presented), but in the trials reported here in 2001 and 2002, Navan developed more foliage blight than Santé. These discrepancies may be due to the presence of major gene resistance in Santé; unfortunately the virulence genes possessed by the isolates used to inoculate the trials were not determined.

The feasibility of reducing inputs on potatoes in a high rainfall area such as Northern Ireland is crucially dependent on the risk of tuber infection. A cultivar with high foliar blight resistance but susceptible to tuber blight is much more problematic for growers than one with moderate foliar, but good tuber resistance. The trials clearly demonstrated the well-known lack of correlation between foliar and tuber blight resistance; thus Lady Balfour has good foliar resistance, but tubers which proved very susceptible, whereas Orla has moderate foliar resistance, but good tuber resistance.

Of all the cultivars evaluated, those from Sárpo proved to be the most resistant to foliar infection, very thorough searches failed to find any lesions on Axona and Tominia in 2002 or on Axona, Tominia and Mira in 2003, a result in agreement with trials elsewhere (Shaw and Johnson, 2004). Although some rots developed in the harvested yield, it is likely that few of these were due to blight, since the direct whole inoculation test showed these cultivars to be very tuber resistant. The basis of their resistance has not been fully established; Shaw and Johnson (2004) concluded that a role of R-genes in their resistance cannot be excluded. Commercial considerations may, however, limit the adoption of these particular Sárpo cultivars by the Northern Ireland market, since they all have deep red skin and the local preference is for white-skinned or parti-coloured varieties.

Disease resistance is only one of the factors which influences variety choice; agronomic factors tend to be more important. Orla, which is white-skinned and has pale yellow flesh, was concluded to be the most attractive option for the Northern Ireland market. Unusually among field-resistant cultivars, it is early maturing and so has a better chance of being harvested in good conditions. Despite relatively rapid and extensive foliar blight development (compared with more foliar resistant cultivars), it yielded well, little tuber infection occurred and the proportion of outgrades was less than for the other cultivars. Of the other cultivars, Milagro also showed potential and stored well. In 2004, Orla is being grown in Northern Ireland using reduced inputs for a commercial potato pre-packer.

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Late blight management in organic seed potato production

ARI LEHTINEN AND ASKO HANNUKKALA

Agricultural Research Centre of Finland, Plant Production Research, Plant Protection
FIN-31600 Jokioinen
ari.lehtinen@mtt.fi, asko.hannukkala@mtt.fi

Summary

The most important issue in seed potato production is the sanitary quality of produced seed. In organic production the quality of yield is very hard to control as there are no effective chemical treatments allowed for pest control. Therefore the volume of organic seed potato production is very low. The aim of this study was to define factors of success and failures in disease management in organic potato production generally due to lack of farms producing seed potato. The efficacy of widening the row space in suppressing the potato late blight epidemic development was investigated in field trials. All farmers interviewed were very concerned about leaf blight, as it has become common that blight stops the growing season by the middle of the August. One reason for early onset of blight epidemics is poor crop rotations as the most common preceding crop of potato was potato. This increases the risk of oospore infections. Another serious drawback was commonly occurring overdose of nitrogen when green manure was used as a fertilizer. The onset of tuber formation was considerably delayed due to excessive release of nitrogen from green manure causing significant tuber size and yield reduction. In our trials widening of the row space did not delay the epidemic, but slowed it down a little. As the widening of the row space always decreased yield we cannot recommend it for blight control.

Keywords: Potato, Potato late blight, *Phytophthora infestans*, organic farming, Seed potato, Nitrogen, Crop rotation, Row space

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Introduction

Potato late blight caused by *Phytophthora infestans* is the main factor determining the end of the growing season of organic potato by killing the canopy. As a polycyclic disease with many asexual cycles, the control of the disease is most effective by protective chemical treatments of the haulm. However, in organic production there are no effective compounds available for blight control. In Finland it is not allowed to use copper and sulphur compounds against late blight although many other countries approve these fungicides also in organic potato production (Cooke 1992, Möller *et al.*, 1996, Meink and Kolbe 1999).

The main aim in the certified seed production is the high sanitary status of the produced seed. In organic seed potato production this is usually harder to achieve, as the available control measures to prevent the contamination by disease are often rare. According to EU legislation organically produced seed must be used in organic production. During the transition period ended at the end 2003 it was legal to use conventionally produced seed if organically produced propagation material was not available. In Finland there was only one packing company in the register of Plant Production Inspection Centre in 2002 marketing organically produced seed potato. The only variety available was Van Gogh. Due to lack of available certified organic seed the transition period was continued by Commission Regulation 1452/2003.

The principle factor prohibiting the organic seed potato production is the threat caused by plant diseases, especially potato late blight. It is a necessity to improve pest management practises to guarantee the availability of organically produced seed potato in organic potato production. The aim of this study was to define factors of success and failures in disease management in organic potato production and test efficacy of widening the row space to suppress the progress of potato late blight epidemics.

Materials and methods

The database maintained by The Information Centre of the Ministry of Agriculture and Forestry was utilised to find potential farmers for the survey and to get background information on their crop management practises. Selected organic potato growers were further interviewed to get more detailed information on their specific crop and disease management practises by a questionnaire. Farms were also visited several times at July and August for studying their potato crops and for recording the onset of blight epidemics. During the visits also potential primary inoculum sources for the epidemic were traced to conclude whether the epidemic was tuber, soil or air borne.

The effect of row space to the onset and progress of the blight epidemic was studied in field experiments at 5 experimental sites in different parts of Finland. At each site the trial was constructed as a complete randomised complete block design with four replicates. The trials were planted with either Bintje or Idole. The row spaces tested were 80 cm, one empty hill at both sides of a single potato hill and one empty hill at both sides of two adjacent hills. All plots had four hills with potato in which recordings were done separately. After the onset of the epidemic the disease progress was scored 2-3 times a week by estimating the percentage of diseased leaf area. The occurrence of tuber blight in the yield was rated in October 2003 and January 2004.

Results and discussion

The Information Centre of the Ministry of Agriculture and Forestry (TIKE) maintain a database containing all field level information required for farmers when they apply for substitutes from EU and Finnish government. According to TIKE approximately 1000 farms produced organic potato in year 2002. The potato area was very small in most of those farms as only 100 farms had more than 1 ha potato. We excluded farms with less than 1 ha potato out of our study as we supposed them to produce potato for home consumption and possibly for fresh markets. We did not consider these as truly professional potato growers. Out of the 100 remaining farmers 25 were interviewed and 40 of them were visited.

All interviewed farmers considered blight as the worst disease in their production. All farmers also regarded the destruction of the canopy as the most important consequence of the blight attack. Majority of the farmers did not consider tuber blight as a big problem. The most probable reason for this is very fast defoliation of unprotected canopy, which reduces the probability of rain showers capable to wash sporangia on the tubers before sporangia lose their viability.

According to TIKE's database potato was the most common preceding crop of potato. Also, 25 percent of the interviewed farmers grew two or more consecutive potato crops. It has been established that oospores are formed at potato canopy in Finland and they are capable to overwinter and still infect potato (Lehtinen *et al.*, 2002). Oospore production is very likely in organic potato field as both mating types are present in Finland (Hermansen *et al.*, 2000). Thus inadequate rotation in organic potato production cause serious risk of early late blight attack.

Approximately half of the farmers who were interviewed used green manure for fertilizing potato. According to TIKE's database green manure was the second common preceding crop of potato. Almost all of the farmers who used green manure grew potato following year. During our visits to the farms we noted that in several cases potato crop following green manure was very vigorous, dense and tall. The onset of tuber formation was considerably delayed due to uncontrolled release of nitrogen from green manure resulting in an overdose in comparison to the requirements of the crop. Delayed tuber formation reduced tuber yield drastically and in one extreme case no tubers were present when we observed the first blight lesions in the canopy. It seems to be easier for the farmer to estimate the content of available soluble nitrogen in manure or compost than in green manure. We did not observe any cases of nitrogen overdose at the farms using manure or composts. Farmers should consider very carefully if it is reasonable to plant potato subsequently after green manure crop. It could be justified to grow one cereal crop between green manure and potato and use manure or compost as additional fertilizer if needed and available before potato.

Wider row space than used in conventional farming was thought as a possible tool for delay and slow down the blight epidemic. Some Finnish farmers also claimed that adoption of this practice has improved blight control in their production. In our trials widening of the row space did not delay the epidemic, but slowed it down a little. However, the same blight rating as in narrowest row space was achieved within one week in widest row space (Figure 1). Widening the row space always decreased the total and marketable yields. Very sparse row space treatments were used, as we wanted to test if row space has any effect of the blight epidemics. Thus it is a practise that we cannot recommend for blight control.

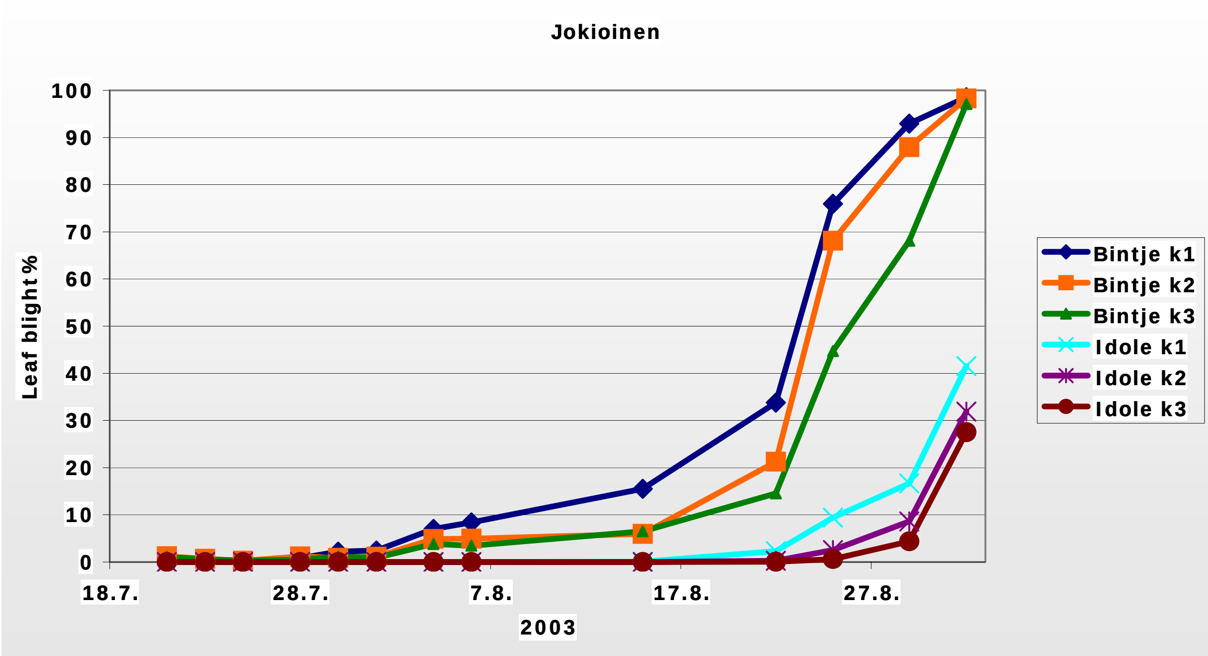

Figure 1. The effect of the widening row space on disease progression in a field trial at Jokioinen. K1 normal row space (80 cm), K2 one empty hill at both sides of two adjacent hills, K3 one empty hill at both sides of a single potato hill.

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Eighth Workshop of an European Network for development of an
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End of season management of tuber blight: preliminary results from a new project

ARNE HERMANSEN[1], RAGNHILD NÆRSTAD[1], VINH HONG LE[1], JAFAR RAZZAGHIAN[1] & ELDRID L. MOLTEBERG[2]

The Norwegian Crop Research Institute (NCRI)
[1]Plant Protection Centre, Dept. of Plant Pathology, Høgskoleveien 7, N-1432 Ås
[2]Apelsvoll Research Centre, Rute 509, 2849 Kapp

Summary

In 2003 a five year project on end of season management in potato crops were started in Norway. Tuber blight, caused by *Phytophthora infestans*, is an important issue in this project. Preliminary results with the cultivar Folva showed that haulm killing 14 days prior to harvest reduced the number of spores in the haulm and soil at harvest and the level of tuber infection related to harvest on "green haulm" with or without treatment with fluazinam 7 days before harvest. However the treatment with fluazinam reduced the number of infective spores in the soil at harvest related to untreated green haulm. Data from these and other experiments in the project will be used to make guidelines for end of season management related to the late blight situation.

Keywords: Potato late blight, *Phytophthora infestans*, tuber blight, haulm killing, desiccation, fluazinam

Introduction

In Norway the growing season is short in the most important potato areas. The main potato crop is planted in mid May and is harvested in mid September. Thus it is important to keep the haulm green as long as possible to obtain high yields. The normal procedure is however to use diquat (Reglone) as a desiccant about 14 days prior to harvest. Some experiments show that harvest ”on green haulm” might improve the tuber quality (skin-set) related to Reglone treatment (Bevis 1985) and that desiccation with chemicals only should be used on physiological mature potatoes (Barten 1986).

Late blight, caused by *Phytophthora infestans*, is an important problem for potato growers in Norway. It is a general opinion that it is risky not to kill the haulm before harvest if late blight is present on the haulm. The potential for tuber infections is high if the cultivars have low level of resistance to tuber blight. Among several other factors, the maturity of the crop is also important for the resistance to tuber infection (Bain & Møller 1999).

One essential question is if it is possible to harvest tubers ”on green haulm” without increasing the risk of tuber blight in certain situations e.g. when the level of leaf blight is low and fungicides are used close to harvest. This question was raised in a project that started in 2003 dealing with tuber quality aspects after different end of season treatments of the potato crop. In addition to NCRI, the Norwegian Food Research Institute and Solør-Odal and SørØst experimental groups are also involved in the project.

The main goal of the late blight part of this project is to find the infection potential of *P. infestans* for tuber blight at low disease severity levels and different end of season management strategies. This information will be used to make guidelines for desiccation of potatoes related to various factors as disease levels, climate, cultivars and soil types.

In this paper some preliminary data from small-plot experiments dealing with maturity and end of season management strategies are presented. The project will continue until 2007.

Materials and methods

Three trial sites in the southern part of Norway (Apelsvoll, Solør and Rygge) were established with the cultivar Folva (rated as 3 for leaf blight resistance and 5 for tuber blight resistance)
A split plot design was used with four end of season management strategies on the large plots:

1. Harvest on untreated green haulm
2. Harvest on green haulm sprayed with fluazinam (Shirlan; 500 g.a.i./litre) using 300 ml Shirlan/ha 7 days before harvest
3. Chemical desiccation with diquat (Reglone; 200 g.a.i/litre) using 3000 ml Reglone/ha 14 days before harvest
4. Partly mechanical haulm killing and 1500 ml Reglone/ha 14 days before harvest

In the small plots two maturity classes were obtained by planting pre-sprouted or cold stored seed potatoes.

The trial at Apelsvoll was established on a moraine soil, and at Solør and Rygge on silty soils.

All the plots were treated with late blight fungicides until 6 weeks before harvest.

The plots were inoculated with a sporangial suspension of *P. infestans* (15.000 sporangia/ml) 4 weeks before harvest.

Leaf blight (percentage infected leaves) was assessed several times during the season.

Tuber blight was recorded on two samples from each plot. One sample of 3 kg potatoes was examined just after harvest. Another sample of 5 kg potatoes was placed humid for 3-4 weeks at 15 °C. The number for tuber blight was the sum of blight and soft rot since the correlation was strongly positive for these two variables. (Soft rot was probably a secondary problem after tuber blight infections in the incubated sample).

Sporangia in the haulm and in the soil were assessed in the plots 14 days before harvest and at harvest. Plants (5 stems per plot) were shaken in a plastic bag containing 500 ml of water for 30 seconds. The number of spores was counted in a haemocytometer. Infective sporangia in the soil were assessed using the tuber slice method described by
Lacey (1965).

Results and discussion

Before the end of season treatments started (14 days before harvest) the percentage infected haulm was low (0.2-0.4 %) at Apelsvoll and medium (4.0-8.3 %) and (3.7-11.7 %) at Solør and Rygge, respectively.

At harvest there were significant differences between fields and end of season treatments in the number of sporangia in the haulm. The Shirlan treatment had more sporangia in the haulm than the other treatments at Rygge (Figure 1). This is probably because of uneven level of infections in the plots at this site. The tuber slice test showed that there were significant effects of end of season treatments on number of viable spores. Lowest level of viable spores was found in the soil from the Reglone treatments. The Shirlan treatment caused lower levels of viable spores than the unsprayed green haulm treatment (Figure 2).

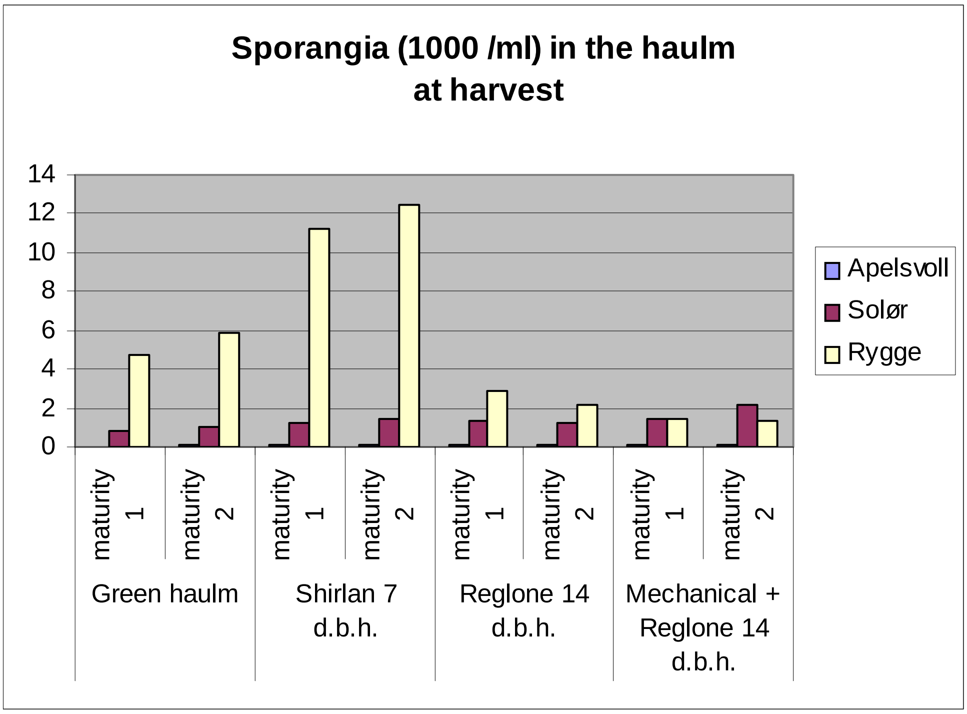

Figure 1. Sporangia in the haulm at harvest at three locations after four different end of season strategies and two maturity classes (1-cold stored seed potatoes, 2- pre sprouted seed tubers).

Haulm killing with Reglone 14 days before harvest caused less tuber blight than harvest on unsprayed green haulm. Treatment with Shirlan 7 days before harvest did not prevent tuber blight although less viable spores in soil were found. There were no differences in tuber blight between the two maturity classes (Figure 3). The differences in maturity was however relatively slight. Although the pre sprouted seed tubers emerged about one week earlier than the cold stored seed tubers, senescence of the haulm did not differ significantly (data not shown).

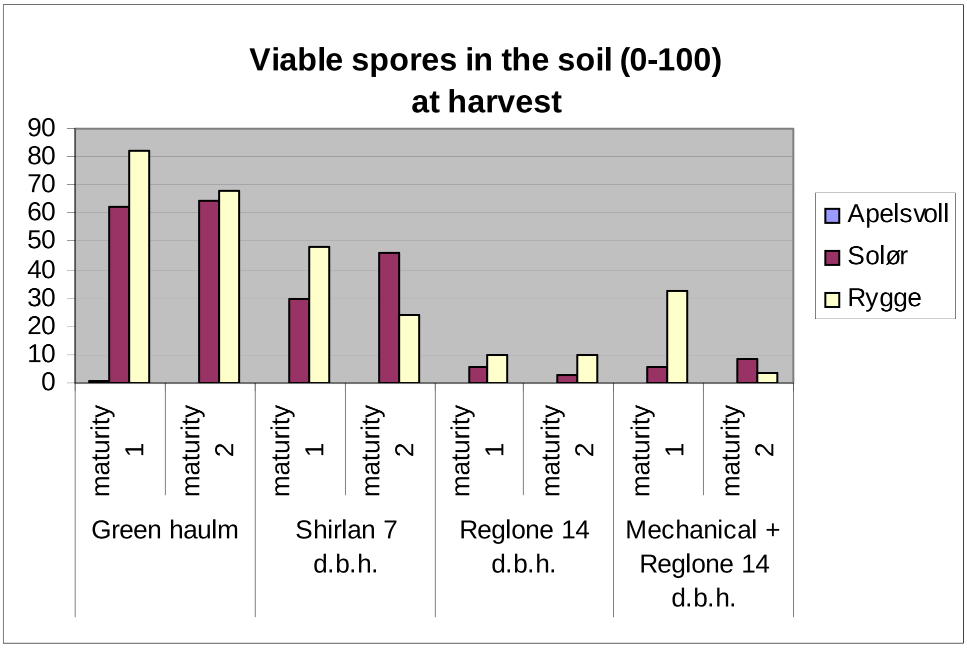

Figure 2. Viable spores in the soil at harvest at three locations after four different end of season strategies and two maturity classes (1-cold stored seed potatoes, 2- pre sprouted seed tubers).

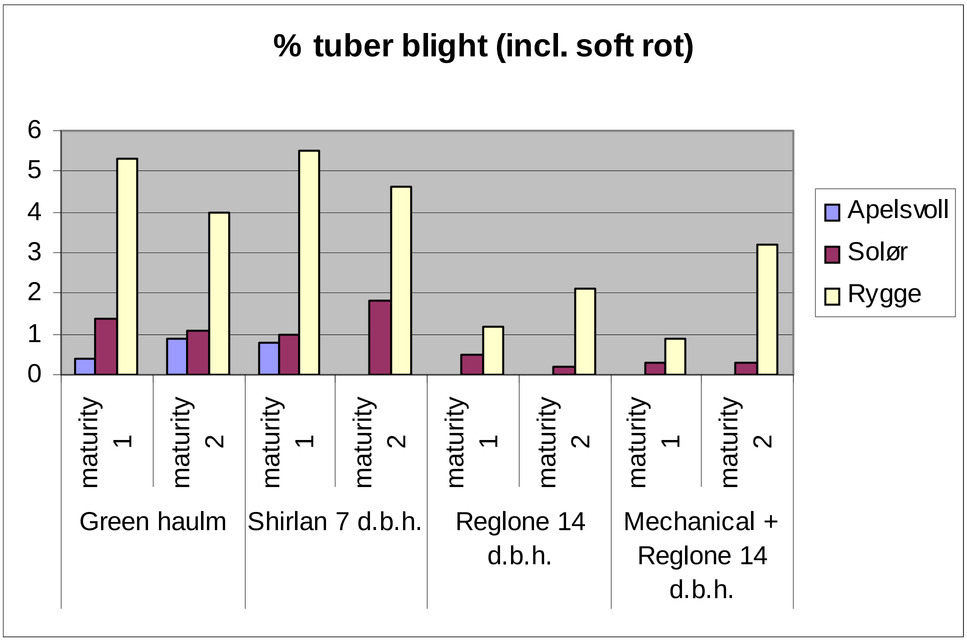

Figure 3. Tuber blight at three locations after four different end of season strategies and two maturity classes (1-cold stored seed potatoes, 2- pre sprouted seed tubers).

There were positive correlations between the infection level of *P. infestans* on the haulm and the number of spores in the haulm both 14 days before harvest and at harvest. There were no significant correlations between spores in the haulm and infective spores in the soil the same day. This is not surprising since the spores in the soil might be washed down from the haulm for a long period starting at the first time of emergence of sporulating lesions. The number of late blight infected tubers was positively correlated with the number of infective spores in the soil and the number of spores in the haulm at harvest.

Conclusions

Data from 2003 with the cultivar Folva shows that if late blight is observed 14 days before harvest, haulm killing should be carried out even at low disease levels. Harvest on green haulm might however be used in the future if more details regarding tuber blight infections are obtained and guidelines for the end of season treatments can be made. A more intense fungicide treatment could also be used to prevent tuber blight, but this is not a preferable strategy when the goal is to reduce the use of fungicides as far as possible. The fungicide strategies in the experiment will be slightly revised for the 2004 season. More data will come from this project in the next years.

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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

The significance of seed tuber-borne blight in two growing seasons

C. KELLY[1], R.A. BAIN[1] AND J-L. GENET[2]

[1] SAC, Ayr Campus, Auchincruive Estate, Ayr KA6 5HW, UK

[2] Du Pont de Nemours, European R&D Center F-68740 Nambsheim, France

Summary

The aim of the experiments in this paper was to examine the spread of *P. infestans* from blighted seed tubers to the growing haulm in two growing seasons. Fortunately the two growing seasons were quite different. 2002 was wet and ideal for blight development from early on whereas in 2003 conditions were considerably drier.

P. infestans originating from the seed tubers contributed little to the progress of the foliar epidemic in 2002. However, in 2003 most of the blighted plants that developed did so from seed-borne *P. infestans*. The recorded incidence of spread from seed to the haulm was 4.9%, generally higher than that reported in the literature. The results suggest that the period of survival of blighted seed tubers after planting is important in determining how extensively *P. infestans* is transmitted from seed tubers to the haulm. In both years the incidence of blackleg (*E. carotovora* spp *atroseptica*) was higher in plots grown from seed inoculated with *P. infestans* compared with non-inoculated tubers.

Blighted tubers were planted at the recommended depth or 2.54 cm deeper or shallower than recommended. As expected, the shallowest planting resulted in more plants with typical symptoms of seed tuber-borne blight than the other two treatments. However, unexpectedly, the deepest planted seed also gave rise to more blighted plants than the recommended planting depth.

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Introduction

There are three main primary sources of *P. infestans* to infect potato crops in the UK. Blighted haulm on dumps or volunteers or blighted seed tubers within the crop. The British Potato Council's Fight Against Blight Campaign was launched in 2003 with one of its main aims the removal of dumps as a primary source of blight inoculum. If this approach is successful then other sources of inoculum, including blighted seed, will become more important.

Infected tubers often rot before emergence has occurred. The rate at which blight develops on the seed and the number of infected tubers determines the infection of the foliage (Doster *et al.*, 1989). If the tubers rot too quickly emergence is reduced and infection of the foliage may not occur. Also the rate of seed borne infection is low, less than 1% (Hirst, 1955), and so can be easily missed.

The aim of the experiments in this paper was to examine the spread of *P. infestans* from blighted seed tubers to the growing haulm in two growing seasons. The spread from latently infected seed tubers was monitored in addition to that from positive controls (artificially inoculated seed tubers) and negative controls (*P. infestans*-free tubers). This paper evaluates the contribution of seed-borne blight to spread by comparing spread from the positive and negative controls. Spread from latently infected seed tubers will be described elsewhere. Fortunately the two growing seasons were quite different. 2002 was wet and ideal for blight development from early in the season whereas in 2003 conditions were considerably drier.

Previous work has shown that planting depth can affect the number of plants infected from the seed tubers (Boyd, 1980). It has been shown that increasing the planting depth decreases the number of plants infected. Therefore an experiment was set up to look at the effect of different planting depths on disease spread to the growing plant from the seed.

Materials and methods

In 2002 and 2003 field trials were set up to look at the movement of *Phytophthora infestans* from the seed to the growing plant. Different stocks were tested for presence of *Phytophthora infestans* by PCR. Stocks used for inoculated and non-inoculated controls tested negative for *P. infestans*. The same stock was used for the positive and negative controls.

Seed tubers were inoculated and stored to allow limited disease development before planting. The concentration of inoculum for these experiments was 200 sporangia in 200µl of sterilised water. Assessments were made weekly to look at the spread of blight on the foliage.

In 2002 seed was inoculated with isolate 05/01 and kept in a cold store (5 ^{o}C) for about two weeks before planting. Tubers were hand planted during the second week in May with a soil covering of 15 cm. For each treatment there were six replicate blocks and 100 tubers in each block. In 2003 seed was inoculated and kept in an ambient store for about two weeks prior to planting. Isolate used in 2003 was 04/01. Tubers were planted by hand during the last week in May with a planting depth of 16 cm. Each treatment had six replicates and 76 tubers in each plot. The experiment looking at planting depth was also planted in 2003. There were three planting depths 13 cm, 16 cm (recommended) and 18.5 cm. There were five replicates with 60 tubers in each plot.

Results and Discussion

In 2002 plant emergence for the inoculated treatment was 65.6% (all percentages stated as angular transformation) compared with 82.5% for the clean stock that year. In 2003 the inoculated treatment had an emergence of 73.9% compared with 86.4% for the clean stock. As can be seen plant emergence was higher in the second year. The results for 2002 suggest that *P. infestans* originating from the seed tubers contributed little to the progress of the foliar epidemic. No symptoms typical of seed tuber-borne blight were observed. Foliar blight was observed on the plants early in the season and the progress of the epidemic was similar in control plots and plots grown from inoculated seed (Fig. 1). No significant difference on any of the dates. This suggests that the *P. infestans* originated from an external source.

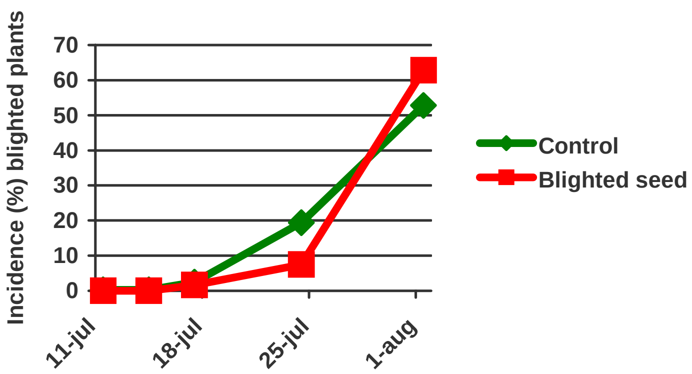

Table 1. LSD values for blight development 2002

Date	LSD
11-Jul	0.69
18-Jul	7.70
25-Jul	22.38
1-Aug	17.53

Figure 1. Development of blight on the haulm in 2002 (angular transformation)

However, in 2003 typical symptoms of seed tuber-borne blight were seen very early, in some cases a week after plant emergence had started (Fig. 3). In 2002 the trial was planted in a heavy soil and the growing season was wet. In contrast the trial was planted in a lighter soil and the growing season was exceptionally dry. There is strong circumstantial evidence that soil conditions in 2002-favoured early decay of seed tubers resulting in poorer emergence and little opportunity for spread of *P. infestans* from seed onto the haulm. In contrast, the soil conditions in 2003 encouraged the long-term survival of blighted seed thus maximising the opportunity for spread. The recorded incidence of spread from seed to the haulm was 4.9%, generally higher than that reported in the literature. Unusually, weather conditions in 2003 were not at all favourable for the spread of blight between plants above ground. Therefore although there was substantial spread of blight from seed tubers onto growing plants the weather conditions prevented a severe epidemic arising from this source of inoculum.

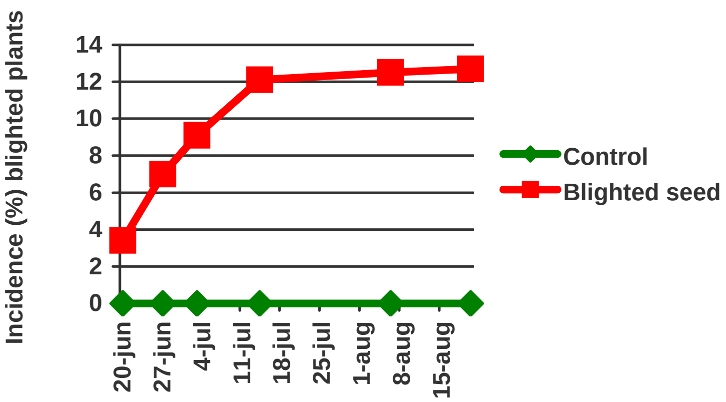

Table 2. LSD values for seed borne blight development 2003.

Date	LSD
20-Jun	2.17
27-Jun	2.49
4-Jul	3.09
18-Jul	2.63
8-Aug	2.98
15-Aug	3.08

Figure 2. Development of blight on the haulm in 2003 (angular transformation)

The spread of blight from seed tubers to the haulm was not related to Smith Periods. The spread of blight from the seed is dependent on sufficient soil moisture and how long the seed tubers survive after planting. How long the seed survives for depends on the size of blight lesion at planting, the moisture content of the soil at and after planting and the size of the seed.

Plants with blight originating from seed tubers can be very difficult to detect in the growing crop for several reasons. Firstly seed-borne blight occurs infrequently. The blight symptoms at first are restricted to the base of the canopy. Often the affected stems are very stunted and often only one stem is affected.

In both years the incidence of blackleg (*E. carotovora* spp *atroseptica*) was higher in plots grown from seed inoculated with *P. infestans* compared with non-inoculated tubers. In 2003 the healthy seed was wounded and stored in the same way as the inoculated treatments so as to eliminate the inoculation method. No blackleg was seen in these treatments only in those inoculated with *P. infestans*. Therefore it seems that the presence of *P. infestans* encouraged the expression of blackleg symptoms by the initially low number of blackleg bacteria on the seed. The most likely explanation is that the disruption of the seed tuber tissue by *P. infestans* provides adequate nutrition for the rapid multiplication of E. carotovora subsp. atroseptica on the inoculated seed tubers.

The impact of blighted seed on blackleg development is likely to be limited in practice because the incidence of blighted tubers will generally be low, especially in certified seed stocks. The exceptions are likely to be stocks of home-saved seed and perhaps where seed is cut and hygiene isn't adequate to prevent spread during the cutting process.

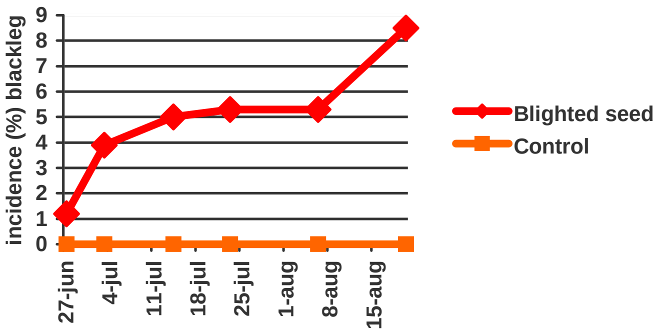

Figure 3. Blackleg development in plots grown from seed inoculated with *P. infestans* or not (control) in 2003 (angular transformation).

Table 3. LSD values for Blackleg development 2003.

Date	LSD
20-Jun	1.48
27-Jun	2.28
4-Jul	2.72
18-Jul	2.88
8-Aug	2.88
15-Aug	2.54

Previous work has shown that the incidence of blighted plants originating from blighted seed tubers is greater when the seed tubers did not have much soil cover compared with a typical depth of planting (Boyd, 1980). The result obtained in this study was more complicated (Fig. 4).

Table 4. LSD values for planting depth blight incidence

Date	LSD
17-Jun	1.09
14-Jul	2.15

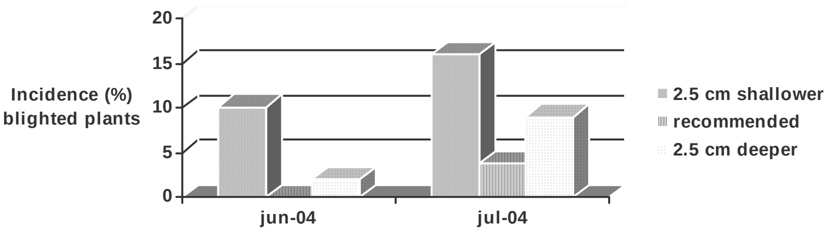

Figure 4. Incidence of blight in relation to planting depth

As expected, the shallowest planting resulted in more plants with typical symptoms of seed tuber-borne blight than the other two treatments. However, the deepest planted seed gave rise to more blighted plants than the recommended planting depth.

The results indicate that growers concerned about blight originating from seed should not plant the seed too shallow because this appears to facilitate the spread of *P. infestans* from seed tubers onto the haulm.

The threat of seed-borne blight must be kept in perspective. At the moment the most common source of blight in the UK remains potato dumps.

Acknowledgements

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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

Occurrence of early blight (*Alternaria* ssp.) at potato crops and results of its chemical control in Polish experiments

J. KAPSA AND J. OSOWSKI

Plant Breeding and Acclimatization Institute,
Department of Potato Protection and Seed Science, 76-009 Bonin, Poland
jkapsa@wp.pl ; j.osowski@wp.pl

Abstract

Early blight is distributed worldwide and essentially occurs wherever potatoes are grown. In the recent years early blight became a serious threat to potato crop. In general, early blight occurs earlier than potato late blight (42-64 days after potato planting) under Polish climatic conditions. Casual agent of early blight infects mainly foliage of potatoes, particularly of these cultivars that are less resistant. In some years symptoms of early blight can be found on potato tubers.

In field experiments crop losses due to early blight infection ranged from 6 to 45%. Chemical protection is one of the methods applied in early blight management programs, particularly in protection of susceptible potato cultivars. All examined products provided efficacy at the similar level i.e. 42%-52% in Bonin and 55%-66.8% in Stare Olesno. However, efficiency of chemical protection in early blight suppressing is not as satisfactory as in late blight control.

Keywords: potato, early blight, occurrence, chemical control

Introduction

Harmfulness of early blight is estimated differently in various regions of the world. According to Reinoch (1974), the disease reduces yields up to 25%, locally 60%. According to Fry

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(1994), maximum documented yield reductions are usually 20-30%. In Polish climatic conditions high regional losses caused by early blight were recorded, however, most were related to cultivars with recognized susceptibility to this disease. The causal agents of the disease are fungi from *Alternaria* genus: *Alternaria alternata* and *Alternaria solani* (the latter appearing mostly in south-western Poland). Morphological symptoms caused by these two fungus species do not differ along with disease development hence, their occurrence is estimated jointly. Sometimes symptoms of the diseases are different on various cultivars (fig. 1).

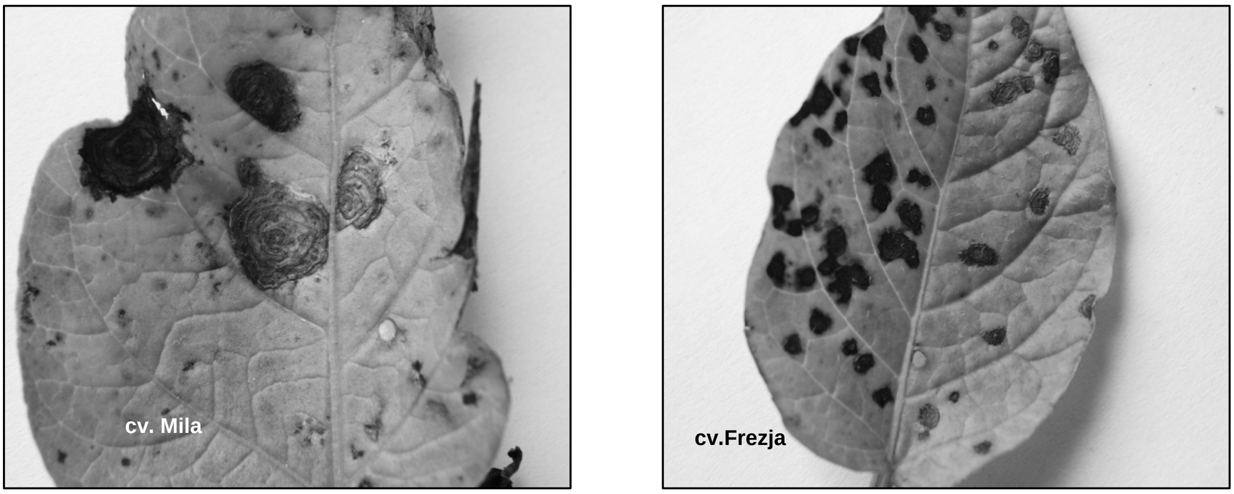

Figure 1. Different symptoms of early blight on various cultivars

High temperature (optimum 25-26 °C for *A. alternata* and 26-27 °C for *A. solani*), alternating dry and high humidity periods create environmental conditions that are conducive to infection and disease outbreak. However, in the recent years, fungus adaptation to lower temperatures has been observed.

Alternaria spp., a casual agent of early blight, is a typical necrotrophic fungus attacking weaker or aging plant tissue (Rotem 1966). Also potato plants infected with some viruses are more susceptible to the early blight infection (Wnękowski, Błaszczak 1997). Each element of good agriculture protection that enhances plants' condition (e.g. foliage fertilization) increases plant resistance to a pathogen (Fry 1994). Nevertheless, chemical protection of potato cultivars very sensitive to early blight infection remains a basic problem. The goal of investigations conducted in the Plant Breeding and Acclimatization Institute, Bonin was an evaluation of an early blight occurrence on potato crops under Polish climatic conditions and estimation of efficacy of selected fungicides applied in control of the disease in field conditions.

Material and methods

In the years 1998-2003 in cooperation with the Plant Health and Seed Inspection Service an evaluation of early blight occurrence on potato crops was carried out throughout Poland. Observations on disease appearance and time of first symptoms were performed on 435 potato crops and then the collected results were analyzed in Bonin.

In the years 2001-2003, efficacies of some selected fungicides in early blight control were examined in field conditions. Field trials were performed in 2 sites differing in climatic conditions (Bonin – in northern Poland and Stare Olesno – in southern Poland) on susceptible to the disease cv. Frezja. Chemical protection began at first symptoms of necrosis found on plants. Usually 2-3 applications were performed depending upon pathogen pressure. The following fungicides were under investigation:

- contact fungicides: mancozeb (Dithane M-45 80WP) at a dose of 2.0 l/ha and propineb (Antracol 70 WP) at a dose of 1.8 kg/ha
- systemic fungicides: metalaxyl-M + mancozeb (Ridomil Gold MZ 68 WP) at a dose of 2.0 l/ha and propamocarb-hydrochloride + chlorothalonil (Tatoo C 750 SC) at a dose of 2.0 l/ha and a new mixture "W-S" (in process of authorization for Poland conditions) at doses of 1.5 and 2.0 l/ha

The results were analyzed in a 2-factorial ANOVA, the factors being years of experiments and the fungicide applied. For statistical analyses data was converted according to formula of Bliss.

Results

In the years 1998-2003 under Polish climatic conditions early blight occurred at different level of incidence on over 87.9% of observed fields (Tab. 1). Time of disease appearance in different regions was close related to climatic conditions. In Poland, the first recorded outbreaks of early blight occur usually at the end of May or the beginning of June (30-36 days after planting). In the growing season of 2002 the disease was recorded unusually early i.e. 34 days after planting (on May 20th).

Considerable differences were recorded in timing of disease occurrence and incidence on untreated control plots in Bonin and Stare Olesno (Fig. 2).

Table 1. Occurrence of early blight on potato crops in Poland.

Year	Number of observed fields	% of fields with EB	Average EB appearance (number of DAP*)
1998	138	78.3	60
1999	93	88.0	65
2000	56	91.1	57
2001	50	94.0	61
2002	64	90.6	56
2003	34	85.3	63
Σ / x	435	87.9	60.3

** DAP - days after planting*

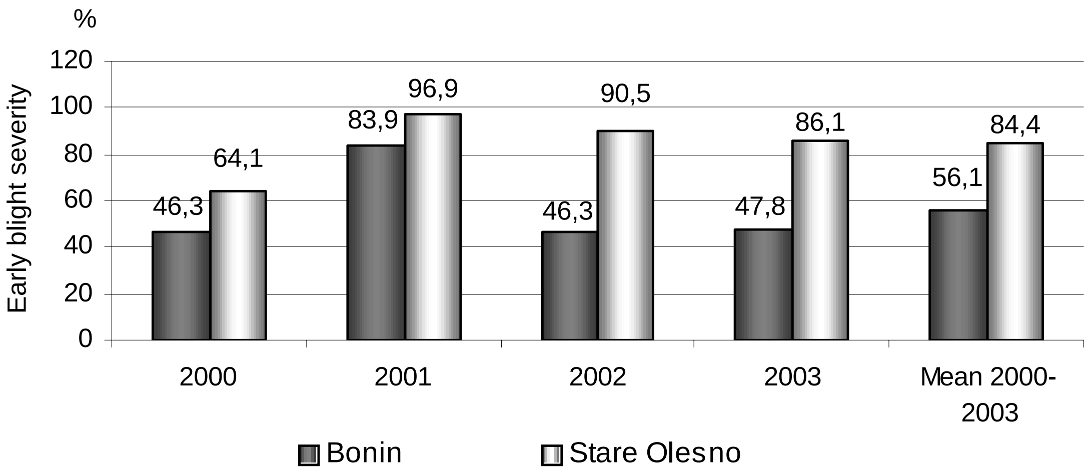

Figure 2. Early blight incidence on control plots in field trials.

Early blight incidence was distinctly lower over 4 years in Bonin (northern Poland). In general, disease infection on control plots did not exceed 50%. The year 2001 was an exception as the disease occurred early and destruction of control plants was 83.9%. In Stare Olesno plant infection was higher each year and ranged from 64.1% to 96.9%. Years 2000-2003 varied in meteorological conditions that affected appearance and development of early blight.

Evaluation of harmfulness of early blight in the years 2000-2003 was based on differences in tuber yield collected from untreated and treated plots according to the same treatment (Fig. 3). Yields differed from 2.7 to 11.1 t/ha and that was 6-45% of obtained yield. Only yield from one chemical treatment was not much lower (2.3 t/ha) than yield from a control (Stare Olesno, 2002).

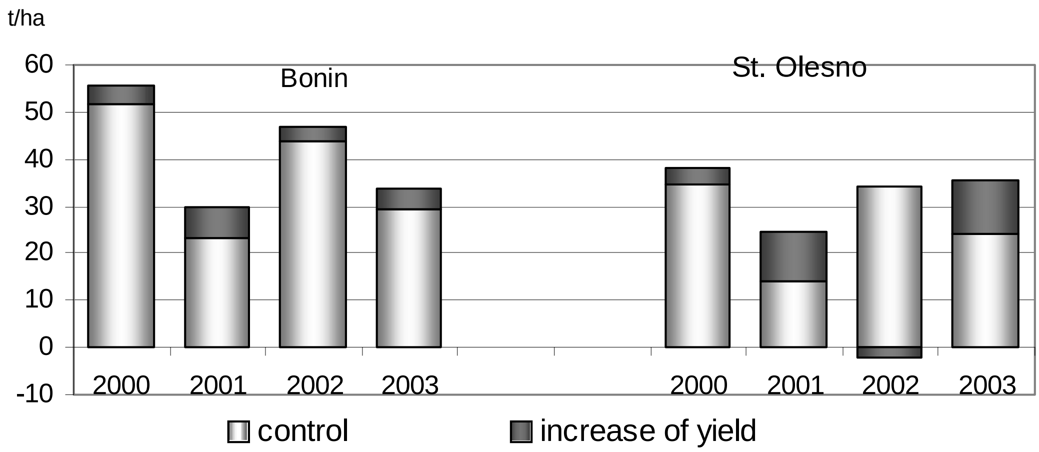

Figure 3. Differences in yield collected from treated and control plots.

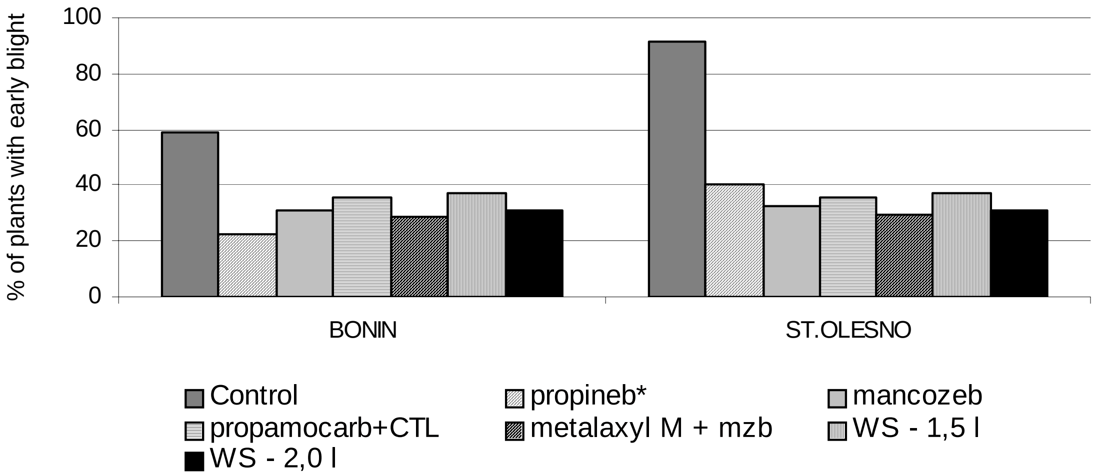

Figure 4. Efficacy of selected fungicides in early blight control (mean from 2001-2003).

Field trials conducted in the years 2001-2003 proved usefulness of examined fungicides in control of early blight. The conducted trials showed that all fungicides suppressed the early blight development compared to the untreated control (Fig. 4).

Efficacy of plant protection program carried out in Bonin over three years varied from 42% to 52%. Effectiveness of selected products was higher in Stare Olesno at higher infection pressure, and ranged from 55% to 66.8%.

Early haulm destruction by development of pathogens affects yield size. The trials conducted in Bonin and Stare Olesno proved that yields from plots protected against early blight were significantly higher that from control (Fig. 5).

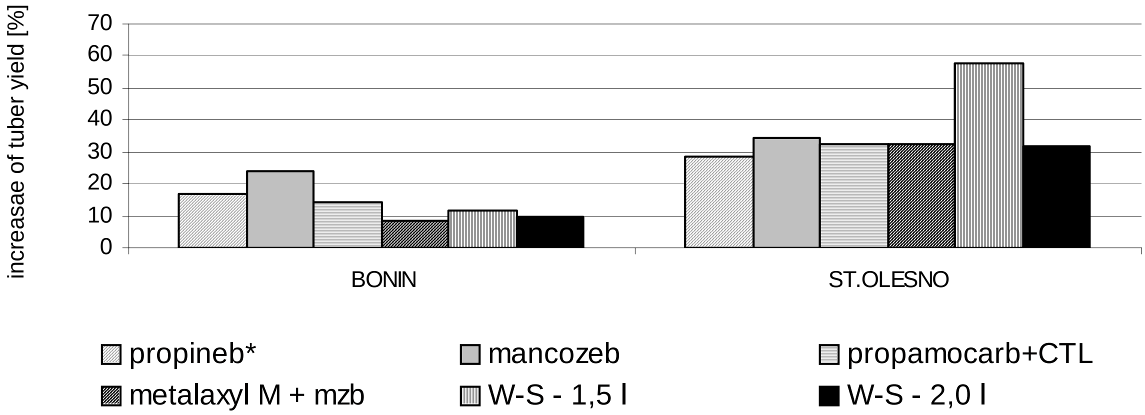

Figure 5. Yield increase on plots protected with selected fungicides compared with untreated control (mean from 2001-2003).

In Bonin, during three years, tuber yield increase varied from 8.4% (mixture metalaxyl M + mzb) to 24.2% (mancozeb). In Stare Olesno, yield increase was very high from 28.7% for propineb to 57.9% for mixture W-S.

Discussion

Observations carried out in the years 1998-2003, revealed that early blight occurrence on potato crop is common in most production areas in Poland. Inspections performed on 435 potato fields confirm early blight occurrence on 87.9% examined fields. The earliest documented symptoms of disease were recorded 30-36 days after planting. On average, the early blight appeared on potato plants 60.3 days after planting and that brings a conclusion that under Polish climatic conditions early blight occurs earlier than late blight on potato crops. These results confirm earlier records on common occurrence of early blight and regional differences in disease incidence (Kapsa & Osowski, 1996, 2003).

The results collected from control plots in Bonin and Stare Olesno show great differences in disease incidence in both localities. Every year pathogen pressure was considerably higher in Stare Olesno (southern Poland) than in Bonin. Larger destruction of plants caused by early blight in southern Poland resulted not only from climatic conditions. In this area climatic conditions also favour greater infection pressure of the viruses. As it has been registered previously potato plants infected with some viruses are more susceptible to the early blight infection (Nagaich & Prased 1971). Virus infections enlarged additionally early blight pressure under Stare Olesno conditions.

Field trials carried out in the Plant Breeding and Acclimatization Institute Bonin Division in the years 2001-2003 revealed much slower development of early blight on these fields when chemical protection was applied compared to untreated control. All examined products provided efficacy at the similar level i.e. 42%-52% in Bonin and 55%-66.8% in Stare Olesno. Good control of early blight resulted in tuber yield increase. In Bonin yield increase varied from 8.4 to 24.2% and in Stare Olesno from 28.7 to 57.9%. Unsatisfactory efficacy of some fungicides in early blight control in Bonin in the years 2000-2003 could be a result of their late application. First symptoms of disease might be missed due to abundant foliage development.

Hence, there is a necessity to develop a model of monitoring of early blight development and systems of forecasting that would allow determining more preciously time of first treatment.

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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

Potato early blight in Sweden: Results from recent field trials

LARS WIIK

Swedish University of Agricultural Sciences, Unit of Applied Field Research, Box 44, 230 53 Alnarp, Sweden. E-mail: lars.wiik@ffe.slu.se

Summary

In 2003 three official fungicide testing field trials, randomized in four complete blocks were carried out in southern Sweden, two in farmers´ fields and one at an agricultural station, performed according to Good Experimental Practice (GEP). Natural infection of early blight occurred in most of the trials and inoculation was not performed. A reduced level of applied nitrogen (~ 100 kg N per hectare) promoted the development of disease in the trials. Early blight and wilting was assessed at several times ending at haulm killing time. The effects of fungicide compounds with strobilurins (Amistar and Signum) or related fungicides (Tanos) were outstanding against early blight, more than 95 per cent control at the final assessment. Second best was a fungicide programme with Acrobat, 38 per cent control at the final assessment. No tuber rot due to *Alternaria* spp. was recorded. Starch yields increased with 600 to 840 kg per hectare for the best treatments as an average of three field trials, however not statistically significant.

Keywords: *Alternaria* spp., fungicides, control, efficacy, fungicide strategies

Introduction

Early blight (causal organism *Alternaria solani* Sorauer) is a common fungal disease in Swedish potato fields. Symptoms of early blight are reported every year, though usually very late in the season, just before defoliation. Traditionally early blight has been considered to be of minor importance in Sweden, but field observations and introductory field trials in recent warm summers suggest that early blight occasionally might be of significance. There are still several aspects of early blight to be examined in Sweden, i.e. the biology of the fungus (fungi, if multiple causal organisms), yield loss studies and control measures. In this study results from three field trials carried out in 2003 are outlined.

Early blight is a considerable problem in some regions in the USA, yield losses of 20-30 % (Johnson *et al.*, 1986) or higher (Harrison and Venette, 1970) have been reported. However, the average yield loss in the USA was estimated to 3 % (James, 1981). The attack of early blight became more common in the north-eastern part of the USA during the 1980's, not least in regions with irrigation (Hide and Lapwood, 1992). This increase was explained by the use of susceptible varieties, inferior efficacy of the new fungicides compared to the old ones concerning early blight and fungicide programmes exclusively aimed at late blight management (Pelletier and Fry, 1990). Considerable yield losses have been reported not only in the USA but also in other countries with warm climate as India, Israel and South Africa (Anon., 1975, Bambawale and Bedi, 1982, Shtienberg, 2001, van der Waals J, 2002) and during recent years in Europe (Schuller and Habermeyer, 2002, Hausladen and Schuller, 2003, Kapsa *et al.*, 2003, Wiik, 2003, Hausladen and Bässler, 2004).

As early as in 1942 Hammarlund wrote in a Swedish description of early blight, "In Europe the fungus is common and has been so for a generation in Denmark and Sweden." In a technical and practical information sheet Olofsson (1993) wrote: "The cause of early blight is the fungus *Alternaria solani*. Early blight appears especially during warm and dry summers. As *A. solani* has a high temperature optimum it is seldom of importance in Sweden. The same is valid for another *Alternaria*-species, *A. alternata* (syn. *A. tenuis*)."

Symptoms of foliage infection are well described in the literature and elsewhere (e.g. van der Waals, 2002). Symptoms on the tubers are not equally recognized but have been described (e.g. Secor and Gudmestad, 1999).

As with other plant diseases an integrated approach is the best way to control early blight. Cultivar resistance is doubtless the best way to avoid problems with plant disease. Differences between varieties, progenies and new sources of resistance are reported by several authors (e.g. Pelletier and Fry, 1989, Pelletier and Fry, 1990, Gopal, 1998) but quite often susceptible varieties have other requested qualities.

Crop rotation and cultural practice may influence the development of early blight. Frequent potato crops in the crop rotation promote early attacks (Shtienberg and Fry, 1990) as well as low levels of nitrogen (MacKenzie, 1981, Persson 2002).

Several fungicide compounds are used to control early blight (e.g. Guenthner *et al.*, 1999). In Israel Shtienberg *et al.* (1996) found tebuconazole, a systemic triazole compound, to be more effective against early blight than tested contact fungicides. Excellent early blight control was provided by azoxystrobin (Quadris, Syngenta Crop Protection, Greensboro, NC) in the USA, but in a few years after the late introduction in 1998 *A. solani* became less sensitive to azoxystrobin. Furthermore fungicide cross-sensitivity was detected between azoxystrobin and pyraclostrobin (Pasche *et al.*, 2004). Efficacy of fungicides with respect to early blight is rated by experts participating in a European network for development of an integrated control strategy of potato late blight. Azoxystrobin is regarded as the best compound, +++ = very good effect (see Bradshaw, this report, page 155). Fungicides are used several times in a potato crop during a growing season and have different characteristics. Therefore the advantage of a specific fungicide should be emphasized in a fungicide programme and the risk of environmental side-effects and fungicide resistance should be minimized. The QoI working group of FRAC, consisting of members from BASF, BayerCropScience, DuPont and Syngenta, is responsible for global fungicide resistance strategies in the Qo inhibitor fungicides (QoI, quinone outside inhibitors). Cases of reduced sensitivity were followed up regarding frequency and practical relevance and presented in the minutes of the latest meeting in November 2003. Resistance factors were confirmed to be low and field performance was good. Guidelines for potatoes and tomatoes against early blight propose the use of QoI fungicides if applied solo not to exceed 33 % of the total number of sprays or a maximum of four. If mixtures are used, 50 % of the total number of sprays are not to be exceeded or a maximum of six QoI fungicide applications, whichever is the lower (see www.frac.info and the discussion in the paper by Pasche *et al.*, 2004). Decision support systems (DSS's) are being used in some countries and in progress in others (Secor and Gudmestad, 1999, Shtienberg, 2001, Hadders, 2003, Hausladen and Schuller, 2003). The

DSS's must probably be adapted to the conditions in each region/country, e.g. a spore trap and growing degree day method used in Colorado USA did not provide reliable prediction of early blight in Wisconsin USA (Pscheidt and Stevenson, 1986). An advantage is if the DSS takes into consideration plant growth and all actual pests and diseases which can be controlled with pesticides, resulting in a comprehensive control programme (Pscheidt and Stevenson, 1986, Johnson *et al.*, 1986, Johnson and Teng, 1990, Johnson K B, 1992).

Materials and Methods

In 2003 three field trials, randomized in four complete blocks were carried out in southern Sweden, two in farmers´ fields and one at an agricultural station. These official fungicide testing field trials were performed according to Good Experimental Practice (GEP) following the EU directive 93/71, KIFS 2004:4, STAFS 2001:1 and Standard Operative Procedures SLU 2004 and supervised by SWEDAC, Swedish Board for Accreditation and Conformity Assessment. Normally the gross plots were about 30 square meters (five rows) and the net plots about 20 square meters (three rows). Cultivar in these trials was the starch variety Kardal in two trials and Bintje in one. Natural infection of early blight occurred in most of the trials and inoculation was not performed. A reduced level of applied nitrogen (~ 100 kg N per hectare) promoted the development of disease in the trials. Early blight and wilting was assessed at several times ending at haulm killing time. Early blight necrotic blotches were assessed as per cent attacked area in relation to the total green leaf area up to 100 per cent attack when the haulm was totally destroyed. Sprayings were usually carried out once a week. Conventional or experimental field sprayers and standard or experimental products from the chemical companies were used. Ten kilogram samples were taken from each plot in order to assess tuber rot due to *Alternaria* spp. At harvest, potato yield was registered, tuber size graded and starch content determined.

Fungicides used in the field trials were 0.3-0.4 litre per hectare Shirlan (active ingredient, a.i. fluazinam 500 g/l, approval by The Swedish Chemicals Inspectorate, KemI March 1993), 0.5 litre per hectare Amistar (a.i. azoxystrobin 250 g/l, approval by KemI February 2002) in a mixture with 0.4 Shirlan, 2.0 kg per hectare Acrobat WG (a.i. mancozeb 60 % by weight and dimetomorph 9 % by weight, approval by KemI February 1997) in a mixture with 0.4 Shirlan, 0.5 kg per hectare Tanos 50 WG (a.i. famoxadone 25 % by weight and cymoxanil 25 % by

weight, approval by KemI April 2004) in a mixture with 0.25 Shirlan, 1.8 litre per hectare Electis 75 WG (a.i. zoxium - zoxamid 8.33 % and mancozeb 66.67 %, not approved by KemI) and 0.25 kg per hectare Signum (a.i. boscalid 26.7 % and pyraclostrobin 6.7 %, not approved by KemI) in a mixture with 0.4 Shirlan. Of these fungicide compounds azoxystrobin a.i. in Amistar, pyraclostrobin a.i. in Signum and famoxadone a.i. belongs to the strobilurins and related fungicides, QoI, quinone outside inhibitors (Bartlett *et al.*, 2002). Shirlan was used as control. Full control of late blight was an option in the fungicide programmes. As an average in each fungicide programme 12 applications was made, consequently the control with Shirlan was treated 12 times. The start of the time-specific early blight treatments was chosen to be when the first attack was seen in the fields (see table 1). Application of Amistar was made two times with start at application time four at trial site 1, application time five at trial site 2 and application time six at trial site 3. Application of Signum, Acrobat and Electis was made three times with the first time as with Amistar. In one fungicide programme Electis was used all through as well as Tanos.
SAS, GLM, Anova was used to test the result.

Results
The attack of early blight was most likely less than 1 % when the first early blight specific treatment with Amistar, Signum, Acrobat and Electis started at application time four, five and six at each respective field trial location (table 1). In the standard control, with repeatedly applications of Shirlan, the attack increased in two field trials (site 2 and 3) but remained at a low level in trial site 1 (table 1). Chemical desiccation was only done at field trial site 1, September 5.

The effects of fungicide compounds with strobilurins or related fungicides (QoI, quinone outside inhibitors) were outstanding, more than 95 per cent control of early blight at the final assessment (table 2). Second best was a fungicide programme with Acrobat, 38 per cent control at the final assessment. No tuber rot due to *Alternaria* spp. was recorded. Starch yields increased with 600 to 840 kg per hectare for the best treatments as an average of three field trials, however not statistically significant.

Table 1. Dates for the first *Alternaria* spp. treatment with Amistar, per cent attack at first *Alternaria* spp. treatment and at final assessment and growth stages according to the decimal code.

Trial site[1]	First Amistar treatment (no.)	DC[2]	First assessment, % attack Date	control	Amistar	Final assessment, % attack date	control	Amistar
1	July 17 (4)	65	July 22	0.6	0.5	Aug 26	2.5	0.1
2	July 23 (5)	65	July 22	0.9	0.2	Sept 19	53.8	2.3
3	July 28 (6)	70	Aug 15	7.8	1.3	Aug 29	25.5	1.3

[1] *Dates of harvest: trial site 1: October 1, trial site 2: October 7 and trial site 3: September 19.*
[2] *DC = decimal code, 61-69 = flowering, 71-79 = development of fruit.*

Table 2. Starch yield, Alternaria spp. and wilting, average values, three field trials fertilized with a suboptimal nitrogen level (100 kg N/hectare) in southernmost Sweden 2003.

Fungicide programmes (no. of applications)	Starch yield ton/ha	*Alternaria* spp. % attack average[1]	*Alternaria* spp. % control at final assessment	Wilting[2] %
Shirlan (12)	8.42	13.5	0	94
Shirlan (10) and Amistar+Shirlan (2)	9.18	1.7	96	73
Shirlan (9) and Signum+Shirlan (3)	9.26	1.9	96	77
Shirlan (9) and Acrobat+Shirlan (3)	8.79	8.1	38	83
Electis (12)	8.89	9.2	27	82
Shirlan (9) and Electis (3)	9.08	11.1	14	87
Tanos+Shirlan (12)	9.06	1.7	95	80
LSD 5 %	0.71	5.4		12

[1] *average of 13 assessments.*
[2] *dates of wilting assessment at trial site 1, 2 respectively 3: Sept 4, Sept 25 and Aug 29.*

Discussion

Both *Alternaria solani* and *A. alternata* were found on leaves with typical symptoms in these field trials, unfortunately not collected in any methodically way. If both *A. solani* and *A. alternata* are the main cause of early blight in Sweden is not clarified in these studies. In Brazil *A. alternata* caused the same symptoms on potato as *A. solani* (Boiteux and Reifschneider, 1994).

As standard control Shirlan was maybe not the right choice as Shirlan has some efficacy on early blight (Bradshaw, 2004). Ranman would have been a better standard control but Ranman was not approved by KemI when these field trials were planned. In the GEP field trials 2004 Ranman is standard control.

Fungicide programmes with Electis gave unsatisfactory effects in these field trials and do not correspond to the rating by Bradshaw (2004) and the result by Kapsa *et al.* 2003. Could this be due to fungicide x nitrogen or fungicide x cultivar interactions? Or could it be due to that QoI - quinone outside inhibitors - were not tested?

Repeatedly applications were carried out with Tanos, i.e. Tanos was not tested in a fungicide programme with only two or three application times as Amistar, Signum, Acrobat and Electis. A comparison of fungicide programmes can only be made within given circumstances.

No tuber rot was recorded in the tuber samples from these field trials. According to Secor and Gudmestad (1999) "It (*A. solani*) almost always affects only the foliar parts of the plant, but can affect tubers, causing a shallow dry rot." This corresponds to our experience. Tuber rot caused by early blight seem to be rare and even more unforeseen than tuber blight.

In demos and field trials during 1999 to 2002 in Sweden yield increases due to the control of early blight fluctuated from zero up to ~ 15 % (Wiik, 2003). During 2003 a starch yield increase of ~ 10 % was achieved in the field trials here reported, however carried out at a reduced nitrogen level to promote the disease. Early blight seems to be a disease well fitted for a DSS (decision support system), due to the infrequent appearance of the disease. Routine control is not recommended.

Conclusions

The effects of strobilurins (Amistar and Signum) or related fungicides (Tanos) - QoI, quinone outside inhibitors - were outstanding against early blight, more than 95 per cent control at the final assessment. Second best was a fungicide programme with Acrobat, 38 per cent control at the final assessment.

Starch yields increased with 600 to 840 kg per hectare for the best treatments as an average of three field trials, however not statistically significant.

The result from these trials can hardly be transferred to conventional potato growing as the nitrogen level is below what is normally used.

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Alternaria control in the USA and Egypt

JAN HADDERS

Dacom Automatisering

P.O. Box 2243, 7801 CE Emmen, The Netherlands

Summary

Alternaria solani is a fungus disease that can cause great damage to a potato crop. For different reasons it looks like *Alternaria* is increasingly becoming a problem. In arid regions of the USA and in Egypt the Alternaria model in the PLANT-Plus DSS has been put into practice.

Keywords: Early Blight, *Alternaria solani*, infection event, PLANT-Plus, communication

Introduction

In the USA just over 500.000 ha of potatoes are grown under very different conditions. In the mid-west region from North Dakota and the Eastern parts of Washington down to New Mexico and Texas, potato growing is only possible with the help of irrigation. This already indicates a relative hot and dry climate. Therefore *Phytophthora infestans* is hardly an issue in this region but Alternaria is a reoccurring problem.

In Egypt about 80.000 ha of potatoes are grown. All growing takes place with irrigation. *Phytophthora* as well as *Alternaria* is a threat to the crop. Frequent and often unnecessary sprayings are carried out.

For the control of *Alternaria* no chemical product with kick-back action is available. This makes the farmer either spray very often, like every 5 – 8 days depending on the crop growth, or makes him use the PLANT-Plus DSS system.

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System

The PLANT-Plus system is a fully automated system that processes information from sources like weather stations and weather forecast regions into a databank. Growers add basic data of the fields and the variety. Subsequently the date, time and dosage for each spraying can be entered. Also crop information such as crop growth, crop stage and crop density is needed. A communication module takes care of the synchronisation of all data with the central databank. Using all this data PLANT-Plus calculates the best course of action for the grower.

Disease

The fungus disease *Alternaria solani* survives the winter as conidia or mycelium on infected plant debris in soil or on seed.

When conditions are favourable spores are formed and dispersed. Whether a spore will infect a potato leave depends on the climatic conditions, the susceptibility of the variety and the crop stage. A young crop is regarded less susceptible then an older crop. The optimal temperature for infection with *Alternaria* is higher then for *Phytophthora infestans*.

Visual characteristics of *Alternaria* are the presence of concentric rings on a lesion and the sharp edges that don't go over veins of the leave. This is in contrast to *Botrytis*.

Egypt

Most or the Egyptian potatoes are grown in the Nile delta. Part of the crop is grown by a large number of small growers but a significant part is grown by just a few growers. These growers often develop new regions for potato growing and other crops.

Some of the characteristics of potato growing in Egypt are:

- Winter season from October to January
- Summer season from December to March
- Always disease pressure because of overlapping crops
- Very Alternaria susceptible varieties grown

- Occasional sand storms causing leave surface damage
- All crop under irrigation
- Relative warm weather conditions

USA

In the USA just over 500.000 ha of potatoes are grown. Just like in all western countries the number of farmers is declining while the average area per farmer is strongly increasing. In the majority potatoes are grown with help of irrigation. Spraying is done by ground rigs, planes and helicopters and by fumigation. A typical management unit for potatoes is between 750 HA and 1.500 HA. It is not considered a problem to cover an area like this on short notice and in one day.

In the mid-west regions extensive losses due to *Alternaria* can take place. This was the case in a dry and warm year like 2003.

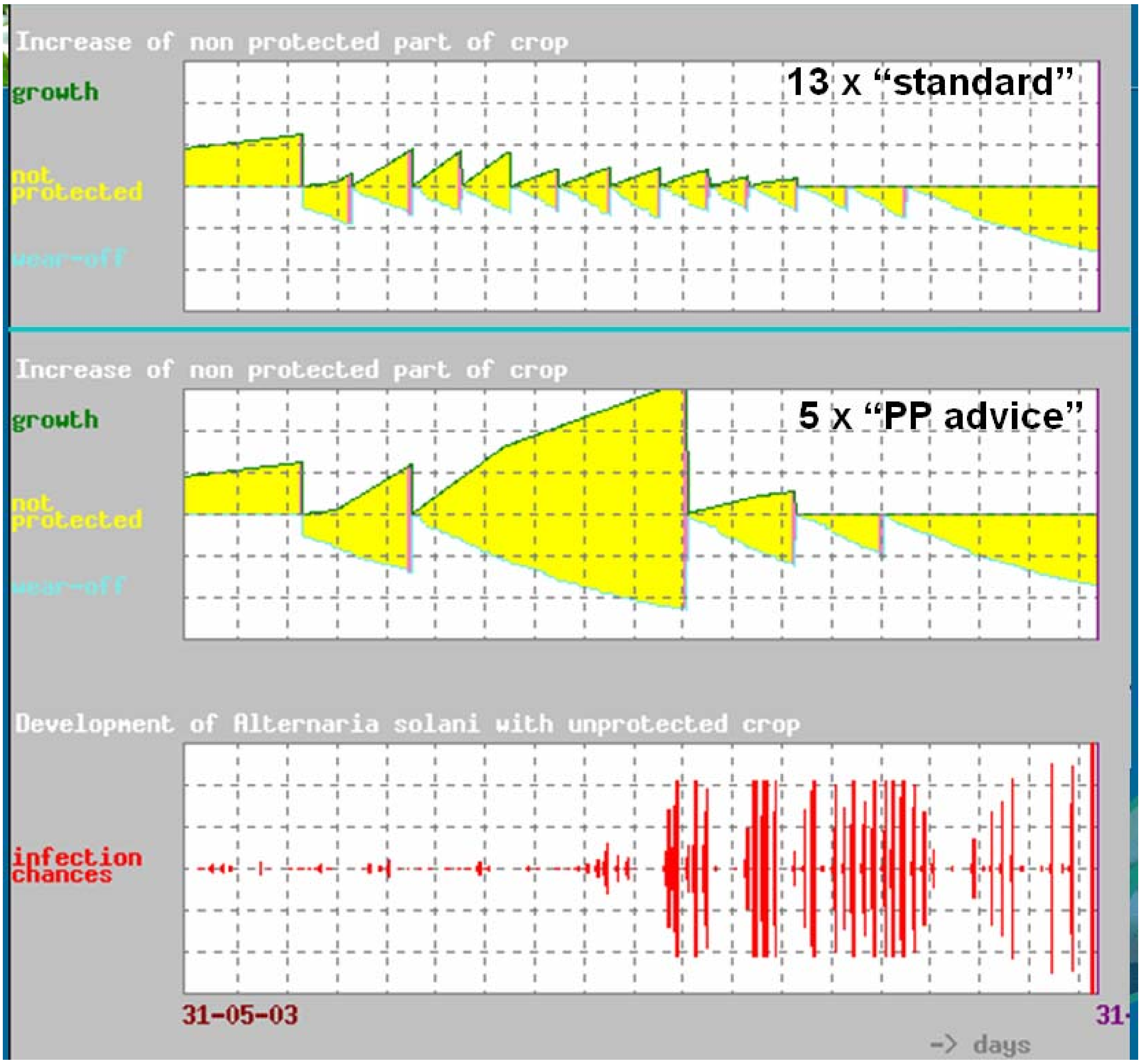
In cooperation with Syngenta demonstration trials were done in 2002, 2003 and 2004 throughout the USA. Some trials are done by the research departments of the Agricultural Universities and other trial on farms.

Until the introduction of PLANT-Plus the only available disease forecasting system is based on the calculation of disease severity values (DSV). A DSV is the sum of indexed points per day. These points are a relation between the measured RH and the duration of a leaf wetness period. For example, a temperature between 21 – 25 °C with a leaf wetness period between 6 – 12 hours results in two DSV points. When a certain threshold is reached a warning is produced. In Wisconsin, W. Stevenson and J.W. Pscheidt fine-tuned the DSV by incorporating the maturity of a crop. Also a bottom and an upper threshold for temperature with an optimum at 21 °C were introduced. In none of the models field specific data is used. Also the presence of the pathogen and the *Alternaria* disease cycle are not taken into account. Results from observations in Colorado from 1998 - 2001 show that in general the P-day system is 4,2 days too early in warning in relation to observed outbreaks. Still this tool does give a general indication when to start spraying as a state wide system.

Trial results

Minden, Nebraska

In this presentation two trials will be discussed. The first one is on a commercial farm using a split pivot set up. One part is treated according to the PLANT-Plus system and the other part according to normal farm practice. The standard field was sprayed 13 times and the PLANT-Plus field 5 times. Both fields had hardly any infection with *Alternaria*. Further field observations and an aerial picture of the trial plot show a relative greener PLANT-Plus field. This is probably due to fewer chemicals. Unfortunate no yield measurements were done.



Aberdeen, Idaho

Another trial was done at the University of Idaho in Aberdeen. This was a real trial set up where the PLANT-Plus system was used as a decision system. All season long, not one spraying was triggered. At the same time, the standard field was sprayed 7 times. A personal observation on August 17 showed in all plots *Alternaria* infected leaves. For the PLANT-Plus plot the conclusion was made that somewhere an infection event must have been missed. Therefore the data from a non-automatic weather station at the field was used for a new calculation of the season. With this data infection events were calculated on July 16, 24/25 and on August 3rd. These events are in line with the observed infections. With this weather data at least a spraying on July 16 would have been triggered. In that case, 6 sprayings would have been saved with the PLANT-Plus system.

Discussion and Conclusion

The conclusion are based on the experience in these two very different countries and based on experiences with Alternaria diseases in other crops. Some of these conclusions are also a good base for discussion.

- Warmer summers, warmer periods
- Better climate for *A. solani*
- Stress in plants caused by heat and shortage of water
- Shift in chemical products with a smaller spectrum for diseases.
- Inoculum
- Early infections possible but no lesion expansion
- Potential source of spore production
- Ready to attack and expand at stressed crop
- Minimized fertilizing gives more risk for deficiency.
- Varieties: some good processing varieties are very susceptible.

New fungicide benthiavalicarb-isopropyl + mancozeb for foliar use in potatoes in Europe

T W HOFMAN, Z VAN OUDHEUSDEN

Certis Europe B.V., P.O. Box 1180, 3600 BD Maarssen, The Netherlands
Email: hofman@certiseurope.nl

Summary

The new fungicide benthiavalicarb-isopropyl offers strong protectant and some curative activity on potato late blight (*Phytophthora infestans*). At the low dose rate of 28 g a.i./ha, benthiavalicarb-isopropyl, in combination with mancozeb, is a new powerful tool during periods of heavy disease pressure. It offers relatively long residual protection against foliar infection of late blight.

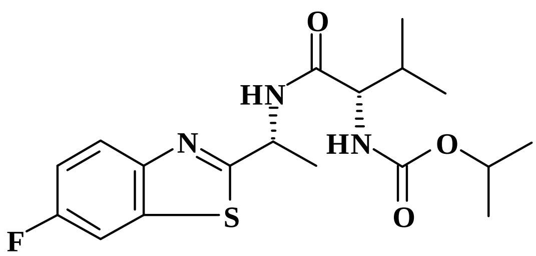
Keywords: KIF-230, *Phytophthora infestans*, benthiavalicarb-isopropyl, curative, amino acid amide carbamate

Introduction

Benthiavalicarb-isopropyl was first discovered by Kumiai Chemical Industry Co., Ltd Japan. The code number during its development phase was KIF-230. The product belongs to a new chemical class with the proposed name of amino acid amide carbamates.

Common name : benthiavalicarb-isopropyl

Structural formula :



Molecular formula : C18H24FN3O3S

Biological properties

Benthiavalicarb-isopropyl has excellent activity against Oomycete fungi, although it has no activity against *Pythium* spp.

Table 1. Fungicidal activity against *Phytophthora* spp.

Pathogen	Inhibition of mycelial growth *MIC
Phytophthora infestans	0.1-0.3 ppm
Phytophthora capsici	0.03-0.1 ppm
Phytophthora palmivora	0.1-0.3 ppm
Phytophthora cactorum	0.03-0.1 ppm
Phytophthora nicotianae	0.1-0.3 ppm
Phytophthora porri	0.1-0.3 ppm
Phytophthora katsurae	0.03-0.1 ppm
Phytophthora megasperma	0.1-0.3 ppm

** Minimum inhibitory concentration*

Benthiavalicarb-isopropyl belongs to the new chemical group of amino acid amide carbamates. However, the mode of action has not yet been fully identified. Nevertheless, the product is not affected by any existing resistance problems in potatoes. Kumiai has observed that for *Phytophthora infestans*, benthiavalicarb-isopropyl has very high activity on mycelial growth, sporulation, and sporangia and zoospore germination (Table 2). The product has no strong activity on zoospore motility and zoospore release (indirect germination) (Miyake, *et al.*, 2003).

Table 2. Activity of benthiavalicarb-isopropyl on different life stages of *Phytophthora infestans*.

	LC90 (mg a.i./litre)					
Treatment	Sporulation	Zoospore release	Zoospore motility	Zoospore germination	Sporangium germination	Mycelial growth
Benthiavalicarb-isopropyl	0,6	>100	>100	0,07	0,03	0,07
Dimethomorph	2,9	22	>100	0,1	0,08	0,95
Mancozeb	>100	3,3	1-3	1-3	66	>100

Benthiavalicarb-isopropyl can penetrate easily into treated leaves of various crops, where it shows its curative properties. Under practical circumstances, benthiavalicarb-isopropyl will be applied at relatively low rates per ha, which make use of its excellent protectant activity. At such rates, a locally systemic activity can be observed as well, but no systemic transportation through the plant takes place. The rapid penetration of the active ingredient into foliage means that it also has a good rainfastness. The activity of benthiavalicarb-isopropyl is not dependant on ambient temperature, so it will be effective in both cool and warm climatic conditions.

Products for use in potatoes

Benthiavalicarb-isopropyl will only be commercialised in combinations with multi-site inhibitors, as a resistance management strategy. Some other molecules with low to moderate resistance risk (cymoxanil and dimethomorph) have been widely used in combination with mancozeb in potatoes. This has not led to field observed resistance of late blight in potatoes.

Since benthiavalicarb-isopropyl is a strong protectant itself, it allows relatively low dose rates of the partner products in these combinations. This by itself can be considered as a benefit with respect to reduction of the total amount of active ingredient brought into the environment.

The combination of benthiavalicarb-isopropyl with mancozeb will be formulated as a WG (water dispersible granule) in order to minimise operator exposure, and maximise ease of use. The leading formulation, will contain 17.5 g benthiavalicarb-isopropyl + 700 g mancozeb / kg (recommended use rate 1.6 kg/ha). In some countries a WG formulation containing 12.5 g benthiavalicarb-isopropyl + 700 g mancozeb / kg will be introduced (recommended use rate 2 kg/ha).

Materials and methods

From 1996 to 2003, large numbers of trials were conducted in Western Europe with benthiavalicarb-isopropyl + mancozeb. A small representative selection of trials is used in this paper to illustrate the properties of benthiavalicarb-isopropyl. All trials were conducted according to Good Agricultural Practice and used standard protocols required for European registrations. All trials used a fully randomised block design with four replicates. If late blight infections did not occur naturally, in the course of the growing season untreated rows of potatoes bordering the trials were infested with a mixture of *Phytophthora infestans* strains originating from different locations.

Results

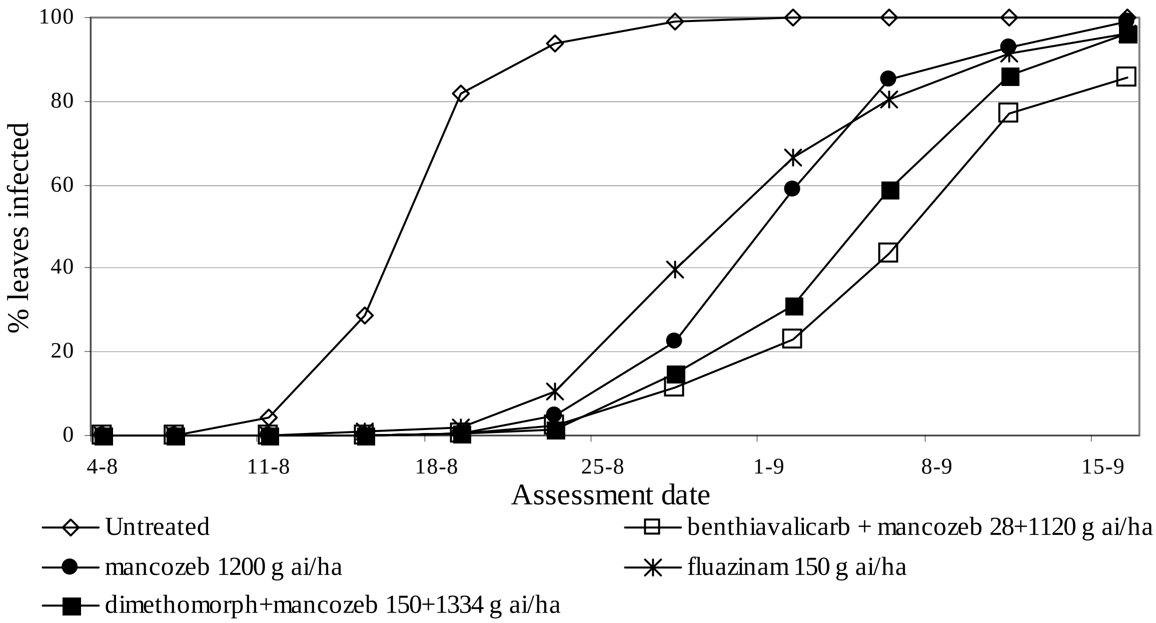


Figure 1. Field performance of benthiavalicarb-isopropyl + mancozeb in comparison to UK standards.

Trials conducted by Agrisearch in the UK demonstrated that 28 g benthiavalicarb-isopropyl / ha has a very strong additive activity on mancozeb used at 1120 g a.i./ha (Figure 1 shows results from the 2000 trials). At these rates, it also performs at least as well as another penetrant product dimethomorph + mancozeb (150 + 1334 g a.i./ha). Also, it is much stronger than fluazinam at its registered use rate in the UK.

Figure 2 shows results of foliar protection under extreme disease pressure in Netherlands with different ratios of benthiavalicarb-isopropyl and mancozeb in 2000. Assessments are made according to the Dutch PD-scale. Here it can be concluded that the slightly higher dose of mancozeb (1400 g a.i./ha) in combination with 25 g benthiavalicarb-isopropyl / ha gives better protection than the combination of 28 + 1120 g benthiavalicarb-isopropyl + mancozeb / ha. Under such disease pressure and climatic conditions, the performance of dimethomorph + mancozeb, cymoxanil + mancozeb and to a minor extent benthiavalicarb-isopropyl + mancozeb at 28 + 1120 g a.i./ha offer less effective disease control than benthiavalicarb-isopropyl + mancozeb at 25 + 1400 g a.i./ha.

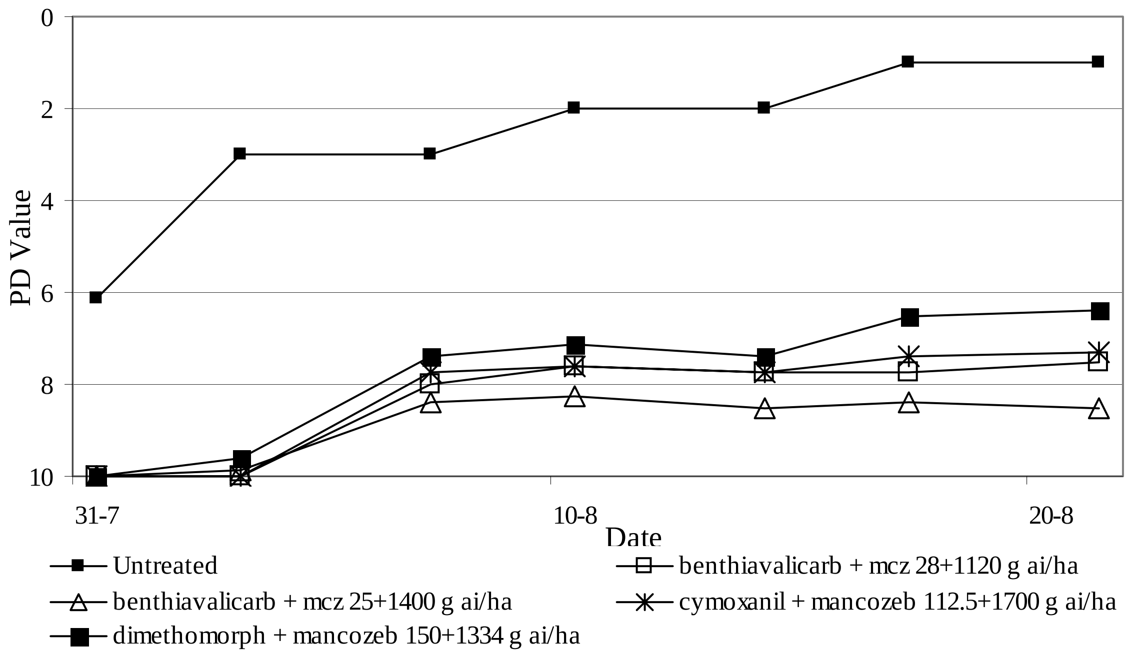


Figure 2. Comparison of 2 different ratio's of benthiavalicarb-isopropyl + mancozeb with standard products in Netherlands under continuous extreme disease pressure.

Yield effects

In all the trials, effects on yield were associated with late blight disease severity in the foliage. Under heavy disease pressure, benthiavalicarb-isopropyl + mancozeb was usually the most effective and consistent product for foliar protection. Therefore, the resulting yields were also among the highest in these trials. In trials with no or very little disease pressure, yields of plots treated with benthiavalicarb-isopropyl + mancozeb were at similar levels to other standards with no significant differences.

Tuber protection

Tuber protection of potatoes by Phytophthora infestans is dependent on a number of factors: Sporulation of late blight on the crop, migration of spores to the tubers (active through swimming in moisture on plant, or passive with rain or irrigation water) and cracks in the soil surface to reach the tubers. Many potatoes are grown in soil types where chances for tuber infection are relatively low, since the number of cracks that could allow spores to infect tubers is relatively small. In most of our field trials, there were therefore no significant differences in tuber infection between benthiavalicarb-isopropyl + mancozeb and reference products (such as fluazinam or organo-tin combinations). However, in those trials conducted in soils where tuber infections are common (e.g. in Dutch trial sites on clay soils), it was observed that benthiavalicarb-isopropyl gave less effective control of tuber infection than fluazinam. In decreasing order of efficacy, it could be concluded that fluazinam gave the highest protection followed by dimethomorph + mancozeb, benthiavalicarb-isopropyl + mancozeb, propamocarb + chlorothalonil and, least effective, cymoxanil + mancozeb. This sequence can be explained by the fact that benthiavalicarb-isopropyl has no effect on motility of zoospores. However, the fact that it has high activity preventing sporulation and mycelial growth, ensures that the effects are better than that of some commonly used other commercial products.

Conclusions

At low rates (25 - 28 g a.i./ha), benthiavalicarb-isopropyl is a highly active molecule with protectant and curative properties in potatoes. The combination with a relatively low rate of mancozeb (1120 g a.i./ha), makes the product a very robust, consistent and reliable tool to protect potatoes from attack by late blight (*Phytophthora infestans*) even under extreme disease pressure. The uptake of the product into the leaves gives it excellent rainfastness making it a valuable tool in modern potato production.

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Eighth Workshop of an European Network for development of an
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Assessing resistance types and levels in potato from late blight progress curves

D. ANDRIVON[1], D. ELLISSÈCHE[2], R. PELLÉ[2]
Address
[1] UMR INRA- Agrocampus Rennes BiO3P, Domaine de la Motte,
BP 35327, F-35653 LE RHEU Cedex
[2] UMR INRA- Agrocampus Rennes APBV, Keraiber, F-29260 PLOUDANIEL

Summary

Genetic resistance in potato cultivars should become one of the key elements of integrated control of late blight. Field resistance, as observed by breeders and growers, can be due to race specific (RS) and/or race non specific (RNS) resistance. The distinction of these two types of resistance is important, because each of them has different epidemiological consequences and durability expectations. This paper illustrates, based on data collected on a set of cultivars with known resistance types, how this distinction can be made directly from the analysis of disease progress curves in the field. It also briefly discusses some of the precautions necessary in the interpretation of curve parameters, and possibilities for using these parameters in DSS to tailor fungicide applications to resistant cultivars.

Keywords: race specific resistance, race non specific resistance, disease progress curve.

Introduction

Late blight, caused by the oomycete *Phytophthora infestans*, remains one of the most serious constraints to potato production world-wide. While blight control has relied for the past half century on fungicide use, both in developed and in developing countries, the economic and environmental limits of systematic, heavy spraying schedules have now been reached, and

now favour strategies based on reasoned applications of pesticides, in combination with prophylactic and genetic means of control. Genetic resistance, obtained in conventional breeding schemes from sources consisting in either ancient potato cultivars and/or wild relatives of *Solanum tuberosum*, has shown a lot of promise, and thus has been for many years, and still remains today, one of the most important traits targeted by potato breeders.
Vanderplank (1968) identified two kinds of resistance: race specific (RS) and race-non specific (RNS). A major difference between the two types of resistance is their stability in time. RS is generally governed by the gene for gene relationship: it usually provide complete resistance (often manifested as hypersensitive lesions) against avirulent races of the pathogen, but succumbs rapidly as virulent races emerge. Conversely, RNS performance depends on the aggressiveness of pathogen isolates, a trait that is generally postulated to be polygenic and hence evolve slowly. As a consequence, RS is normally highly efficient but short lived, whereas RNS is providing only partial, but more lasting protection.

Due to the lack of durability of RS in current cropping schemes, based on cultures of single cultivars over large areas, some recent efforts in breeding potatoes for resistance to *P. infestans* have focused on increasing levels of RNS rather than on the use of race-specific R genes. However, this breeding strategy implies that

1) RS be recognised and its effects eliminated (for instance by using compatible isolates) during breeding operations, and
2) that levels of RNS can be reliably assessed.

Over the past few years, several attempts have also been made to integrate cultivar resistance into major decision support systems for late blight control. This integration is often based on an overall level of resistance, usually estimated on a 1-9 scale of increasing performance in official cultivar assessments (e.g. Duvauchelle & Dubois, 1999; Wander *et al.*, 2003) or, less frequently, on areas under the disease progress curves (AUDPCs; Gans 1995) or on single epidemiological components, such as infection efficiency (Kessel *et al.*, 2003). However, RS and RNS have different epidemiological consequences, which should be taken into account for tailoring decisions on fungicide applications. While RS basically delays the start of the epidemic, but does not alter apparent infection rates, RNS reduces the speed of epidemic progress without affecting the date of initial disease outbreak (Vanderplank, 1968).Therefore, fungicide applications on RS cultivars should start later, but then be as frequent and with the same doses as on susceptible cultivars, whereas spraying schedules on RNS cultivars should start at the same time as on susceptible cultivars, but might be adjusted for intervals and/or dose rates.

As breeding programmes involve the screening of a large number of genotypes, the basic information available to the breeder is a bunch of disease progress curves. The choice of genotypes is most commonly based AUDPCs, as compared to those of reference cultivars of known behaviour. Unfortunately, AUDPCs do not provide information on the type of resistance present in the genotypes, and hence on their potential durability. However, the epidemiological effects of the different types of resistance, described above, are translated into characteristics of the disease progress curves. These curves can thus be used to infer the resistance types present in the respective cultivars. Many authors proposed mathematical models for transforming incidence or severity data (e.g. Campbell *et al.*, 1980; Pennypacker et al., 1980), designed statistical tests for comparing apparent infection rates (e.g., Fulton, 1979), or identified parameters to compare disease progress curves (e.g., Kranz, 1968; Mora-Aguilera *et al.*, 1996). This paper demonstrates how some of these tools can be used to infer resistance types in cultivars from field data, and discusses their limitations.

Material and methods

DPCs for the various genotypes are expressed as yi= f(t), where yi is disease severity (often expressed as the percentage of foliage area diseased in the case of necrosing pathogens) for genotype i and t is time. These curves are usually sigmoids with a more or less erect shape. Plotting the disease severity data transformed as Yi = log (yi/1-yi) against time yields equations of straight lines (transformed DPCs, Yi= ai.t + bi). From these equations, it is then easy to derive two parameters describing the relationships between the DPCs of the genotypes of interest and those of reference genotypes, namely:

$\Delta t = t_{0i} - t_{0s}$, where t_{0i} and t_{0s} are the dates of appearance of the first visible symptoms on the genotype of interest and the standard susceptible genotype, respectively;

$\Delta a = a_i - a_s$, where a_i and a_s are the slopes of the transformed DPCs for the genotype of interest and the standard susceptible genotype, respectively.

Δt is a measure of the delay in the epidemic onset (characteristic of RS) and Δa is a measure of the reduction of the rate of epidemic progress (characteristic of RNS). Based on these two parameters, resistance types can thus be postulated:

Δt	Δa	Type of resistance
≤ 0	≥ 0	none (susceptible)
> 0	≥ 0	race-specific (RS)
≤ 0	< 0	race-non-specific (RNS)
> 0	< 0	RS + RNS (or RS not overcome)

The validity of the aforementioned criteria was checked using DPCs observed in Ploudaniel, Western France, in 1995 on a set of cultivars representing known types of resistance, and some breeding genotypes of unknown resistance type(s). These genotypes included Bintje (susceptible standard), Maritta (R1), Arka (R1, R3), Pentland Dell (R1, R2, R3), and Pimpernel (RNS standard reference).

Results and discussion

The Δt and Δa values for these genotypes relative to Bintje (Table 1) are in general consistent with the types of resistance present in the reference genotypes and with the distribution of races of *P. infestans* in western France at that time. The main race in this area was 1.3.4.7.10.11, and over 90 % of the isolates were virulent to R1 (Lebreton *et al.*, 1998); conversely, only two of the several hundred isolates tested between 1991 and 1995 were able to overcome R2. This explains the longer delay in epidemic onset for Pentland Dell compared to Maritta. The data also show some delay in epidemic onset resulting from RNS. Indeed, the higher level of RNS in Arka relative to Maritta protected this genotype as efficiently as the R2 gene in Pentland Dell.

These data indicate that Δt and Δa are good predictors of the type of resistance present in the various genotypes. However, the use of these parameters, particularly Δt, requires a bit of caution, since it depends on the timing of disease scorings. For instance, the 10-day delay observed in Pimpernel does not necessarily indicate the presence of RS in this genotype, because this was exactly the delay between two consecutive scorings of the genotypes. Δt might thus have been lower in this genotype, had more frequent scorings been made. It is noteworthy that this delay is exactly the same in Maritta: this is due to the fact that R1, present in this cultivar, was overcome by almost all isolates present in the area, and had thus no effect on the epidemic curve.

Table 1. Parameters of late blight progress curves on 7 potato genotypes in Ploudaniel in 1995. Δt is the number of days separating the observation of the first symptoms in a given genotype and in Bintje (susceptible standard), and Δa is the difference between the slopes of the linearised progress curves for these genotypes and Bintje.

Genotype	rAUDPC	Δt (days)	Δa	Type of resistance
Bintje	0.409	0	0	none
Pentland Dell	0.234	28	0.131	RS
Maritta	0.340	10	- 0.225	RS + RNS
Arka	0.174	28	- 0.311	RS + RNS
Pimpernel	0.369	10	- 0.236	RNS

While the use of the information generated by the computation of Δt and Δa by breeders is easily grasped, the usefulness of these two parameters for DSS targeting late blight control is more difficult to assess. We do not think that these parameters can be directly integrated into the risk computation itself, because both Δt and Δa are synthetic parameters integrating multiple effects on single epidemic stages (infection efficiency, latent period, lesion expansion, spore production, etc…). However, they can – and in our opinion should- be used to define cultivar susceptibility types, for which the spraying schedules could be adjusted according to the risk calculated from meteorological data. This approach, developed in the MILPV DSS (Dubois and Duvauchelle, this volume), and proves very promising.

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Eighth Workshop of an European Network for development of an
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Jersey, England/France, 31st of March – 4th of April 2004

Late Blight Management in Early Potato Production in Brittany

S. THÉVENOT

Agronomic adviser

COTIG, La Rimbaudais, F-35350 St Meloir-des-Ondes

Abstract

The objective of this paper is to present the Late Blight Management in Early Potato Production in Brittany. Firstly, a presentation of the early potato production in Brittany and secondly, the recommended strategies given to farmers to manage Late Blight according to the different types of production will be given.

Introduction

Potato production in Brittany represented a total of 12.080 ha in 2002. These include 4585 ha of certified seed production, 4337 ha for ware potato production and 3158 ha for early potato production. Early potatoes are produced in the North of Brittany in Saint Pol de Leon (1034 ha), Paimpol (1265 ha) and Saint Malo (859 ha).

The production of early potatoes is quite diverse, it comprises crops grown within greenhouses and harvested by hand (0.5%), crops grown under plastic covers and harvested by hand (7%), crops of conventional early potatoes (early planting and early mechanical harvest with peeling skin) (29.5%) and crops conventionally harvested at skin set (43%). There are also early processing potatoes grown for chips or fries (21%). All are produced and sold under the Prince de Bretagne brand.

For each type of production, a specific strategy is necessary to control late blight.

Early potatoes within green houses:

Early potatoes produced within green houses, generally measuring 800 m², are planted in

December and harvested in April. During the growing phase, the crop is inspected by farmers and if a late blight contamination is discovered, the grower opens the green house to reduce humidity and temperature. Infected plants are destroyed to remove the inoculum, when possible and a chemical application is performed to protect the remaining plants.

Early potatoes under plastic covers:

Early potatoes under plastic covers are generally located in the most western county, the Finistère, in small fields (less than 1 ha) by the vicinity of the sea. These crops are planted around February and harvested in May. Seeds are generally produced as “farm-saved seeds” and may sometimes carry latent late blight infections. The prominent factor in managing late blight under such conditions is to remove the plastic covers within enough time to prevent late blight development, without exposing the crop to wind or frost. An agronomic adviser from The Chambre d’Agriculture monitors this specific production in order to assist farmers with such decisions. Advisers collect temperature and humidity data with a thermo-hygrometer placed under plastic covers. First late blight outbreaks are most likely to occur around the first half of May, when temperatures remain over 20°C for several days at humidity levels over 90%. Advisers use the Guntz-Divoux table to determine critical points in decision making for chemical treatment

When climatic conditions for late blight development are reached, the agronomic adviser alerts all farmers, recommending them to remove plastic covers and to apply a chemical treatment. Additionally, an official request is granted by the farmers’ organizations asking the removal of plastic covers. If conditions get worse, it is also advised to protect the uncovered fields.

Uncovered early potatoes:

The traditional uncovered early production evolves into a production of potatoes with set skin. Some years ago, the production was scheduled between February and May, with cultivars requiring 80 to 90 days of growth cycle, under climatic conditions unfavourable to the development of late blight. Currently, the cultivated cultivars require 100 to 120 days for optimal yield, between March (later planting date) and July, with climatic conditions quite favourable for the development of late blight. Additionally, farmers are not accustomed to monitor their crops.

In 2002 there was an average of 2.3 chemical applications within a range of 0 to 10 treatments a year with a great deal of blight; in 2003 same scheduling though with less blight pressure! Therefore, it is necessary to instruct farmers for a more appropriate management of late blight chemical control.

For this production, late blight contaminations mostly occur due to the following factors:

- Early season inoculum: refuse piles, volunteer plants, gardens and organic farming
- Infected fields (initially covered with plastic) in the vicinity

Consequently, as soon as the conditions are favourable, the disease present is rapidly developing and spreading

Strategies

Strategies to better manage late blight are performed in two steps:

- First step: field inspections are done by the SRPV/FEREDEC and the agronomic advisers, who are sending results to the SRPV/FEREDEC. Weekly recommendations are noted by the SRPV and sent to the agronomic advisers, who also receive information from technicians working in the area.
- The second step is the communication, where a note is written by the agronomic advisers and sent to the farmers' organisations and involved technicians. The weekly message is also recorded on an answering machine that farmers can contact anytime.

If there is a high risk, a letter is sent to all farmers, warning them of the danger and recommending chemical treatments.

Note: All farmers are receiving a technical document providing guidance about Late Blight at the beginning of the growing season.

In summary, Late Blight Management in early potato production in Brittany:

- Is a recent problem.
- Has to be improved: strategies and communication.

Decision Support systems have to be adapted for potatoes growing under plastic covers.

Control of *Phytophthora infestans* in seed potato production: three year experiments with SRPV/FEREDEC warning system in Brittany

SÉBASTIEN GUTMANN

Feredec Bretagne, 280 rue de fougères – BP 80118
35701 Rennes cedex 7
e-mail : sebastien.gutmann@feredec-bretagne.com

Summary

In order to urge more and more growers to follow up an integrated pest management for potato production, we use the decision support system: Milsol and Guntz-Divoux.
Fungicides treatments against potato late blight must be done when environmental conditions reach risk points and only so. The follow-up of such activities is described for three consecutive potato seed production cycles in Brittany.

Keywords: Potato seed, *Phytophthora infestans*, DSS, integrated pest management.

Introduction

In the last decade, potato late blight has been monitored for early potato production in areas located in the Northern coasts of Brittany. For the last 3 campaigns, a similar monitoring procedure has been implemented, at an experimental level, for seed potato production in collaboration with Germicopa. Two major seed production areas have been involved : Finistere and Morbihan counties. *P. infestans* epidemics have been followed up by scouting fields and theirs environments. Met data and contamination risks integrated into Milsol and Guntz-Divoux models generated field specific recommendations for chemical control at the right time and when necessary. The implementation of such agricultural practices aimed at the substitution of routine chemical control for an integrated pest management in potato seed production in Brittany.

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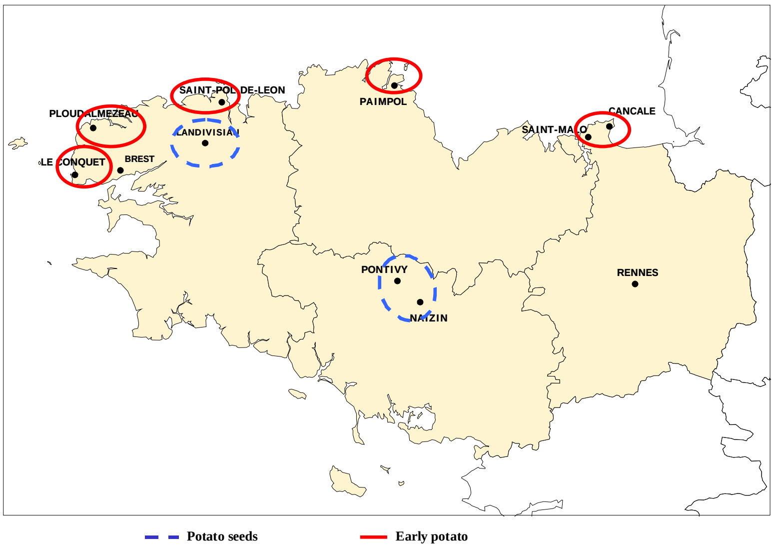


Figure 1. Geographical areas of potato monitoring.

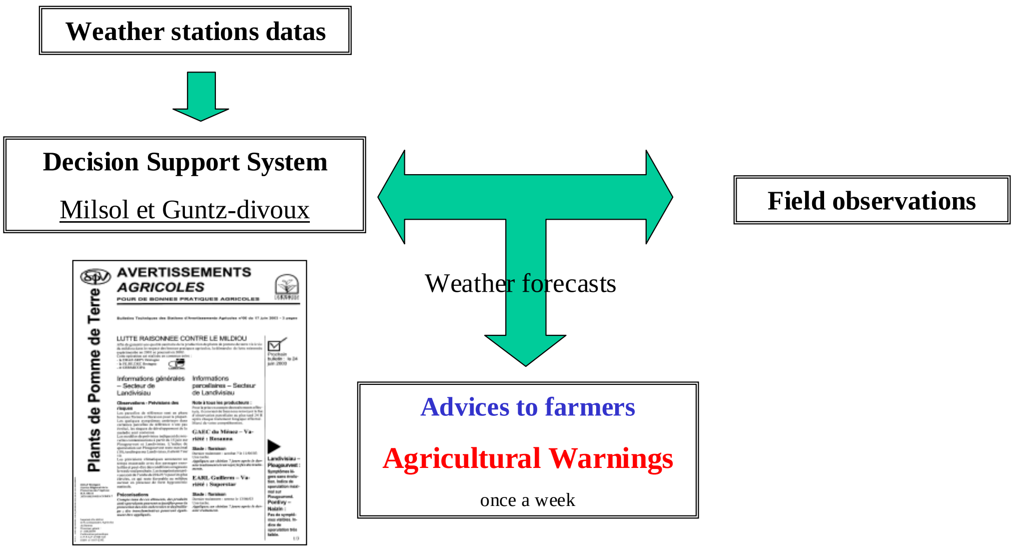
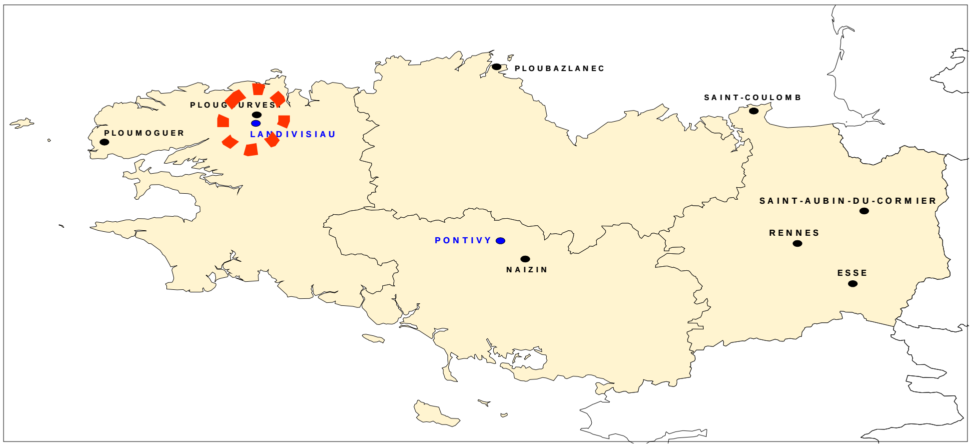


Figure 2. Late blight monitoring procedure.

Materials & Methods

For each major area, meteorological data are supplied on an hourly basis and integrated automatically (via internet) into epidemiological models (Guntz-Divoux/Milsol). Reference tested fields as well as their neighbouring environments are scouted by technicians once to twice a week for late blight situation. Modelling results of met data and *P. infestans* pressure lead to field specific warnings (Avertissements Agricoles), transmitted to farmers at least once a week (fig 2).



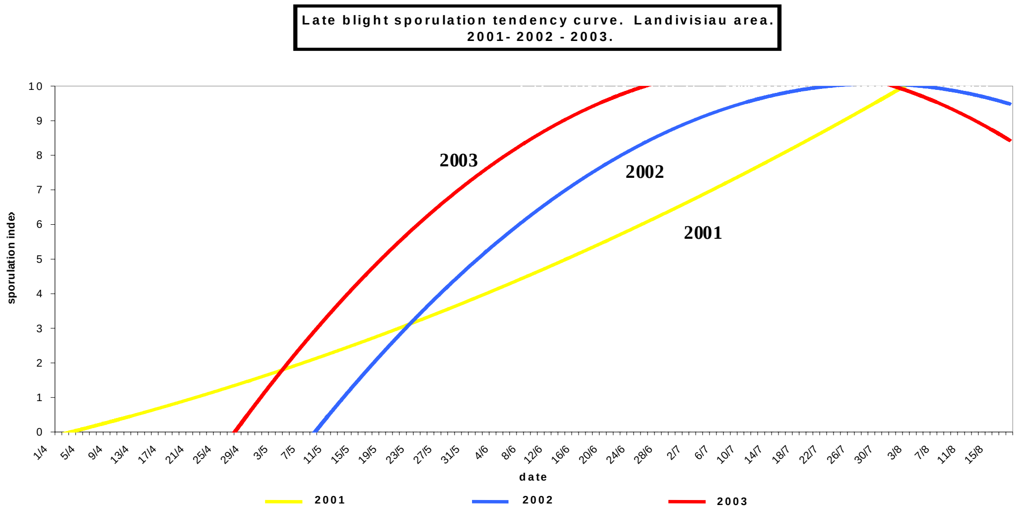


Figure 3. Landivisiau area monitoring.

Results

Landivisiau area (fig 3):

Epidemic evolution in this area of seed production indicated an homogeneous pattern over the 3 year period. First occurrence of late blight is tightly linked to the late blight situation in coastal areas further north where potatoes can grow earlier in the season. It can vary from early may to mid June. Then later in the season, *P. infestans* pressure usually increases with favourable climatic conditions. Chemical control is then recommended according to *P. infestans* evolution and potato growth stages. Postponing the first treatment has been possible in the event of early planting and slow progressing curve. For delayed planting, high contamination risks may exist from the beginning of the growing period.

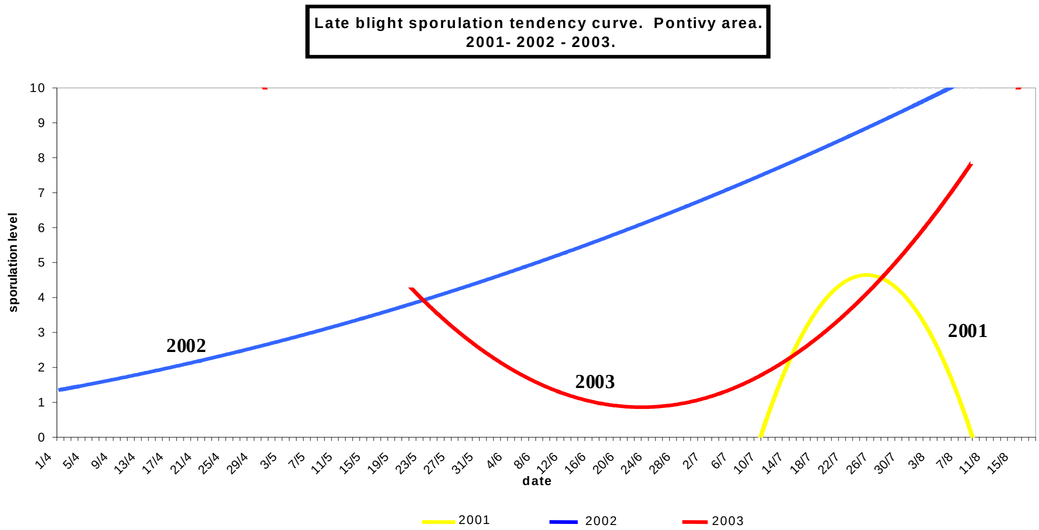


Figure 4. Pontivy area monitoring.

Pontivy area (fig. 4):

In this area, the *P. infestans* progress curve did vary much during the 3 year period and also differed much from the Landivisiau area. Climatic conditions are more continental with drier and warmer temperatures overall. However late blight pressure is always present but usually remains low throughout the season; cultural practices usually require irrigation for optimum potato production. Monitoring late blight under such conditions has facilitated the delay of the first treatment and reduction of overall treatments during the growing period.

Discussion

During the 3 year experiments, late blight epidemics has been completely different according to seed production areas as well as years (table 1).

Table 1. Three year experiments summary.

Summary	Pontivy area			Landivisiau area		
	2001	2002	2003	2001	2002	2003
number of tracked fields	2	4	4	5	12	10
late blight pressure	late, low	medium-high	(very) low	late, high	high	high
average number of treatments	4.5	8.25	6.25	9.2	10.5	8
maximum rate of symptoms	4	4	2	5	8	2

NB: routine treatments every 7 days from 50% emergence: between 10 and 12 treatments

Symptom scale

rate	symptom description
0	no symptom
1	one contaminated leaf
2	a few contaminated leaves
3	one contaminated seed (stem+leaves)
4	a few contaminated seeds (stem+leaves)
5	sparse contaminated seeds in the field or one source (1 m^2 at least)
6	one source (1 m^2 at least) + sparse contaminated seeds in the field
7	several sources(1 m^2 each)
8	several sources(several m^2 each)
9	all the field is contaminated
10	all the field is destroyed by late blight

In fact, Pontivy's pressure being overall of less intensity, the number of fungicide treatments can be less important compared to the situation in the Northern Finistere area and generally preventive contact chemicals (except in case of irrigation or symptom occurrences) are usually sufficient to maintain late blight at an undamaging level.

In Landivisiau, high contamination risks require foliage protection with more treatments, including highly performing active ingredients (for one thing against rainfastness).

In 2003, we can note that in Pontivy area, with an equal risk, the number of treatments is higher than the one in 2001. The fact is that late blight pressure in 2003 appeared sooner than in 2001. So, we had to start a preventive protection earlier than in 2001.

In the Northern Finistere, despite of a constant late blight pressure, the amount of fungicide treatments decreased in 2003 because of the downturn of the first one.

As far as symptoms are concerned, the attacks in tracked fields have been much lower in 2003. Overall, the sporulating spots on leaves and/or stems caused by late blight have been well controlled in 2003 ; there have been less *P. infestans* sources than in 2002, in particular on susceptible cultivars. Weather conditions have certainly contributed to this situation.

Conclusions

Monitoring of potato late blight in seed potato production in Brittany allowed farmers to optimize chemical control with high quality seed production (no tuber blight) thanks to an integrated chemical control. Due to environmental concerns, this procedure should be extended, involving more and more potato seed producers in the coming years.

Integrated control against potato enemies particularly late blight by Plant Protection Service in France

Warning System – New DSS: MILPV

LUDOVIC DUBOIS - SERGE DUVAUCHELLE

Nord Pas-de-Calais Regional Plant Protection Service
BP 47 62750 LOOS EN GOHELLE

Summary
The warning system for all the enemies of the potato crop is very useful for advisory services towards the growers. The DSS MILPV is a new improvement.

Keywords: Late blight, warning system, Decision Support System, integrated control.

The Warning System is based on two important approaches:

- The epidemiological risk forecast and the observations of fields and crop surroundings
- To set up the epidemiological risk, the Plant Protection Service (PPS) uses automatic weather stations checked by phone each day.

The risks are calculated each day by two models: Guntz Divoux (qualitative) and MILSOL (quantitative).

The observations on fields (growth of the crop, all diseases and pests, physiological symptoms), and crop surroundings (dumps, volunteers, gardens, organic crops, etc.) are made by PPS technicians and correspondents: (growers, professional technicians).

Information from studies and trials (variety susceptibility, fungicide, efficacy, rainfastness) are inserted in the criteria.

Other data: new regulations, analysis of samples in the laboratory are introduced.

The technician makes the synthesis of the warning advice concerning late blight, but also other enemies, which is sent by paper, mail and mostly fax, twice a week to many growers.

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These last three years important improvements have been realised:

- For the calculation of epidemiological risks, the introduction of weather forecast (H° T°: every three hours for three days);
- More precision for the sprays against late blight according to the potato variety susceptibility. (Three levels of potential sporulation to decide the spray moment during the epidemic, three "delays" at the beginning of the campaign);
- Automatic catching of the meteorological data and risk calculation of each meteorological station.

The warning system is a very interesting tool to advice the growers who take their own decisions.

The Decision Support System MILPV is based of the tools of the warning system but it is adapted to each field.

The DSS software is installed on the growers' computer.

The grower imports the data of each field:

> Identification, variety, agronomic technique, stage, observations of the field and surrounding of this field, previous sprays (product, dose), last and future irrigation, rain in the field.

The PPS put all the epidemiological risks and observations on Internet.

The grower can catch the risks of the nearest weather station of the farm.

The DSS works with the epidemiological risks and the data of the grower and gives the advice: date of the sprays and type of fungicide for each field.

With the system the grower can catch on Internet all the data of the warning system (regulation, advices, maps, advices on other enemies, etc.).

If the grower gives his authorisation, all the observations are collected in a data bank of the Plant Protection Service to improve the warning system.

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.

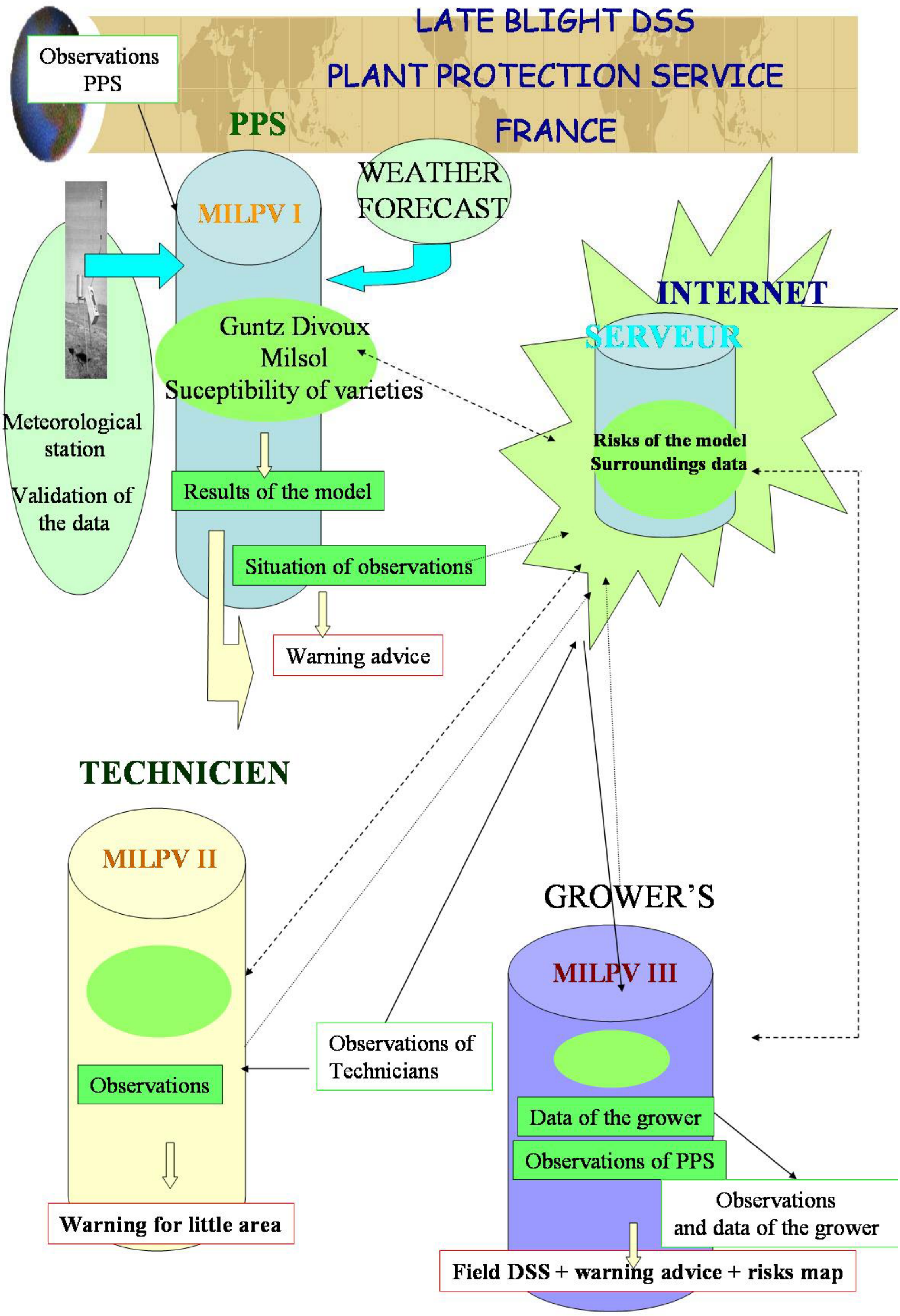
He can, if the grower authorises, catch the observations and the sprays of the grower.

This new system improves the warning system. It is based on a network: PPS, technicians, and growers.
It is based on exchange between all partners. It is a very good tool to survey the diseases and enemies of all around the country.

It is a real tool to develop integrated protection of the potato crops. For example in 2003 in a trial in Nord Pas-de-Calais the numbers of sprays against late blight were:

Grower practice on bintje : 13
MILPV on bintje : 8
on samba : 5
on santana : 4
on bondeville : 4
on eden : 2

And no treatment was recommended on aphids on ware potatoes by the warning system linked in the same region.



LudovicDubois – Serge Duvauchelle : 03.21.08.62.70
Ludovic.dubois@agriculture.gouv.fr/Serge.duvauchelle@agriculture.gouv.fr

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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

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

N.J. BRADSHAW

ADAS Consulting Ltd., Henstaff Court Business Centre, Groesfaen,
Cardiff, Wales CF72 8NG, UK

Participants:

Ruairidh Bain (UK)
Eileen Bardsley (Bayer CropScience , UK)
Hans Bestman (BASF, Germany)
Erno Bouma (NL)
Jan Bouwman (Syngenta, NL)
Nick Bradshaw (UK)
Linda Bucena (Syngenta, Latvia)
Riccardo Bugiani (Italy)
Rosemary Collier (Jersey)
Marina Collina (Italy)
Louise Cooke (UK)
Serge Duvauchelle (France)
John Edmonds (Dow AgroSciences, UK)
Bert Evenhuis (NL)
Asko Hannukkala (Finland)
Hans Hausladen (Germany)

Chairman : Huub Schepers (NL)

Betty Heremans (Belgium)
Tjaart Hofman (Certis, NL)
Jozefa Kapsa (Poland)
Roeland Kalkdijk (NL)
Simon Leak (Belchim Crop Protection, UK)
George Little (UK)
David Michelante (Belgium)
Bent Nielsen (Denmark)
Frank Niepold (Germany)
Zeger Van Oudheusden (Certis, NL)
Michel Petit (Syngenta, France)
Christophe Prechonnet (France)
Mente Spanninga (DuPont, NL)
Jos Testers (Belchim Crop Protection, NL)
Kees Vogelaar (OptiCrop, NL)
Lars Wiik (Sweden)

Objective:

The objective of the sub-group meeting was to review and update the ratings given 2002 for the various properties and characteristics of early and late blight fungicides at the Poznan workshop in October (PPO-Special Report No 9, pp 23-26).

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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 now been amended and lists the commercially available mixtures
- The ratings are based on publicly available information and a consensus of experience of both independent sub-group members and delegates from the crop protection industry of a particular product in practical use. They are intended as a guide only.
- Products containing fentin acetate, fentin hydroxide and oxadixyl were removed from the list because they are no longer registered in Europe.
- 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.
- Although iprovalicarb has recently been registered for use in Italy & Poland, the sub-group decided not to include it in Table 2 until there had been wider experience in other EU Countries.
- A presentation by Evenhuis, Spits & Schepers (see report on pages 00-11 in these proceedings) suggested changes to the current definition of 'new growing point' and 'eradicant activity'. After considerable debate, it was agreed that the definitions should not be changed.
- A harmonised protocol for the evaluation of fungicide rainfastness was proposed by Nielsen, Duvauchelle, Hausladen & Schepers and agreed by the subgroup. A report on these proposals can be seen at page xx of these proceedings.

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 growing point - The ratings for the protection of the new growing point indicate the protection of new foliage due to the systemic movement of the fungicide. It is assumed that new leaves were not present at the time of fungicide application.

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.

Eradicant activity - *P. infestans* is killed within sporulating lesions thereby preventing further lesion development. This mode of action prevents sporangiophore formation and therefore anti-sporulant activity is included within the definition of eradicant activity.

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 of the foliar epidemic.

N.B. The information in the table 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 straight 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 (both independent scientists and delegates from the crop protection industry) at the Jersey late blight workshop, 2004 and are based on field experiments and experience of their performance when used in commercial conditions.

Product [1]	**Effectiveness**				**Mode of Action**			**Rainfast ness**	**Mobility in the plant**
	Leaf blight	New growing point	Stem Blight	Tuber blight	Protec-tant	Cura-tive	Eradi-cant		
chlorothalonil	++	0	(+)	0	++	0	0	++(+)	contact
copper	+	0	+	+	+(+)	0	0	+	contact
cyazofamid	+++	0	+	+++	+++	0	0	+++	contact
dithiocarbamates [2]	++	0	+	0	++	0	0	+(+)	contact
famoxadone+**cymoxanil**	++	0	+(+)[4]	N/A	++	++	+	++(+)	contact+ **translaminar**
fluazinam	+++	0	+	++(+)	+++	0	0	++(+)	contact
zoxamide+**mancozeb**	+++	0	+ [4]	++	+++	0	0	++(+)	contact+**contact**
cymoxanil+**mancozeb** or **metiram**	++(+)	0	+(+)	0	++	++	+	++	translaminar+ **contact**
dimethomorph+**mancozeb**	++(+)	0	+(+)	++	++(+)	+	++	++(+)	translaminar+ **contact**
fenamidone+**mancozeb**	++(+)	0	+(+)[4]	++	++(+)	0	0	++	translaminar+ **contact**
benalaxyl+**mancozeb** [3]	++	++	++	N/A	++(+)	+(+)	++(+)	+++	systemic+ **contact**
metalaxyl-M + **mancozeb** or **fluazinam** [3]	+++	++	++	N/A	++(+)	++(+)	++(+)	+++	systemic+ **contact**
propamocarb-HCl+ **mancozeb** or **chlorothalonil**	++(+)	+(+)	++	++	++(+)	++	++	+++	systemic+ **contact**

[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.*

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 Jersey late blight workshop, 2004 and are based on field experiments and (very) limited experience under commercial conditions.

Product [1]	**Effectiveness**				**Mode of Action**			**Rainfast ness**	**Mobility in the plant**
	Leaf blight	New growing point	Stem Blight	Tuber blight	Protec-tant	Cura-tive	Eradi-cant		
Benthiavalicarb+**mancozeb**	+++	?	?	+(+)	+++	+(+)	+	++(+)	Translaminar+ **contact**
fenamidone+**propamocarb - HCl**	+++	?	?	++(+)	++(+)	?	?	?	translaminar+ **systemic**

[1] The scores of individual products are based on the label recommendation(to be registered) 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.

Key to ratings : *0 = no effect ; + = reasonable effect ; ++ = good effect ; +++ = very good effect ; ? = 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)*. The information that is available on the efficacy of (late blight) fungicides against this disease complex is presented Table 3, they are rated in the same way as for late blight fungicides.

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

Product	**Efficacy** [1]
Azoxystrobin	+++
Fluazinam	(+)
Mancozeb	++
Propineb	++
Chlorothalonil	+(+)
famoxadone+cymoxanil	++
fenamidone+mancozeb	++
zoxamide+mancozeb	++(+)

[1] ***Key to ratings :*** *0 = no effect ; + = reasonable effect ; ++ = good effect ; +++ very good effect*

Preventive protection of new leaf growth against *Phytophthora infestans* in fungicide schedules with spray intervals of four and seven days

A proposal for new ratings

A. EVENHUIS[1], H.G. SPITS[2] AND H.T.A.M. SCHEPERS[2]

[1] Applied Plant Research, Wageningen University Research
P.O. Box 16, 6700 AA Wageningen, The Netherlands
Email: bert.evenhuis@wur.nl
T: +31 (0) 317 478 949; F: +31 (0) 317 418 094
[2] Applied Plant Research, Wageningen University Research
P.O. Box 430, 8200 AK Lelystad , The Netherlands

Abstract

Experiments were carried out to explore the efficacy of fungicides to protect new growth. Three experiments were carried out between 2000 and 2002. Contact, translaminar and systemic fungicides were applied in field trials at Lelystad in the centre of the Netherlands. Efficacy of the fungicides was established in a bioassay. Detached new grown leaflets were inoculated with *Phytophthora infestans*. Disease incidence was assessed after incubation for approximately a week. Protection of new growth depended on the property of the fungicides, the spray interval and the growth rate of potato leaves. No evidence was found that a build up of fungicides after several applications increased protection of the leaves against *Phytophthora infestans*.

Definitions on protection of new growth are discussed. The ratings of the fungicides for preventive protection of new growth given in Poznan (Bradshaw, 2003) were not adjusted in the Jersey meeting. A proposal for new ratings is made.

Keywords: potato, *Solanum tuberosum*, *Phytophthora*, late blight, fungicides, spray intervals, new growth.

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Introduction

Potato plants are sprayed preventively with fungicides to protect them against *Phytophthora infestans*. Until now only the systemic mode of action of fungicides was considered to preventively protect new growth. The definition agreed upon by members of the European network for development of an integrated control strategy of potato late blight was (Bradshaw, 2003): "The ratings for the protection of the new growing point indicate the protection of new foliage due to systemic movement of the fungicide. It is assumed that new leaves were not present at the time of fungicide application." However indications are found that non-systemic fungicides, given certain circumstances, can protect new growth as well (Spits & Schepers, 2001; 2002). The objective of the research was to determine the preventive protection of new growth after application of contact, translaminar and systemic fungicides. Results of the experiments suggested that the definitions on new growth and protection of new growth could be adjusted.

Results and conclusions

New growth can be defined as growth consisting of: growth and development of leaves, however small, present at the time of the last fungicide application and newly formed leaflets / leaves

The efficacy of fungicides to protect new growth against *P. infestans* has been tested in experiments with four and seven day spray intervals. In the first 14 days of the experiments the protection of new growth was clearly better in the trial with four-day spray intervals compared to the trial with seven-day spray intervals (Spits & Schepers, 2002). Shorter time between spraying and inoculation resulted in a better (re)distribution of (contact) fungicides on the new growth resulting in a better protection.

In the beginning of the growing season protection of new growth was not effective with all fungicides (Spits & Schepers, 2001 & 2002). This is most clearly demonstrated after the first two fungicide applications. Ridomil Gold MZ, with a systemic component metalaxyl-m, resulted in the best protection of new growth. In both strategies, the level of protection increased later in the season with lower growth rates.

Most fungicides with a spray interval of 7 days do not sufficiently protect a developing growing point of a crop with a high growth rate. The (contact) fungicide Ranman + ADD protects a developing growing point clearly better than all other fungicides. Fungicides with a curative action mode such as Curzate M, Aviso DF and Tattoo C were included in the experiments. It could be possible that in practice new growth is better protected by these fungicides than these test results showed, because the curative action mode can than also add to the protection.

The efficacy of fungicides to protect new growth differed. Also fungicides with a contact and translaminar mode of action controlled late blight on new growth to some extent. Therefore we propose these fungicides should have a rating for the protection of new growth.

We propose to change the definition of Bradshaw (2003) on protection of new growth as follows. The ratings for the protection of new growth indicate the protection of new foliage due to systemic or translaminar movement and redistribution of contact fungicides. Based on our results we propose adjusted ratings of fungicides for the protection of new growth, as described in Table 1. At the Jersey meeting the proposal was not accepted since little experience by other members of the committee on the protection of new growth by protectant and translaminar fungicides was available. When more data become available ratings might be adjusted in the next meeting.

References

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Table 1. Proposed ratings for the protection of new growth by systemic, translaminar and contact fungicides used to control late blight in potato.

Fungicide (a.i.)	Score 2002	Proposed
Chlorothalonil	0	?
Copper	0	?
Cyazofamid	0	++
Dithiocarbamate	0	+(+)
Fentin acetate	0	*
Fentin hydroxide	0	*
Fluazinam	0	(+)
Fenamidone + Mancozeb	0	++
Zoxamide + Mancozeb	0	?
Famoxadone + Cymoxanil	0	+(+)
Cymoxanil + Mancozeb	0	+(+)
Cymoxanil + Metiram	0	+(+)
Dimethomorph + Mancozeb	0	+(+)
Benalaxyl + Mancozeb	++	++
Mefenoxam + Mancozeb	++	++(+)
Oxadixyl + Mancozeb	++	*
Propamocarb + Chlorothalonil	+(+)	+(+)

**: no rating, since these fungicides are no longer registered in Europe.*

Harmonised protocol for evaluation of rainfastness of late blight fungicides

H.T.A.M. SCHEPERS[1], B.J. NIELSEN[2] & S. DUVAUCHELLE[3]

[1]Applied Plant Research, P. O. Box 430, 8200 AK Lelystad, The Netherlands

[2]Danish Institute of Agricultural Sciences, Department of Crop Protection, Research Centre Flakkebjerg, DK-4200 Slagelse

[3]Nord Pas-de-Calais Regional Plant Protection Service, BP 47 62750 Loos en Gohelle

Introduction

In preventively controlling late blight in potato the rainfastness of fungicides is an important characteristic. However, the results of trials in which rainfastness is determined strongly depend on the protocol that has been used. Important factors in the protocol are timing, amount and intensity of rain and the method used to measure the biological efficacy. The protocols used by Bødker & Nielsen (2002), Emery *et al.* (2000), Evenhuis *et al.* (1998) and Schepers (1996) are presented in Table 1. Based on these (and other) trials, ratings are given for the rainfastness of fungicides used in Europe (Bradshaw, 2004). Due to the different protocols it is difficult to compare the results and it was therefore suggested to propose a harmonised protocol for evaluation of rainfastness.

Harmonised protocol

During the meeting of the subgroup fungicides a harmonised protocol for rainfastness trials was presented and discussed. It was decided by the subgroup that the following elements should be part of a harmonised protocol.

- A late blight susceptible variety
- Application of the full dose of a fungicide
- Application of rain after 1(-4) hours which will provide information whether a fungicide has to be resprayed

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- Amount of rain applied 0, 20 and 40 mm (optionally 60 mm)
- Inoculation on the same day as fungicide and rain application

Other elements that can be a part of rainfastness trials were discussed but it was decided not to include them in the harmonised protocol and are therefore considered optional.
This includes the following elements:

- Application of lower dose rates of the fungicide.
- Although it is known that the hardiness of the leaves can influence the results both field trials and trials with potted potato plants can be carried out as long as the potted potato plants are grown outside.
- Although it is known that the intensity and droplet size of rain can influence the results it was decided that rain can be applied with an irrigation boom, sprinklers or a rain simulator.
- Both artificial inoculation in the field as well as inoculation of detached leaves can be carried out. Spore concentration per leaflet can vary from 104-105 spores per leaflet. Inoculation can be carried out on upper and underside of the leaflets.
- Inoculation 5-7 days after application of fungicide and rain which will provide information on the necessity to shorten the spray interval.

Table 1. Details of protocols used for rainfastness trials by different authors.

	Bødker & Nielsen	Emery *et al.*	Schepers/Evenhuis *et al.*
Spray volume fungicide	300 l/ha	300 l/ha	250 l/ha
Rain applied in stage potato crop	40-50 cm, field crop	30-40 cm, field crop	30-40 cm, potted plants
Amount of rain (mm)	0-20-40, irrigation boom	0-20-40, sprinklers	0-(20)-40, rain simulator
Timing of rain (hours after fungicide application)	6-8	12-24	0.5-6
Biological efficacy	Artificial inoculation in the field, bioassay at T0[1]	Bioassay at T+2, T+5, T+7	Bioassay at T0, T+4, T+7
Inoculation	Upper side with 104 spores	Upper and lower side with 104-105 spores	Upper side with 104 spores

[1] *T0 means detachment of leaves at day 0 (=day when rain was applied), T+2 = two days after etc.*

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Studies on the Mechanism of Tuber Blight Control by Zoxamide: Investigations into Effects on Sporangia and Zoospores of *Phytophthora capsici*

J. EDMONDS[1] AND D. YOUNG[2]

[1]Dow AgroSciences, Latchmore Court, Hitchin, UK
[2]Dow AgroSciences LLC, Zionsville Road, Indianapolis, Indiana, USA

Summary

Zoxamide had no effect on motility when added to swimming zoospores, and when added to sporangia it only affected zoospore release at the highest concentration (10 ppm).

A "sandwich" plate technique was developed which allows *P. capsici* to be exposed to zoxamide specifically during the development of sporangiophores and maturation of sporangia. Using this method, zoxamide was found to reduce the production of sporangia at concentrations ≥ 2 ppm suggesting a possible antisporulant effect in the field. Sporangia which formed in the presence of zoxamide contained nuclei of abnormal shape, size and distribution. Even at low concentrations (0.4 ppm) these sporangia were severely compromised in their ability to release motile zoospores.

In a field situation it seems likely that the reduced production of motile zoospores from sporangia which are exposed to zoxamide on the leaf surface or in the cuticle during emergence of sporangiophores from the stomata of infected leaves is the most important factor involved in tuber blight control.

Introduction

Although zoxamide is highly effective in controlling tuber blight in potatoes caused by *Phytophthora infestans*, the mechanism of control is unclear. The present studies were carried out in an effort to better understand the underlying mechanism.

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Tuber infection is caused primarily by infections produced by motile zoospores which are released from sporangia either on the leaf surface or from sporangia which have been washed onto the soil. Consequently, control of tuber blight presumably requires either an inhibition of sporangia production, an effect on zoospore release or motility, or inhibition of the pathogen at the infection site. Since zoxamide is not systemic, has a short half-life and low mobility in the soil it seems unlikely that sufficient fungicide is present in or on the tubers to prevent infection. For this reason we have focused our research on better understanding effects on sporangial production and zoospore release and motility. We decided to use *Phytophthora capsici* as a model organism in our studies instead of *P. infestans* since under laboratory conditions sporangial production and zoospore release is more easily controlled with *P. capsici*.

Methods

Zoxamide

Technical zoxamide was dissolved in dimethylsulfoxide (DMSO) then diluted into water or medium as appropriate to give the desired experimental concentration.

Growth and sporulation

Phytophthora capsici (ATCC15399) was maintained on V-8 agar, pH 7.0, containing 200 ml V-8 juice, 4 g $CaCO_3$ and 20 g agar per liter. For production of sporangia and zoospores, petri plates 9 cm in diameter containing 15 ml of freshly prepared medium were inoculated with 7-mm plugs from a 1- to 2-week old culture, and incubated at 25 ^{o}C in the dark for 4 days. Plates were then placed under cool-white fluorescent lights at room temperature for 48 hr to induce sporulation.

Direct effect on zoospore motility

Sterile water (15 ml) was added to a sporulating culture, and the plate incubated for 20 min at 4 ^{o}C then a further 20 min at room temperature to induce zoospore release. The aqueous zoospore suspension was recovered and adjusted to 6 X 105 zoospores/ml. Aliquots (1 ml) of zoospore suspension were added to 1 ml amounts of aqueous solutions of zoxamide at different concentrations in wells of Lab-Tek 2-chamber plastic slides, and the slides incubated for 3 hours at 25 ^{o}C. The well contents were then mixed carefully using a glass Pasteur pipette and transferred to a glass vial. The wells were washed with 1 ml of water and the wash pooled with the zoospore sample, which was then evaluated immediately for the number of motile zoospores by counting in a haemocytometer. Six replicate wells were evaluated for each treatment.

Direct effect on release of zoospores from sporangia

Aqueous solutions of zoxamide (15 ml) were added to sporulating cultures, the surface mycelium was scraped gently with a sterile plastic loop, and the resulting suspension filtered through sterile cheesecloth to remove mycelial fragments. The sporangial suspensions were transferred to chamber slides (2 ml per well) and the slides incubated for 3 hours at 25 ^{o}C. The number of motile zoospores was determined as described above.

Production of sporangia in the presence of zoxamide

To evaluate effects of zoxamide on sporangia formation and development plates were inoculated and allowed to grow in the dark for 4 days as described above. "Sandwich" plates were then prepared by cutting a 7 cm disk of agar with mycelium from the centre of each plate and transferring the disk to a fresh plate containing 30 ml of 2% water agar containing the desired concentration of zoxamide. For production of sporangia, the sandwich plates were then placed under cool-white fluorescent lights at room temperature for 48 h to induce sporulation. The design of these sandwich plates allows zoxamide to diffuse from the water agar of the lower layer into the sporulating mycelium of the upper layer. It should be noted that we have not determined the amount of zoxamide taken up by the developing sporangia, and that it is likely to be less, at least in the initial stages of sporangium development, than the concentration in the water agar.

Sporangia were harvested from the plates by transferring the V-8 layer of the "sandwich" with sporulating mycelium to a fresh empty petri plate, adding 15 ml of sterile water, scraping the entire surface of the mycelium gently with a sterile plastic loop, and filtering the resulting suspension through sterile cheesecloth. In studies of zoospore release and motility, 2 ml of sporangial suspension was added to each well of Lab-Tek 2-chamber plastic slides, and incubated at 20oC for the desired time. The overall procedure is outlined in Fig. 1.

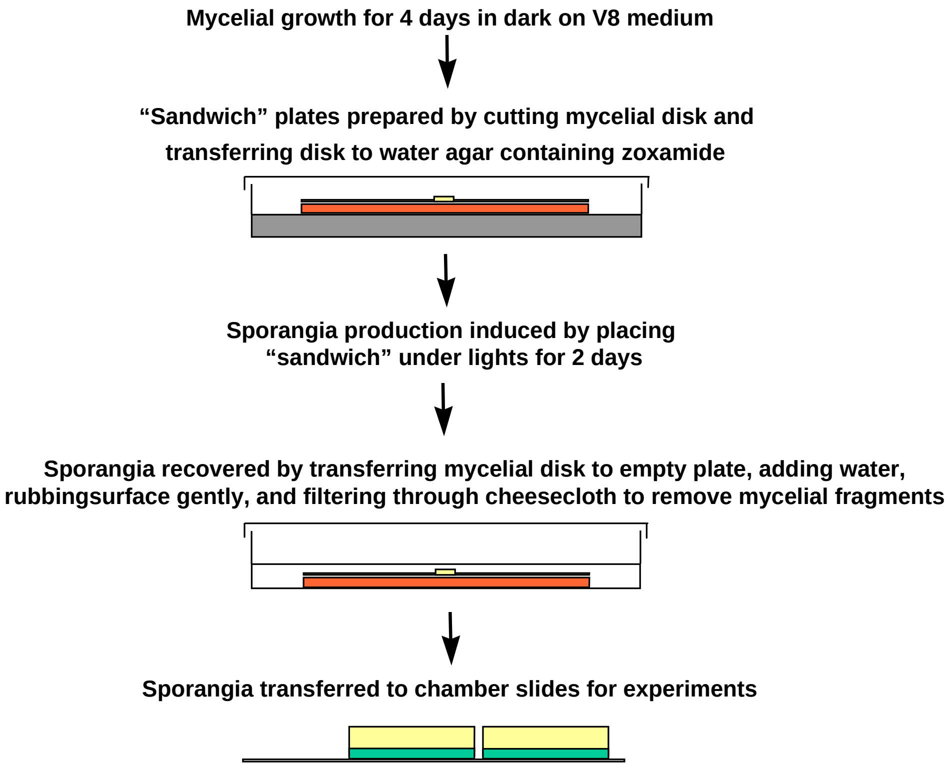

Figure 1. "Sandwich" plate technique for the production of sporangia in the presence of zoxamide.

To evaluate zoospore release, 1 ml of 15% glutaraldehyde was added to each well to fix the samples, and the slides stored overnight at 4 ^{o}C before determining the percentage of empty sporangia (at least 200 sporangia were evaluated for each treatment).

To determine the number of motile zoospores, slides were incubated as above for the desired time. The well contents were then mixed carefully using a glass pasteur pipet and transferred to a glass vial. The wells were washed with 1 ml of water and the wash pooled with the zoospore sample, which was then evaluated immediately for the number of motile zoospores by counting in a haemocytometer. Six replicate wells were evaluated for each treatment.

Nuclear staining

Sporangia were harvested from sandwich plates as described above, and 0.5 ml was added to 0.5 ml of 10% glutaraldehyde. After 30 min at room temperature, the sporangia were centrifuged at 1,000 g for 2 min. The supernatant was discarded and the spores resuspended in 50 mM sodium phosphate buffer, pH 7.0, recentrifuged, washed again and then resuspended in 50 µl of buffer containing mithramycin at 100 µg/ml and magnesium chloride at 15 mM. The stained sporangia were examined by epifluorescence microscopy using Zeiss filter set number 5 (excitation filter BP 400-440, dichromatic beam splitter FT 460, and barrier filter LP 470.

Results and Conclusions

Direct effect on zoospores

When zoxamide was added to swimming zoospores, no effect on the numbers of zoospores still swimming after a 3 h period was found (Fig. 2).

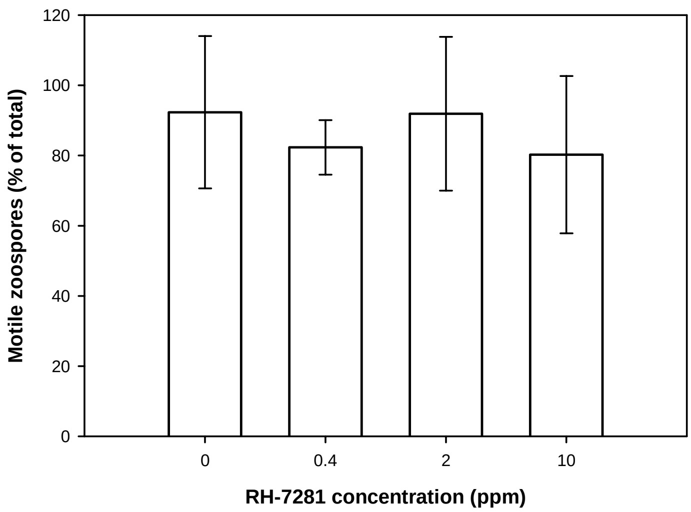

Figure 2. Direct effect of zoxamide on zoospore motility.

Direct effect on release of zoospores from sporangia

To investigate a possible direct effect of zoxamide on release of motile zoospores from sporangia, zoxamide was added to the water used for harvesting sporangia from sporulating cultures and the sporangial suspension incubated for 3 h in chamber slides before examining the yield of motile zoospores. Zoospore yield was unaffected by zoxamide except at the highest concentration (10 ppm) (Fig. 3).

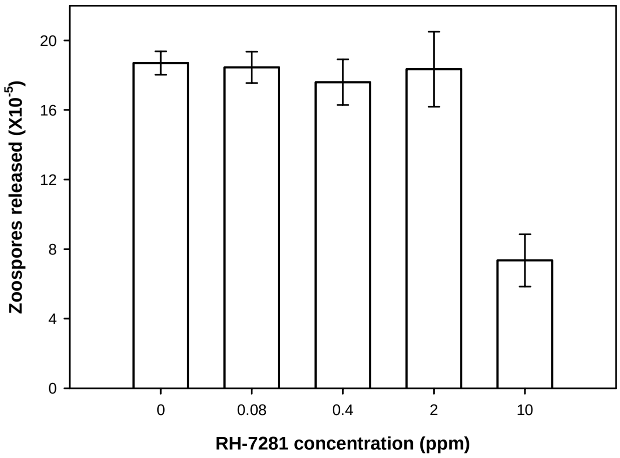

Figure 3. Direct effect of zoxamide on release of zoospores from sporangia.

Effect of zoxamide on the number of sporangia produced on "sandwich" plates

On "sandwich" plates designed to allow zoxamide to diffuse from the water agar of the lower layer into the sporulating mycelium in the upper layer the yield of sporangia was reduced at concentrations ≥ 2 ppm in the water agar.

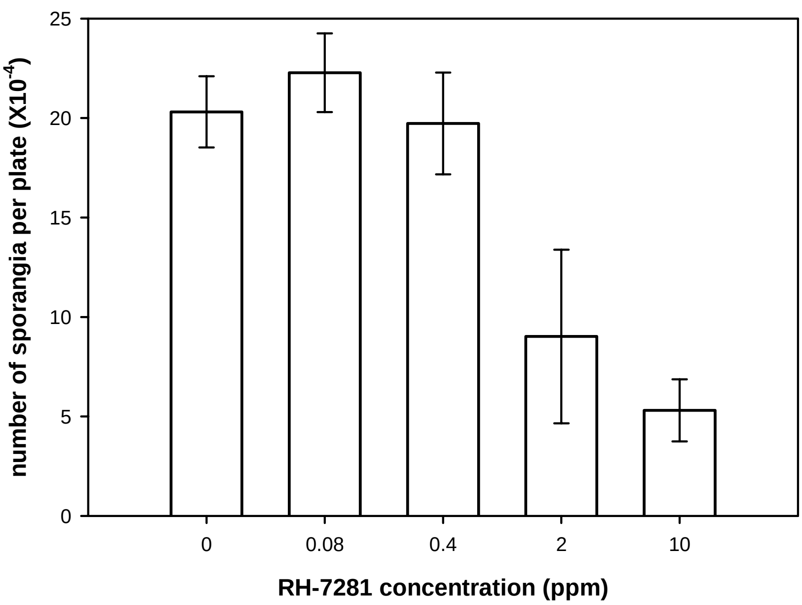

Figure 4. Effect of zoxamide on the number of sporangia produced on "sandwich" plates.

Effect of zoxamide in "sandwich" plates on emptying of sporangia and production of motile zoospores

Release of zoospores from sporangia harvested from "sandwich" plates without zoxamide was complete within 30 min (Fig. 5 and 7). In contrast, the emptying of sporangia harvested from "sandwich" plates containing zoxamide was delayed, and this delay was dose-dependent such that for the 10 ppm treatment 43% of sporangia still had not emptied after 3 h (Fig. 5 and 7). For plates without zoxamide the material released from sporangia consisted of motile zoospores. In contrast, for the zoxamide plates it was found that, although most sporangia did eventually empty their contents, the released material was nonmotile. This nonmotile material appeared amorphous or as round vesicles of various sizes (Fig. 7, 180 min), some of which on longer incubation produced germ tubes indicating viability. As shown in Fig. 6, the number of motile zoospores obtained from sporangia produced on zoxamide-containing "sandwich" plates was greatly reduced even at low concentrations (0.4 ppm).

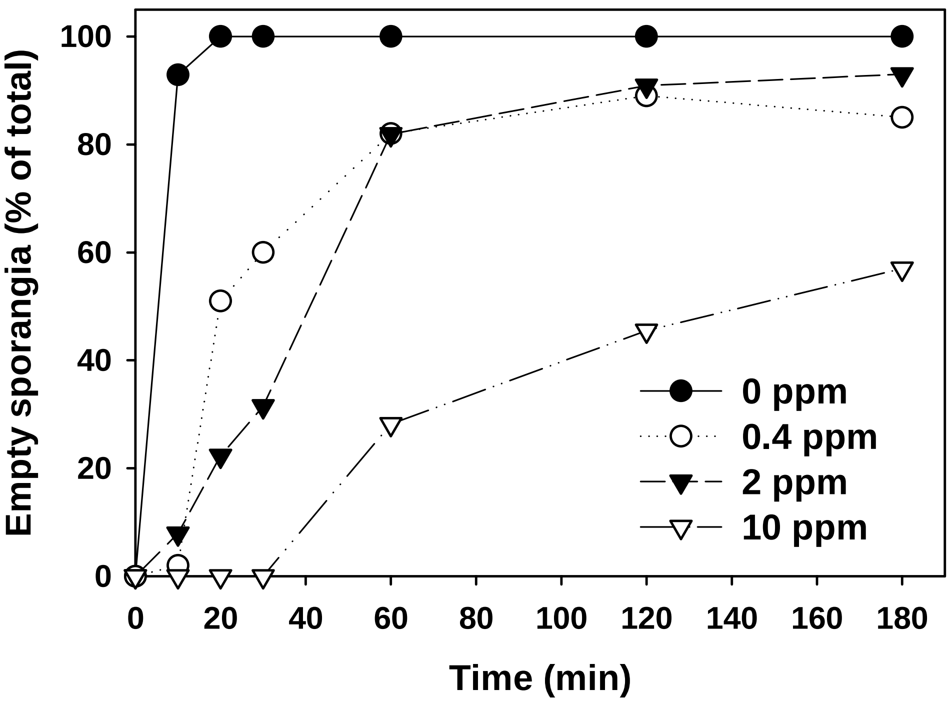

Figure 5. Effect of zoxamide in "sandwich" plates on emptying of sporangia.

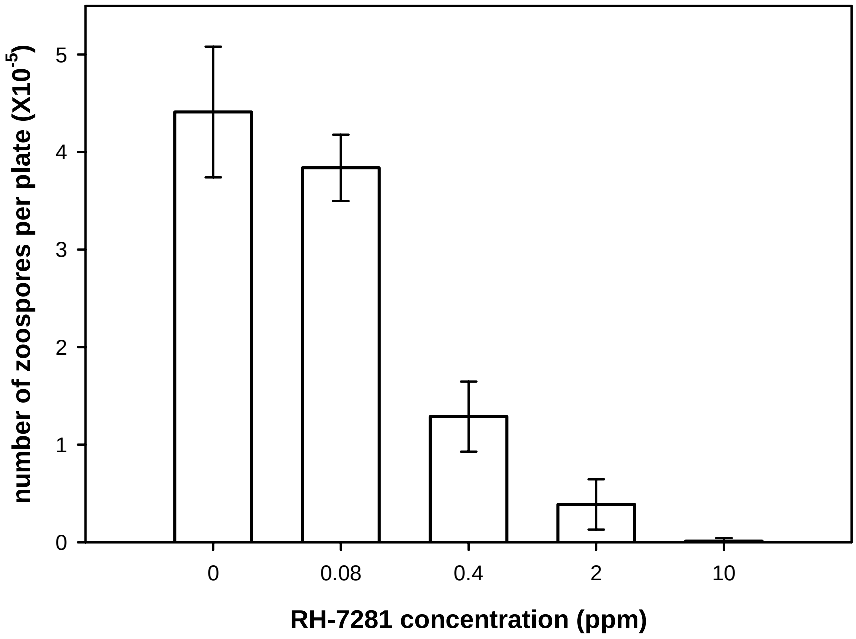

Figure 6. Effect of zoxamide in "sandwich" plates on production of motile zoospores.

Early blight of potato

H. HAUSLADEN, E. BÄSSLER, N. ASENSIO

TU München, Wissenschaftszentrum Weihenstephan, Lehrstuhl für Phytopathologie
Am Hochanger 2a, D – 85350 Freising, Germany

Summary

Early blight of potato, caused by the fungi *Alternaria solani* and *Alternaria alternata*, result in significant yield losses. The pathogens became more and more important in all German potato growing areas. An early blight research project at the technical university in Munich-Weihenstephan deals with the basics of the epidemics and with fungicide strategies to control the disease.

Keywords: *Alternaria solani*, *Alternaria alternata*, early blight, yield reduction, fungicide strategy

Early blight situation in Germany

During the last five years we reported the early blight epidemic in fungicide treated fields. In 2002 and 2003 we found the disease in all potato production areas at the beginning of July. In both years severe attacks were observed in the eastern and southern parts of Germany.
More early blight could be detected one month later. In August we found moderate and high disease levels in all fields. This can be imputed to the high temperatures in July.

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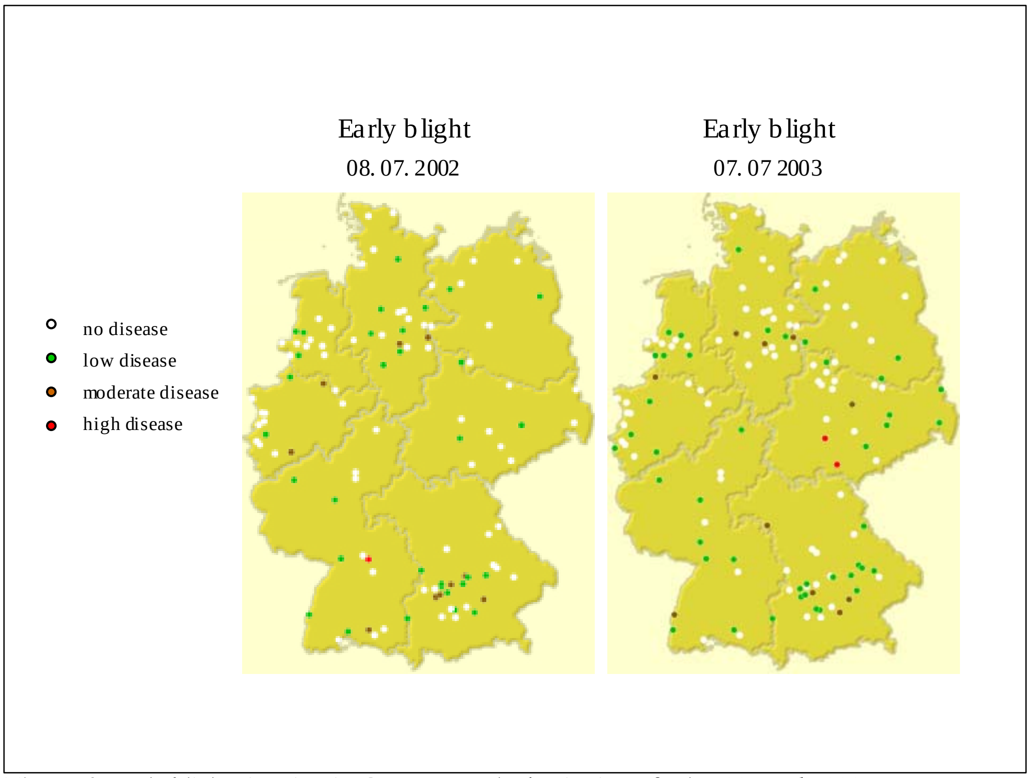


Figure 1. Early blight situation in Germany at the beginning of July 2002 and 2003.

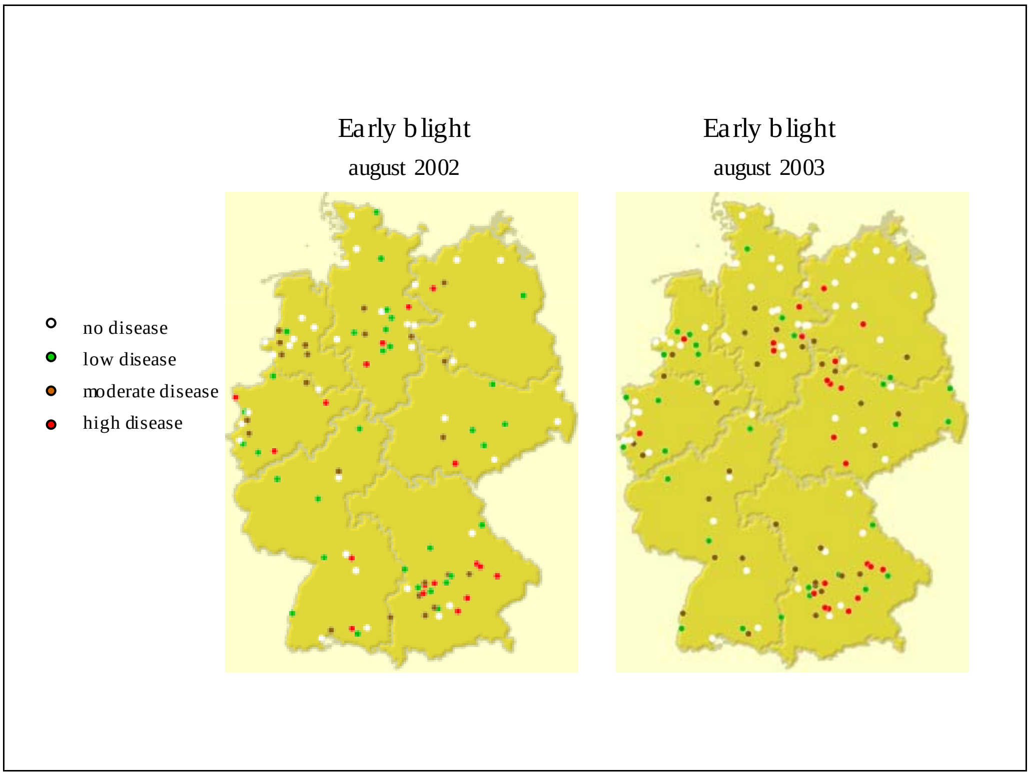


Figure 2. Early blight situation in august 2002 and 2003.

Field trials

Figure 3 shows the development of the early blight disease in an untreated plot. At the moment it is not possible to distinguish if the necrotic spot is caused by *A. solani* or *A. alternata*. For this reason in field trials early blight is imputed to *Alternaria* ssp..

Three weeks after crop emergence the first symptoms can be found in the field.

For about four to six weeks there is no further development of the disease (1% necrotic leaf area). At the end of July, during a period of higher temperature, a development of early blight can be observed. On 25th of July we found 5% necrotic leaves. Only three weeks later more than 80% of the leaves were destroyed by the fungus.

Fungicide treatment delayed significantly disease progress compared to untreated (fig. 4).

Chemical control of *Alternaria* ssp. resulted in increased potato yield. The starch yield showed significant differences between the untreated und the treated plots.

According to our experiences from the past years 10 to 25% yield losses are due to early blight.

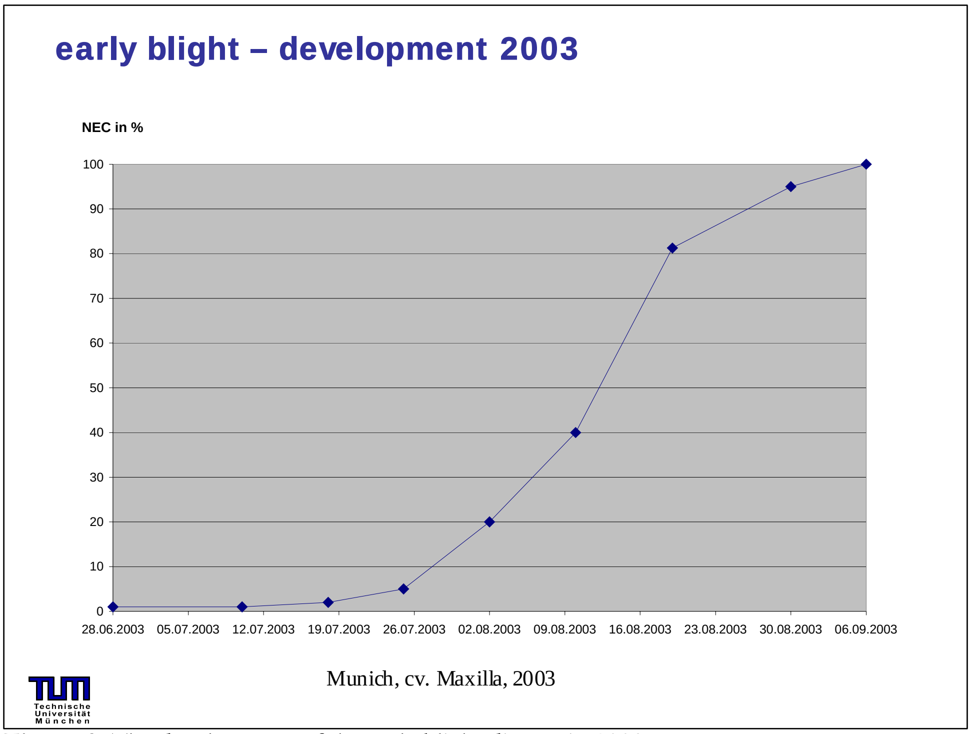


Figure 3. The development of the early blight disease in 2003.

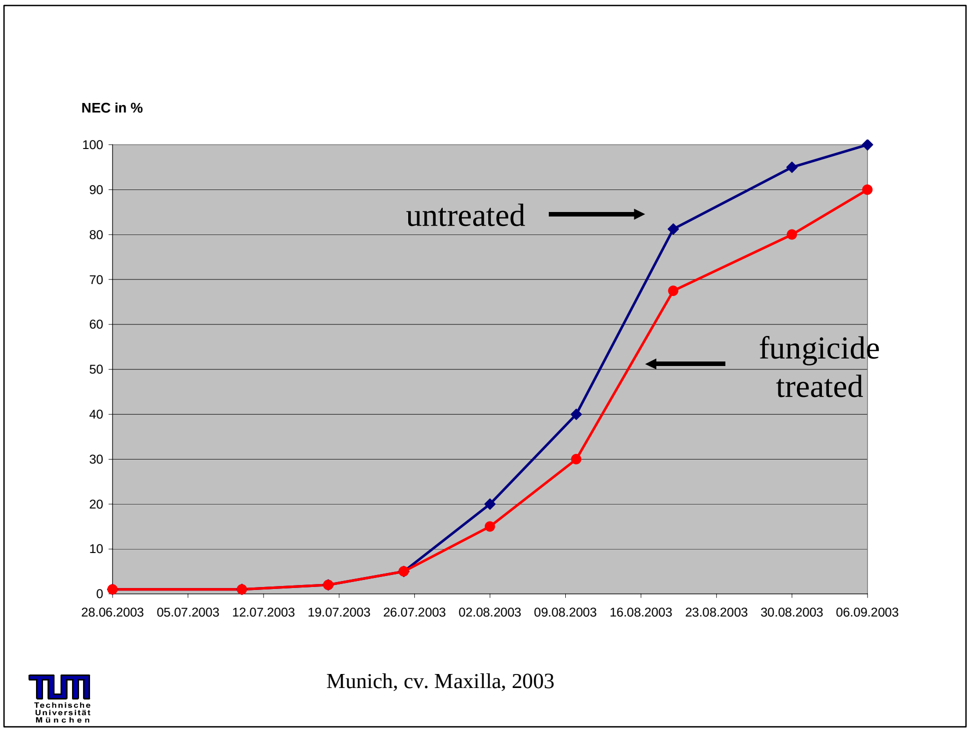


Figure 4. Fungicide treatment delayed significantly disease progress compared to untreated.

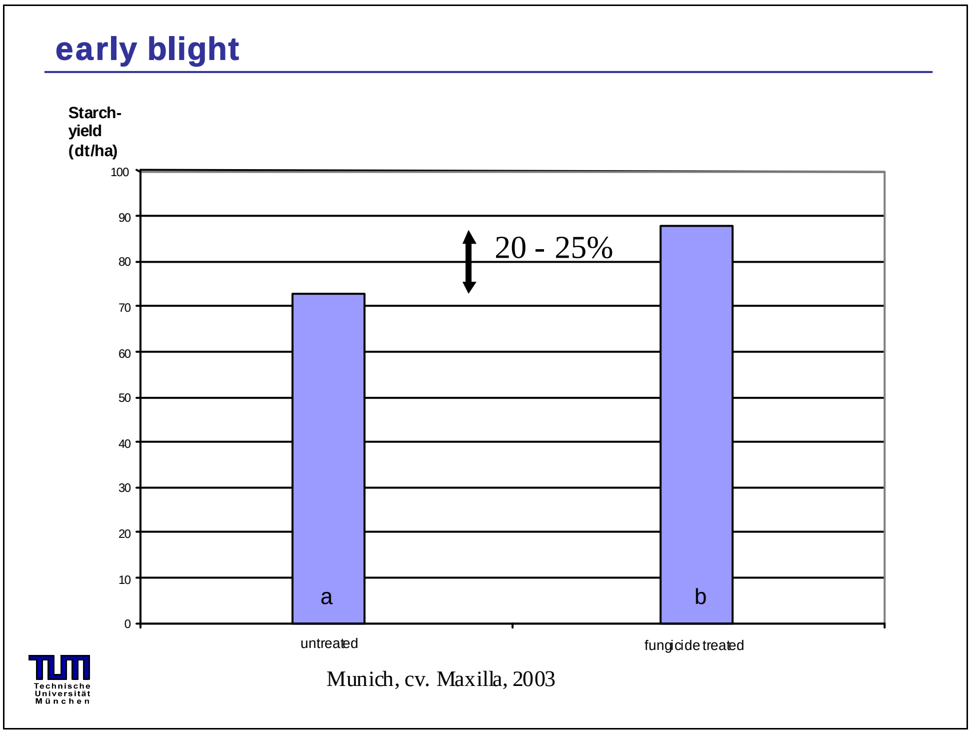


Figure 5. *Alternaria* ssp. causes yield losses up to 25% .

Alternaria solani* - *Alternaria alternata ?

Early blight is caused by *A. solani* and *A. alternata*.
One key question at the moment is: Which one of the two pathogens occurs first in the field?
By using the PCR-technique it was shown that in the field trial 2003 in Weihenstephan *Alternaria alternata* occurred first. In further investigations no other pathogens (*Colletotrichum, Verticillium, Fusarium*) were found.
The results show that *Alternaria alternata* can be regarded as a "real pathogen".
The typical symptoms of early blight (concentric ring in the necrotic leaf area) can be caused by *Alternaria alternata*.

Later on (end of July) both fungi, *A. solani* and *A. alternata*, could be detected by using the PCR.

The control of Alternaria solani (early blight) with azoxystrobin in potatoes

J.J. BOUWMAN AND G. RIJKERS

Syngenta Crop Protection B.V., P.O.Box 1043, 4700 BA, Roosendaal, the Netherlands

Summary

Research in the laboratory and in the field was carried out to investigate the efficacy of azoxystrobin against *Alternaria solani* in potatoes.

Azoxystrobin shows good preventative control with excellent antisporulant activity and efficacy against germination. Good control and a yield benefit with Amistar in a rate of 0.25 l/ha (applied twice in August) in field trials confirm laboratory data.

Keywords: Amistar, azoxystrobin, *Alternaria solani*, potatoes

Introduction

Azoxystrobin (trade name: Amistar) belongs to the chemical group of the strobilurines. It is a high active fungicide demonstrating a broad spectrum of disease control to major ascomycete, basidiomycete, deuteromycete and oomycete plant pathogens.

The compound has eradicant, protectant, translaminar and systemic properties.

In The Netherlands azoxystrobin has a registration in cereals, vegetables, ornamentals and recently it achieved a registration against *Rhizoctonia solani* in potatoes (soil and in furrow treatment).

Alternaria solani (a deuteromycete), despite of the name "early blight", is occurring in Europe quite late in the season. The disease is visible in the leaves by developing big (up till 2 cm) spots clearly angular and bounded by the nerves. In the lesions concentric rings are present.

Up till some years ago the disease was a minor problem in the Netherlands because fungicides used to control *Phytophthora* also gave efficacy against *Alternaria solani*. Due to the limitation of mancozeb the disease increased.

In the last couple of years research was carried out on Syngenta Jealott's Hill International Research Centre in the UK and Applied Plant Research, Wageningen University in The Netherlands to investigate profoundly the intrinsic properties of azoxystrobin against *A . solani*. During the same period field trials were carried out in the Netherlands by Syngenta Crop Protection to compare the strength of Amistar with other registered compounds. Amistar has a registration for the control of *A. solani* in potatoes in Sweden. In several countries in Europe (incl. The Netherlands) the dossier to achieve registration has been submitted. In this paper a short summary is given of the results obtained.

Material and Methods

Research by Applied Plant Research, Wageningen University, the Netherlands (2003).

A. solani seldom produces conidia (spores) on artificial media, therefore the conidia were taken from diseased leaves fresh from the field. To determine the effect of the fungicides on the germination of the conidia of *A. solani* a spore suspension was made by washing off conidia from infected potato leaves. Each fungicide was mixed with a fixed amount of PDA-medium in the petri dishes in a concentration of 100, 10, 1 and 0.1% of the label dose rate.

Table 1. Fungicides used in the in vitro test.

Fungicide	Active ingredients (a.i.)	Label dose rate
Shirlan	fluazinam (500 g/l)	0.4 l/ha
Dithane DG	mancozeb (75%)	2.0 kg/ha
Amistar	azoxystrobin (250 g/l)	0.25 l/ha
Untreated	-	-

Table 2. Concentration rate of active ingredients in ppm.

% label dose rate	Active ingredient (ppm)		
	fluazinam	mancozeb	azoxystrobin
100	800	6000	250
10	80	600	25
1	8	60	2.5
0.1	0.8	6	0.25

The germination of spores is reported as + and - scale, related to the exuberant germination of the untreated object assessed on the 11th, 15th and 19th of September 2003.

Research by Syngenta Jealott's Hill International Research Centre in the UK (2002)

a. Preventative activity

Three days before inoculation of a spore suspension of *Alternaria solani* a preventative spray was carried out with three different compounds (chlorothalonil, difenoconazole and azoxystrobin) in four different dose rates. Six days after inoculation the % disease control was assessed.

b. Eradicant activity (2 days)

Two days after inoculation of a spore suspension of *Alternaria solani* the same three compounds were sprayed in four different dose rates. Six days after inoculation (=4 days after spraying) the % disease control was assessed.

c. Antisporulant activity

In this test plants were treated 5 days after inoculation, kept in a 24ºC humidity cabinet for 24 hours to enhance sporulation and assessed six days after inoculation (DAI).

New conidium
- long, thin
- light coloured

Old conidium
- broken in segments
  along transverse septa
-Pdark brown

For assessment at 6 DAI the leaves were washed in 15 ml deionised water, rubbed extensively with a camel hair brush and finally cut into small pieces and shaken in a glass test tube in order to dislodge all conidia. The newly formed conidia (readily differentiated from old conidia formed prior to treatment (see picture)) were then counted on a Sedgewick-Rafter counting cell using a light microscope.

When the assessment was made, only the new *A. solani* conidia (picture left) that were formed in the 24ºC humidity cabinet after treatment were counted. Old conidia (picture right) were disregarded because they were formed before fungicide treatment.

Field trials in the Netherlands by Syngenta Crop Protection (2002 and 2003)

The trials were conducted in commercial potato crops grown according to commercial practice. The sites were located in the major ware potato crop growing region in The Netherlands. The range of varieties tested represented the major commercial cultivars grown in The Netherlands. Varieties were selected for their susceptibility to *Alternaria solani*.

Each trial was of randomised block design with four replicated plots. Plot size was 30 m^2. The trials were marked out to accommodate the application equipment and were sufficiently large to carry out biological assessments including yield. Treatments were applied with a hand-held small plot sprayer of 3 metres wide fitted with 8 nozzles. The sprayer was based on the principle of compressed air. Volume of application was 250 l/ha of water. Up till the beginning of August a weekly spray was carried out to control *Phytophthora infestans* (no difference in plot treatment). From that time onwards plot differentiation was made. Amistar (in a rate of 0.25 l/ha sprayed 1-2 times) was always mixed with a compound to control *Phytophthora*. Foliar disease control was determined by estimating disease area (PD scale 1-10, LEATT = Leaf Attack). In this assessment scale 10 = complete healthy crop, no disease and 1 = crop completely dead because of the disease. The assessments were carried out 4-5 times with an interval of 6-8 days. Yield was assessed by harvesting an area of 11.25 m^2.

Results

Research by Applied Plant Research, Wageningen University, the Netherlands (2003)

Table 3 shows an exuberant germination of *A. solani* spores in untreated. It is clear that all fungicides had a strong effect on the germination of the conidia of *A. solani*. Only at 0.1% of the label dose rate Dithane is not able to restrain the germination of the conidia anymore.

Table 3. Germination of *A. solani* conidia on PDA medium mixed with fungicide concentrations at three assessment dates.

	100% Label dose rate			10% Label dose rate			1% Label dose rate			0.1% Label dose rate		
fungicide	11/9	15/9	22/9	11/9	15/9	22/9	11/9	15/9	22/9	11/9	15/9	22/9
Shirlan	-	-	-	-	-	-	-	-	-	-	-	-
Dithane	-	-	-	-	-	-	+/-	+/-	+/-	++	++	++
Amistar	-	-	-	-	-	-	-	-	-	-	-	-
untreated	+++	+++	+++									

-	*no germination*	-	*no germination of spores*
+/-	*small germination*	+/-	*small germination, no mycelium growth*
++	*good germination*	+	*germination; mycelium growth restrained*
+++	*exuberant germination*	+++	*exuberant germination and mycelium growth*

Research by Syngenta Jealott's Hill International Research Centre in the UK (2002)

a. Preventative activity (3 days)

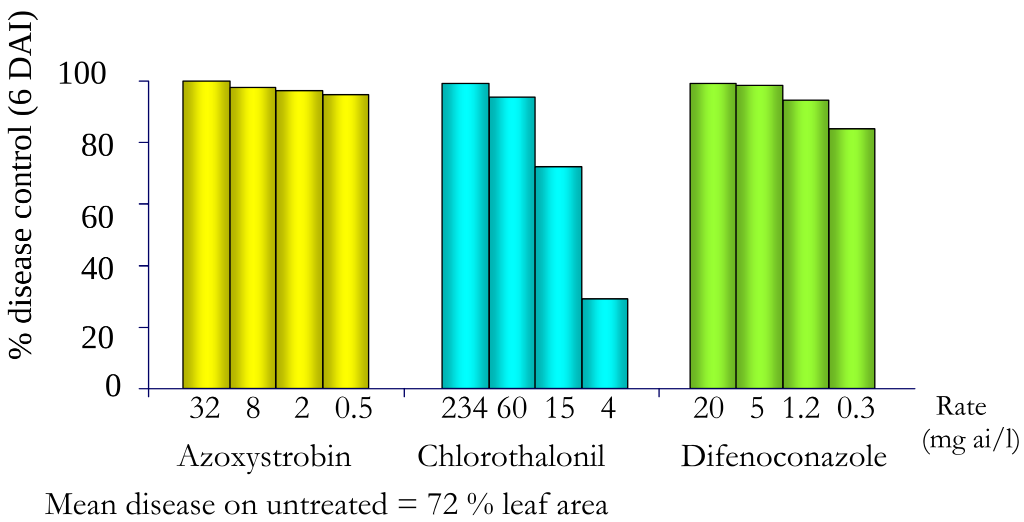


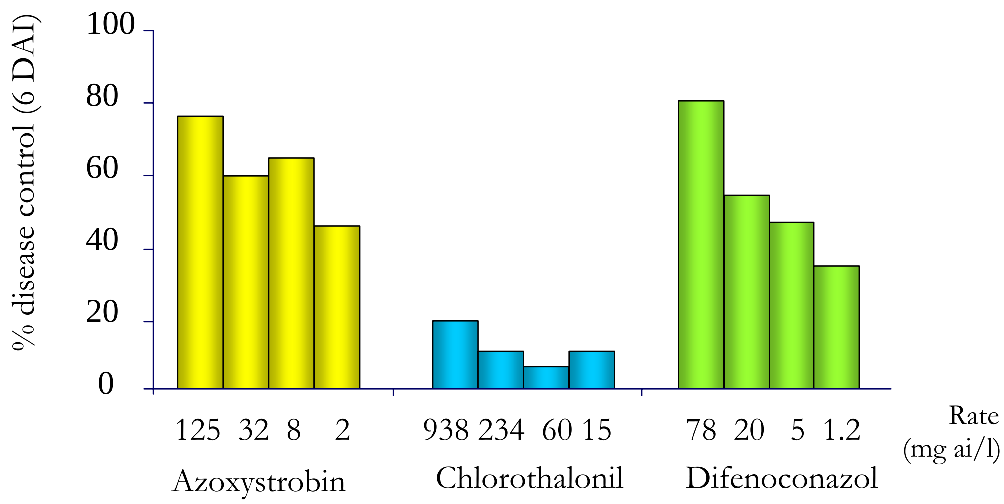
Figure 1. Preventative control of *A. solani* by azoxystrobin, chlorothalonil and difenoconazole at four different dose rates.

Figure 1 shows the preventative control of *A. solani* by azoxystrobin, chlorothalonil and difenoconazole at four different dose rates. In untreated 72% of the leaf area was infected. It is clear that both azoxystrobin and difenoconazole are intrinsic the strongest active ingredients with for both flat dose responses. For azoxystrobin and difenoconazole resp. 0.5

and 0.3 mg/l were the lowest rates in the 3 day preventative study giving respectively 96 and 84% of disease control.

b. Eradicant activity (2 days).

The same three active ingredients are tested in four different dose rates (fig. 2). In untreated 95% of the leaf area was infected. Again both azoxystrobin and to a lesser extend difenoconazole out performed chlorothalonil. Chlorothalonil, as expected, had no effect on disease development when applied at this timing. Difenoconazole showed good disease control at the two highest rates, but was inferior to azoxystrobin at the two lowest rates tested.



Mean disease on untreated = 95 % leaf area

Figure 2. Three active ingredients tested in four different dose rates.

Azoxystrobin was less effective as a 2 day eradicant treatment then as a 1 day treatment (not showed here) which was again less effective then a preventative treatment.

The eradicant activity of azoxystrobin is most likely due to azoxystrobin causing collapse of the mycelium within the leaf. However more work is required to determine such effects of azoxystrobin on fungal development of *A. solani*.

c. Antisporulant activity

Azoxystrobin demonstrated excellent antisporulant activity, inhibiting sporulation by more then 90% at all four rates when compared to the control treatment (mean number of newly formed conidia 8950 on the untreated leaves). This antisporulant activity was by far superior to the poor effect that difenoconazole or chlorothalonil had on sporulation.

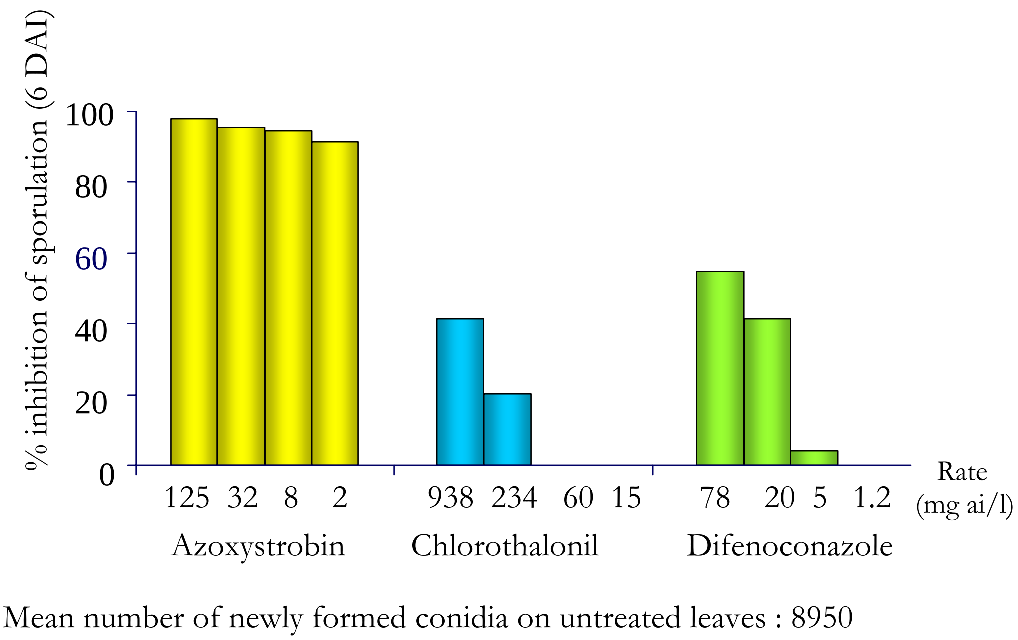


Figure 3. Antisporulant activity of three active ingredients.

Field trials in the Netherlands carried out by Syngenta Crop Protection (2002 and 2003)

In 2002 four trials were done. The results are split over 2 graphs, figures 4 and 5. In all the trials a heavy attack of *A. solani* in untreated (beginning of September untreated scale 3) occurred. Although in both series Shirlan (sprayed 5 times in a weekly schedule) gave some effect on *A. solani*, it is clear that addition of 2 sprays of Amistar (2x 0.25 l/ha) gave a clear efficacy increase, which was better then adding 2 times 900 grams of mancozeb. All four trials were harvested. The efficacy response gave also rise to a clear yield benefit of about 4 ton/ha.

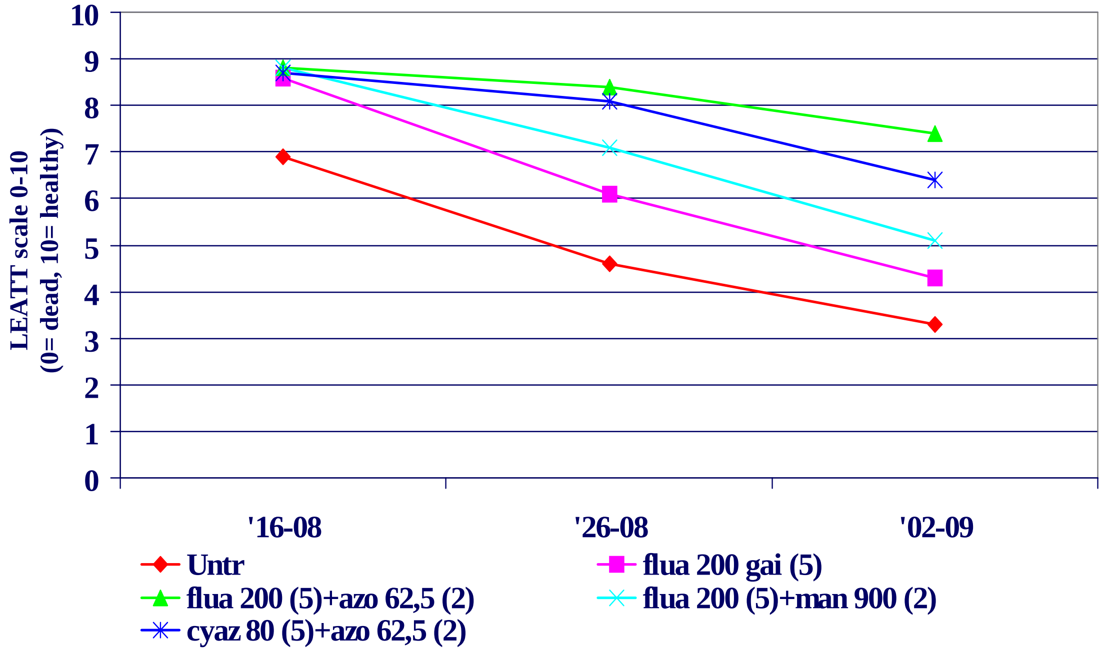


Figure 4. Average of 2 trials 2002.

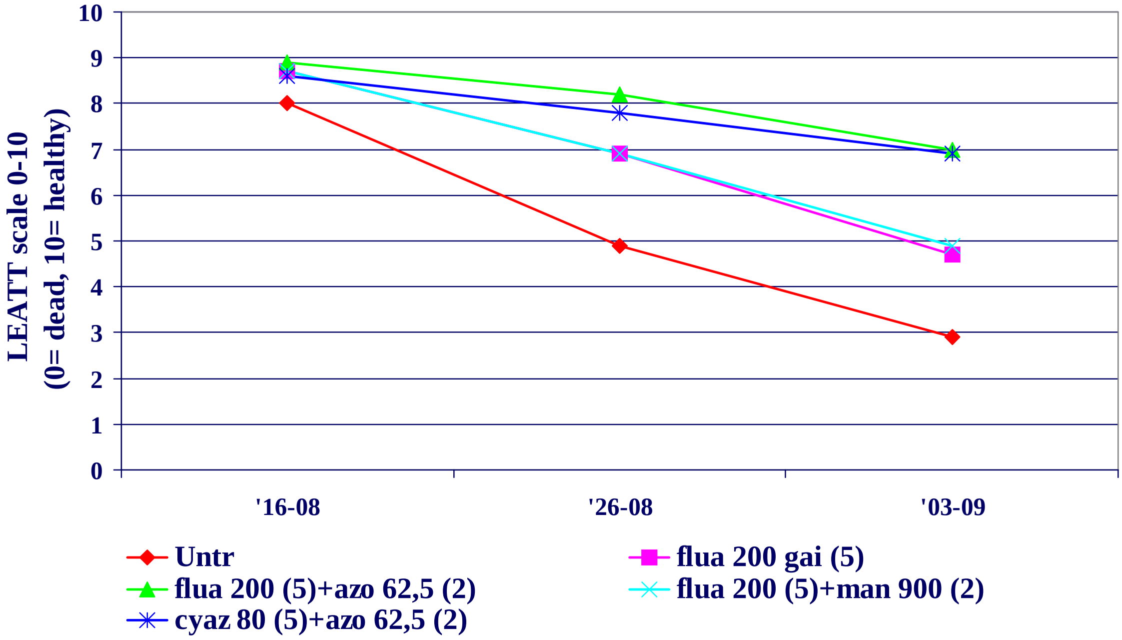


Figure 5. Average of the other 2 trials 2002

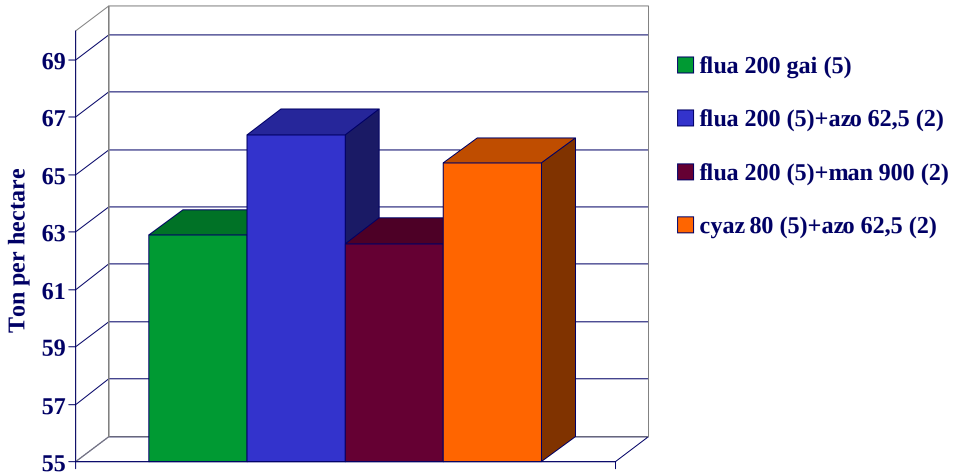


Figure 6. Yield average of 4 trials in 2002.

Also the trials done in 2003 (only one trial shown here, figure 7) gave the same indication. No difference between untreated and cyazofamid, (= ran), Shirlan shows some activity. A clear benefit to both cyazofamid and Shirlan when 2 times on addition is given of 0.25 l/ha Amistar.

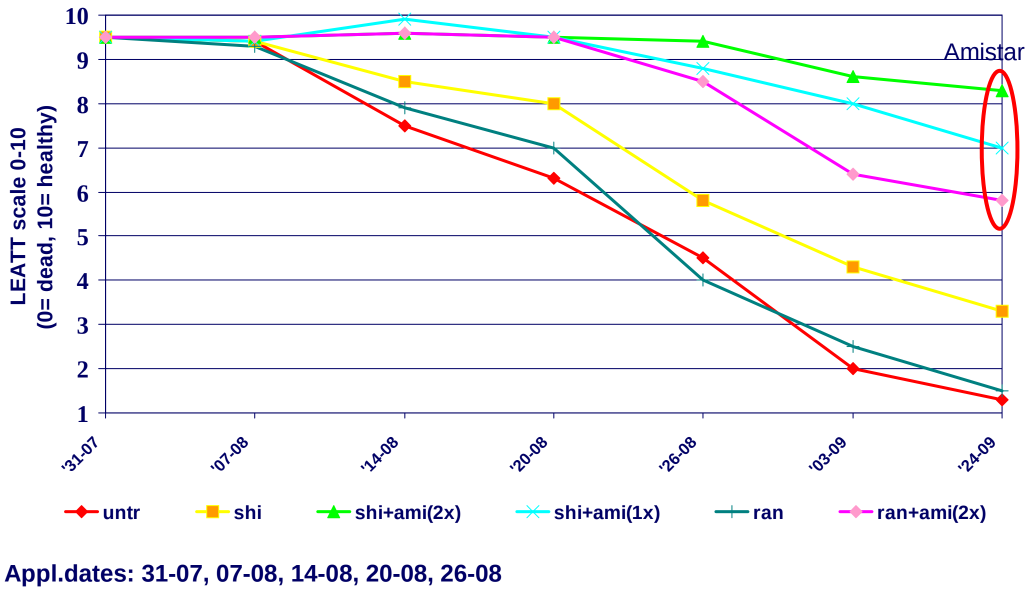


Figure 7. Clear effect of Amistar in a field trial in 2003.

Conclusions

- All three fungicides tested in the laboratory, chlorothalonil, difenoconazole and azoxystrobin, demonstrated excellent activity against *A. solani* with azoxystrobin being the most promising.
- Azoxystrobin showed eradicant activity equivalent or slightly superior to difenoconazole and markedly superior to chlorothalonil.
- Azoxystrobin demonstrated excellent inhibition of germination and antisporulant activity.
- Azoxystrobin was most effective when applied preventatively against *A. solani.*
- Field trials in The Netherlands confirmed the laboratory data that 2 times 0.25 l/ha Amistar sprayed in August gave good control of *A. solani* resulting in a yield benefit.

Rescue experiments for evaluating fungicide insensitive *Phytophthora infestans* isolates

FRANK NIEPOLD

Federal Research Centre for Agriculture and Forestry
Institute for Plant Protection in Crops and Grassland
Messeweg 11-12, D-38104 Braunschweig

Summary

During the year 2002 a Shirlan (Fluazinam) insensitive *P. infestans* isolate (# 69) was isolated in Germany which could not be stopped even by applying a higher fungicide concentrations. To show whether this isolate was still vital and pathogenic, a so called "rescue method" was performed. By using this rescue method it is not only possible to determine fungicide insensitivity in the lab, but also the remaining infectivity of *P. infestans* after treatment with the fungicide can be shown.

Introduction

When working with *Phytophthora isolates*, which grow even when applying fungicides, there are basically two mechanisms which can be distinguished when the efficiency of a fungicide is either reduced or totally lacking: In the case of a "shifting" there is an adaptation of the fungus to a slow increase of fungicide concentrations. This mechanism is a more physiological mechanism since a lack of fungicide pressure over a longer period of time results in a susceptibility of a fungus against the used fungicide. In the case of a "resistance" the fungus acquires a permanent reduced sensitivity against a fungicide, which is genetically manifested. This kind of "non effect" towards a fungicide is more dramatic since such fungal isolates can not be controlled by this fungicide anymore, even if there is a higher dosage of this fungicide is used. In addition, this kind of fungicide resistance is still present, even when over a longer period of time this fungicide has not been applied.

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In the year 2002 a Shirlan (Fluazinam) insensitive *P. infestans isolate* (# 69) was isolated in Germany which could not be stopped even by applying this fungicide in the proper concentration. Therefore a fungicide insensitivity of this *P. infestans* isolate # 69 was tested and also, whether or not the vitality and pathogenicity of this isolate still existed. This led to the performance of a so called rescue experiment.

Results and Discussion

To perform a rescue experiment, this *P. infestans* isolate # 69 was grown first on agar plates (pea or rye extracts) without containing the fungicide Shirlan. After a thick mycelium growth the *P. infestans* isolate # 69 was transferred onto a rye extract agar plate containing different Shirlan concentrations. The growth after 7 days was evaluated and an untypical growth pattern of the mycelium was observed compared to the growth pattern of the same isolate on a fungicide free agar plate.

Parts of this differently grown mycelium of the *P. infestans* isolate # 69 was sterile cut out with the agar and put between two disinfected potato tuber slices (1 cm thick). The tuber slices were put into plastic petri dishes and maintained moist for two days in the dark at 15 °C. After incubation the potato slices were opened up and the inner part was put on the bottom of the tray. If the isolate is still infective, it should grow through the tuber and show a mycelium on the top of the tuber slice. In the case of the *P. infestans* isolate # 69 it was able to grow through the slice showing that it was not killed by the fungicide. The formed mycelium was harvested and a portion was put into sterile water and incubated for 3 h to release zoospores. After filtration, zoospores could be detected under the microscope. A defined concentration of the zoospores (103 zoospores per ml) is used for insensitivity tests to be sprayed on previously with Shirlan treated greenhouse potato plants. In the case of the insensitive *P. infestans* isolate # 69 after 3 days the typical late blight disease symptoms appeared showing that the Shirlan insensitive isolate can be infective.

A lab test was also developed by incubating sporangia from *P. infestans* isolate # 69 in a watery suspension of Shirlan (50 ppm). After 5 days incubation at 4 °C the sporangia produced a visible germination tube, showing that Shirlan was not able to inhibit sporulation. However, the release of zoospores was prevented. To rescue the Shirlan insensitive sporangia the germinated sporangia were transferred onto rye agar without containing the fungicide. Also, the sporangia were put between two potato tuber slices and incubated for one week. Growth was observed after 3 days on a rye agar plate and on the surface of the tuber slices after one week when the isolate had grown through the 1cm thick slices.

In the control experiment Shirlan sensitive sporangia from *P. infestans* isolates were used. No tube formation was observed in the Shirlan suspension and after rescue no growth on rye agar plates or on tuber slides was visible. In the other control experiment water was used, showing that the greater part of the sporangia was releasing their zoospores whereas only a minor part was forming germination tubes, visible under the microscope.

These results indicate that under field conditions the rescue situation can occur also, where a fungicide insensitive *P. infestans* isolate is momentarily inhibited by being in contact with the fungicide. However, this situation lasts only that long until this isolate can grow out of the fungicide containing area into an area which lacks the contact fungicide. This can normally be due to problems of an evenly distribution of the fungicide during spraying or can occur in plant areas where the fungicide has been already washed away by rain.

The rescue experiment as a lab procedure can give in a very short time relevant data on the behaviour of certain *P. infestans* isolates occurring in the fields. The experiments can give an indication, whether a fungicide is still effective and if -after releasing the fungicide pressure- the isolate is capable of forming infective zoospores.

Figure 1. Microscopic picture of the different growth habit of the Shirlan insensitive *P. infestans* isolate # 69 on rye agar.

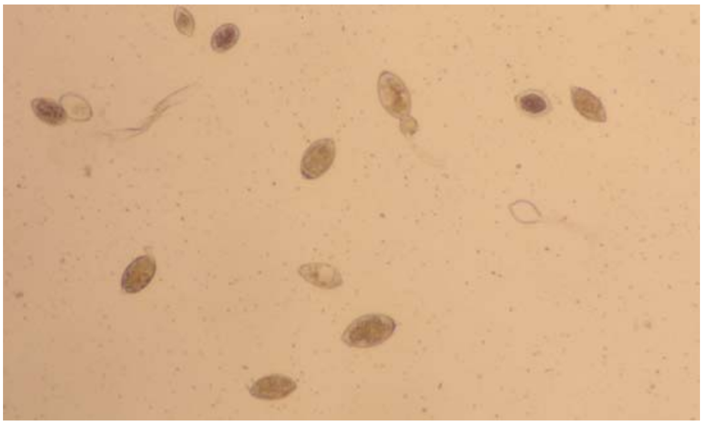

Figure 2. Normal growth habit of the Shirlan insensitive P. infestans isolate # 69 on untreated rye agar, microscopic picture.

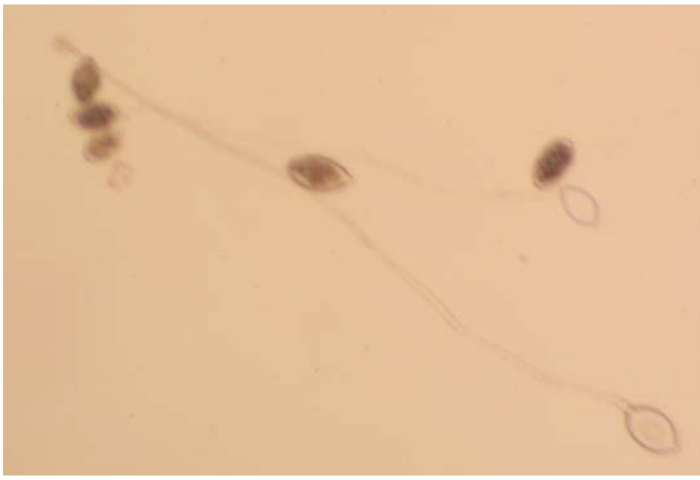

Figure 3. Tube formation of the Shirlan insensitive P. infestans isolate # 69 in a watery 50 ppm Shirlan suspension after 5 days, microscopic picture.

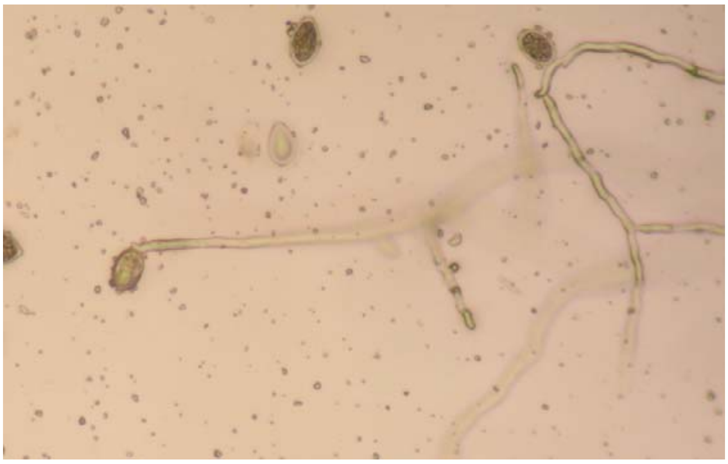

Figure 4. Mycelium growth of the Shirlan insensitive P. infestans isolate # 69 on untreated rye agar after grown on Shirlan containing agar or in watery Shirlan solution (rescue experiment), microscopic picture.

Report of the subgroup meeting Decision Support Systems Jersey 2004

Improving user acceptance of DSS and possibilities for further technical improvements.

G.J.T. KESSEL[1] AND H.G. SPITS[2]

[1] Plant Research International, P.O. Box 16, 6700 AA Wageningen, the Netherlands.

[2] Applied Plant Research, P.O. Box 430, 8200 AK, Lelystad, the Netherlands.

Follow up on DSS discussion 2002

EUREPGAP requires crop protection to be achieved with an appropriate and minimal chemical input. Wherever possible growers must apply recognised IPM techniques on a preventive basis. Non chemical measures are preferred over chemical measures (Source: Eurepgap protocol for fresh fruit and vegetable).

During the 2002 discussion of this subgroup in Poznan (Poland) it was agreed to try and bring DSS to the attention of EUREPGAP. DSS's are ideally suited to help growers fulfil EUREPGAP requirements AND justify the remaining chemical input at the same time.

This topic was brought to the attention of the Wageningen –UR member of the EUREPGAP scientific committee who raised it during the EUREPGAP Conference in Madrid, September 2003.

As a response, EUREPGAP sees the benefits of DSS, but they prefer DSS's providing support for the entire chain for specific crops or even for complete cropping systems. The next update of the "EUREPGAP Protocol for Fresh Fruit and Vegetables" is planned in 4 years time.

The discussion following this introduction focussed on:

- whether or not incorporation of DSS – use into EUREPGAP protocol would be economically beneficial to the farmers ;
- how to change the current European mind set (consumer, grower, government and retail) towards fungicide(pesticide) use in agriculture.

Regarding the first point it was the common opinion that farmers would most likely have to carry the (financial) burden of incorporating DSS's into EUREPGAP protocol.

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Take home message regarding the 2nd point should be that pesticides are unavoidable in the current high yielding European agriculture. However, durability of the production systems requires pesticides only to be used when strictly necessary. DSS's help growers decide when to spray and what to spray, thus justifying the necessity of this chemical input. In addition to this, DSS application often results in better disease control with fewer chemicals.

It was decided to bring this message to the attention of consumers, growers, government (EU) and retail organisations.

Incorporation of cultivar resistance in DSS

The discussion focussed on why and how to incorporate cultivar resistance into DSS.

Incorporating cultivar resistance into DSS's is expected to reduce the chemical input into the cropping system thus reducing the chemical burden on the environment. How this should be achieved technically was not agreed upon.

Cultivar resistance could potentially be incorporated into decision making by using one of two quantitative traits:

- The overall resistance level of a crop, based on AUDPC.
- The resistance to infection with infection efficiency (IE) as the component of resistance most directly involved in "fending off" infection attempts.

It was agreed that specific traits of the (local) *P. infestans* population (such as virulence and aggressiveness) should at least be taken into account. Furthermore, the overall strategy should maintain it's preventive nature. A difference of opinion remained (at least) between the French and Dutch groups who preferred the AUDPC approach and IE approach respectively.

Both Dutch commercial DSS providers were of the opinion that a system based on IE could be implemented to relate dose rate to cultivar. Implementation of a preventive control strategy based on AUDPC values is difficult. DSS prototypes based on IE can be produced so that we can learn by doing it in practice.

We have to keep in mind however that farmers do not (only) decide based on rational data. Emotional matters are just as important or even more important. DSS's are frequently used by farmers to confirm or verify the decisions already made.

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

Analyzing "DON'T CALL US, WE CALL YOU"

JAN HADDERS

Dacom Automatisering

P.O. Box 2243, 7801 CE Emmen, The Netherlands

Summary

In The Netherlands, the future of potato growing is under pressure by the intensive usage of fungicides. Therefore the farmers-organisation LTO started the "Masterplan *Phytophthora*". The mission of the Masterplan is to co-ordinate all actions aimed at effectively controlling Late Blight. Together with Dacom Plant Service a project was designed to contact each registered potato grower by phone each time a Late Blight infection event was forecasted in their region. The objectives are to alert farmers and to make them consider actions to protect the potato crop. The conclusion after three operational seasons is that the objectives were achieved.

Keywords: Late Blight, infection event, PLANT-Plus, communication

Introduction

In the Netherlands, over 180.000 HA of potatoes are grown each year. Due to the more aggressive strains of *Phytophthora infestans*, an increasing number of fungicides are used to control this disease.

In 1999 the farmers-organisation LTO started the "Masterplan *Phytophthora*". The mission of the Masterplan is to co-ordinate all actions by commercial companies, research information services and the government, aimed at controlling the Late Blight problem.

Dacom Plant Service is a company that started in 1987 to develop systems for plant production. In 1994 the PLANT-Plus system was developed as an integrated system for crop

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recording, weather information and Decision Support System modules (DSS). To collect weather data, Dacom operated a network of over 100 weather stations in the Netherlands, covering most potato growing regions. The complete system was developed within the company. The PLANT-Plus potato models are now successfully used in many countries around the world from very wet climates to very arid conditions.

In 2001 a contract between LTO-The Masterplan Dacom was signed to contact all potato growers with a personal telephone message as soon as an infection event in their region was forecasted.

During the EU Late Blight Workshop in Edinburgh in 2001, this project was presented. This presentation analyzed the results over the past three seasons.

Data collection

In order to collect all the information needed for calculating an infection event, different types of information had to be gathered. Information about the farmers, the weather conditions and infected area's were needed. As the basic system, the PLANT-Plus infrastructure for data management and communication was used. All extra systems were designed and built by Dacom staff.

Farmers

The central registration of all potato growers was used to fill the Dacom database. Because of privacy reasons, only the postal code and the telephone number were supplied. From the postal code, the first four digits relate to the location of the address. The average distance of a farmer to a weather station was 7.2 KM and 76% of the growers was within 10 KM of a weather station.

Weather data

In the Netherlands, Dacom manages a network of weather stations that covered most of the potato growing areas. In some regions, agreements with other weather station owners were made to purchase this data. All the data was stored in the Dacom databank. For the weather forecast, Dacom purchased a 5 day forecast for all regions in the Netherlands from the weather office WNI. Based on the geographical information the weather stations and the weather forecast regions were matched with the postal code of the farmers.

Infected fields

In the Netherlands, Dacom has been active for many years to organize the central registration of Late Blight infected spots. Infections were recorded by date, location (co-ordinates) and the severity of infection. In this way, a good picture of the presence of spore in a region could be calculated.

Infection event

An infection event is a successive series of events that result in the infection of an unprotected crop. Within the PLANT-Plus model, these events are: spore formation, spore release and spore dispersal, germination and penetration of a spore into a leaf. For calculating the penetration time of the spores, the susceptibility of the variety Bintje was used. The combination of the number of spores present and the duration of the penetration period defined if the threshold of an infection event was reached. Because Dacom did not know the grower or his crop, a standard, fixed value for unprotected leaf area was used.

Decision making

Calculation of "infection events"

The calculation of an infection event occurred every time a new set of weather data was received, which happened between every hour to a few times a day. This interval depends on the type of weather station. The results were displayed on a monitor as a coloured dot per weather station on the Dutch map. Red coloured weather station meant that an infection event has been calculated for that particular region.

Manual decision of a warning call.

Based on the exact information, it was possible to phone the numbers connected to the specific weather station. The record in the database was marked for a "preventive" or a "curative" call. If the weather forecast showed an infection event coming up, a manual decision was made and a "preventive" call was conducted. The decision depends on the level of the infection event in combination with the probability of the forecast. Special days, like Sunday, were taken into account for the decision of the exact moment of the call. Sometimes, a forecasted period of bad spraying weather triggered an earlier call. In these cases, a number of Dacom experts were involved in the decision making. Sometimes deliberation with the

Masterplan took place. If an infection event was missed by the weather forecast but recorded by the weather station, a "curative" call took place. After the database had been marked for a call, an automated process started calling all the farmers in the list.

All actions of this process and all the reactions of the farmers were recorded in a database. Every week, a complete review of this information was send to the Masterplan.

The Call

When the telephone was picked up the message started:

"Dear potato grower. You are listening to an automated Phytophthora warning of the Masterplan *Phytophthora*. In your region, the coming 24 hours, the weather conditions are favourable for *Phytophthora*. There is a big chance that the disease will infect an unprotected crop. We urge you to take this into account in your disease control actions in your potatoes. If you want more information about the disease pressure for the coming occurrence, you can consult your advisory system or your crop advisor. If after three days again a big change of an infection is calculated, you will receive another call of this warning service.

In order to listen to this message again, press 1. If you rather receive this message next time by SMS, press 2. If you rather receive this message next time by SMS, press 3. If you don't want to receive these warning calls anymore, press 9."

(Action of the called person)

1 → repeat the message

2 → "enter the mobile phone number and close the bracket. …."

3 → "enter the 10-digit fax number and close the bracket. …."

9 → "Are you sure you don't want to receive this message anymore? Push 1 if you are sure, press 2 to listen again to the message.

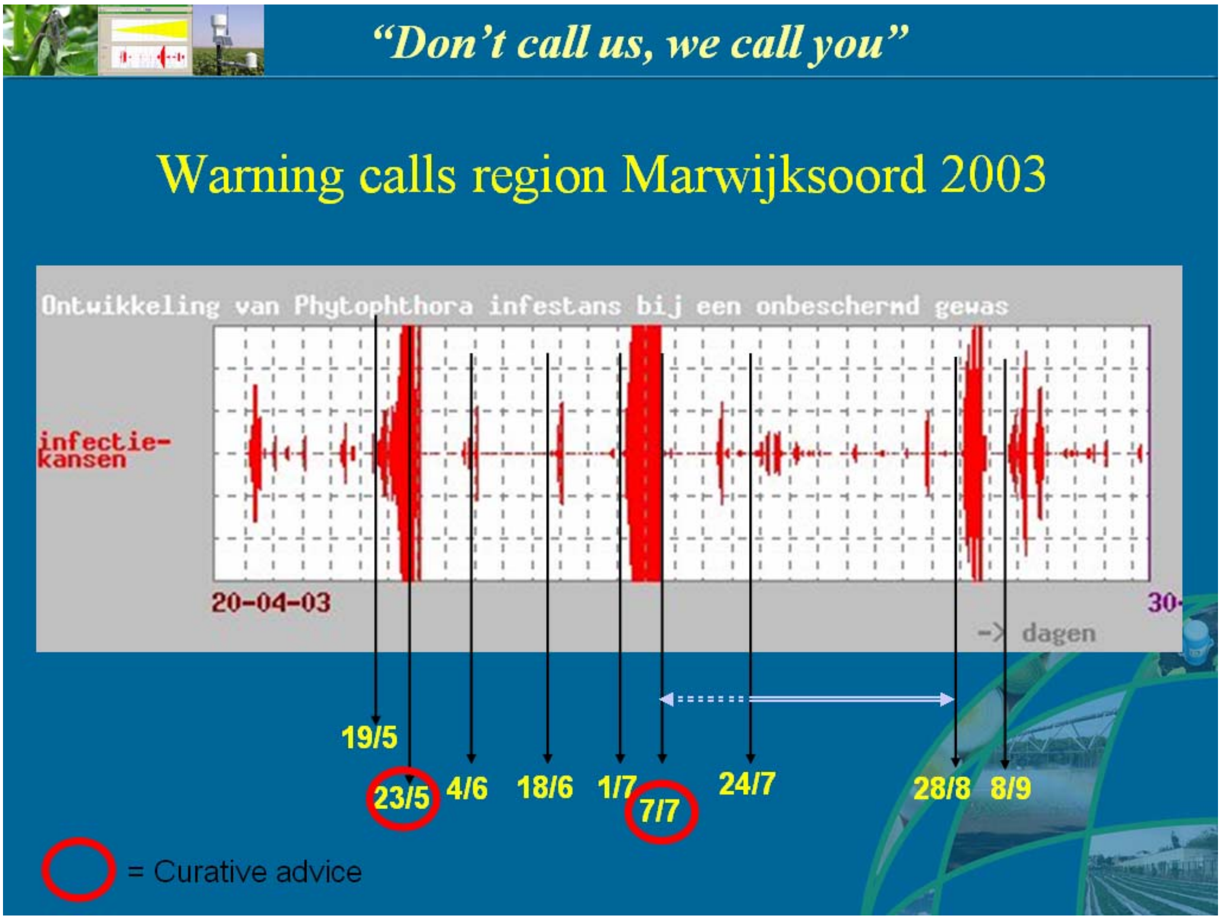
Thank you for your interest. The Masterplan *Phytophthora* wishes you a successful and disease free potato crop. We cut the connection now."

The fax message and SMS message relay the same kind of information as the voice service. The SMS message suggests to call ALPHI at 0900-8585000.

Results

As an example the data of 2003 for the region "Marwijksoord" in the North Eastern parts of the Netherlands will be looked at. Growers in this region received nine warning calls. The first two calls were on May 19 and May 26 of which the second call was a "curative" warning. A number of growers neglected these warning calls as they were considered "too early in the season". This resulted in many outbreaks of *Phytophthora*. Fortunately the weather changed after that to unfavourable conditions for *Phytophthora*. The next infection event was in the beginning of July and lasted almost 7 days. This resulted again in extensive outbreaks but also this time a dry period followed. As one potato magazine wrote "Phytophthora 2003: Saved by the weather".

The graph shows the infection events and the dates of the phone calls.



Calling numbers:

Over the past three years the following numbers of farmers have been called:

Year	2001	%	2002	%	2003	%
Landline	98500	77	68000	67	54500	67
SMS	6000	5	8300	8	6500	8
FAX	16000	13	18000	18	14000	17
Out	7500	6	8000	7	6500	8
Total	128000		102300		81500	

The figures are stable although into the future more SMS messages are expected. The total number of calls gives some information on the *Phytophthora* situation in a given year.

Telephone Inquiry results:

A telephone inquiry has been carried out by the Masterplan to get an insight in the reaction of the potato growers to the telephone calls. A summery of this enquiry shows the following results:

- You spray directly after call: 15% = yes
- Motivation to consider: 57%
- No other DSS: 74%
- PC <> FAX: 50 – 50
- 84% award a "7" on scale 1-10
- You want to pay for it: NO
- You want the service next year: "yes" say 65%

Assuming that half of the 74% that considered to spray put on an application within one or two days, about 50% of the farmers sprayed right after a warning. Also a number of growers was advised already by their own computer warning system or put on an application within their regular schedule. This still leaves a group of growers not reacting on the advice. This is especially the case in the beginning of the season when the timing is considered too early by some growers and by some advisors.

Different reactions

Chemical supply companies:
Receive extra calls about treatment Appreciate opportunity for contact Don't believe in infection events Rather sell beforehand on a weekly schedule Consider this system a possible competition
Farmers:
Supports my DSS system I received one call last season Let a lady with an attractive voice make the call

In the phone message the grower is advised to contact his advisor. Often this is a person from a chemical supply company. Most of these persons are pleased with being contacted by the farmers as they can give a good specific advice. A number of these advisors are added to the telephone list. Other advisors are against the whole system. They rather make an agreement with the grower before the season to purchase the fungicides based on a weekly schedule. Also some consider the message as competition to their own advice.

One reaction was from a lady suggesting we should change the dark brown male voice for an attractive female voice.

The North Eastern part of the Netherlands is a very intensive potato growing region. Therefore it would be expected to find problems with *Phytophthora* infections. This expectation is sustained by field observations. However, data published in the magazine "Optimeel" shows a different picture. Only 2 – 4 % admitted to have a problem with controlling Phytophthora. The rest doesn't consider it as a problem.

Were to put our energy in future

We have proven over and again that an infection event can be identified and that a crop has to be protected at such an event. Some fine tuning can be done towards dose rates of chemicals and warning thresholds of DSS's in combination with variety susceptibility. The problem is a collective awareness of the need to protect a crop before an infection event, regardless of the timing in the season. Much more effort should be put into changing the attitude of growers and the supply chain towards the control of *Phytophthora*.

Discussion

Controlling *Phytophthora* in potatoes is, as in any country, an exciting job in The Netherlands. The consequences of a mistake are far-reaching, specific in ware potatoes. A Decision Support System like PLANT-Plus has been tested and proven over the years to be very accurate in calculating infection events. The technical possibilities of delivering a message to large groups of growers in a very short time are also available now. The difficulty is to get growers to react on the messages in a proper way. There are two obstacles to implement this reaction by the grower. Because the need to spray is weather related it is hard to plan ahead for the season. This makes the operational management of the spraying capacity more of a challenge.

The other obstacle is that many people with influence on the behaviour of a grower don't back up a system of precise targeted applications. They either don't see *Phytophthora* as a problem or prefer a fixed schedule of spraying.

Conclusion

The objectives were to alert farmers and to make them to consider action to protect their potato crop as part of a strategy to reduce chemical dependency. The system has proven to contribute to this objective over the past years. The service will be continued at least until 2006.

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Eighth Workshop of an European Network for development of an
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Jersey, England/France, 31st of March – 4th of April 2004

Progress in the selection of cultivars with resistance to late-blight disease

DAVID SHAW AND LUCY JOHNSON

Sárvári Research Trust

Henfaes Research Centre, Abergwyngregyn, Llanfairfechan LL33 0LB, UK

Summary

Intense selection for resistance to foliar blight over many years by Sárpo Kft in Hungary has resulted in cultivars with exceptional resistance. Results of a trial in 2003 showed that six Sárpo cultivars had total foliar resistance to a fairly low pathogen pressure from a wild population of *P. infestans*. Two Sárpo cultivars and cultivars Stirling and Lady Balfour showed a slow-blighting phenotype. Cultivars Cara, Cosmos, Remarka, Sante and Valor had lower foliar resistance. Marketable yield was as high in Sárpo cultivars as in non-Sárpo cultivars. Natural tuber blight assessed after harvest was noted in Sante (7.8% of tubers), Cosmos (3.7%), Triplo (0.5%) and Valor (0.5%). Only one blighted tuber was detected in one Sárpo cultivar (87.4.001). The results are consistent with a high level of horizontal resistance to foliar blight in Sárpo cultivars.

Keywords: late blight; *P. infestans*; foliar resistance; foliage resistance; slow blighting; tuber resistance; R-gene differential

Introduction

It is generally agreed that every effort should be made to reduce applications of chemicals to growing crops of potato to a minimum, consistent with adequate control of late-blight disease. This is being driven by consumer demand for organic and zero-residue produce and by the need to reduce pesticides in the environment. Thus cultivars are required that can be grown without chemicals for organic agriculture and cultivars needing minimal or no protection for conventional growing. As the pathogen evolves and diversifies, cultivars are

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needed that will retain high levels of resistance to as many populations of *P. infestans* as possible for as long as possible.

Modern cultivars exhibit a range of resistance expressed in foliage and/or tuber. Under early and severe blight pressures, even the most resistant of available varieties defoliate in mid-season and may show tuber blight at harvest or in store. There is a need to select new clones with higher levels of resistance that is expressed against all known (and unknown) populations of the pathogen. These new clones must also satisfy the end-user in respect of a multitude of other traits; they must have no serious defects for grower, processor or consumer.

The Sárvári family from Hungary have been breeding for improved resistance to late blight and to common viruses as priorities for the past 50 years. Their work continues within the Hungarian registered company, Sárpo Kft. The Sárvári Research Trust, now based at University of Wales, Bangor, was set up in 2002 to assess new blight resistant varieties and guide further breeding work.

A comparison of the blight resistance of some Sárpo cultivars and other readily available established cultivars was made at Henfaes Research Centre, University of Wales, Bangor in 2003. The results of the trial are reported here.

Materials and methods

Eight Sárpo cultivars: Kifli (95.20.1); Baby Rose; Mira (87.4.120); Tominia (87.4.0133); Axona (87.4.18); 87.4.15; 87.4.001; 86.27.1546 and eight other cultivars with reputed blight resistance (Anon, 1999): Cara; Cosmos; Lady Balfour; Remarka; Sante; Stirling; Valor; Triplo, were grown in 72-plant plots in a randomised block design with three replicates. The field was fertilised and de-stoned before planting on 23 April; herbicide was applied pre-emergence. Spreader rows of Charlotte and Sárpo 84.4.6 were planted on the margins of the trial and between each cultivar within the trial. Although natural infection was observed on lower stems of several plants of Charlotte on 1st August, this was boosted with cut, infected foliage from a naturally infected crop in N.W. Wales which was distributed along the rows of Charlotte and kept wet with a seep-hose. Due to continued dry weather after infection, spread of blight from the spreader rows into the trial was slow and thus was stimulated with overhead, drip irrigation which maintained some leaf wetness for 20 days from 22 August.

Natural rainfall on the field was 10.5 mm during August and was 130.7 mm during September.

The percentage of leaf area destroyed by blight was recorded at intervals between 19 August and 26 September (days 1 – 39). The assessment key of Dowley *et al.*, (1999) was used. Samples of 20 plants were hand-dug from the centre of each plot between 27 October and 7 November. Tubers were graded and assessed for tuber blight between 10 and 18 November.

Results

Progression of foliar blight

Of the 16 cultivars, Sante allowed the most rapid progression of blight, followed closely by Cosmos then by Valor and Remarka (Fig. 1). Foliage of Cara was significantly more resistant than that of these four cvs. Stirling and Lady Balfour became infected at about the same date as the others but progress of the disease was much slower, reaching only around 10% by the end of the score period. Triplo, a second early, ripened off soon after the beginning of the scoring but did appear to have useful resistance as only the odd lesion was recorded during ripening.

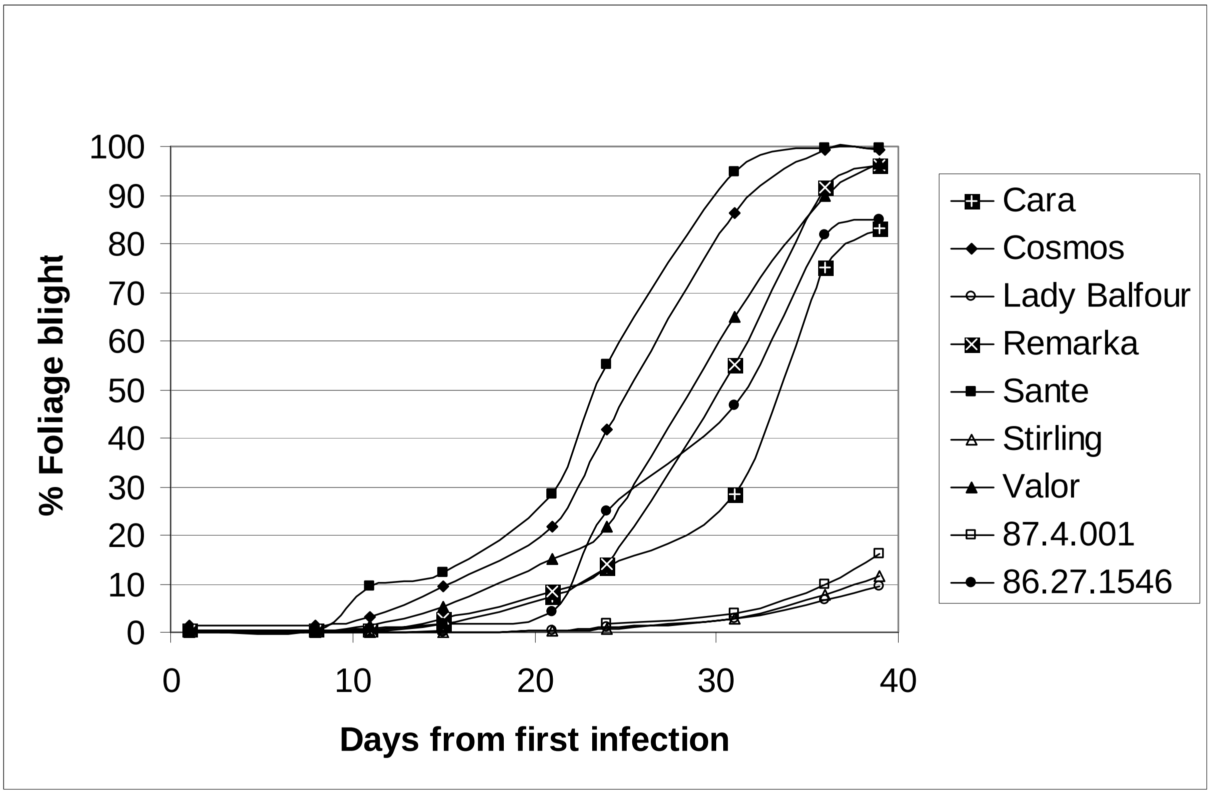

Figure 1. Progression of foliar blight in 9 cultivars which became infected. Triplo had ripened off before blight developed in the trial. Kifli (95.20.1), Baby Rose, Mira (87.4.120), Tominia (87.4.0133), 87.4.15 and Axona (87.4.18) remained healthy.

Of the eight Sárpo cultivars, Kifli (95.20.1), Baby Rose, Mira (87.4.120), Tominia (87.4.0133), 87.4.15 and Axona (87.4.18) remained healthy throughout the period of scoring. Sárpo 86.27.1546 was more than 70% blighted by the end of the scoring period and had similar resistance to Remarka and Valor. The resistance of Sárpo 87.4.001 (less than 15% blighted by the end of scoring period) was similar to that of Stirling and Lady Balfour. The lower resistance of these two Sárpo cultivars is consistent with their performance in many other trials in previous years.

Tuber yield

Total yields averaged 32.2kg/20 plants and ranged from 27.5kg/20 plants (37.7t/ha) for Cara to 39.5kg/20 plants (54.2t/ha) for Stirling (Fig. 2). Total marketable yields (45mm – 85mm) ranged from 14.1kg for Remarka to 31.4kg for Stirling. The mean marketable yield for Sárpo cultivars and the mean marketable yield for non-Sárpo cultivars were identical (21.6kg/20 plants).

Tuber blight

There was a low incidence of blight on harvested tubers. Blight was not detected on 11 cultivars. Cultivar Sante had most blighted tubers of marketable size (7.8 %) and cv Cosmos had 3.7%. Cultivars Triplo and Valor had <0.5% blighted tubers. Blight was detected on one tuber of Sárpo 87.4.001 (0.3%). No blight was detected on tubers of other Sárpo varieties.

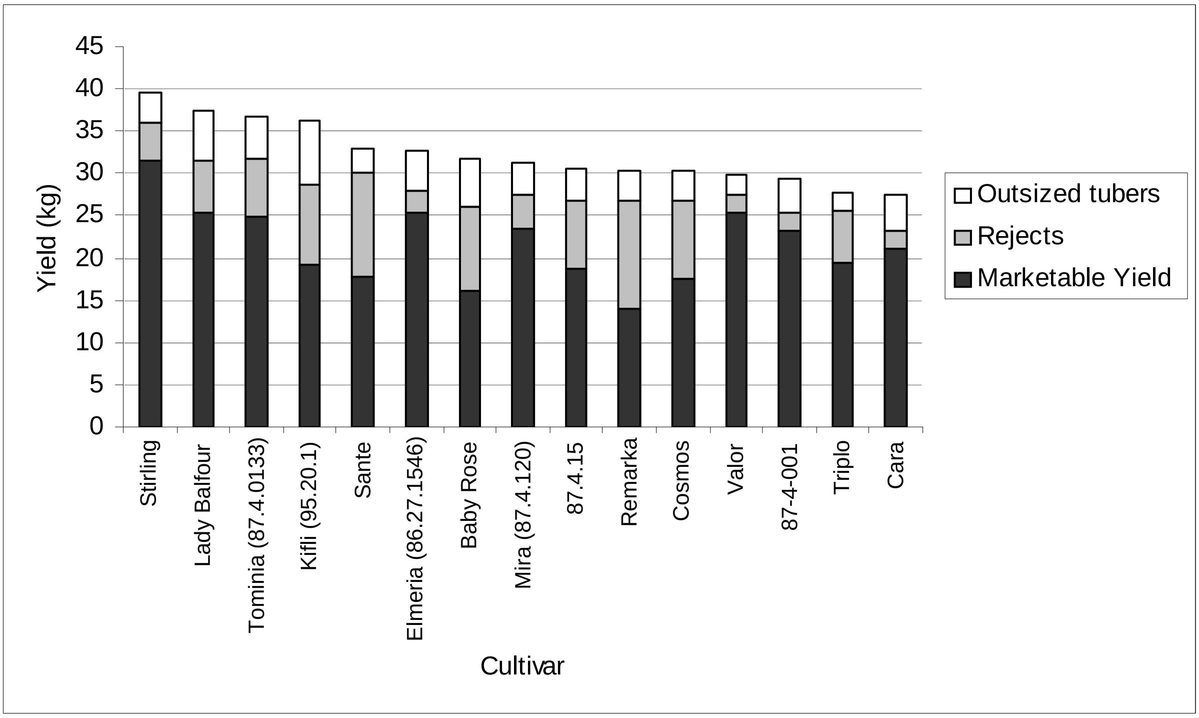

Figure 2. Yields of marketable, outsized and reject tubers from the trial at Henfaes Research Centre, 2003. Yields for Sárpo Axona were not collected.

Discussion

The dry season at Henfaes resulted in low blight pressure during August and September. Areas of N.W. Wales with higher rainfall and humidity had a more normal blight year with destruction of susceptible varieties before the end of August. The introduction of blighted foliage and drip irrigation resulted in rapid colonisation of spreader rows of Charlotte but spreader rows of Sárpo 84.4.6, known to have intermediate resistance in previous trials, remained healthy throughout the growing season. Blight spread into the trial plots and also into susceptible cultivars outside the trial but in adjacent parts of the same field. The latter were rapidly destroyed by blight.

The foliage of six of the eight Sárpo cvs remained blight-free until harvest. The same result was obtained for these cultivars at several sites in UK in drier seasons e.g. Cooke & Little, 2004. All of these cultivars showed varying degrees of slow-blighting in a trial at Henfaes in 2002 when disease pressure remained high from July until October. Thus, the total resistance here may have been a result of low disease pressure. Alternatively, the pathogen population may have been unable to overcome certain resistance genes in these cultivars. Two plants of each of the late-blight differential clones were planted within the trial and were assessed on

29 August and again on 23 September for the presence of lesions. Clones carrying single resistance genes R1, R2, R3, R4, R7, R10 and R11 were blighted but those carrying R5, R6, R8 and R9 remained healthy. This indicates that the pathogen population was not able to overcome these latter R-genes. It is thus not possible to reject the hypothesis that an immune cultivar in the trial possessed one or several of these genes or other R-genes not belonging to the R1 – R11 series.

In the present trial, Sárpo cultivars 87.4.001 and particularly 86.27.1546 proved to be less resistant. This is again consistent with results from other trials in which foliar blight on these cultivars progressed more rapidly than on the other Sárpo cultivars in this trial. Of the other non-Sárpo cultivars, Stirling and Lady Balfour stood out as being slow-blighting varieties. Small differences in rate of progression of foliar blight were apparent in the other varieties with Cara showing more resistance than Sante, Cosmos, Valor and Remarka. The incidence of tuber blight was very low so that estimates of frequency based on samples from 20 plants were of low accuracy. However, the higher frequency of tuber blight in Sante and lower levels in Cosmos would seem to be valid.

It is not known if marketable yields of the less resistant cultivars were affected by blighting of their foliage. Appreciable loss of photosynthetic area did not take place until late in the season and probably after most of the bulking had been completed. The second early, Triplo, certainly avoided blight by ripening early but may also have useful blight resistance. It yielded close to the average for marketable tubers despite its early ripening. This cultivar should be assessed when blight pressure is early and heavy.

This trial and others in various sites show that several Sárpo cultivars have potential for growing without fungicides whereas others could be grown with minimal fungicide application. Sárpo Mira was nationally listed in UK in 2002 and Axona and Tominia are now being assessed. These are red-skinned, high-yielding, maincrop varieties with high dry matter content; they are vigorous and able to suppress weeds in organic trials. They have resistance to common viruses A, X, PLRV and Y. Taste tests indicate that they are acceptable to the consumer.

New clones from Sárpo Kft have recently been selected in Hungary, not only for high blight and virus resistance but also for earlier maturity and improved uniformity and skin finish. These and the present Sárpo cultivars will be assessed in future trials alongside a range of standard cultivars of known resistance. These standards have been agreed by the European Concerted Action "EUCABLIGHT" (http://www.eucablight.org/EucaBlight.asp) and their use will allow assessments of new clones and cultivars at different sites and in different countries to be more comparable.

Conclusions

The resistance shown by six Sárpo cultivars exceeded that of cultivars Stirling and Lady Balfour which themselves were more resistant than Cara, Cosmos, Remarka, Sante and Valor. So far, the resistance has proved durable and results are consistent with resistance being horizontal. The Sárpo varieties have other characteristics which make them suitable for growing in low-input systems.

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Exploitation of cultivar resistance using reduced fungicide dose rates, the Wageningen UR approach

G.J.T. KESSEL[1], W.G. FLIER[1], H.G. SPITS[2], J.G.N. WANDER[2] AND H.T.A.M. SCHEPERS[2]

[1] Plant Research International, P.O. Box 16, 6700 AA Wageningen, The Netherlands
[2] Applied Plant Research (PPO), P.O. Box 430, 8200 AK Lelystad, The Netherlands

Key words: *Phytophthora infestans*, decision support systems, potato late blight, fluazinam

Introduction

In 2004, the umbrella plan Phytophthora, a new initiative on potato late blight control in the Netherlands, was launched. Within the umbrella plan Phytophthora the Dutch grower organisation LTO, the potato industry, the potato trade and Wageningen UR co-operate to achieve the common goal of a 75 % reduction of the environmental burden due to late blight control within 10 years. Within Wageningen – UR, all *P. infestans* related research is co-ordinated and focussed on this goal. The Dutch Ministry of Agriculture, Nature and Food Quality is funding the Wageningen UR Research of the umbrella plan.

One of the aims of the umbrella plan is to better exploit the possibilities of (more) resistant cultivars within a potato late blight (PLB) control strategy to reduce the chemical input when possible. The objective of this paper is to outline the approach developed by Wageningen UR to be able to reliably reduce fungicide dose rates while maintaining adequate PLB control..

Concepts

Possibilities to better exploit cultivar resistance in potato late blight (PLB) control include application of fungicides in reduced dose rates and application of longer spray intervals. In both cases, growers rely on a reduced level of chemical protection (at least for some period of time) which must be "supplemented" by cultivar resistance to achieve the required level of protection.

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Protective control strategy

Current PLB control strategies aim to protect potato crops against infection. For this purpose, protective fungicides are applied prior to periods conducive to *P. infestans* infection. When application of a protectant has been delayed due to e.g. bad weather, a curative fungicide can be employed up to approximately two days after the potential infection event. When this curative treatment cannot be applied, growers can wait and spray an eradicant in case of infection or resume with a protectant when infection has not taken place.

Disease pressure

Disease pressure is a rather loosely defined concept describing the infection risk as e.g. low, moderate or high. Estimates for disease pressure are based on an observer's opinion on local weather and influx of inoculum or they are derived from local historical weather data and a weather forecast. A quantitative estimate of the infection risk of a crop could help to refine control measures. Quantification of the actual infection risk to a crop would have to include estimates on the (predicted) influx of airborne inoculum, host resistance and (predicted) chemical protection level in combination with a local weather forecast. Influx of inoculum: Ideally, estimates for influx of inoculum should be based on accurate information on available sources and local weather so that source strength, release, survival of sporangia during atmospheric transport and deposition can be estimated. Information on local *P. infestans* sources will however never be complete. To avoid unnecessary risks to the crop, information on local sources could be replaced by the assumption that sources are available.

Cultivar resistance

For the purpose of this paper, cultivar resistance may be separated into vertical (absolute) resistance and horizontal (partial) resistance. In the absence of compatible *P. infestans*, vertical resistance provides absolute protection against infection and, at least theoretically, does not require extra chemical protection. Unfortunately, virulence against many or all R- genes or available R- gene combinations is present in most European *P. infestans* populations. In the presence of a (partially) virulent *P. infestans* population, R-gene containing cultivars can become infected when a compatible isolate "lands" in the crop. Thus, when the *P. infestans* population is partially compatible, presence of (an) R-gene(s) may bring about a delay in first infection.

Table 1. Components of resistance constituting the level of partial resistance of potato cultivars

Component of resistance	Symbol	Unit	Description
Infection Efficiency	IE	[-]	Fraction of successfully infecting spores
Latent Period	LP	[day]	Time span between infection and production of the first spore
Lesion Growth Rate	LGR	[mm day^{-1}]	Radial growth rate of a lesion
Sporulation Rate	SR	mm^{-2} day^{-1}]	Number of sporangia produced per mm^2 of leaf per day
Infectious Period	IP	[days]	Time span during which potato tissue remains infective

Partial resistance provides an intermediate level of resistance against PLB. Usually, four or five components of resistance are recognised that together constitute a cultivars partial resistance level. These components relate directly to the *P. infestans* infection cycle and are given in Table 1. Partially resistant cultivars are prone to infection but the higher the level of partial resistance, the slower the epidemic.

In practice, potato cultivars combine different levels of vertical resistance and partial resistance but for the purpose of a protective control strategy in the presence of compatible isolates the Infection Efficiency (IE) is the only component of resistance from which an infection risk can be derived.

Infection risk

Theoretically, the infection risk of a crop at any moment in time can be derived from the partial level of resistance (IE), the (remaining) level of chemical protection, the estimated influx of sporangia and the weather conditions in the near future (e.g. expected leaf wetness duration). During the growing season this estimated infection risk has to be kept below the maximum acceptable infection risk.

The maximum acceptable risk can be derived from e.g. the infection risk of a fully susceptible cultivar just before it has to be sprayed again with a protectant.

To be able to implement this strategy, a series of field experiments was carried out, reported upon elsewhere in this volume) in which IE was estimated for the 30 most important cultivars in the Netherlands. Additionally, in a second series of field experiments each of these cultivars was sprayed with 6 Shirlan dose rates (0%, 20%, 40%, 60%, 80% and 100% of the recommended dose rate) to derive the minimum dose rate required. Both the minimum dose rate required and the IE are used to derive the dose rate for a set of 5 cultivars, representing a range for IE, used in two validation field experiments under practical conditions.

The infection risk is influenced by cultivar, (expected) weather, atmospheric influx of sporangia, the remaining level of chemical protection and the dose rate applied. From these factors, the dose rate applied can be adapted to achieve the required protection level.

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DSS development focussed on variety resistance in The Netherlands, 2003

H.G. SPITS[1], J.G.N. WANDER[1] AND G.J.T. KESSEL[2]

[1] Applied Plant Research (PPO), P.O. Box 430, 8200 AK Lelystad, The Netherlands

[2] Plant Research International, P.O. Box 16, 6700 AA Wageningen, The Netherlands

Summary

In the Netherlands, potato late blight DSS's are important tools for future reductions of the chemical input. Possibilities to adapt recommendations to an increasing public and governmental environmental awareness include exploration of possibilities to incorporate variety resistance in a better way. Thus, the current potato late blight control efficiency could be maintained while at the same time the chemical input is reduced. With this objective the 2003 trials in the Netherlands were conducted.

Standard and experimental versions of the commercially available DSS's PLANT-Plus and ProPhy were incorporated in two field experiments together with a WUR-experimental system using infection efficiency to determine the dose rate and PLANT-Plus to determine the timing of applications. Four potato varieties, differing in resistance to potato late blight, were incorporated in the experiment.

Standard versions of ProPhy and PLANT-Plus hardly differentiated between varieties regarding the number of sprays and the dose rate of Shirlan. PLANT-Plus experimental reduced the number of sprays on more resistant varieties. ProPhy experimental reduced the number of sprays as well as the average Shirlan dose rate on more resistant varieties.

Keywords: *Phytophthora infestans*, variety resistance, decision support systems, potato late blight, fluazinam

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Introduction

During the period 1999 - 2001 each year, 3 trials were conducted in the Netherlands to compare and validate European Decision Support Systems (DSS). In 2002 and 2003 this field evaluation continued focussing on possibilities to incorporate variety resistance into DSS systems. The aim was to exploit moderate and high variety resistance to *Phytophthora infestans* to reduce fungicide dose rates.

Materials and methods

In 2003 two trials were conducted. Both trials were set up as randomised block experiments including three replications, four potato cultivars and five different DSS's per experiment. Fertilisation, insecticides and herbicides were applied according to good agricultural practice. The weather during these trials was hot and dry. As a result, disease pressure and disease severity in the trials was low.

Trial one was located on a loamy soil in Lelystad, The Netherlands. Trial two was located on a peaty soil in Valthermond, The Netherlands. Commercial and experimental versions of ProPhy and PLANT-Plus and the WUR experimental system were included in both trials. In Lelystad potato cultivars Bintje (3/4.5), Santé (4.5/7), Agria (5.5/8) and Aziza (7.5/8) were included. In Valthermond potato cultivars Bintje (3/4.5), Starga (5.5/4.5), Seresta (7/8) and Karnico (8/6.5) were included. Ratings between brackets represent foliar and tuber resistance to potato late blight respectively. Plot sizes were 10.5 x 10 m gross and 4.5 x 8 m net in Lelystad and 12 x 9 m gross and 10 x 4.5 m net in Valthermond. Seed tubers were planted on ridges at 75 cm between ridges and 32 cm within the ridge. Eighty percent emergence was reached on 30 May in Lelystad and on 26 May in Valthermond. Trials were desiccated on 2 and 3 September in Lelystad and Valthermond respectively. Both trials were not harvested because hardly any late blight was observed.

Fungicides used in the experiments were: Shirlan Flow (50 % a.i. fluazinam), Tanos (25 % a.i. cymoxanil, 25 % a.i. famoxadone) and Curzate M (4.5% a.i. cymoxanil, 68% a.i. mancozeb). Shirlan was applied at variable dose rates, Tanos at 0.6 kg/ha and Cuzate M at 2.5 kg/ha.

Application of the DSS's

The systems were consulted daily (before 9:30 A.M.) except on Sundays. Experimental versions of ProPhy and PLANT-Plus were built by Opticrop and Dacom. Aim of all experimental systems (including the WUR experimental system) was to minimise the fungicide input on resistant varieties.

A Dacom automated weather station was situated within 1 km of both trials. Opticrop automated weather stations were situated in the trial at Lelystad and at a distance of about 2 km in Valthermond. Hourly measurements of air temperature, precipitation, relative humidity, wind direction and wind speed at 150 cm height measured by Dacom weather stations were used for PLANT-Plus. For ProPhy, these measurements were provided by the Opticrop weather stations and supplemented by in crop measurements on temperature and relative humidity. PLANT-Plus and ProPhy both used 3-hourly, five-day regional weather forecasts.

ProPhy

The 2003 version of ProPhy (CROP 2003, version 3.1) was used. ProPhy recommends the type of fungicide, spray interval and dose rate for individual varieties. Fungicide and dose rates were used according to recommendation. Timing of the spray application in this trial was dictated by the interval recommended for the least resistant variety. Thus all varieties were sprayed at the same moment with potentially different dose rates.

ProPhy-experimental

ProPhy experimental provides the same functionality as the ProPhy standard version with the following differences:

1) possibility to postpone the first spray,

2) resistant varieties are protected longer (until flowering),

3) a lower dose rate has no effect on the protection period,

4) overruling from the calculated disease pressure is reduced and

5) the minimum dose rate recommended on resistant cultivars is lower.

PLANT-Plus

The Windows version 4.01 of PLANT-Plus was used. Spray interval and recommended fungicide were calculated independently for the individual varieties. A recommendation was followed when the threshold of 200 was exceeded. The first spray was carried out when the advice "consider first spray" (threshold 50 points) was given.

PLANT-Plus-experimental

PLANT-Plus-experimental provides the same functionality as the PLANT-Plus standard version with the following differences:

1) A recommendation was only followed when "carry out a spray today" was advised.

2) The threshold triggering a spray recommendation was higher on more resistant varieties.

WUR experimental system

Spray intervals were calculated by PLANT-Plus-experimental. Shirlan was always used, irrespective whether a spray recommendation could be followed immediately or had to be postponed (except for Bintje). The Shirlan dose rate was based on the level of resistance: Bintje 0.4 l/ha, Agria and Starga 0.32 l/ha, Santé 0.24 l/ha, Seresta 0.16 l/ha and Aziza and Karnico 0.08 l/ha.

Results

Sprays

With ProPhy all varieties were sprayed on the same day. In Lelystad the average dose rate recommended for Aziza was lower than the average dose rate for Bintje (Table 2). In Valthermond the average dose rate for Bintje and Starga was the same. Average dose rates were also the same for Seresta and Karnico. However, the average dose rate for Seresta and Karnico was lower than for Bintje and Starga. On both locations ProPhy-experimental resulted in a reduction of the number of sprays as well as a lower average dose rate on varieties with a higher level of resistance.

Table 2. Average dose of Shirlan (l/ha) on ProPhy and ProPhy-experimental and the total number of sprays (between brackets) in Lelystad and in Valthermond.

Trial site	Lelystad		Valthermond		
Variety ↓	ProPhy	ProPhy exp.	variety ↓	ProPhy	ProPhy exp.
Bintje	0.40 (9)	0.36 (9)	Bintje	0.40 (8)	0.35 (7)
Santé	0.40 (9)	0.30 (8)	Starga	0.40 (8)	0.33 (7)
Agria	0.39 (9)	0.26 (8)	Seresta	0.33 (8)	0.29 (6)
Aziza	0.31 (9)	0.21 (7)	Karnico	0.33 (8)	0.22 (6)

The average dose rate and the number of recommended sprays for PLANT-Plus is given in Table 3. In Lelystad differences in the number of spray applications was small. In Valthermond the number of recommended sprays for Bintje and Starga (10) was the same. The number of recommended sprays for Seresta and Karnico (9) was the same for both varieties and 1 spray less than recommended for Bintje and Starga.

On both locations the use of PLANT-Plus-experimental resulted in a decrease of the number of applications on varieties with a higher level of resistance.

The timing of spray applications for the WUR-experimental system was based on PLANT-Plus-experimental (cv. Bintje). The more resistance varieties were sprayed with a fixed and reduced dose rate (Table 4).

Table 3. Average dose of Shirlan (l/ha) on PLANT-Plus and PLANT-Plus-experimental and the total number of sprays (between brackets) in Lelystad and in Valthermond

Trial site	Lelystad		Valthermond		
Variety ↓	PLANT-Plus	PLANT-Plus exp.	variety ↓	PLANT-Plus	PLANT-Plus-exp.
Bintje	0.40 (7)	0.40 (7)	Bintje	0.40 (10)	0.40 (8)
Santé	0.40 (8)	0.40 (6)	Starga	0.40 (10)	0.40 (8)
Agria	0.40 (8)	0.40 (6)	Seresta	0.40 (9)	0.40 (5)
Aziza	0.40 (8)	0.40 (5)	Karnico	0.40 (9)	0.40 (6)

Table 4. Average dose of Shirlan (l/ha) on WUR-experimental system and the total number of sprays (between brackets) in Lelystad and in Valthermond.

Variety ↓	Lelystad	Variety ↓	Valthermond
Bintje	0.40 (7)	Bintje	0.40 (8)
Santé	0.24 (7)	Starga	0.32 (8)
Agria	0.32 (7)	Seresta	0.16 (8)
Aziza	0.08 (7)	Karnico	0.08 (8)

Late blight

Due to the hot and dry weather, conditions for disease development were unfavourable (Table 5). The number of lesions per plot was calculated based on the number of lesions counted in four rows per plot. In Lelystad hardly any infection was found. In Valthermond some infection was found but severity levels generally remained very low.

Table 5. Calculated number of infected leaflets per DSS in Lelystad and Valthermond at 28 august 2003.

Lelystad		Variety:	Bintje	Santé	Agria	Aziza
DSS:	ProPhy		0.3	0.0	0.0	0.0
	ProPhy-experimental		0.0	5.1	0.0	0.0
	PLANT-Plus		0.0	0.0	0.0	0.0
	PLANT-Plus-experimental		0.0	0.0	0.0	0.0
	WUR-experimental		0.0	3.7	0.0	0.3

Valthermond		Variety:	Bintje	Starga	Seresta	Karnico
DSS:	ProPhy		0.0	0.0	0.0	0.3
	ProPhy-experimental		7.0	23.6	0.0	11.6
	PLANT-Plus		0.0	0.0	1.3	0.0
	PLANT-Plus-experimental		0.0	1.7	8.0	38.6
	WUR-experimental		0.0	0.0	0.0	0.3

Discussion

Experimental DSS's were developed to explore options to incorporate variety resistance into warning systems such that the chemical input can be reduced on more resistant varieties. Field trials were carried out in which three experimental systems were compared to two, Dutch, commercially available DSS's. The WUR-experimental system used infection efficiency (IE) to adapt the Shirlan dose rate for each of the potato cultivars. Both commercial DSS's modified their basic principles underlying the systems to allow incorporation of cultivar resistance.

Experimental plots did not have to remain blight free throughout the season, thus stimulating the experimental systems to pursuit a maximum reduction of the fungicide input and explore the limits to this approach at the same time.

WUR experimental system: Assuming that IE is the most important parameter regarding cultivar resistance when using a preventive control strategy, laboratory estimates of this quantitative trait should provide some insight into the possibilities to decrease the dose rate of protectant fungicides. IE estimates as determined by W. Flier (PRI, The Netherlands, pers. comm.) in a laboratory assay are given in Table 6. The low late blight resistance for Bintje (3) corresponds with a high IE. The relatively low resistance rating of Santé (4.5) however does not correspond very well with the relatively low IE found in the laboratory experiment. Also the high resistance rating of Seresta (7) does not correspond with the relative high IE. These differences accentuate the difference between resistance ratings based on poly-cyclic and mono-cyclic infection events.

Apart from the cultivar, the foliar fungicide concentration, the micro-climate and the disease pressure also affect the infection risk at any time during the growing season. In this context, it makes sense to determine the “effective IE” on cultivars sprayed with different dose rates and determine the time course of this effective IE as influenced by climate and disease pressure. The effective IE for any cultivar should always be equal or remain below the effective IE for a susceptible cultivar sprayed with a protectant at its recommended dose rate near the end of the protection period.

Table 6. Infection efficiency (IE) of *P. infestans* on different cultivars (W.G. Flier, PRI, Netherlands).

Cultivar	IE (prob.)	Foliar resistance
Aziza	0,014	7,5
Karnico	0,017	8
Starga	0,020	7
Agria	0,022	5,5
Sante	0,023	4,5
Seresta	0,029	7
Bintje	0,037	3

PLANT-Plus: Remarkably, the number of sprays on the susceptible variety Bintje at PLANT-Plus in Lelystad was less than for the more resistant varieties (Table 2). In retrospect, this can be explained by a more optimal placement of spray applications over the whole growing season on Bintje than on any of the other cultivars: During a high risk period, Bintje was sprayed more recently than any of the other cultivars and did not exceed its critical threshold. Whereas a spray recommendation was triggered on the other cultivars. The next spray recommendation for Bintje coincided with a recommendation on the other cultivars.

In Valthermond PLANT-plus-experimental recommended one spray more recommended for the most resistant variety (Karnico) than for the less resistant variety (Seresta). The explanation for this is that in the plots of Karnico some attack by late blight was observed. This attack was incorporate in the system and led to an extra spraying advice.

ProPhy: With ProPhy, all varieties were sprayed at the same moment with potentially

different dose rates. In Lelystad differences in dose rate between the varieties Bintje, Santé and Agria were not observed. Most likely the biological demolition of the fungicide is more important in the recommendation than the variety resistance under a low disease pressure. Which result in almost de same recommendations (Table 1).
In Valthermond, spraying Starga according to ProPhy-experimental resulted in more infected leaflets than in the susceptible variety Bintje, while timing and dose rate of the recommended sprays were the same. The explanation for this was that only in one of the Starga plots a small focus of infection was found. The other plots of Starga were free of infection.

Due to the hot and dry weather conditions during the 2003 growing season the number of spray applications was generally low. At the end of the growing season this led to a large spray interval of 31 days for PLANT-Plus-experimental in Lelystad. In both trials the final level of late blight severity was also low. In Valthermond most infected leaflets were found in plots sprayed according to the experimental DSS's. As compared with the standard versions the stretched spraying intervals (in combination with a lower dose rate for ProPhy) on the resistant varieties most likely exceeded the safety limits at least in some instances. The lowered Shirlan dose rates did probably not contribute too much to this level of infection since there was no infection found in the plots sprayed according the WUR-research tool.

Both trials showed that it is possible to reduce the chemical input in more resistance varieties. More detailed knowledge on the effective IE and its time course following a spray application as influenced by weather and disease pressure will enable more specific recommendations and explanation of the current results. More field research has to be done to determine whether these results are consistent under a wider range of disease pressure.

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A new challenge for DSS improvement: more accurate foliar late blight assessment for commercial potato cultivars

C. CHATOT AND D.S. BERSIHAND

GERMICOPA R&D, Kerguivarch, F-29520 Chateauneuf du Faou

Summary

Integrated Pest Management for potato late blight in Europe has been constantly improved for the last decade either by more accurate *Phytophthora infestans* risk assessment tools and methodology or by using more efficient agrochemicals. Plant resistance, i.e. potato cultivars more resistant to *P. infestans*, is a component of IPM that still could be improved. A more descriptive foliar late blight behaviour of potato cultivars –through more accurate disease progress curve analysis- is proposed in order to integrate and optimize potato resistance into current decision support systems. Data from commercial cultivars, currently available for various purposes like early, ware production, processing and/or export types, are provided.

Keywords: IPM, *Phytophthora infestans*, potato cultivar, foliage resistance, epidemiological parameters, Decision Support System.

Introduction

Plant resistance is a highly desired component in any pest management scheme (Anon., 2001) and potato late blight model has been a reference for integrated pest management. All components of IPM tools are evolving : DSS's are becoming more and more accurate because of powerful modelling assisted with efficient computer supports, as well as fungicide active ingredients becoming more and more efficient at low dosage.

On the plant side, genetics have progressed in the second half of the last century and European potato breeders are continuously breeding 'foliage less susceptibility to *Phytophthora infestans*', into new potato cultivars well adapted to highly specialized economical markets.

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However, among the different tools in DSS implementation, potato varietal resistance has only recently been considered as a lever for a better control of late blight, one of the possible explanations is the difficulty of interpreting such variable component. Conventional description of resistance traits, namely *P. infestans* foliar resistance, consists of an overall assessment of foliar late blight during the growing season (Dowley *et al*, 1999, Anon. 2004b), whether this trait is rated on a scale from 9 (resistant) to 1(highly susceptible) or by the relative area under the disease progress curve -rAUDPC- (Fry, 1978). None of these data can be easily incorporated into late blight risk assessment models (Andrivon *et al*, 2004).
Because of the current demand of European societies for reduction of agricultural pesticide inputs, optimizing the performance of current DSS's needs now a better understanding of *P. infestans* epidemiology on potato cultivated varieties (Hansen *et al*, 2001). Ellisèche *et al* (1999) have identified, from different genetic sources of resistance to *P. infestans*, two major epidemiological parameters that can describe more precisely the foliage behaviour to *P. infestans* from the analysis of the epidemiological curve under maximum late blight pressure.
For a given genotype, these data, Δt and Δa, characterize the epidemic delay (in days) and the relative infection rate (in %) of the epidemic progress compared to the most susceptible control, respectively.

This paper describes the contribution of potato breeder for a more exhaustive description of potato newly bred material before it is developed on the different commercial markets and in order to optimize its use, whether it is susceptible or more resistant to late blight, under the best agricultural practices (Anon. 2000, Anon. 2001).

Materials and methods

Potato Cultivars

Twenty-two potato cultivars either bred by Germicopa or public accessions, are assessed for foliar late blight behaviour, under field conditions, for accurate evaluation of the epidemiological parameters. They belong, for the majority, to the "ware" potato type, with differential levels of maturity (early season and general ware and export) requiring from 80 to 100 days of growth cycle as well as belonging to the "processing" types (chips, French fries and starch), the latter requiring a longer growth cycle, between 120 and 150 days.

In the same experimental trial, standard cultivars (Eersteling, Bintje, Majestic, Pentland Dell, Desiree, Cara, Irene, Pimpernel and Robijn) and R-gene differentials are also included. Their presence in such a trial firstly validates the results for new genotypes, allows comparison year after year and also characterizes the naturally occurring *P. infestans* populations. The full range of levels of resistance, from susceptible to partial resistant and totally resistant allows to classify the newly assessed plant material accordingly.

Field Design & Experimental Conditions

The trial site is located in Brittany where late blight occurs naturally almost every year. The field design is specific for aerial propagation of the disease and includes infector rows of the moderately susceptible cultivar Samba. Each microplot, 2 rows of 10 tubers, is adjacent to an infector row to ensure even distribution of the disease throughout the whole trial for the duration of the experiment. This specific trial has no replicate but, for each genotype, the assessment of over 4 consecutive years is available.

Planting time occurred April 15, 2003 and the inoculation of the infector rows was carried out 60 days after (June 17, 2003). The inoculum suspension was prepared from a mixture of separate local isolates, carrying the following virulent genes : 1, (2), 3, 4, (6), 7, 11.

Due to naturally occurring humidity, no irrigation system is required. After inoculation on the infector rows, the disease usually spreads evenly.

Assessment & Data Transformations

Foliar blight is assessed at seven days intervals, starting the day of inoculation, i.e. June 17 and until all foliage and stems of most cultivars are dead. Scores for infected tissue are calibrated according the scale of Cruickshank *et al* (1982), either for the 9 to 1 score as well as for the percentage of necrotic tissue. The latter is used for official (and estimated) late blight foliage score, the former is used for estimation of AUDPC as well as epidemiological parameters, Δt and Δa.

These raw data have to be analyzed after different transformations.

The overall "9-1" score is estimated by the weighted mean of 3 consecutive scores (Bersihand, 2003). At first, the analysis of row data of standard cultivars and R-gene differentials transformed with date-combinations allows the choice of the best date-combination to be applied on unknown cultivars.

Percentages of necrotic tissue are transformed into the area under the disease progress curve (AUDPC) as indicated by Fry (1978).

The epidemiological parameters, Δt and Δa, are defined in Ellissèche *et al* (1999). The excel spreadsheet for rapid computation has kindly been provided by Roland Pellé (UMR Bio3P, INRA F-Le Rheu).

Results

Though the 2003 summer has been exceptionally hot all over Europe, this field trial has been successfully carried out in the early summer and all plant materials were assessed when the very high temperatures occurred, i.e. late July. Most of the 2003 genotypes had already been assessed in the same field design experiment in 2002. Only 2003 data are presented in this paper. The first scoring started on June 17 when all tested genotypes were rated 9 -or 0 % infected tissue- and the subsequent scores occurred at 7day intervals. The final scoring was on August, 12 when most of the genotypes were totally destroyed by late blight.

Data validation

The analysis of the standard control cultivars as well as the R-gene differentials is presented in Table 1. The estimated LB foliage scores are in agreement with official data provided by official registration on national lists. Among the standard cultivars, one can note the apparent erosion of resistance of cv Pimpernel, officially assessed in the late 50's. Also, cv Pentland Dell, registered in the United Kingdom, cannot resist to British *P. infestans* isolates because of the presence of the virulent gene 2, thus conferring a susceptible score of 4. On the other hand, under climatic conditions prevailing in Brittany and because of the absence of the virulent gene 2 among local *P. infestans* populations, this cultivar has always behaved as more resistant (10 years data) than in the UK. The LB foliage score of each R-gene differential confirms the biological characteristics of local *P. infestans* populations, i.e. presence of the following virulent genes :1, (2), 3, 4, (6), 7, 11.

Table 1. Field assessment of foliar late blight behaviour, 2003, standard control cultivars and R-gene differentials.

	Official LB Foliage Score	Estimated LB Foliage Score	Estimated rAUDPC (x 10-4))	Estimated Δt (1)	Estimated Δa (2)
ROBIJN	9	7.3	141	7	-0.26
PIMPERNEL	8	6.7	652	0	-0.09
IRENE	7	6.2	1152	7	0.05
CARA	6	6.7	609	0	-0.13
DESIREE	5	5.5	1666	0	-0.02
PENTLAND DELL	4	8.4	38	14	-0.20
MAJESTIC	4	5.1	1888	0	0.04
BINTJE	3	3.7	2732	0	0
EERSTELING	3	4	2526	0	0.14
INRA 92T120.16	-	8.8	4	35	0.06
INRA 92T114.76	-	7.9	155	14	-0.21
R 01	-	4.5	1946	0	-0.04
R 02	-	8.3	81	14	-0.06
R 03	-	3.5	2818	0	0.23
R 04	-	4.5	2211	0	0.04
R 05	-	8.8	4	35	0.06
R 06	-	8.5	34	14	-0.11
R 07	-	5.9	559	0	-0.15
R 10	-	8.7	10	22	-0.14
R 11	-	6.2	680	0	-0.17

: Delay of first symptoms on tested cv compared to the onset of the disease on cv Bintje
: Relative infection rate of tested cv compared to cv Bintje

Varietal assessment

Results of varietal behaviour representing different levels of late blight resistance (Bintje-3 ; Daisy-4 ; Alowa-6 and INRA 92T114.76-8) are shown as disease progress curves in Figure 1.

The delay of infection, Δt, is evident for all cultivars but Bintje. The relative infection rate, Δa when negative and the closer to 0.50, is the indication of valuable level of field resistance.

In all subsequent analyses, data of other genotypes are compared to the performance of the most susceptible cv Bintje, whatever growth cycle group they belong to.

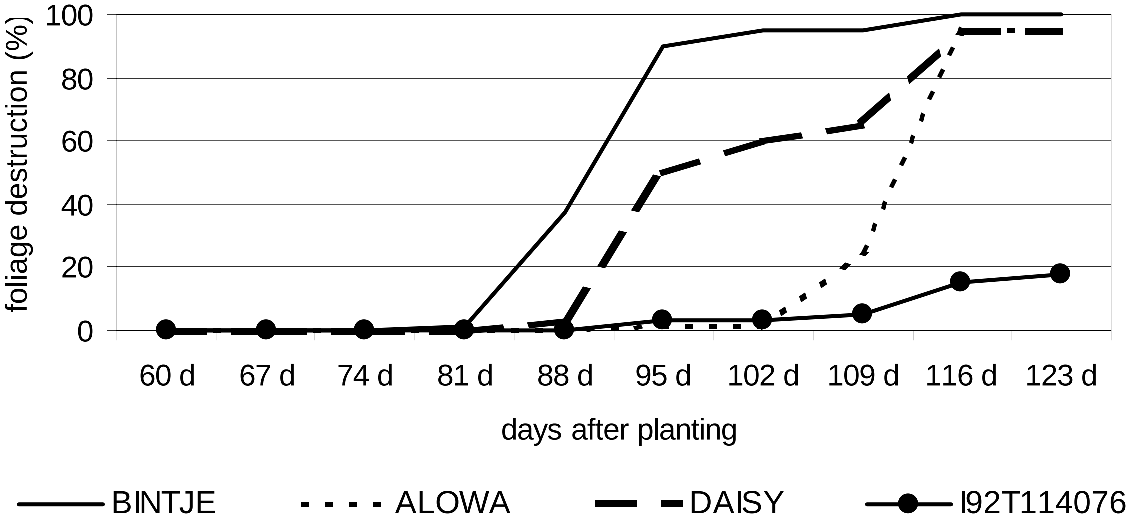

Figure 1. Disease Progress Curves of Cultivars with different levels of Late Blight Resistance, 2003 data.

In Table 2, all data are presented for the tested set of commercial cultivars grouped by « end user » type (or growth cycle length). When comparing cultivars with a similar rAUDPC value, for example cv's Alowa and Santé, respective Δt and Δa are different, namely Δa is negative for Santé, potentially triggering different chemical scheme. For such genotypes, difference of rAUDPC was not sufficiently informative. The same statement can be made for cv's Corolle and Manuela.

These data are also informative about the potential sources of resistance, race-specific and/or race- non specific, as proposed by Ellisèche *et al* (1999). Because of the really applied objectives of this study, such information is not relevant to the purpose in the short term.

Table 2. Field assessments of foliage late blight behaviour, 2003

	Official LB Foliage Score	Estimated LB Foliage Score	Estimated rAUDPC (x 10-4))	Estimated Δt (1)	Estimated Δa (2)
80-days Growth Cycle					
APOLLO	7	6.6	1011	7	-0.08
ALOWA	6	6.7	592	14	0.13
AMANDINE	6	3.7	2704	0	0.20
ROSANNA	4	4	2551	0	0.06
CHERIE	3	3.5	2761	0	0.23
SIRTEMA	3	4	2643	0	0.19
100-days Growth Cycle					
MAESTRO	6	8.7	9	35	-0.11
COROLLE	6	7.5	149	14	0.05
MANUELA	6	7.5	158	7	-0.18
SPUNTA	5	5.4	1575	7	-0.06
JOSEPHINE	4	5.1	2830	0	0.09
CHARLOTTE	4	3.5	2818	0	0.38
120-days Growth Cycle					
ESCORT	7	8.8	4	35	0.06
JULIETTE	6	6	1192	7	-0.16
SANTE	5	7	356	7	-0.13
NICOLA	5	4.3	2498	0	0.03
BF 15	4	4.8	2109	0	-0.01
140-days Growth Cycle					
STARTER	6	8.1	75	14	-0.09
RECTOR	6	8.6	15	28	-0.02
SATURNA	5	5.4	1805	7	-0.08
STEMSTER	5	5.1	1907	7	-0.07
DAISY	4	5.4	1777	7	-0.11

Commercial cultivars listed according their “days” requirement for complete growth cycle.

Discussion and conclusions

Such data transformations are indeed providing complementary information about foliar late blight behaviour. More precise evaluations of the epidemiological parameters, Δt and Δa, could be achieved by more frequent scoring dates at the beginning of the epidemic as recommended by Dowley *et al* (1999). This would aim at shorting the potential values of Δt, thus being more precise.

For this set of cultivars tested in this study, the 2003 results are in agreement with previous results gathered by various technical institutions, testing in different sites and previous years (Anon.2003, Anon. 2004a).

These data also need to be consolidated over years and sites to take into account all potential effects of «environment x genotype» interactions and potential erosion of *P. infestans* resistance durability.

Meanwhile this progress towards optimizing plant resistance into IPM is worth exploiting at the end user's level and by doing so, giving an novel opportunity, firstly to manage even more efficiently fungicide input and secondly to valorise consequent conventional potato breeding efforts throughout European countries.

Acknowledgements

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Control strategies against potato late blight using weekly model with fixed intervals but adjusted fungicide dose

B.J. NIELSEN

Danish Institute of Agricultural Sciences, Department of Crop Protection
Research Centre Flakkebjerg, DK-4200 Slagelse

Summary

In Denmark, there is a political pressure to reduce fungicide input in general and especially in potatoes because a large amount of the total fungicide consumption is used in this crop. The aim is a treatment frequency index (TFI, number of sprayings with the standard dose in a season) in seed potato, starch potato and ware potato on 5, 7.5 and 5 respectively. The challenge is to build a DSS system that is able to reduce the fungicide input in potato without reducing the net yield or quality. One way to reach the goal is to use different fungicide doses and intervals in relation to actual weather and weather forecast. For farmers with a large area of potato spraying at fixed intervals is, however more practical. Spraying at weekly intervals will give the necessary protection of the new leaves and the dose could be varied according to the actual need. The model was suggested by Andersen (2003) for starch potatoes in Denmark using Shirlan. The model was tested at Research Centre Flakkebjerg in field trials in 2003 with different fungicides but with the same change in dose level. It was obvious that some fungicides were more effective at lower doses than others and in 2004 a new model is tested where the fungicides are divided in two groups after their dose response curves.

Keywords: Late blight, *Phytophthora infestans*, control, fungicides, reduced input, DSS

Model with weekly sprayings but variable dose

The criteria for spraying is number of days (last 7 days and 2 days prognosis) with risk for late blight (table 3 and www.planteinfo.dk):

HR 10 hours with more than 87 % RH (read value in Planteinfo)

R 10 hours with more than 85 % RH (yellow in Planteinfo)

In the model the fungicide dose varies according to the risk and the variety (table 3). Some fungicides, however have a higher dose reduction potential than others. The fungicides that are tested in 2004 are divided in two groups according to their dose response curves:

Table 1. Fungicides with high dose potential..
Dose per ha at the different model levels (100%=normal dose).

	100%	75%	50%	25%
Shirlan	0.40	0.30	0.20	0.10
Ranman	0.20	0.15	0.10	0.05
Additive to Ranman	0.15	0.11	0.08	0.04

Table 2. Fungicides with low dose potential.
Dose per ha at the different model levels (100%=normal dose).

	100%	75%	50%	25%
Dithane NT	2.00	1.50	1.00	0.50
Electis	1.80	1.35	0.90	0.45
Tanos	0.70	0.53	0.35	0.18
Sereno	1.25	0.94	0.63	0.31
Acrobat WG	2.00	1.50	1.00	0.50

Discussion

Experiments with dynamic adjustment of fungicide dosages based on prognosis for blight-favourable weather shows good results. There is, however a need for more development and testing of the strategies before they can be implemented in the existing DSS. In 2004 field trials will be performed with the weekly model (table 3) where the dose is adjusted according to the variety type (RV, MRV and SV), the risk of late blight (HR and R) and the general level of blight in the area or field (phase 1: No attack in the area, phase 2: Attack in the area and phase 3: attack in the field). The model is compared with routine sprayings (Shirlan 0.3 l at weekly intervals) and a DSS on www.planteinfo.dk where prognosis for blight-favourable weather is combined with a dynamic model, which include adjusted doses, intervals and resistance level in the potato. The aim is to supplement this more advanced model with a simpler module.

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Table 3. Dose level for the different fungicide types sprayed at weekly intervals in three different variety classes and under different risk for late blight. Preliminary model tested in 2004.

Dose levels for fungicides with LOW dose potential: Dithane NT, Electis, Tanos, Sereno, Acrobat WG

No.of risk days		Phase 1			Phase 2			Phase 3		
Last 7 days + 2 days prognosis		No attack in the area			Attack in the area or after 15. July			Attack in the field or from 15. August		
HR	R	RV	MRV	SV	RV	MRV	SV	RV	MRV	SV
0	2	50	50	75	50	50	75	50	50	75
max. 1	3	50	75	75	50	75	75	75	75	100
max. 3	4	50	75	100	75	100	100	75	100	100
4	5	75	100	100	100	100	100	100	100	100

Dose levels for fungicides with HIGH dose potential: Shirlan, Ranman

No.of risk days		Phase 1			Phase 2			Phase 3		
Last 7 days+ 2 days prognosis		No attack in the area			Attack in the area or after 15. July			Attack in the field or from 15. August		
HR	R	RV	MRV	SV	RV	MRV	SV	RV	MRV	SV
0	2	25	25	50	25	25	50	25	25	50
max. 1	3	25	50	50	25	50	50	50	50	75
max. 3	4	25	50	75	50	75	75	50	75	75
4	5	50	75	75	75	75	75	75	75	100

HR and R see text

Dose level 100 = standard dose (see table 1 and 2)

RV: Resistent variety (e.g. Kuras)

MRV: Moderate resistant variety (e.g. Producent)

SV:Susceptible variety (e.g. Dianella)

Eighth Workshop of an European Network for development of an
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The 'Fight against Blight' campaign 2003

N J BRADSHAW[1], R A BAIN[2], M PRENTICE[3] AND R C CLAYTON[3]

[1]ADAS Consulting Ltd., Henstaff Court Business Centre, Groesfaen, Cardiff, Wales. CF 38 2 JP, UK.

[2] SAC, Ayr Campus, Auchincruive Estate, Ayr, Scotland. KA6 5HW, UK.

[3] British Potato Council, 4300 Nash Court, John Smith Drive, Oxford Business Park South, Oxford, England. OX4 2RT, UK.

Summary

In 2003, the British Potato Council (BPC) launched an initiative called the 'Fight against Blight' campaign. The aim of the campaign was to provide up to date, quality controlled information on the development of the blight epidemic in England, Scotland and Wales to enable potato growers and their agronomists to make more informed judgements about blight risk. Scouts recruited as part of the campaign were requested to send suspect blight samples for laboratory confirmation and the results were presented on the BPC web site which was updated daily. Information on best practice aspects of potato blight control was also made available as Growers Advice sheets. These were also available from the BPC website. Isolates of *P. infestans*, taken from the samples of blight received for confirmation were also tested to determine their mating type status. Field trials established in England and in Scotland showed the benefit of early fungicide application in the presence of blight inoculum. They also demonstrated control of tuber blight 50 days after the treatments had been applied.

Keywords: Late blight, *Phytophthora infestans*, blight mapping, web site, fungicide efficacy evaluation

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Introduction

The 'Fight against Blight' campaign in Great Britain was launched by the British Potato Council (BPC) on the 5th of December 2002. At the launch, representatives from the UK agricultural press were invited to ensure widespread industry awareness. This was considered crucial to the success of the campaign in its' first year of operation. Levy payers were individually informed of the campaign's objectives by letter and then though a series of grower meetings throughout England, Scotland & Wales. Packers and processors were also consulted at CEO level and through technical managers. In this way, maximum support from all sectors of the industry in GB was achieved.

Aims of the campaign

The main aims of the campaign were:-

- To reduce the overall cost of late blight to the GB potato industry.
- To engage the GB grower and advisory base through discussions with agrochemical manufacturers, potato producing and processing businesses, advisory groups and press to establish channels for regular communications.
- To generate information on the development of potato blight in England, Scotland & Wales in 2003 to help growers make a more informed assessment of disease risk.
- To establish and retain a network of 'scouts' that would report potato blight outbreaks on dumps, volunteer potatoes, conventional and organically grown crops. All sectors of the industry were invited to participate in and contribute to this new blight intelligence network. Participants included growers, processors and grower group agronomists, the agrochemical industry, distributors, private consultants and consultant organisations. Scout 'packs' were made available and these included guidance on where to look for blight in crops (Fig. 1), sampling and packaging instructions for official confirmation.
- To establish an appropriate quality assurance procedure to ensure that blight outbreaks were being correctly diagnosed by suitably qualified specialists. This task was undertaken by CSL, York. Samples of blight were also checked to determine their mating type status at the Sávári Research Trust, Bangor.

- To provide a map of blight outbreaks in England, Scotland & Wales on the BPC web site (www.potato.org/blight) with links to other web sites which provide information on weather based forecasting systems (Blight Alert on www.syngenta-co.uk and BlightWatch on www.potatocrop.com). The map was updated daily and showed the location of suspected and confirmed outbreaks at post code level (first half only, e.g.OX4).
- To prepare a series of best practice Growers Advice sheets on practical aspects of late blight control which would be made freely available to all sectors of the GB potato industry and would be available via the BPC website.
- To evaluate fungicide efficacy in field trials at two locations in England and in Scotland.
- To carry out benchmark surveys of the GB potato industry that measure the effectiveness of the campaign on growers' attitudes to blight control.

Results

Scout recruitment and blight mapping

In 2003, a total of 335 Blight Scouts were recruited from various sectors of the industry – farmers , agronomists, advisors and the supply chain companies. Conditions in 2003 were not favourable for blight development and between 21 May and 29 August, a total of 167 samples were received for confirmation. Of these, 104 (62%) were positive. However, only 30% of registered scouts actually sent in samples. The majority of scouts sent in less than four samples and feedback from scouts suggests that the maps contributed to an understanding of local risk and that later in the season, the system was used to confirm their own diagnoses. The majority of confirmed outbreaks were from conventional crops (64%) followed by dump sites (17%). The latter was significant in that the first seven samples were from dumps and this is the first hard evidence from the UK that some farmers were still not controlling this important primary source of infection. The remaining outbreaks were from volunteers and organic crops (7% each) and allotments/private gardens (2%).

Growers Advice sheets

During the course of the 2003 season, best practice advice sheets were prepared on the following blight control subjects:-

- Dump Hygiene
- Seed Health
- Planting
- Volunteer Control
- How to Use Blight Maps
- Spray Application Technique
- Spray Programme
- Responding to a Crop Infection
- Irrigation
- Haulm Destruction
- Harvest
- Store Loading
- Storage
- Advice for Growers of Organic Crops

These are currently available on the BPC's web site (www.potato.org.uk)

Mating type analysis

Previous surveys of the *P. infestans* population in GB in the 1990s showed that it was mostly a single A1 clonal lineage with A2 strains detected at less than 10% of sites and fewer than 5% of isolates. Following confirmation of late blight infection on samples from blight scouts, the frequency of A1/A2 mating types was determined by Dr D Shaw, Sávári Research Trust, Bangor. Samples were received from 100 sites in 2003. However, most sites were represented by a single isolate and the detection of the A2 mating type at less than 5% of sites may be an underestimate (D Shaw, pers.comm.).

Fungicide trials

Materials and Methods

A range of fungicide spray programmes was evaluated in two field experiments at ADAS Rosemaund, Herefordshire, England and at SAC, Auchincruive, Ayrshire, Scotland. The same protocols were followed at each site where comparisons were made between fungicides applied early in the development of a crop. The fungicides were applied to the blight susceptible variety King Edward and unsprayed guard areas surrounding the trials at both sites were inoculated to stimulate an early epidemic. Overhead misting was also used to encourage the epidemic to develop and progress into the trial plots. At Rosemaund, the trial area was surrounded by maize to reduce the effects of winds and increase the spray days and help maintain leaf wetness and humidity at the site.

Progress of the foliar blight epidemic was visually assessed throughout the season (Large 1952; Anon, 1976) and the effect of the treatments on the incidence of tuber blight and total ware yield was measured at SAC Auchincruive. Details of the fungicides, active ingredients, rates of use and spray programmes tested are shown in Tables 1 and 2 below.

Spray programmes started at 100% emergence and spray intervals were 10- reducing to 7-days. The first four sprays coincided with 100% emergence, rosette stage and haulm meeting along the rows and seven days later and continued as Dithane over sprays until differences in the level of foliar blight developed. At SAC, tuber blight assessments were made.

Table 1. Fungicides, active ingredients and rates of use

Fungicide	Active Ingredients (a.i.)		Rate (kg or l/ha)	
Product	Common name	g/kg (l) product	Active Ingredient	Product
Dithane DF NT	mancozeb	750	1.275	1.7
Invader WG*	dimethomorph +	75 +	0.15 +	2.0
	mancozeb	667	1.334	
Shirlan 500SC	fluazinam	500/l	0.15	0.3 (l)
Sonata*	fenamidone +	100+	0.15+	1.5
	mancozeb	500	0.75	
Tanos*	famoxadone +	250+	0.125-0.175+	0.5-0.7
	cymoxanil	250	0.125-0.175	

**Formulated mixture*

Table 2. Spray programmes

Treatment Description
T1: Dithane DF NT** (@ 1.7 kg/ha)
T2: Dithane DF NT (@ 1.7 kg/ha) (x 5 – 6 sprays)
T3: Shirlan (@ 0.3 l/ha) (x 4 sprays) followed by Dithane DF NT (@ 1.7 kg/ha)
T4: Tanos (@ 0.5 kg/ha)(x 1 spray), followed by Tanos (@ 0.7 kg/ha) (x 3 sprays) then Dithane DF NT (@ 1.7 kg/ha
T5: Sonata (@1.5 kg/ha)(x 4 sprays) followed by Dithane DF NT (@ 1.7 kg/ha)
T6: Invader (@ 2.0 kg/ha)(x 4 sprays) followed by Dithane DF NT (@ 1.7 kg/ha)

*** The first application of Dithane in this treatment was made at the same time as the fifth treatment was applied in treatments 2 – 6*

ADAS Rosemaund

The crop at Rosemaund was planted on 7 May and emergence occurred from 30 May onwards reaching 100% emergence by approximately 9 June. Blight favourable conditions as defined by Smith Periods together with 'Near Misses' were taken from the Shobdon synoptic met. station which is approximately 10 miles away.

Very few Smith Periods were recorded at Shobden in June (9/10), July (7/9 and 29/30) and August (7/8) and subsequent weather conditions were not favourable for blight development for the remainder of the growing period. Unsprayed guard areas within & surrounding the site were inoculated in the middle of June (12 and 27) and infection was encouraged to develop by misting/irrigation. This encouraged significant disease development in the early fungicide application trial, which was desiccated in mid August having achieved its objectives.

SAC Auchincruive

The trial at Auchincruive was planted on 16 June, deliberately late so that plants would emerge when there was more inoculum present to challenge the crop at early growth stages. Unsprayed infector areas were inoculated on 14 July, 11 and 18 August.

Smith Periods were recorded at Auchincruive on 24/25 July, 28/29 July and 6/7 August. There was no further blight favourable weather for the remainder of the growing period. Two periods of prolonged high temperatures prevented the three Smith Periods recorded leading to the normal extensive spread of blight. Between 14 and 16 July the maximum air temperature ranged between 27.4 and 30.0ºC. Maximum air temperatures were very high again between 4 and 9 August. Spread of blight into the experimental plots was encouraged by repeatedly irrigating the infector areas when temperatures were suitable and relative humidity was high.

Results and discussion

The progress of foliar blight at Rosemaund & Auchincruive (including tuber blight infection) are given in Tables 3 and & 4 respectively.

At both sites, there was a clear benefit from the early use of fungicides for the control of foliar blight. In these experiments however, disease was artificially introduced and subsequently manipulated which exaggerates what happens in commercial practice.

The benefit of early fungicide use remained evident for a considerable period of time at Rosemaund and effects were recorded well after the treatments had been applied. This suggests that fungicides were suppressing blight inoculum before visible symptoms became evident.

As expected, the control of haulm blight was poor where the first four fungicide applications were omitted, even under low foliar disease pressure at Auchincruive.

Of the fungicides tested at Rosemaund, the newly introduced fungicide Sonata (fenamidone+ mancozeb) gave the best control of foliar blight followed by Invader (dimethomorph+ mancozeb).

Sonata gave more effective control in this experiment compared with Dithane DF NT, Shirlan and Tanos.

There is preliminary evidence from the Auchincruive site of a significant benefit in tuber blight control from the early, repeated use of some fungicide products. Of the fungicides tested at this spray timing, Shirlan gave the best control of tuber blight followed by Sonata.

It should be noted that the final applications of Shirlan and Sonata were made on 3 August and that tuber infection at the site did not occur until late in September. Control of tuber blight from the application of Sonata early in the development of the crop has not been reported before.

These results do not change the current advice in GB which is to use systemic fungicides early in the life of a crop to take advantage of their mobility within the plant during the rapid growth phase. Also, the first fungicide applications in a spray programme should be made when the haulm is meeting along the rows and not as early as 100 % emergence unless local risk is judged to be extremely high.

Further details are given in the project report (Bradshaw and Bain, 2004).

Conclusions

A network of scouts reporting outbreaks of blight was established in 2003 and together with the rapid reporting via the BPC website became a valuable tool for the GB potato industry. Now that such a system has been developed it will continue with appropriate updates and improvements in future. The benchmark survey has confirmed an increased awareness of blight and the importance of farm hygiene and particularly control of dumps to reduce early sources of blight inoculum. Approximately 50% of respondents claimed not to have dumps of waste potatoes. Less than 30% of respondents used the website in 2003, considering that fungicides remained the most important means of blight control. Links established to other web sites providing weather based blight forecasting information should increase the value of the blight maps over time as the GB industry becomes more familiar with the system. A repeat of the benchmark survey is planned in 2004.

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Table 3. Early fungicides applications trial - Foliar blight assessments - ADAS Rosemaund, 2003

Mean Percentage Leaf Area Destroyed by Blight - MAFF Key 2.1.1									
Date	10 July	17 July	21 July	25 July	28 July	02 Aug	06 Aug	08 Aug	13 Aug
Growth stage*	430	430	440	440	600	600	600	650	650
Untreated/ Dithane DF NT	0.25	9.00	58.33	75.00	81.17	90.00	91.20	93.00	94.50
Dithane NT DF	0.23	4.25	10.17	23.67	28.67	32.70	35.20	38.67	44.17
Shirlan/ Dithane DF NT	0.17	3.55	7.50	15.33	19.67	23.30	24.70	27.50	33.17
Tanos/ Dithane NT DF	0.22	3.42	9.83	18.17	23.50	22.70	24.50	28.33	33.67
Sonata/ Dithane NT DF	0.10	1.45	3.88	6.17	6.42	8.30	9.30	12.00	14.83
Invader/ Dithane NT DF	0.12	2.45	5.30	9.83	10.67	13.70	14.70	18.17	20.83
LSD (5% level)	0.1923	1.536	6.862	10.07	12.46	12.19	12.44	12.88	14.62

** Jeffries & Lawson, (1991).*

Table 4. Early fungicide applications trial- Foliar blight assessments – SAC Auchincruive, 2003

Mean Percentage Leaf Area Destroyed by Blight - MAFF Key 2.1.1								% Tuber Blight (pre-storage)	
	11 Aug	19 Aug	25 Aug	1 Sep	8 Sep	15 Sep	22 Sep	by tuber weight	by tuber number
Untreated/ Dithane DF NT	0.22	2.73	6.8	9.4	13.6	14.5	15.9	7.3	7.1
Dithane NT DF	0.00	0.00	0.0	0.1	0.1	0.2	0.5	4.8	5.2
Shirlan/ Dithane DF NT	0.00	0.02	0.0	0.0	0.1	0.3	0.3	1.6	2.2
Tanos/ Dithane NT DF	0.00	0.02	0.1	0.1	0.1	0.4	0.5	7.8	7.1
Sonata/ Dithane NT DF	0.00	0.02	0.1	0.1	0.1	0.3	0.4	2.7	2.6
Invader/ Dithane NT DF	0.00	0.00	0.0	0.0	0.1	0.2	0.4	5.4	6.2
LSD (5% level)		NS	NS	NS	NS	NS	NS	3.14	3.23

Untreated/Dithane DF NT excluded from the analyses of foliar blight

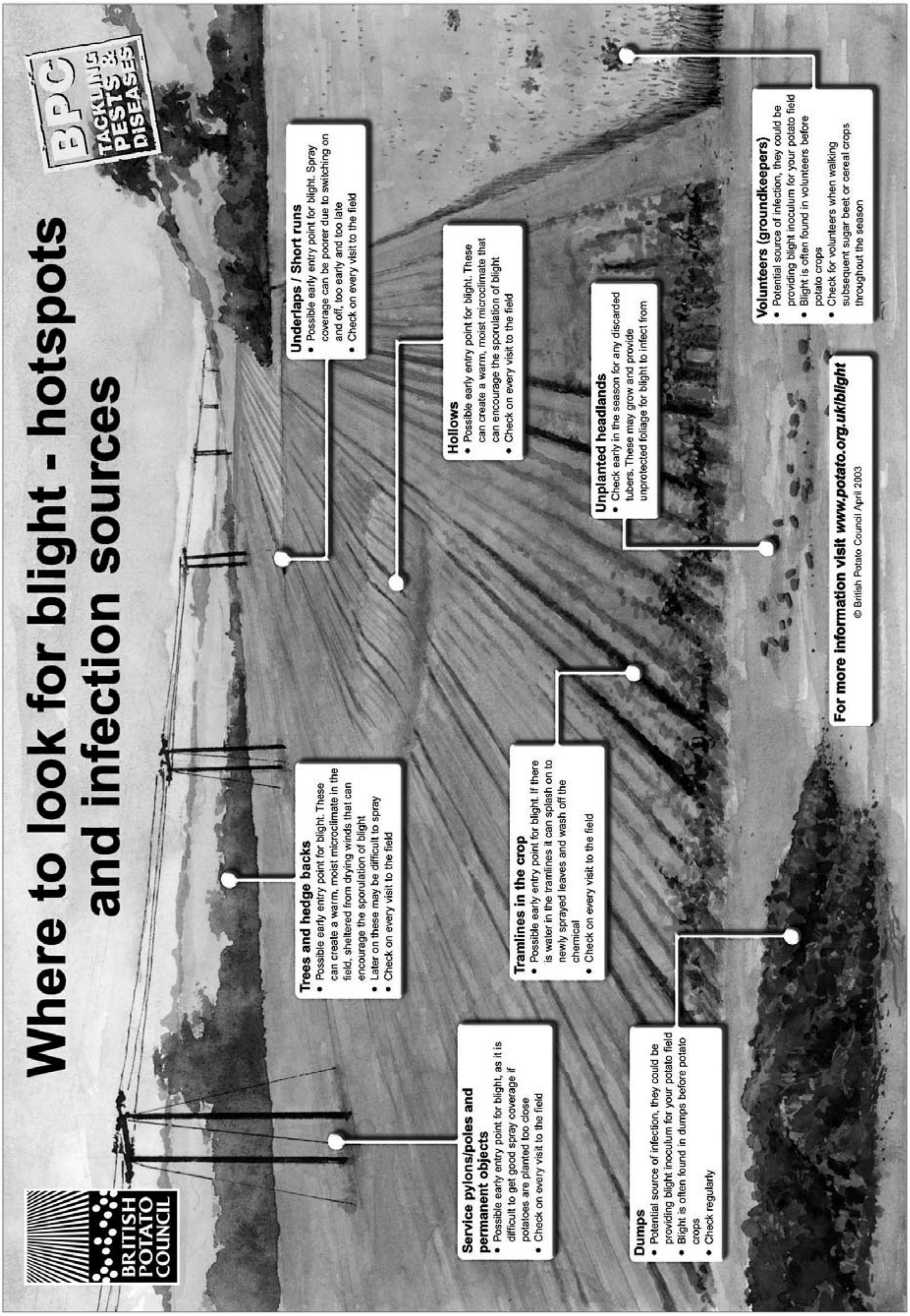

Figure 1. Guidance on most likely locations of blight outbreaks

Late blight on potato in Flanders, Belgium: field trials and characteristics of the *Phytophthora infestans* population.

B. HEREMANS[1] AND G. HAESAERT[2]

[1] Hogeschool Gent – Proefhoeve Bottelare, Department of Biotechnology, Landscape architecture and Agriculture, Diepestraat 1, B-9820 Merelbeke, Belgium

[2] Hogeschool Gent, Department of Biotechnology, Landscape architecture and Agriculture, Voskenslaan 270, 9000 Gent, Belgium

Betty.Heremans@hogent.be

Summary

Commercial fungicides were tested in the field for efficacy on foliar late blight caused by *Phytophthora infestans*. The fungicide treatments for late blight control were conducted at either 7- or 10-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 July and at the beginning of August due to high temperatures and lasting drought. Foliar disease severity significantly affected potato tuber yields. Lowest tuber yield was noted in plots with high late blight infection levels (nontreated control and an experimental mixture of organic acids (Vi-Care, 1 l/ha)) while highest yields were recorded in plots with low late blight infection. Late blight infection on leaf level was not significantly correlated with % tubers that showed late blight symptoms. No fungicide scheme completely arrested epidemic development under the environmental conditions of the trial. The effect of propamocarb hydrochloride + chlorothalonil (Tattoo C, 2.5 kg/ha) was less suppressive for *P. infestans* than the other fungicides tested for both interval systems. However, fenamidone + mancozeb (Sereno, 1.5 kg/ha), zoxamide + mancozeb (Unikat Pro, 1.8 kg/ha), dimethomorph + mancozeb (Acrobat, 2 kg/ha), cyazofamide + heptamethyltrisiloxane (Ranman 200 ml A/ha + 150 ml B/ha) and cymoxanil + famoxadone (Tanos, 0.6 kg/ha) controlled P. infestans most effectively for both interval systems. Also the other fungicides

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controlled foliar late blight sufficiently. Only small differences were observed between the different treatments.

A total of 51 isolates of *P. infestans* were collected from disease outbreaks in commercial potato crops and private gardens in 2003. Isolates were recovered successfully from single lesions of diseased potato foliage. Not from all isolates pure cultures were obtained due to contaminations with *Fusarium* species and bacteria. The structure of the population was analysed phenotypically. Characteristics of the isolates included in vitro growth rate, mating type, in vitro sensitivity to the phenylamide fungicide metalaxyl-M and allozyme genotype at glucose-6-phosphate isomerase (Gpi) and peptidase (Pep) loci.

Keywords: potato, late blight, *Phytophthora infestans*, fungicide efficacy, mating type, metalaxyl-resistance, Gpi, Pep

Introduction

The control of potato late blight, *P. infestans*, requires repeated applications of several fungicides during the potato growing season. Fungicides sprays for late blight are a significant cost input in Belgian potato production. Normal practice is to start spraying when plant canopies closed rows and to continue at 7 to 10 days intervals until the crop is ready for harvest or desiccation. On the susceptible cultivar 'Bintje' professional growers will apply 10 to 14 sprays in most seasons that cost between 200-400 €/ha for the fungicides depending on product choice. In contrast, a restrictive government policy on the use of pesticides and an increasing public concern regarding food safety and the environment call for drastic reduction of the chemical inputs in agriculture. Decision support systems such as the Flemish warning system based on the Guntz-Divoux epidemiological model, have the potential to reduce cost inputs and the input of fungicides by increasing spray intervals when disease risk is low.

Furthermore, the 'new' populations of *P. infestans* consisting of both mating types is present in most parts of the world. In these populations sexual reproduction may be expected to occur, which would have important consequences for potato late blight control.

The purpose of this study was to compare new commercial potato fungicides commonly used to control late blight and to investigate the efficacy of these new fungicides for the control of foliar and tuber blight.

P. infestans isolates were collected from disease outbreaks in commercial potato crops and private gardens and phenotypically characterised to study the biological diversity within the *P. infestans* population in Flanders.

Material and methods

Field trial

A field experiment was carried out on the experimental farm of the 'University College Ghent' at Bottelare during the growing season 2003. Several fungicides (Table 1) were compared in a spray system based on 7- and 10-day intervals. The experiment was set up with the variety 'Bintje'. Treatments were carried out with a AKZO sprayer to 3 m wide and 8 m long plots. The spray boom was equipped with TJet nozzles (XR Tjet 8003) spaced 50 cm apart. The water volume was always 300 l/ha. The experimental design was a split block design with the spray intervals as sub-blocks. The fungicide treatments were randomised within the blocks.

Table 1. Fungicides used in the field trial 2003.

Commercial product	Active matter
Tanos	150 g/ha cymoxanil + 150 g/ha famoxadone
Ranman	80 g/ha cyazofamide + 126 g/ha heptamethyltrisiloxane
Shirlan	200 g/ha fluazinam
Unikat Pro	1.2 kg/ha mancozeb + 149.3 g/ha zoxamide
Sereno	0.125 kg/ha fenamidone + 0.625 kg/ha mancozeb
Tattoo C	0.938 kg/ha propamocarb + 0.938 kg/ha chlorothalonil
Acrobat extra WG	0.12 kg/ha dimethomorph + 1.07 kg/ha mancozeb
Stamina + Unikat Pro	1.5 kg/ha potassium phosphite + 1.2 kg/ha mancozeb + 149.3 g/ha zoxamide
Stamina + chlorothalonil	1.5 kg/ha potassium phosphite + 1 kg/ha chlorothalonil
Stamina + Shirlan	1.5 kg/ha potassium phosphite + 160 g/ha fluazinam
Vi-Care	experimental mixture based on organic acids

Following crop husbandry measures were taken: planting date of certified seed potatoes: 9 April 2003; row distance: 0.68 m; fertilisation: in autumn 35 ton digested dung, in spring 104 kg/ha N, 31 kg/ha P_2O_5 and 260 kg/ha K_2O; herbicide treatment: prosulphocarb + metobromuron: 3.6 kg + 1.0 kg/ha (Defi + Patoran: 4.5 l).

Inoculum production and foliage inoculation

A mixture of 8 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 104 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 border rows across the experimental plots were inoculated by spraying 8.700 sporangia/plant on 18 June in the late afternoon. In total 72 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. Between 23 June and 4 July the mean temperature fluctuated between 14.9 and 20 °C. And between 30 June and 3 July 52.5 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. Eleven active matters were studied (Table 1). Fungicide applications began after plant canopies closed rows and are summarized in table 2.

Table 2. Summary of treatments of the field trial 2003.

Treatments	Date of treatment																													
	9/05	29/05	5/06	12/06	18/06	19/06	26/06	2/07	4/07	10/07	15/07	17/07	22/07	24/07	29/07	31/07	5/08	6/08	7/08	11/08	14/08	19/08	23/08	25/08	27/08	29/08	30/08	16/09	18/09	25/09
Planting	■																													
Herbicide treatment		■																												
Block I (disease-free)			■	■																										
~~Infection (7 + 10 days)~~					■																									
Block II: 7 days						II	II	II																						
10 days						II		II			II																			
Block III: 7 days										III		III																		
10 days													III		III															
Block IV: 7 days														IV		IV		IV												
10 days																	IV				IV			IV						
Harvest: 7 days																												■		
10 days																													■	

All plots were sprayed with 1.6 kg/ha mancozeb (Dithane 2 kg/ha, Protex) on a weekly basis to protect foliage from natural infection by *P. infestans* (block I). Thereafter, the plots were 3 times treated with the different fungicides (Table 1) at either 7-day or 10-day intervals (block II). After the last application the experimental fields were sprayed twice on a 7-day basis with

1.3 kg/ha mancozeb + 90 g/ha cymoxanil (Curzate M 2 kg/ha, Du Pont) (block III). After the last treatment, the different fungicides were applied 3 times at either 7-day or 10-day intervals (block IV).

Diquat 600 g/ha (3 l/ha Reglone, Zeneca) was used to desiccate leaves and stems. During the growing season foliage destructions were also carried out in the infected border rows and 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 per plot was assessed at regular intervals.

Data were analysed by performing analysis of variance (SPSS10.0). The Duncan- and paired t-test were used to compare treatment means.

Harvest

Tubers were harvested by hand to minimise wounding. Two rows over a distance of 5 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*.

Purification and characterization of *P. infestans* isolates

The isolates were recovered successfully from single lesions of diseased potato foliage. Not from all isolates pure cultures were obtained due to contaminations with *Fusarium* species and bacteria. A selective pea broth agar amended with 2 ppm griseofulvine, 19 ppm nystatine, 10 ppm Benlate (50 % benomyl), 30 ppm rifampicine50 ppm nalidic acid, 40 ppm 8-azaguanine and 30 ppm neomycine was used. After isolation into pure culture, isolates were kept on pea broth agar at 15 °C in the dark and routinely maintained.

Mating type was determined by pairing the isolates individually with isolates of known mating type on pea broth agar. After 3 to 4 weeks of incubation at 18 °C in darkness, the plates were microscopically examined for oospores at the hyphal interfaces between the isolates.

The response to metalaxyl-M was determined by inoculating a hyphal plug of *P. infestans* isolates onto pea broth agar amended with 0, 5 and 100 ppm metalaxyl-M. Plates were incubated at 18 °C in the dark and after 7 days colony diameters were measured.

Genotypes at the polymorphic loci Gpi (EC 5.3.1.9.) and Pep (EC 3.4.3.1.) were determined using the protocol of Goodwin et al. (1995). The genotypes of unknown isolates were determined by comparing their banding patterns with those of proper controls.

Results and discussion

The incidence of foliar blight was scored 77, 85, 92, 99, 106, 113 and 119 days after planting. The field experiment in 2003 indicated that all the tested fungicides had a strong suppressive effect on established epidemics at 7-day and 10-day application intervals compared to untreated plots (Fig. 1, Fig. 2). Only the experimental mixture Vi-Care presented a bad foliage protection against late blight at both spray intervals used. In 7-day spray intervals the control plots and plots sprayed with Vi-Care were rapidly infected for 50 %. The plots sprayed with Vi-Care were treated already with diquat on 6 August to decrease the disease pressure in the surrounding plots. The differences in control efficiency for the other fungicides tested were rather small and statistically not significant. In 10-day spray intervals significant differences between the fungicides were observed: propamocarb + chlorothalonil, mancozeb + potassium phosphite + zoxamide and fluazinam gave a significant lower foliage protection than the other fungicides tested. In the plots sprayed with Vi-Care the percentage of foliar blight was after 5 weeks as high as in the control plots.

A lower tuber yield was observed for the untreated plots and plots sprayed with Vi-Care at the two spray intervals tested (Fig. 3). No significant differences were observed for the other fungicides tested for the 7-day spray interval. The average tuber yield fluctuated between 48.6 and 52.2 ton/ha and the mean yield of all treatments was 50.0 ton/ha. In the 7-day application interval the percent tuber rot was significantly higher for cymoxanil + famoxadone and potassium phosphite + chlorothalonil, respectively 3.5 and 3.2 % (Fig. 4). The amount of diseased tubers was significantly lower with fenamidone + mancozeb and fluazinam, respectively 0.1 and 0.3 %. At 10-day application schemes cymoxanil + famoxadone had the highest tuber yield: 55.8 ton/ha. For the other fungicides tested the yield fluctuated between 43.4 and 55.1 ton/ha and the mean yield for all treatments was 49.9 ton/ha. In the 10-day spray interval the plots treated with propamocarb + chlorothalonil, mancozeb + zoxamide, mancozeb + potassium phosphite + zoxamide and potassium phosphite + chlorothalonil had the highest number of tuber blight, 2.9, 2.8, 2.7 and 2.6 % respectively. For the other fungicides the amount of infected tubers fluctuated between 0.7 and 1.6 %. For the amount of infected tubers there were no significant differences between the different treatments at the 10-day spray interval. At both application intervals mancozeb + fenamidone and fluazinam showed the best protection against tuber blight.
Taking into account all the parameters evaluated (disease incidence, tuber yield, tuber blight) a 7-day application interval protects the foliage better against late blight then a 10-day-spray interval. Mancozeb + fenamidone, mancozeb + dimethomorph and potassium phosphite + chlorothalonil protected the potato crop slightly better then the other fungicides tested. But the differences were small and statistically not different.

Significant differences in growth rate were observed among the 41 isolates grown on pea medium by comparing the main radial growth of the isolates after 7 days.
All the isolates tested were of the A1 mating type.

Isolates with sensitive, intermediate and resistant responses to metalaxyl-M were detected in the population. Thirty isolates had a growth of less then 40 % at 5 µg metalaxyl-M per ml. Two isolates had a growth of less then 40 % at 100 µg metalaxyl-M per ml. Eight isolates had a growth of more then 40 % at 5 and 100 µg metalaxyl-M per ml.

Cellulose acetate electrophoresis was used to examine Gpi and Pep banding pattern of the population of *P. infestans* attacking potato in Flanders. All the isolates tested produced the 100/100 Gpi isozyme electromorph. This Gpi isozyme type is characteristic for the new population of *P. infestans*. Five different allozyme genotypes of the Pep loci were identified: 92/92, 96/96, 100/100, 92/100, 83/100. The dominating banding pattern for Pep was 100/100 (10 isolates). Eight isolates produced the 96/96 Pep isozyme type and 8 isolates had the 92/100 Pep genotype. The Pep allozyme type 92/100 is characteristic for the old population of *P. infestans*.

Notwithstanding the fact that no A2 mating type was isolated, a high level of biological diversity was detected within the population of isolates analysed. This diversity may have evolved from local processes including sexual recombination and selection rather than through long-distance migration.

Acknowledgements

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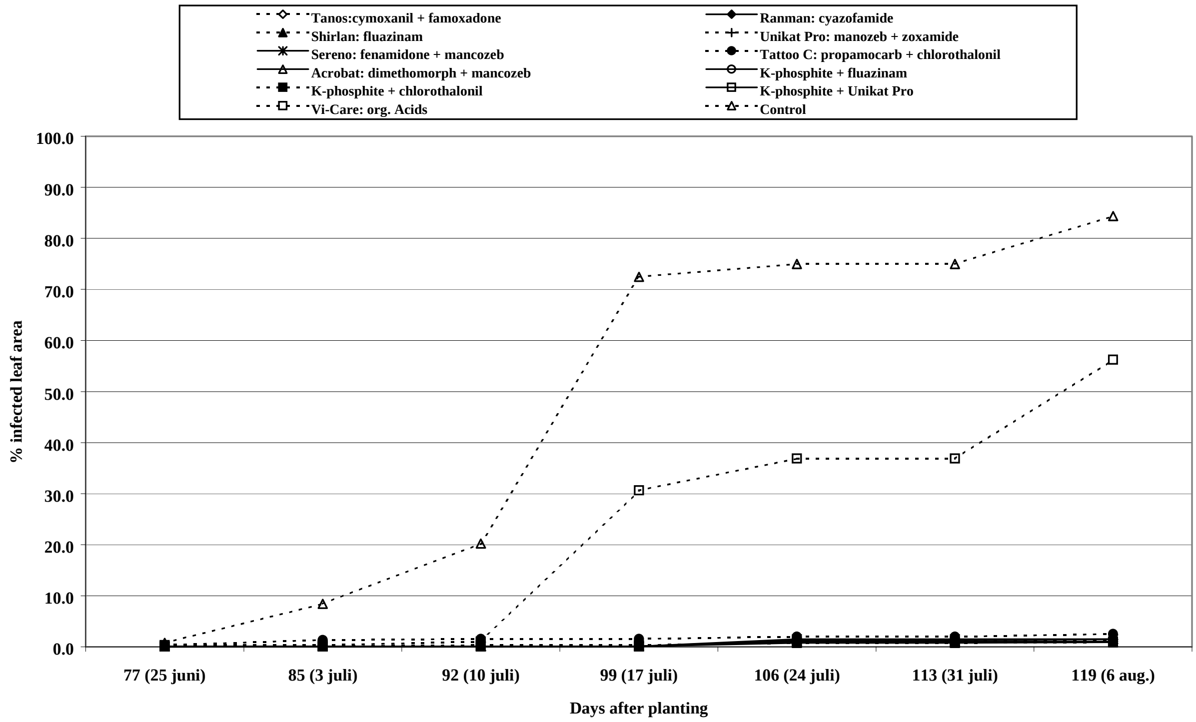

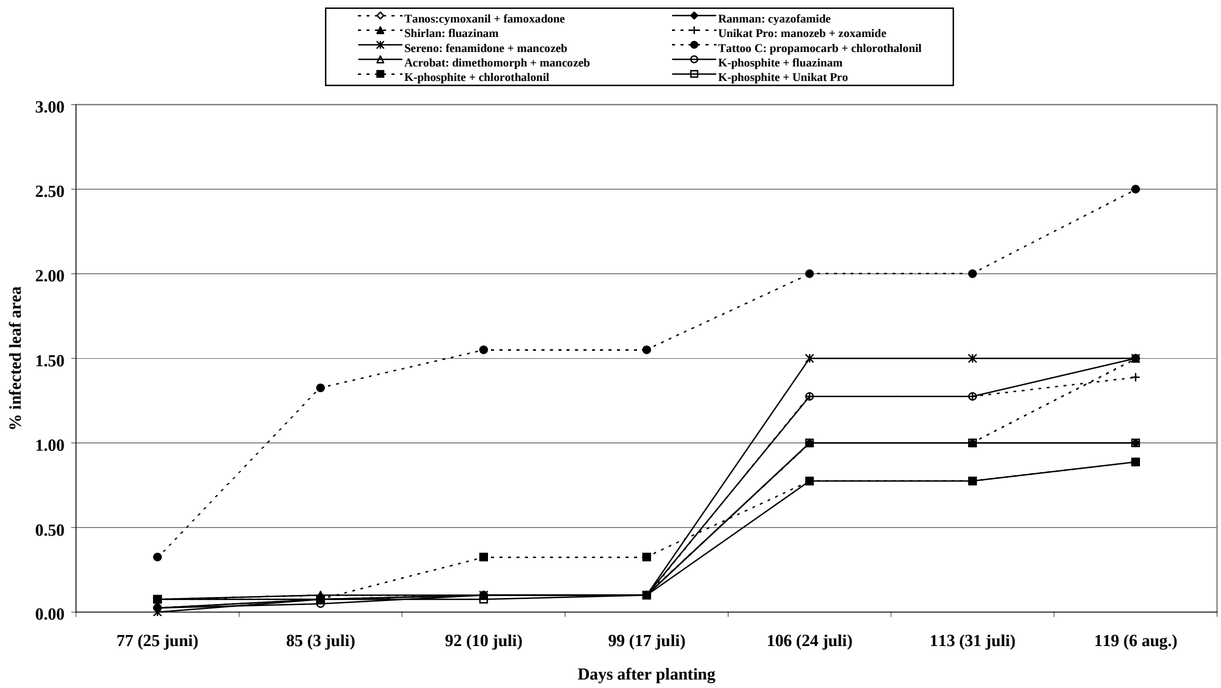

Figure 1. Influence of the fungicides applied in 7-day intervals on the infection level of late blight of 'Bintje' during the growing season 2003

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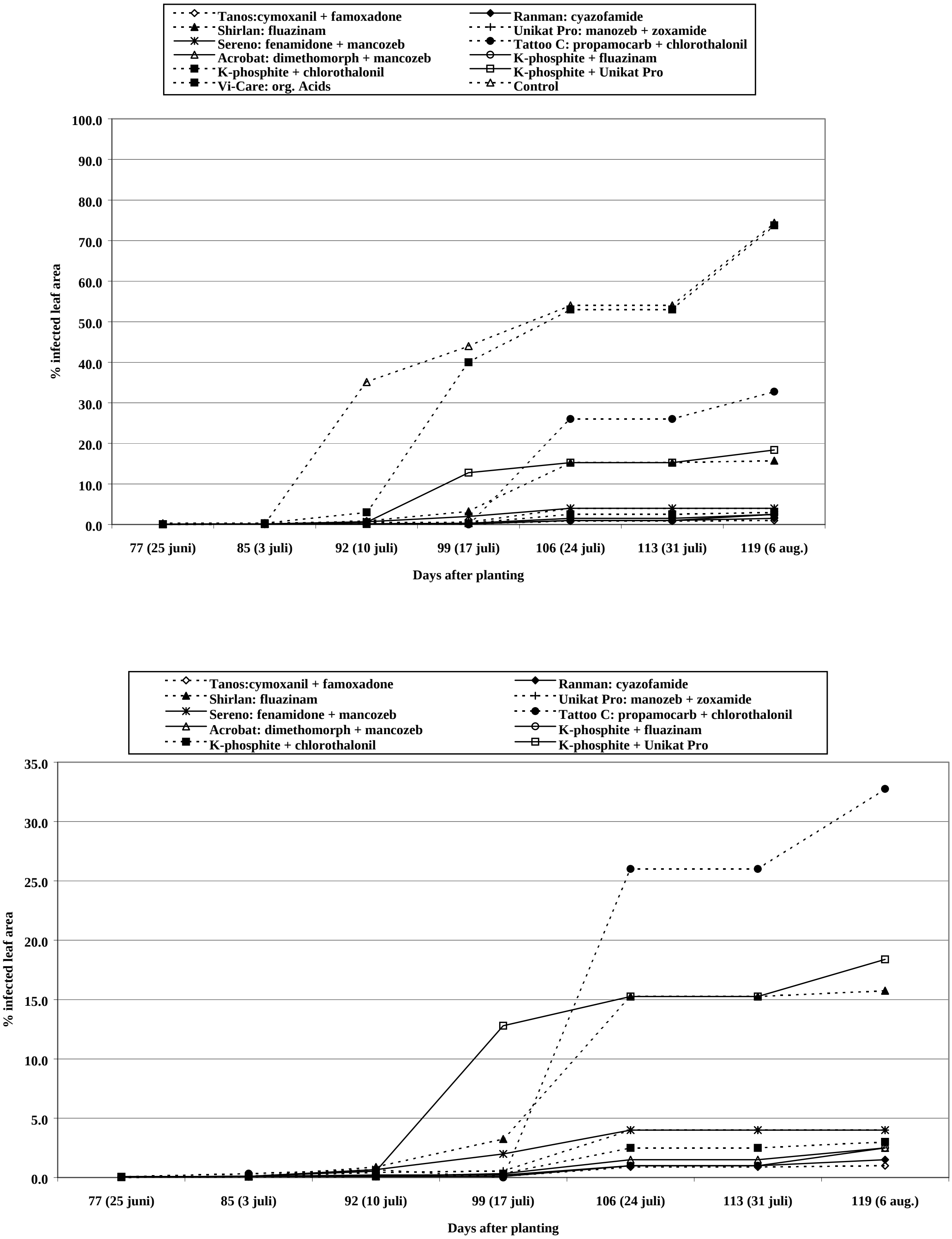


Figure 2. Influence of the fungicides applied in 10-day intervals on the infection level of late blight of 'Bintje' during the growing season 2003.

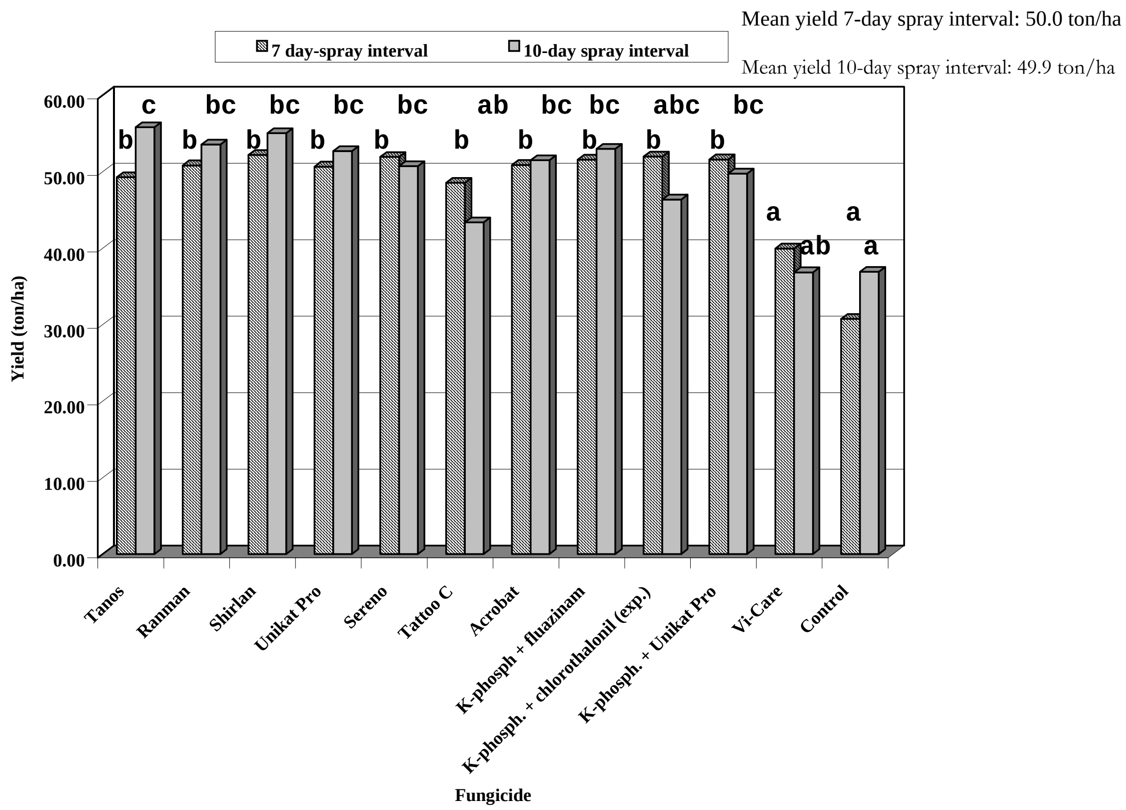
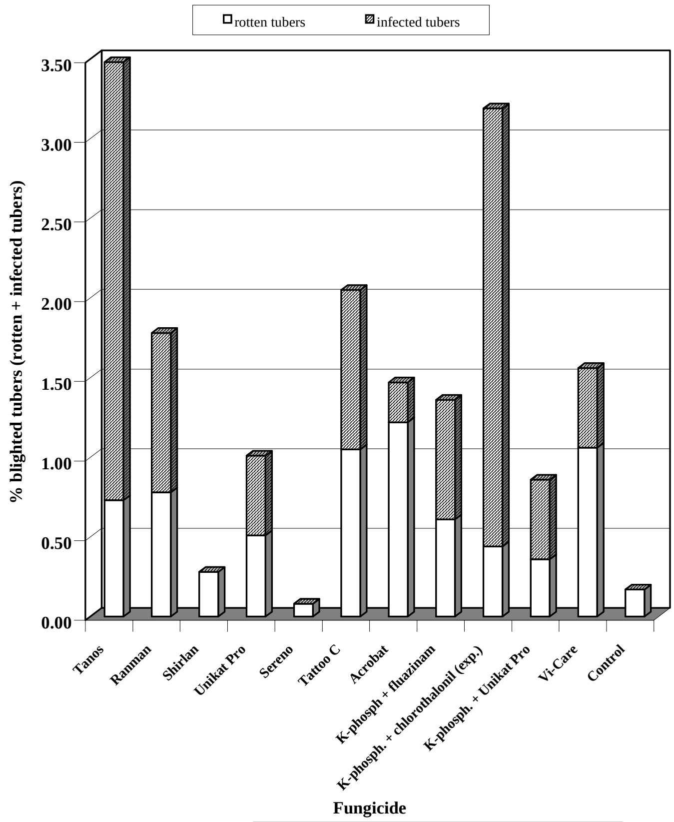


Figure 3: Influence of fungicides applied at 7-day and 10-day intervals on tuber yield in 'Bintje' during the growing season 2003.



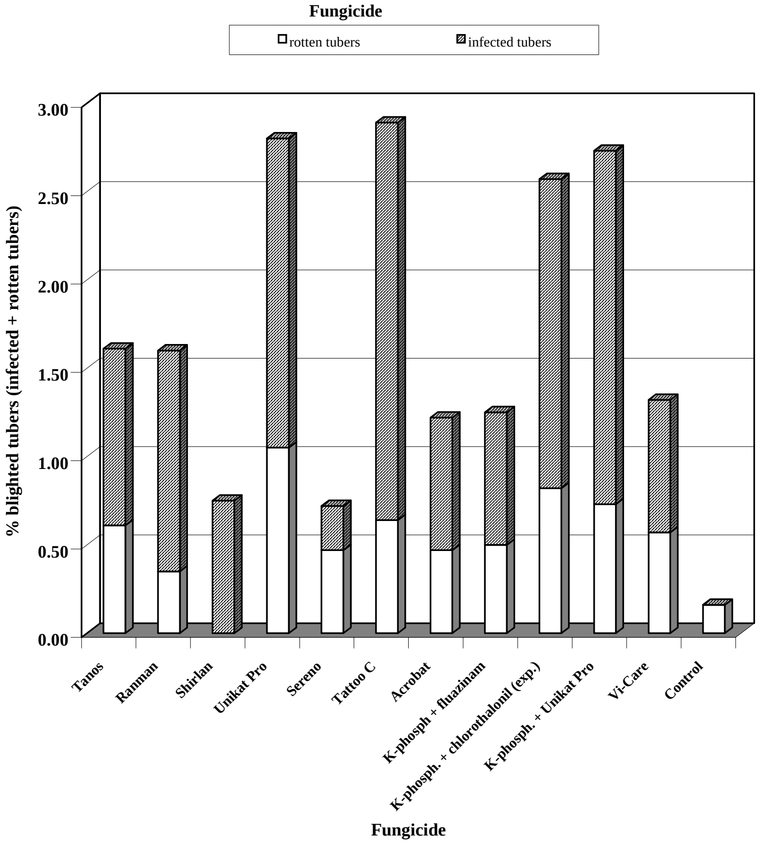


Figure 4. Influence of fungicides applied at 7-day (A) and 10-day (B) intervals on tuber blight in 'Bintje' during the growing season 2003.

Interactions of development rate and dynamics of potato late blight using different control strategies

G. BIMSTEINE, I. TURKA

Latvia University of Agriculture, Department of Plant Biology and Protection
2 Liela, Jelgava, LV 3001, Email: iturka@cs.llu.lv

Summary

Since the rate of a late blight epidemic is mainly determined by biotic and abiotic factors the result depends largely on the local situation. Therefore all results will be presented on the basis of Latvian agro ecological conditions.

It is well known that during the control process of late blight we mainly wish to reduce the rate of disease increase. First of all several control measures are practiced for reducing the primary infection before potato planting. No proper background has been found in order to idealize fungicide treatments. In the beginning of vegetation period development of late blight is slow or similar in treated and untreated fields. In our research 5 different variants were studied.

Keywords: potato late blight, *Phytophthora infestans*, disease development rate

Introduction

Potato late blight, caused by *Phytophthora infestans* (Mont.) de Bary, has an important role in potato pest management.

The main control strategy of potato late blight is standardised approach in Latvia. According to standardised approach the average numbers of fungicide applications in Latvia are 2 to 4 and first field treatment was made during row closing (Turka 1999). The regular fungicide treatments were made each 7 to 14 days according to expert decisions or chemical companies' recommendations. During the period 1999 – 2002 the Danish decision support

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system NegFry was adapted and compared with standard approach in Latvia (Turka 1999; Hansen *et al.*, 2000; Koppel *et al.*, 2002).

Efficacy of disease control depends on resistance of potato cultivars and fungicide application in the field. Both mentioned factors reduce the rate of epidemic development but the fungicide application is more easily influenced (Fry 1977).

Severity of potato late blight depends on the time of outbreak and the rate of disease development. The apparent infection rate (r) is often reported term (MacKenzie *et al.* 1983). Apparent infection rates are measure of how fast disease epidemic has progressed over time from observation of first symptoms. The infection rate can be calculated during definite period or during all growing season. For potato late blight r value can increase to 0.6 units per day (Fry 1977).

Influence of different control strategies on decrease of apparent infection rate and disease development in the different growing seasons are compared. Analysed data are described in this paper.

Materials and methods

Field trials were carried out in the years 2000 – 2002, during implementation of Danish decision support system NegFry at Latvia University of Agriculture Study and Training farm "Vecauce".

Moderately susceptible variety 'Sante' was used for testing. The experiments were established according verified scheme into four replicates (small plot trials). Following control strategies were used:

- Control – without fungicides
- Recommendation of chemical companies – treatments with contact fungicides, used at 7 – 10 days interval. First treatment was done during row closing
- NegFry + meteodata from Metpole – treatment with contact fungicides according to NegFry model with meteodata from Hardi metpoles
- NegFry + meteodata from HMS - treatment with contact fungicides according to NegFry model with meteodata from stationary hydrometeorological stations
- Expert decision – two first treatments with systemic fungicide and subsequent treatments with contact fungicides. First treatment when late blight in observed in the region.

Appearance of first symptoms, number of fungicide treatments, changes of apparent infection rate and disease severity at the end of season were compared and analysed.
The changes of disease apparent infection rate (r) were calculated during growing season with different potato late control. Disease assessment were made before fungicide application and after guaranteed time of fungicide effect. The apparent infection rate was calculated as describe by Hughes (2003).

$$r = \frac{1}{t2 - t1} * \left(\log \frac{X2}{1 - X2} - \log \frac{X1}{1 - X1} \right) \quad (1)$$

r – apparent infection rate
t1 – time before fungicide application
t2 – time after guaranteed time of fungicide effect
X1 – disease severity before fungicide application
X2 – disease severity after guaranteed time of fungicide effect

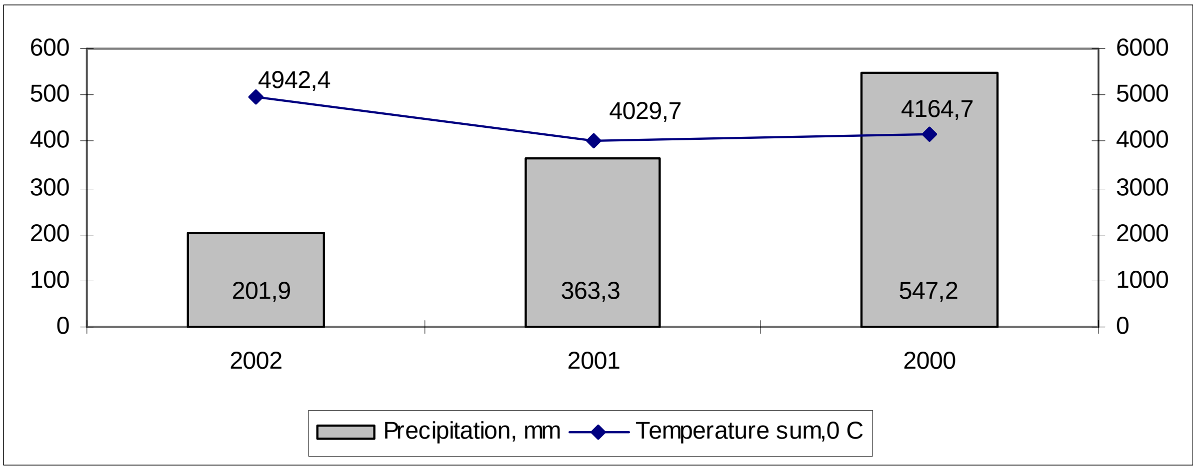


Figure 1. Temperatures sum and amount of precipitation during growing seasons 2000 - 2001

The weather conditions were different in growing seasons 2000 – 2002 (Figure 1). The end of growing season 2000 and growing season 2001 was favourable for development of potato late blight. In the growing season 2001 the sum of temperatures and amount of precipitations were in optimum and it was the most favourable for disease development. Whereas, the growing season 2002 was hot and amount of precipitation were less, compare with other years. The disease development was stopped in the August, because the air temperature in some days exceeded 300 C.

Results and discussion

The year 2001 was very favourable for development of potato late blight and first symptoms were observed only 35 days after potato germination in untreated and treated with fungicides fields. To compare it was 2 – 4 weeks earlier than in the year 2002 and 5 - 7 weeks earlier than in the year 2000 (Table 1). In the years 2000 and 2002 there were differences between untreated and treated with fungicides fields. The first symptoms were observed 1 – 2 weeks earlier in untreated control.

Table 1. Appearance of first symptoms (days from potato germination) 2000 – 2002

	2000	2001	2002
Control	69	35	52
Recommendations of chemical companies	81	35	59
NegFry + Metpole	81	35	63
NegFry + HMS	81	35	63
Expert decision	81	35	59

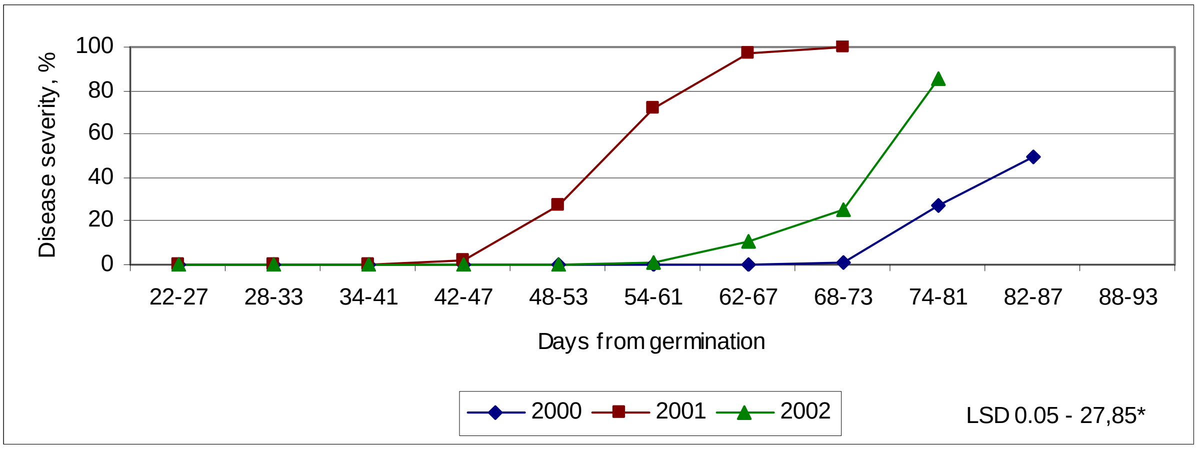
Effect of fungicide treatment on potato late blight development was analysed. All fungicide treatments reduced the disease severity at the end of season compared with control variant (Table 2). The disease severity was remarkably lower during the growing seasons 2001 and 2002. Statistically there are significant differences between results obtained in these seasons and between untreated and treated with fungicides variants, but no significant differences between different controls strategies were observed in each certain year.

Table 2. Disease severity at the end of season (%) and number of fungicide treatment, 2000 – 2002

	2000		2001		2002	
Control	50 %	0	100 %	0	85.5 %	0
Recommendations of chemical companies	25 %	5	70 %	4	4.2 %	5
NegFry + Metpole	25 %	3	72.5 %	4	2.6 %	3
NegFry + HMS	30 %	4	83.9 %	4	8.3 %	4
Expert decision	27 %	4	71.2 %	4	2.8 %	4

Considering number of treatments there were found differences between used control strategies, except the year 2001 (Table 2). In the year 2001 number of treatments was the same in all treated variants. Less fungicide treatments were recommended by NegFry +

Metpole in the years 2000 and 2002. These are years when conditions have not been so favourable for late blight. Whereas, according to recommendation of chemical companies' number of treatments was higher in the same years. It could be explained with comparatively early first treatment of fungicides and using of contact fungicides.



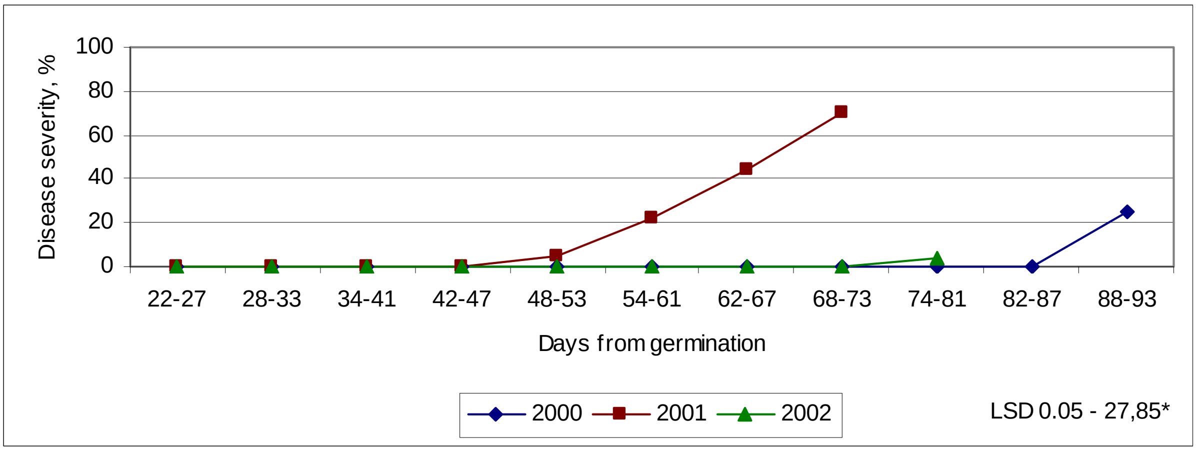
** LSD for final disease severity*

Figure 2. Development of potato late blight in the untreated fields, 2000 – 2002

The disease progress curves for control variant are shown in Figure 2. In the year 2001 disease severity at the end of season was 100 %. In the years 2000 and 2002 disease progress was slow but nevertheless the disease severity at the end of season was very high.

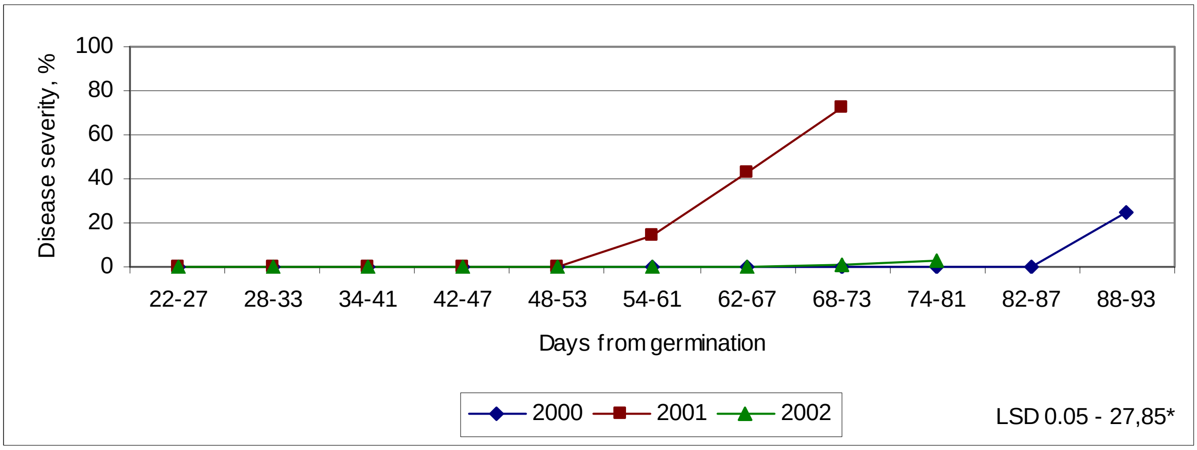
Late blight spread slowly in the all treated with fungicides variants, however the disease severity at the end of season was very high in the year 2001 (70 – 83 %). The disease progress curves for the variant 'treated according to recommendation of chemical companies' are shown in Figure 3 and for the 'NegFry + Metpole' variant in Figure 4. The same tendencies were observed in the variants treated according to 'NegFry + HMS' model and Expert decisions.

The first symptoms of late blight were observed very late of growing season, correspondingly 69 – 81 days after germination in the year 2000 and 52 – 63 days in the year 2002. The effect of fungicide application on disease apparent infection rate was not significant or not observed at all. In the year 2002 the disease progress was observed after guaranteed time of fungicide application (Figure 5).



** LSD for final disease severity*

Figure 3. Development of potato late blight in the fields treated according to recommendations of chemical companies, 2000 – 2002



** LSD for final disease severity*

Figure 4. Development of potato late blight in the fields treated according to NegFry + Metpole, 2000 – 2002

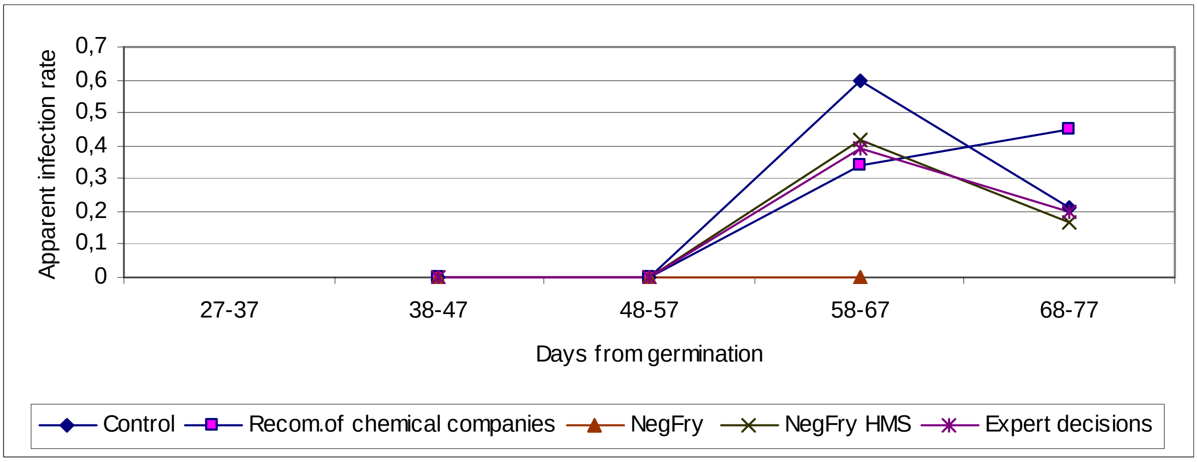


Figure 5. Changes of apparent infection rate during growing season 2002

Remarkable changes of apparent infection rate in growing season were observed in the year 2001 (Figure 6). To compare untreated and treated with fungicide fields there were no differences found out in the beginning of growing season. The apparent infection rate was 0.46, except variant where treatment was done according to expert decision - there it was lover - 0.35. During growing season almost all fungicide treatments influenced the disease development rate and it was lower than in untreated variant. There were not significant differences found to compare different control strategies.

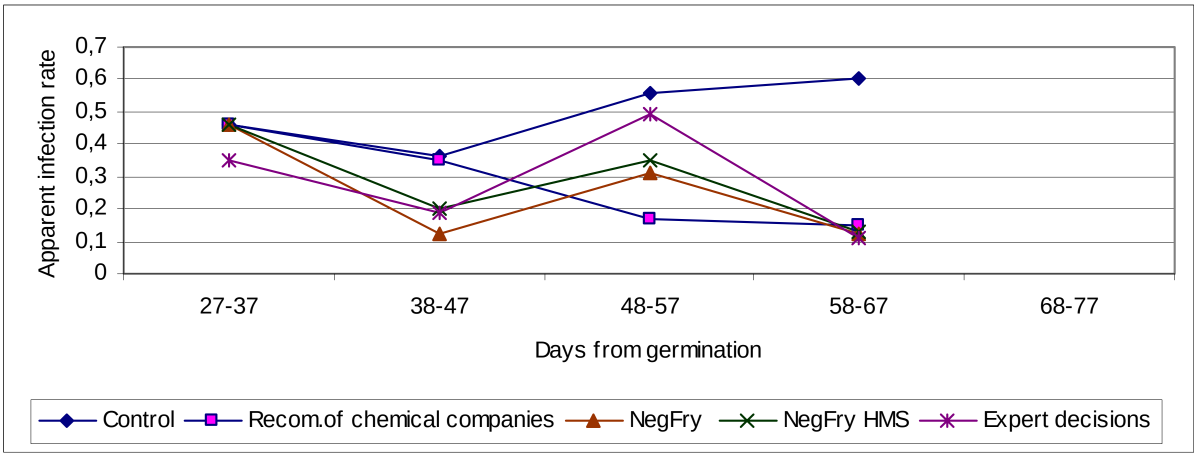


Figure 6. Changes of apparent infection rate during growing season 2001

Conclusions

All analysed potato late blight control strategies reduced the disease severity only at the end of growing season.

In the favourable season for the late blight development all tested control strategies shown similar results: 4 treatments were predicted in all variants.

In the unfavourable season for the late blight development, different numbers of treatments (3 to 5) were predicted by models.

During growing season all analysed control strategies influenced the disease apparent infection rate, but there were no significant differences observed in each certain year.

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Posters

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Management of potato late blight in Finland in 2003

ASKO HANNUKKALA, ARI LEHTINEN AND PEPPI LAINE

MMT, Agrifood Research Finland, Plant Production Research, Plant Protection
FIN-31600 Jokioinen
ari.lehtinen@mtt.fi, asko.hannukkala@mtt.fi

The weather conditions during the season 2003 were fluctuating within and between different regions in Finland. Periods with heavy rain showers very conductive to blight development altered with long, dry and exceptionally warm periods. Therefore there was enormous variation in infection pressure and blight risk from one location to another.

The first potato late blight lesions were observed in south-eastern corner of the country at 13th of June, which is somewhat earlier than during past three seasons. During the first half of July blight was found throughout the Southern and Central Finland. The regions of very intensive potato production along the west cost, where first attacks often are recorded, remained free from blight until late August, due to serious drought. In the middle of the July blight was also found in Lapland 100 km north from the Polar Circle, where blight has hardly ever been present until few recent years.

In most cases blight appeared as normal brown lesions in leaves. In 2003 also necrosis on veins caused by blight was very common as well as stem blight. Mosaic like discolouration on lowest leaves connected to soil borne primary infection was not commonly found in 2003.

In conventional farming fungicide applications were started in time and no severe blight attacks were reported. In certain regions heavy rain showers disturbed the spray programs and single blight lesions were more common than usual in fungicide treated fields. In seemingly dry locations many growers lost their attention to blight control, extended the spray intervals too much and finally also got more blight lesions in their crop than usual. The weather during end of August was very warm and dry followed by severe frost killing the

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haulm suddenly at 2nd September. Weather conditions at harvest were excellent and the yield in commercial production was practically free from tuber blight in spite of relatively frequent occurrence of leaf blight also in protected crop at the end of August.

During past few years Shirlan has become the most widely used blight fungicide exceeding the dominant role of mancozeb products. Mancozeb products together with Shirlan cover approximately 90 % of the treated potato growing area. The rest of potato area is sprayed with Acrobat and Tattoo, which are used for 1-2 applications at the period of excessive growth of crop. Epok and copper products have very marginal use and are gradually withdrawn from the markets.

The recommended spray interval for contact fungicides is 7-10 days and 10-14 days for the products containing translaminar active ingredients. The recommendations are based on international standards, which do not apply well in Nordic growth conditions. Especially in Northern Finland potato shoots can grow for more than 15 cm in length within one week. In blight conductive weather conditions there is considerable amount of unprotected tissue to be infected already after a few days following treatment at the most hectic periods of leaf expansion.

In fungicide efficacy trials at Jokioinen all fungicide programs protected crop from leaf blight reasonable well. The treatments with Shirlan in 7-day intervals (7 treatments) and Tattoo in 10-day intervals (5 treatments) protected the crop completely. Dithane NT in 7-day intervals failed at the very end of the season and the final disease rating was 10% of the leaf area defoliated by blight. There was also almost 10 % of tuber blight in spite of 7 Dithane NT treatments while only 0,5% and 2,5% of the tubers were diseased after 7 Shirlan and 5 Tattoo treatments respectively.

In practice the number of fungicide treatments varied 3-7 depending on blight pressure, form of production and farmers choice of acceptable risk for crop loss. In Finland seed potato growers as well as contract growers of foodstuff processing industry are most aware of blight risk and apply the highest number of sprays. In contrary to many other countries in Europe starch potato producers are not very much concerned about blight. The lowest number of applications per season is normally connected with starch potato producers.

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Competitive selection of *Phytophthora infestans* in the US and Northern Ireland

GILLIAN K. YOUNG[1,2], LOUISE R. COOKE[1], WILLIAM W. KIRK[2] AND PAVANI TUMBALAM[2]

[1]Department of Applied Plant Science, Queen's University of Belfast, Newforge Lane, Belfast, BT9 5PX, UK
[2]Plant Pathology Department, Michigan State University, East Lansing, Michigan, 48824, US

Summary
Distinct clonal lineages of *Phytophthora infestans* have evolved in the US and across Europe. Knowledge of competitive interactions between genotypes will allow better understanding of the role of the cultivar in population selection. Representative groups of isolates were chosen from Michigan and Northern Ireland for inoculation onto two field trials in 2003, one in Michigan and one in Northern Ireland. Isolates were characterized using common genotypic and phenotypic tests. Four cultivars with differing levels of field resistance to late blight were planted in each trial, two cultivars (Atlantic, Stirling) were grown at both sites while the other two differed between locations (Milagro, Sante in Northern Ireland; Jacqueline Lee, Pike in Michigan). Single-lesions were removed from the trials at 1% infection, characterized and re-assigned to their respective groupings. In Northern Ireland, selection by cultivar was evident with fewer isolates infecting the more resistant cultivars. By contrast, in the US the highly aggressive US-8 genotype dominated the infection of all cultivars regardless of resistance to foliar late blight.

Keywords: *Phytophthora infestans*, potato late blight, competition, selection

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Introduction

Late blight caused by the oomycete *Phytophthora infestans* remains a major threat to potato production worldwide. Since the 1970s separate migrations, presumably from Mexico, have led to the spread of 'new' strains or genotypes of P. infestans throughout Europe and the US. These genotypes have rapidly displaced the 'old' US-1 clonal lineage which previously dominated pan-globally (Kato *et al.*, 1997, Goodwin *et al.*, 1995b). It has been suggested that higher aggressiveness of these 'new' genotypes gave a competitive advantage which led to their rapid increase in frequency (Goodwin, 1997).

Comparison of the competitive ability of multiple genotypes has to date been limited to tuber infection, detached leaflet experiments and whole plants in growth chambers, with few studies testing fitness and competition in the field environment. The current investigation uses multiple cultivars and genotypes to study the isolate-cultivar interaction, and thus determine the potential influence of variety on selection of the surrounding late blight population.

Methods

Six representative groups were chosen from the local *P. infestans* populations of Northern Ireland (NI) and the US based on phenotypic and genotypic differences (Table 1). Isolates were distinguished by mating type (Cooke *et al.*, 1995), glucose-6-phosphate isomerase (Gpi) and peptidase (Pep) allozyme genotyping (Goodwin *et al.*, 1995a), mitochondrial haplotype (Griffith and Shaw, 1998) and sensitivity to the fungicide metalaxyl (leaf disk method of Cooke, 1986).

Field trials were planted in early summer 2003 in NI and Michigan State. Cultivars with differing resistance ratings to foliar late blight were included. Ratings are based on NIAB or breeder's estimates for foliar resistance on a 1-9 scale where 9 is maximum resistance. Four cultivars were planted at both sites. The commercial varieties Atlantic (NIAB rating 3) and Stirling (NIAB rating 8) were included in both trials as common varieties. Pike (breeder's estimate 3) and Jacqueline Lee (breeder's estimate 8) were planted in the US, and Sante (NIAB rating 7) and Milagro (breeder's estimate 8) in the NI field trial. Milagro was bred at the N I Horticultural and Plant Breeding Station while Jacqueline Lee was bred at Michigan State University.

Each cultivar was replicated four times in a randomized complete block design. Six rows of susceptible infector plants (cv. FL1979 in the US and Desiree in NI) were planted, surrounding the trial plots, two on both sides and two in the centre. Each infector row was inoculated with equal amounts of standardized inoculum from each of the six groups. Every third plant was inoculated with an individual group chosen at random. An epidemic was established and allowed to spread to surrounding test cultivars. Foliage infection was assessed throughout the season (data not reported). Forty single-lesions were removed from each cultivar at 1% infection for isolation. These isolates were then characterized and re-assigned to their respective groupings.

Table 7 Groups chosen to represent *P. infestans* populations of N. Ireland and the US

Site	Group Number	Metalaxyl Sensitivity [a]	Pep genotype[b]	Haplotype
N. Ireland	1	R	100/100	IIa
	2	S	100/100	IIa
	3	R	100/100	Ia
	4	S	100/100	Ia
	5	R	96/100	Ia
	6	R	83/100	Ia
Site	Group Number	Mating Type	Gpi genotype[c]	Genotype[d]
US	1	A1	86/100	US-1
	2	A1	100/100	US-6
	3	A2	100/111/122	US-8
	4	A2	111/111/122	US-10
	5	A1	100/100/111	US-11
	6	A2	100/122	US-14

[a] *Sensitivity to the fungicide metalaxyl,* R *= resistant. S = sensitive.*
[b] *Determined by Pep allozyme genotype.*
[c] *Determined by Gpi allozyme genotype.*
[d] *Genotype grouping as designated by Goodwin et. al., 1995b.*

Results

From the NI field trial all six groups of isolates were successfully recovered from the susceptible variety Atlantic (Figure 1). Fewer groups were recovered from the more resistant cultivars. From the moderately resistant Sante only groups 2, 3 and 6 were recovered. From the resistant Milagro only group 6 isolates were recovered and from the resistant Stirling only groups 3 and 4 isolates were recovered.

From the US field trial only two groups of genotypes were detected (Figure 2). From Atlantic, Stirling and Jacqueline Lee only US-8 was recovered. From the susceptible Pike one US-14 isolate was found with the remainder all being the US-8 genotype.

Conclusions

In the US field trial, the US-8 clonal lineage was by far the most aggressive with only one other genotype (US-14) being detected. It is likely that the US-8 isolate out-competed all others through higher aggressiveness independently of any isolate x cultivar interaction. In contrast, competitive selection was apparent in the NI field trial where certain genotypic groups were able to infect certain cultivars. This was particularly obvious in the resistant Stirling where only the Pep 100/100, haplotype Ia genotype was recovered and the resistant Milagro where only the Pep 83/100, a rare genotype in the NI population, successfully infected. The results will be followed up in further field trials in Michigan and NI in 2004. These findings illustrate the importance of exposing new cultivars to a wide range of genotypes in the field before marketing them as blight-resistant.

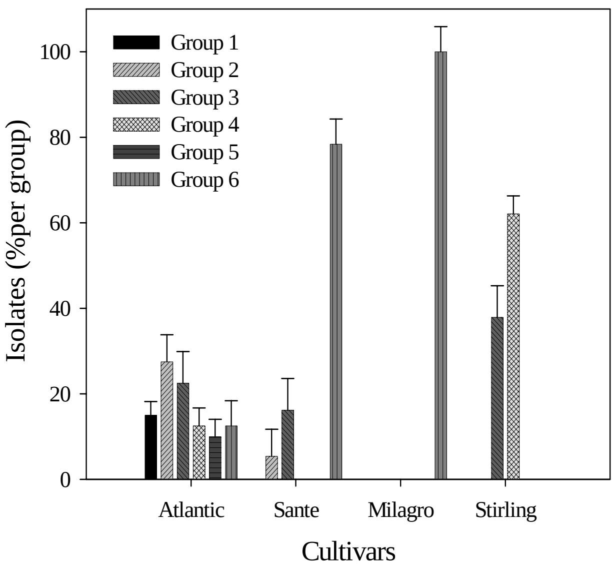

Figure 1. Percentage infection per group of the N. Ireland field trial.

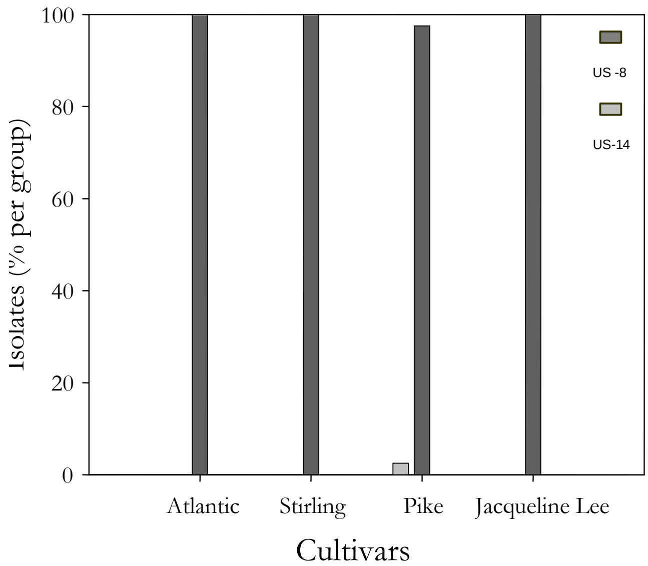

Figure 2. Percentage infection per group of the US field trial.

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The diversity in mitochondrial DNA in geographically distinct populations of *Phytophthora infestans*

K.L. DEAHL, F.G. PEREZ & B.C. MORAVAC

E-mail Kenneth Deahl: deahlk@ba.ars.usda.gov

The diversity in mitochondrial DNA (mtDNA) was assessed within putative clonal and sexual populations of the late blight pathogen, *Phytophthora infestans*. Studying the mitochondrial genome provides new information about the evolution of this species, taking advantage of the fact that some regions of the genome are under more stringent selective pressure than others. Monosporangial *P. infestans* isolates (n=317) collected in 1998-2001 (characterized previously for mating type, metalaxyl sensitivity, alleles at the glucose-6-phosphate isomerases locus and RFLP bands detected by probe RG57) were analyzed for mtDNA haplotype.

Strains were obtained from naturally-infected hosts including potato (cultivated and wild Solanum species), tomato, woody and hairy nightshade, tree tomato and pepino. Every isolate tested (n=37) from central Mexico had a different RG57 fingerprint, but only mtDNA haplotype Ia was found. Other countries where isolates were exclusively of the Ia haplotype were Lebanon (n=12); Indonesia (n=2) and Costa Rica (n=6). Only the Ib haplotype was isolated in Nepal (n=2) and only IIa in Uruguay (n=25). A shift from Ib to IIb was detected among Taiwan isolates (n=86). Two haplotypes were found in Wales (Ia, IIa) and in Morocco (Ia, Ib) and three in the United States (Ia, IIa, IIb), Ecuador (Ia, Ib, IIa) and Northern Ireland (Ia, IIa, IIb).

Additional sampling may help to unravel historical and recent migrations as well as providing new insights into the forces shaping diversity in populations.

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Phenotypic and genetic characterization of *Phytophthora infestans* populations from Northern and Central Italy

M. COLLINA[1], E. SALA[1], L LANDI[2], M.F. DO NASCIMENTO[2]

[1]Dipartimento di Protezione e Valorizzazione Agroalimentare, Università di Bologna
Viale G. Fanin 46 - 40127 Bologna (ITALY)
[2]Dipartimento di Scienze Ambientali e delle Produzioni Vegetali, Università Politecnica delle Marche, Via Brecce Bianche, 60131 Ancona (ITALY)

Summary

Mating type, sensitivity to fungicides, and random amplified polymorphic DNA (RAPD) markers were used to characterize the phenotypic and genetic variations among Italian isolates of *Phytophthora infestans*. Thirty-five isolates of *P. infestans* were randomly collected from naturally infected leaves from potato and tomato fields located in the Emilia Romagna, Marche and Lombardia regions of Italy. Identification was performed by phenotypic analysis. These data were examined alongside cropping details to determine the population structure in the context of existing disease management strategies. A1 and A2 mating type isolates were present in both commercial potato and tomato crops. Assays carried out with four fungicides (metalaxyl, cymoxanil, azoxystrobin and dimethomorph) showed the sensitivity in all *P. infestans* populations tested. RAPD analysis showed that the isolates cluster according to the locations of their origins, and in subgroups that generally correlate with mating type and host.

Keywords: *Phytophthora infestans*, sensitivity to fungicides, mating type, RAPD

Introduction

Phytophthora infestans (Mont.) de Bary is the causal agent of late blight disease in potatoes (*Solanum tuberosum* L.) and tomatoes (*Lycopersicon esculentum* Mill). Late blight is principally a disease of the foliage and stems, and of the potato tubers and tomato fruits.

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Isolates of *P. infestans* resistant to phenylamides appeared in Europe and in North America in the late 1970s and early 1990s, respectively. Concurrent, but coincidental, with both of these events, there were radical structural shifts in the pathogen populations as immigrant genotypes from Mexico displaced the indigenous populations. Both A1 and A2 mating type isolates are now present in blighted crops, which allows an alternative inoculum via germination of sexually produced oospores, and thus influences the dynamics of late blight populations. Since 1999, late blight has become a significant problem for Italian potato and tomato production, especially in the north-eastern areas of Italy (Bugiani *et al.*, 2001). The increased prevalence and severity of the disease that has been observed in recent years has been attributed to new immigrant isolates of *P. infestans* that can grow together with the previous forms of the pathogen (Fry *et al* 1991, 1992, 1993; Goodwin *et al* 1994, 1995). In the search for an explanation of these changes in the observed disease severity, the recent introduction into Italy of the A2 mating type (Cristinzio & Testa, 1997) has been identified as a potential source of increased losses due to a greater aggressiveness of the pathogen, earlier outbreaks of the disease, and increased resistance to fungicides. Furthermore, many metalaxyl-resistant populations of the pathogen have been reported for Italy since 1996 (Cristinzio & Testa 1998). The aim of this study was to carry out a survey in order to characterize the specific phenotypes (sensitivity to fungicides and mating type) and the genotypes of *P. infestans* populations in Italy. For the latter, polymerase chain reaction (PCR) and random amplified polymorphic DNA (RAPD) analyses were used, which are recognised as efficient molecular tools and are widely used for the rapid characterisation of many plant pathogens.

Materials and Methods

Thirty five isolates of *P. infestans* were collected and isolated from potato and tomato leaves of commercial fields located in the Emilia Romagna, Lombardia and Marche regions of Italy during 2002 and 2003 (Figure 1 and Table 1). In some cases, more than one isolate was taken from the same field (e.g. AP2A, AP2B, AP2C).

All of the populations were purified and cultured in V8

Figure 1. Italian areas where *P. infestans* populations were collected.

medium (V8, 250 ml; 15.0 g agar, 2.7 g CaCO3, distilled water to 1.0 litre) containing 100 mg/l vancomycin, 10 mg/l neomycin, 10 mg/l benomyl, 2 mg/l prochloraz and 100 mg/l rifampicin. The phenotypic characterizations included sensitivity to fungicides (metalaxyl, azoxystrobin, cymoxanil and dimethomorph) and mating type tests. The genetic characterizations were performed by RAPD analysis.

Phenotypic Characterization

Mating type: This was determined for all of the isolates by pairing each unknown with two isolates of known A1 and A2 mating types in petri dishes containing 10% V8 medium. The plates were then placed in an incubator at 20 °C in the dark. After one week, each pairing was examined under the microscope for the presence of oospores indicating where the two colonies had interacted. Sexual structures (antheridia and oogonia) are induced only in the presence of the opposite mating type, and the genetic fusion results in oospores. In contrast, isolates of the same mating type tend to repel each other at the juncture of the two mycelia.

Sensitivity to fungicides: Metalaxyl, azoxystrobin, cymoxanil and dimethomorph sensitivities were determined in radial growth, by inoculating 9mm Ø plugs of twenty *P. infestans* isolates onto 10% V8-agar medium containing different concentrations of each fungicide. The concentration ranges used were: metalaxyl, 0 (control), 0.1, 1.0, 5.0, 10, 50 and 100 mg/l; azoxystrobin, 0, 0.01, 0.05, 0.10, 0.50 and 1.0 mg/l; cymoxanil, 0, 0.1, 0.5, 1.0, 2.5, 5.0 and 10 mg/l; and dimethomorph, 0, 0.1, 0.5, 1.0, 2.5 and 5.0 mg/l. The data were processed with probits to calculate the ED50 values. In the case of metalaxyl, based on the percentage of hyphal growth relative to the controls, individual isolates were classified as being sensitive (S: growth <10% of the control), intermediate (I: growth 10-60% of the control) or resistant (R: growth >60% of the control) in their responses, using the criteria of Shattock (1988).

Genetic Characterization

RAPD-PCR amplification and data analysis: Twenty-two isolates were grown over sterile discs of cellophane on V8 plates to facilitate the subsequent removal of the mycelia from the agar. Total DNA was extracted according to the CTAB methods of Mulcahy *et al.* (1995), with slight modifications, as follows. The axenic fungal cultures were ground to a fine powder in liquid nitrogen, mixed with 1 ml extraction buffer (100 mM Tris-HCl, pH 8.0, 1.4 M NaCl, 20 mM EDTA, 2.0% CTAB, 0.4% □-mercaptoethanol), and incubated at 65 °C for 15 min.

The DNA was extracted with an equal volume of chloroform:octanol (24:1, v/v) and centrifuged at 8,000 rpm for 5 min. The supernatants were transferred to fresh tubes, to which was added 0.6 volume isopropanol. After centrifugation at 14,000 rpm for 10 min, the supernatant was discarded and the DNA pellet was washed with 70% ethanol. The dried pellet was dissolved in 50 µl TE buffer (10 mM Tris-HCl, 0.1 mM EDTA, pH 8.0).

RAPD markers were used to determine the frequency of DNA polymorphism and the genetic distances among the isolates of *P. infestans*. A set of 10 random decamer oligonucleotides (Pharmacia and Genenco) was used for the single primers for the amplification of the RAPD sequences. The amplifications were performed in a 20-µl volume, containing 10 µl MasterMixTaq DNA Polymerase (Qiagen), 5 □M of each primer, and 20/40 ng of template DNA. DNA amplification was performed in a Bio-Rad iCycler System (BioRad), and the conditions used were: 95 °C for 10 min for the first phase, followed by 39 cycles of 95 °C for 1.00 min, 36 °C for 1.30 min, and 72 °C for 1.30 min. The reaction products were analysed alongside small molecular weight markers (Sigma) on 1.5% agarose gels in the presence of ethidium bromide. The gels were then photographed under UV light using type MP-4 Polaroid film.

The calculations of the similarity coefficients (Nei & Li, 1979) and the generation of the bootstrapped dendrogram (UPGMA, Sneath & Sokal, 1973) were completed using the TREECON 1.3b programme (van de Peer & de Wachter, 1994).

Results and discussion

Phenotypic characterization: Of the 35 isolates tested for mating type, 74% were A1 and 26% were A2. The majority of samples with mating type A1 were from the tomato crops. In the Marche region, all of the isolates were A1 (Table 1). The A2 mating type has been present in Italy since 1996 (Cristinzio & Testa, 1997), and hence it has had enough time to become widespread. The frequencies and distributions of both mating types were of key importance in the assessment of the likelihood of sexual recombination, with its potential to impact on practical control measures and to affect the rate of genetic changes within populations of *P. infestans* in the longer term. The in vitro growth responses to the fungicides were also determined in 20 isolates. These results showed all of the 20 isolates to be sensitive to all of the fungicides tested. Across the isolates, the ED50 values ranged from <0.001 to 0.3 mg/l for metalaxyl, from 0.03 to 1.89 mg/l for cymoxanil, from 0.004 to 0.1 mg/l for azoxystrobin

Graf. 1 - Sensitivity of *P. infestans* to fungicides (ED_{50})

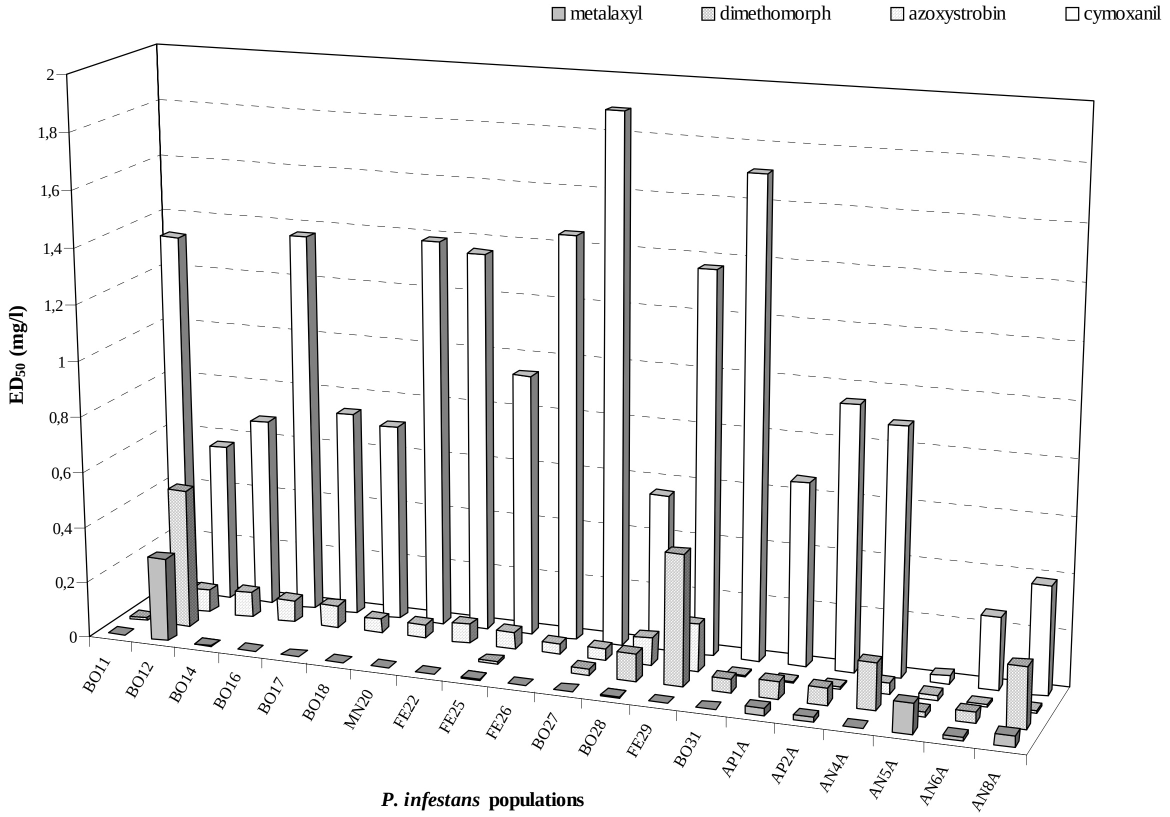

Table 1. Origin and mating type of *P. infestans* populations

P. infestans populations	Italian region	Host	Mating type	*P. infestans* populations	Italian region	Host	Mating type
BO 11	ER	potato	A2	AP 2B	M	tomato	A1
BO 12	ER	potato	A1	AP 2C	M	tomato	A1
BO 14	ER	potato	A2	AN 3	M	tomato	A1
BO 16	ER	potato	A2	AN 4A	M	tomato	A1
BO 17	ER	potato	A2	AN 4B	M	tomato	A1
BO 18	ER	potato	A2	AN 4C	M	tomato	A1
BO 26	ER	tomato	A1	AN 5A	M	tomato	A1
BO 27	ER	tomato	A1	AN 5B	M	tomato	A1
BO 28	ER	tomato	A2	AN 6A	M	tomato	A1
BO 31	ER	tomato	A1	AN 6B	M	tomato	A1
FE 22	ER	tomato	A2	AN 7A	M	tomato	A1
FE 25	ER	tomato	A1	AN 7B	M	tomato	A1
FE 26	ER	tomato	A1	AN 7C	M	tomato	A1
FE 29	ER	tomato	A2	AN 8A	M	tomato	A1
MN 20	L	tomato	A2	AN 8B	M	tomato	A1
AP 1A	M	tomato	A1	AN 9	M	tomato	A1
AP 1B	M	tomato	A1	AN 10	M	potato	A1
AP 2A	M	tomato	A1				

ER= Emilia Romagna; L= Lombardia; M= Marche

Table 2. Sensitivity classes of P. infestans populations tested towards metalaxyl

P. infestans populations	Concentrations of metalaxyl (mg/l)					
	100	50	10	5	1	0.1
BO 11	S	nt	S	S	S	S
BO 12	S	nt	I	I	I	I
BO 14	S	nt	S	I	I	I
BO 16	S	nt	S	S	S	S
BO 17	S	nt	S	I	I	I
BO 18	S	nt	S	S	S	I
BO 27	S	nt	S	S	S	S
BO 28	nt	S	S	S	S	I
BO 31	nt	I	I	I	I	I
FE 22	S	nt	S	S	S	S
FE 25	S	nt	S	S	I	S
FE 26	S	nt	S	S	I	I
FE 29	nt	S	I	I	I	I
MN 20	S	nt	S	S	S	S
AP 1A	nt	S	S	S	I	I
AP 2A	nt	S	I	I	I	I
AN 4A	nt	S	I	I	I	I
AN 5A	nt	S	I	I	I	I
AN 6A	nt	S	I	I	I	I
AN 8A	nt	S	S	I	I	I

S = Sensitive class; I = Intermediate class; nt = not tested

and from 0.008 to 0.5 mg/l for dimethomorph (Graph. 1). The metalaxyl sensitivity assessments of all of the isolates collected during the period 2002-2003 were also classified as either sensitive (S) or intermediate (I), as no metalaxyl-resistant (R) isolates were found (table 2).

Genetic characterization: The RAPD patterns were obtained from the DNA from 22 isolates of *P. infestans*. The molecular weights of the amplicons ranged from 0.2 to 3.5 Kb, and the 10-decamer primers generated 52 scorable polymorphic bands. The dendrogram shows the hierarchical clustering represented by a single group that can be subdivided into three main sub-clusters according to their similarity coefficients (Fig. 2). The isolate FE22 is the most genetically distant, cluster to the main group. The first sub-cluster is divided into four further subgroups. The first of these subgroups includes all of the isolates from potato plants near Bologna, which have the A2 mating type (A2mt), and also the FE25 A1mt isolate from Ferrara. The second subgroup consists of the isolates BO27 and BO26 from tomato, with an A1mt. A further subgroup includes MN20, AP1A and AN3. The last subgroup of this main sub-cluster is composed of three isolates from Ancona: AN10, AN7A and AN8A. The only A1mt isolate from Bologna is also linked to this main sub-cluster. Isolates AN5A, AP2A, AN9 and FE29 group into the third sub-cluster, along with AN4A and AN6A.

These preliminary results, indicated by a low bootstrap values, show that the isolates initially tend to cluster according to their geographic origins. Similar results were described by Carlisle *et al.* (2001). Mating type and host show some influence at the subgroup level. A separate group according to mating type, from RAPD analysis, was proposed by Mahuku *et al.* (2000). The absence of fungicide-resistant populations did not allow genetic analysis and fungicide sensitivity data to be related here. This could prove to be an interesting aspect of this study for the development of an effective strategy in the control of late blight in potato and tomato crops.

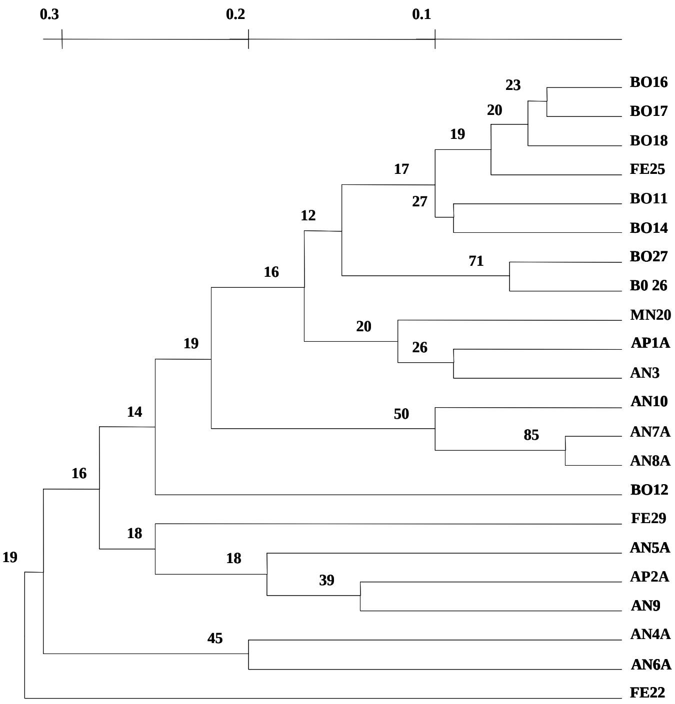

Figure 2. Dendrogram indicating the relatedness of isolates of *P. infestans*. The analysis was based on Nei and Li genetic diversity calculated for 52 RAPD markers. Isolates are as given in Table 1.

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Comparison of different DSS for the prediction and control of potato late blight in Emilia-Romagna region(Italy)

R.BUGIANI[1], L.ANTONIACCI[1], B.KLEINHENZ[2], U.PREISS[2], H.R.FORRER[3], T.MUSA-STEENBLOCK[3]

[1] Servizio Fitosanitario (Plant Protection Service) – Regione Emilia-Romagna, Via Corticella 133, 40129 Bologna (Italy)

[2] Agroscope, FAL Reckenholz, Research for Agriculture and Nature. Dpt. of Ecological Farming Systems, CH-8046 Zürich, Switzerland

[3] ZEPP (Central Institution for Decision Support Systems and Programmes in Crop Protection) Rüdesheimer Str. 60-68, 55545 Bad Kreuznach

Summary

IPI model is currently used in Italy both on potato and tomato to determine when to apply the first spray to control late blight. However the model provides no information about the subsequent sprays. Field evaluation of a combined use of IPI model and other DSS(decision support systems) for correct timing of chemical sprays was carried out over three years, and compared with a routine strategy. In 2001and 2002, MISP, Fry and Simphyt II and III models were compared while in 2003 only MISP and Simphyt II and III were tested. All the DSS were tested with natural infection. Disease occurred only in 2002. The results however showed, that Simphyt model performance in timing the sprays and controlling the disease was better in years with medium disease pressure. On the contrary, in years unfavourable for blight development MISP proved to be the most effective in saving useless sprays. Further validation in years with high blight pressure would be necessary. In 2002 infection pressure was underestimated by MISP model, an effect that could be due to irrigation which was not taken into account for the determination of the MISP-days. We assume that irrigation can have a great influence on the development of late blight and that its' effect should be implemented in DSS for the timing of a first and of subsequent fungicide applications.

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Keywords: potato, late blight, decision support system, field validation

Introduction

In order to determine the risk of blight onset in the field the negative prognosis I.P.I. (Infection Potential Index) model was originally developed for tomato crop in the early '90 (Bugiani R. *et al.*, 1993). The model calculates the cumulated daily risk index on the basis of daily meteorological data from potato emergence (green rows) until risk threshold for the first spray is achieved. The model was then validated for potato crop and used on tomato and potato by the regional Warning Service (Bugiani R. *et al.*, 1997,1998). IPI model proved to be the most suitable for our region to indicate the first treatment, yet it is not able to provide any information about the subsequent infectious events.

Present work aims to evaluate in field trials other forecasting criteria in combination with I.P.I. model to correctly time the subsequent sprays once accumulated IPI Index reaches the threshold for the first spray. Model considered were Fry (Fry W.E. *et al.*, 1983), Simphyt II and III (Kleinhenz *et al.*, 1999, Jörg *et al*, 1999, Gutsche *et al.*, 1998) and MISP (Cao K.Q. *et al.*, 1997; Ruckstuhl M. & Forrer H.R., 1998; Bugiani R. *et al.*, 1999), developed in USA, Germany and Switzerland respectively.

Material and methods

Field trials were carried out over the years 2001-2003 in a potato growing area located near Bologna (Emilia-Romagna region), Italy. The experiment was carried out on the highly susceptible cultivar Agata (2001) and Primura (2002-2003) following a randomised complete block design with 4 replicates. Each plot measured about 27 m2 (6 rows x 5 m). The first treatment was applied once IPI model reached the risk threshold. Further sprays were applied following different criteria: Fry, MISP and Simphyt II and III. Untreated plots were used as checks along with commonly used routine applications based on 7 days fixed schedule. Bi-hourly meteorological data of a weather station located near the experimental field were used to run the models. Surveys were carried out twice a week and sometimes weekly to determine the crop phenological stage, the occurrence of first symptoms and disease progress as percentage of disease severity. Active ingredients, doses and time of applications in every year are summarized in table 1 and 2.

Table 1. Timing, dosage and formulation of fungicides used in the experimental trials over 2001-2003

Model strategy	Formulation	Dose	Time of application
2001			
1 Check	--	--	--
2 Routine applications	Ridomil R	3 l/ha	09 May
	Curzate R	3 kg/ha	25 May
	Curzate R	3 kg/ha	31 May
	Curzate R	3 kg/ha	8 June
	Curzate R	3 kg/ha	19 June
3 MISP	Curzate R	3 kg/ha	25 May
	Curzate R	2.50 kg/hl	8 June
4 Simphyt II & III	Curzate R	3 kg/hl	25 May
	Curzate R	3 kg/ha	8 June
5 Fry	Curzate R	3 kg/ha	25 May
	Curzate R	3 kg/ha	31 May
	Curzate R	3 kg/ha	8 June
2002			
1 check	--	--	--
2 Routine applications	Equation pro	0.4 kg/ha	05 May
	Ridomil R	4 kg/ha	15 May
	Ridomil R	4 kg/ha	31 May
	Curzate R	3 kg/ha	7 June
	Equation pro	0.4 kg/ha	18 June
3 MISP	Equation pro	0.4 kg/ha	05 May
4 Simphyt II & III	Equation pro	0.4 kg/ha	05 May
	Ridomil R	4 kg/ha	31 May
	Equation pro	0.4 kg/ha	18 June
5 Fry	Equation pro	0.4 kg/ha	05 May
	Ridomil R	4 kg/ha	15 May
	Ridomil R	4 kg/ha	31 May
	Equation pro	0.4 kg/ha	18 June
2003			
1 Check	--	--	--
2 Routine applications	Equation pro	0.4 kg/ha	13 May
	Equation pro	0.4 kg/ha	22 May
	Curzate R	1.25 kg/ha	30 May
	Ridomil R	4 kg/ha	6 June
	Curzate R	1.25 kg/ha	20 June
3 MISP	Equation pro	0.4 kg/ha	23 May
4 Simphyt II & III	Equation pro	0.4 kg/ha	13 May
	Ridomil R	4 kg/ha	6 June

Table 2. Cultivar, soil type and phenology of potato crop in the experimental trials over 2001-2003

year	2001	2002	2003
location	Imola	Castel S. Pietro	Imola
soil type	Loamy-Clayey	Loamy-Clayey	Loamy-Clayey
cultivar:	Agata	Primura	Primura
sowing	19 march	11 march	17 march
80-85% green rows	26 April	20 April	22 April
ground coverage on the rows	16 May	14 May	16 May
complete ground coverage	28 May	24 May	26 May
harvest	09 July	18 July	16 July

Results

In 2001, disease pressure was medium to low levels throughout the growing in accordance to Simphyt III model output (fig 4). Risk of first infection was correctly warned by I.P.I. model for most of the weather stations on 3-5 May. First symptoms of late blight occurred in the potato growing area on 14 May. However, on the experimental plots, no disease occurred throughout the growing season. As summarized in table 1- MISP and Simphyt model warned for 2 sprays, Fry model warned for 3 sprays, while 5 sprays were applied following the calendar strategy. At harvest, potato yields of all the different strategies were not statistically different.

On the contrary, in 2002, disease pressure was medium to high in May while for the rest of the growing season decreased from low to very low levels (fig 5). I.P.I. model warned for the first spray on 2-3 May. Infections took place in the potato growing area on 5-7 May and first symptoms of late blight occurred both on sprayed and unsprayed farms on 14 May. In the experimental plots first symptoms of the disease appeared on 22 May due to rainy events occurred on 11-12 May. At harvest the percentage of affected leaves on the unsprayed plot reached roughly 13%, showing a medium to low disease pressure. Besides, yields of the different strategies tested, estimated at the end of the growing season, showed no statistical differences. On the whole, MISP model warned for 1 spray, Simphyt model and Fry warned for 3 and 4 sprays respectively, while 5 sprays were applied following a routine strategy. Percentage of affected leaves was estimated on 22/5, 5/6, 14/6 and 17/7. Until 5 June all the different strategies were statistically different from the unsprayed plots, but no differences were recorded between each other. On the other hand , survey carried out on 14 June and three days after, confirmed that Simphyt and routine strategies were the most effective in controlling the disease, while MISP and Fry models were not at the same level. This might be due to irrigations carried out after the first blight occurrence on 25 May and 4 June. This could have penalized MISP strategy, since irrigations were not taken in account to determine MISP days

In 2003, disease pressure was even lower than the previous years due to particularly dry conditions with extremely high temperature and very sporadic rainy events throughout the season. Late blight did not occur in all the potato growing area. Just few symptoms occurred in an organic farm at the end of May but failed to sporulate and give raise to the epidemic. I.P.I. model warned for the first spray on 22 May and after that no infectious events occurred until harvest. MISP and Simphyt models warned for 1 and 2 sprays respectively, while 5 sprays were applied for the routine strategy. The particularly unfavourable climate conditions for late blight development can be underlined by the fact that even 5 irrigations applied throughout the season failed to trigger blight epidemic in the field.

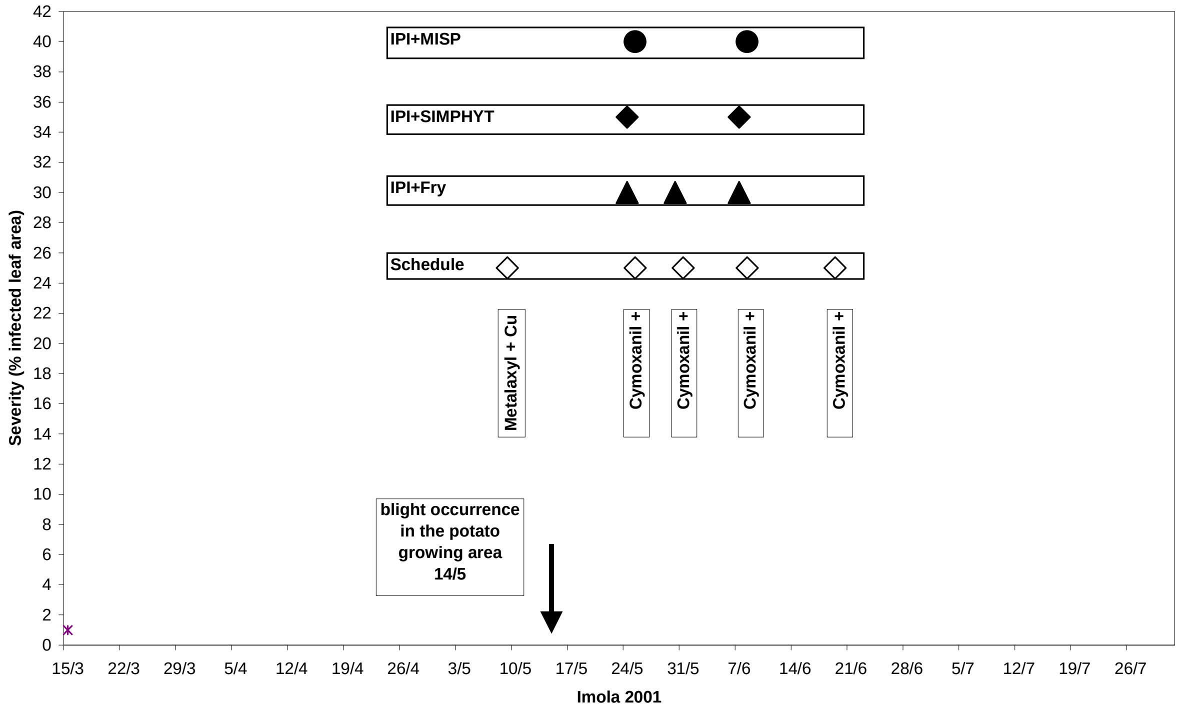

Fig. 1: IPI risk index and late blight occurrences in the potato growing area in 2001

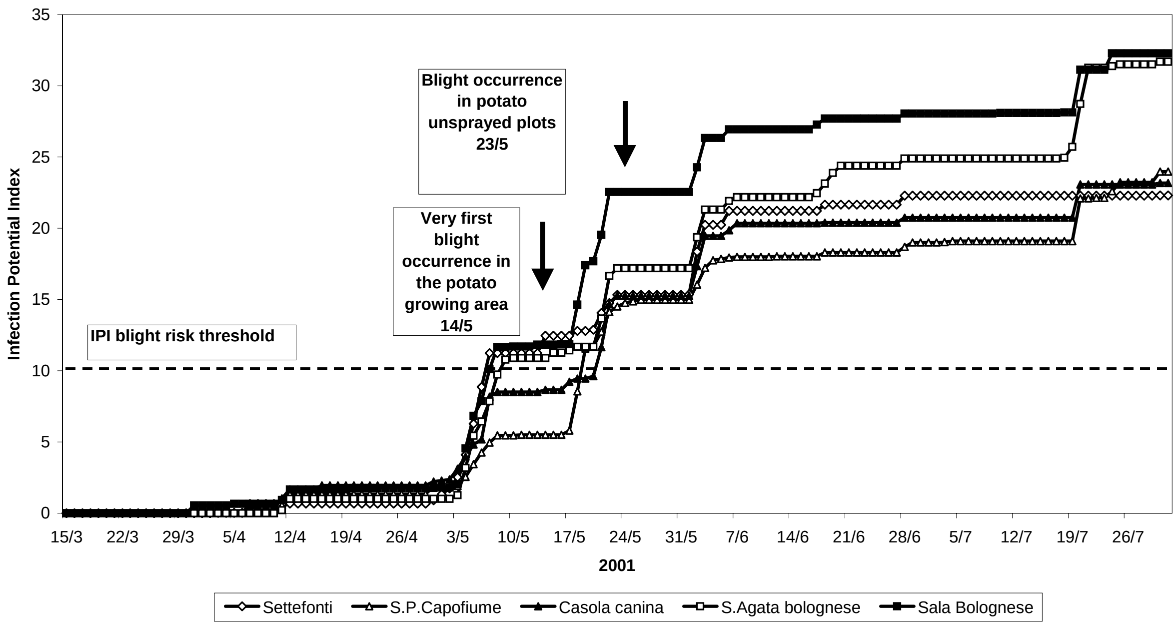

Fig. 2: Disease severity and timing of fungicides in validation trial in 2001

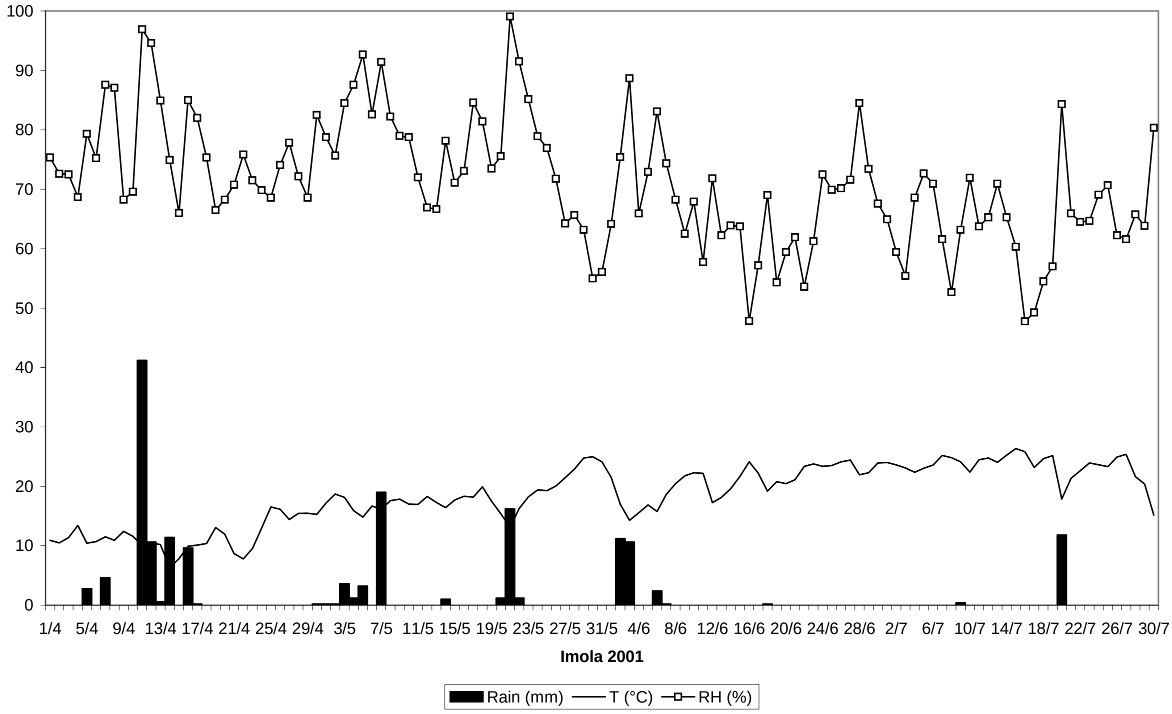

Fig. 3: Climate conditions in 2001

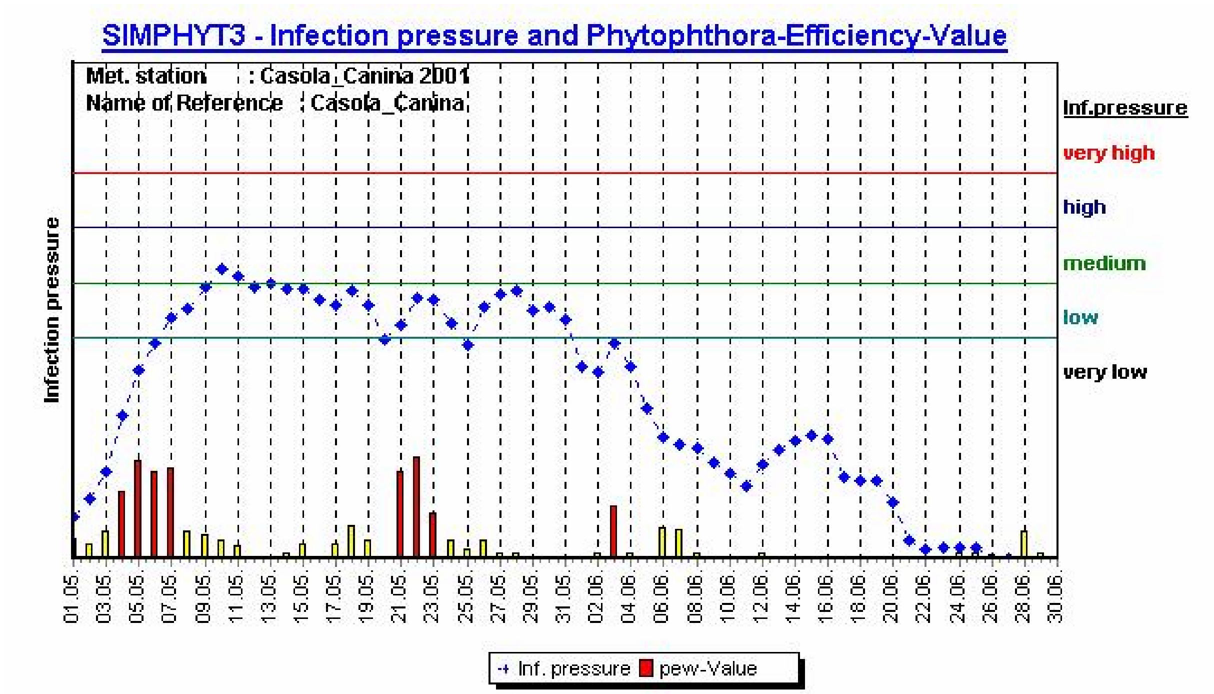

Fig. 4: Disease pressure and Infection efficiency values as estimated by Simphyt III in 2001

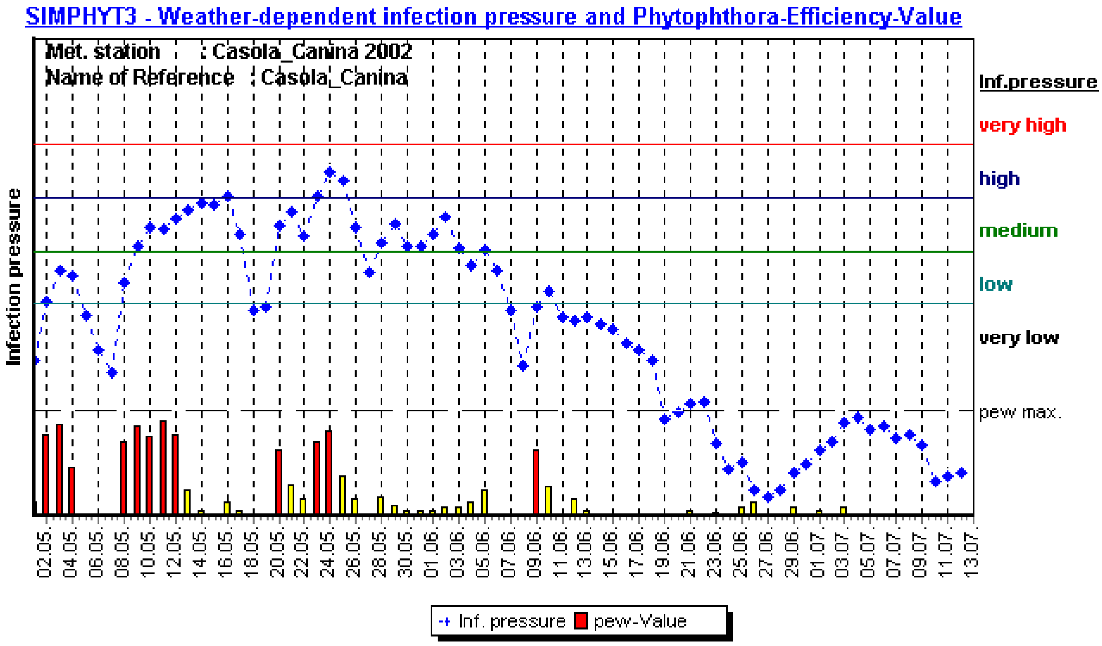

Fig. 5: Disease pressure and Infection efficiency values as estimated by Simphyt III model in 2002

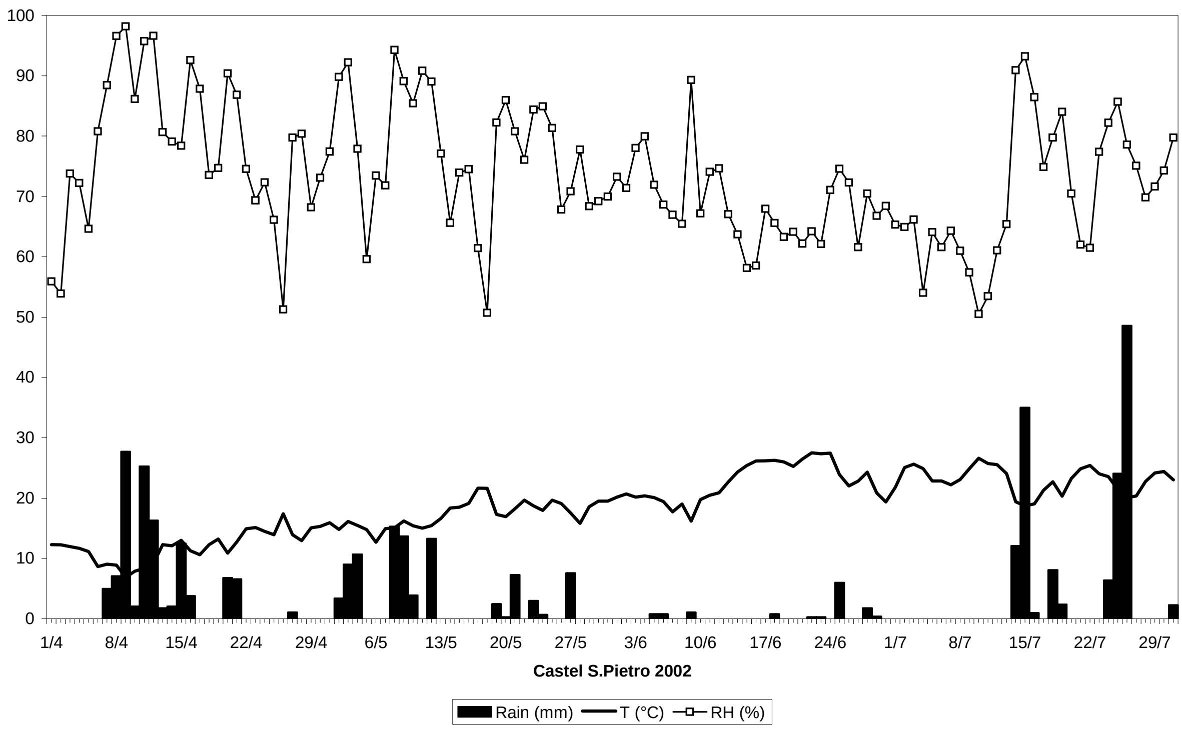

Fig. 6: Climate conditions in 2002

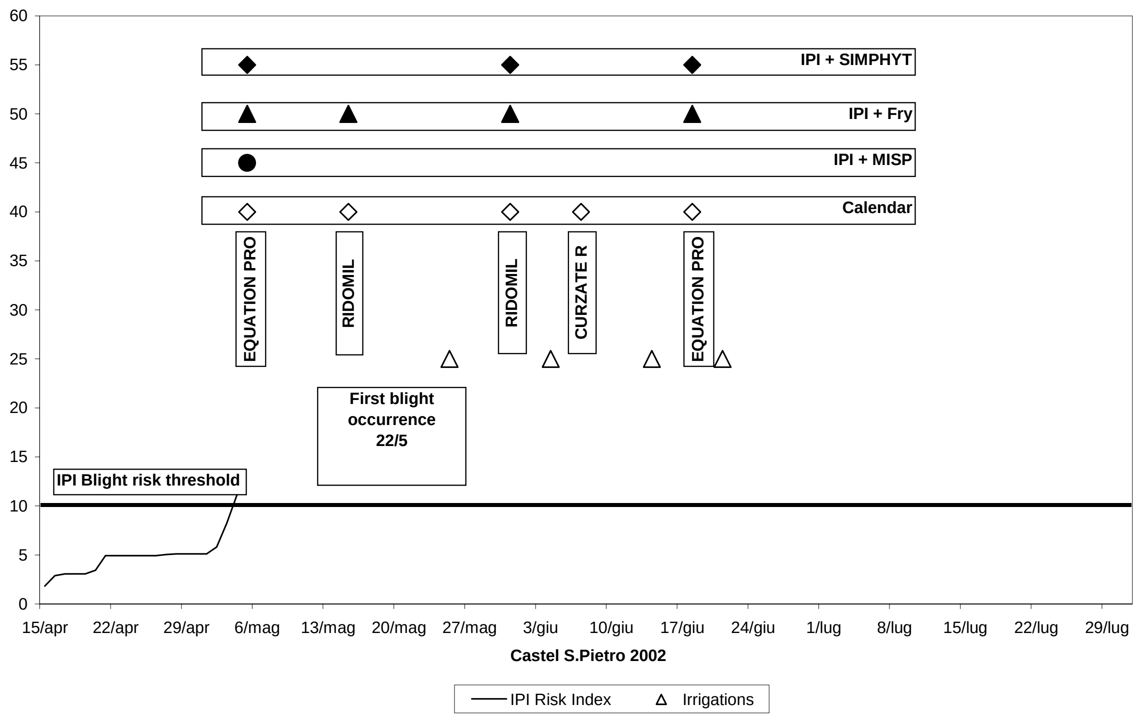

Fig. 7: Timing of fungicides and irrigations in validation trial in 2002

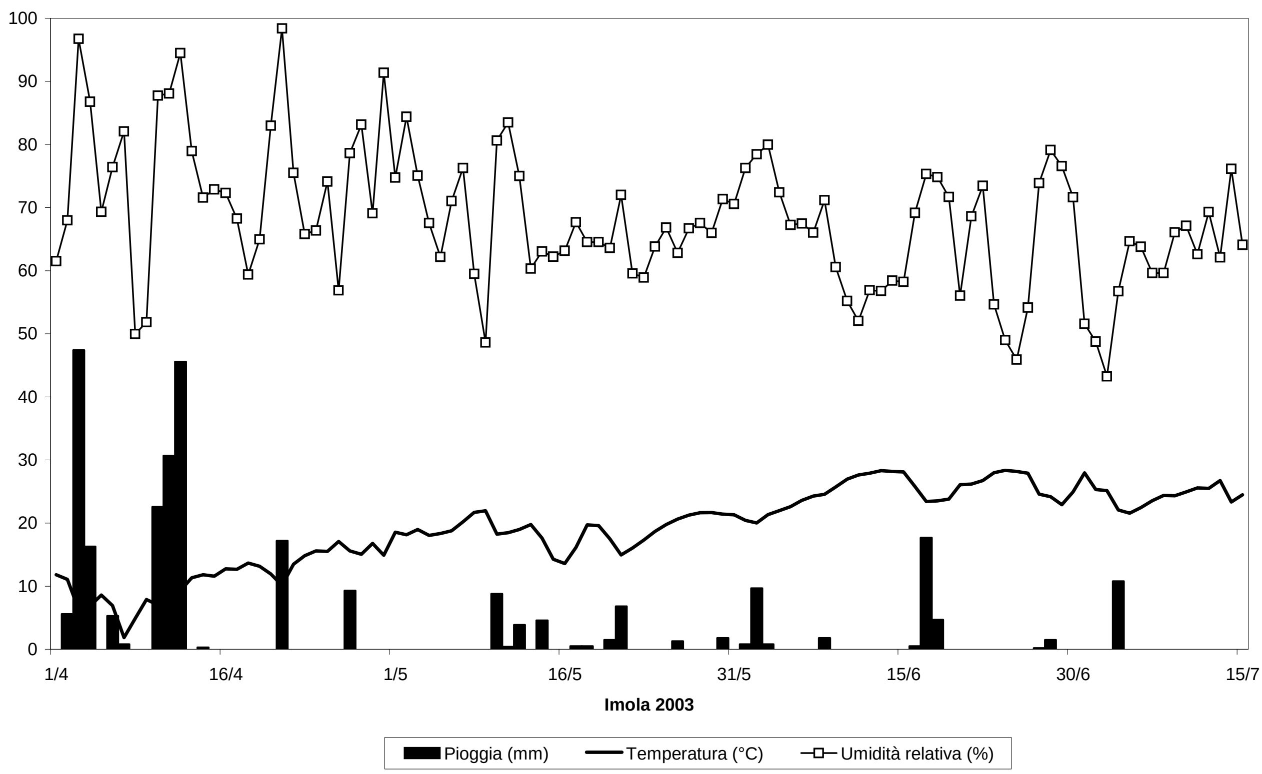

Fig. 8: climate conditions in 2003.

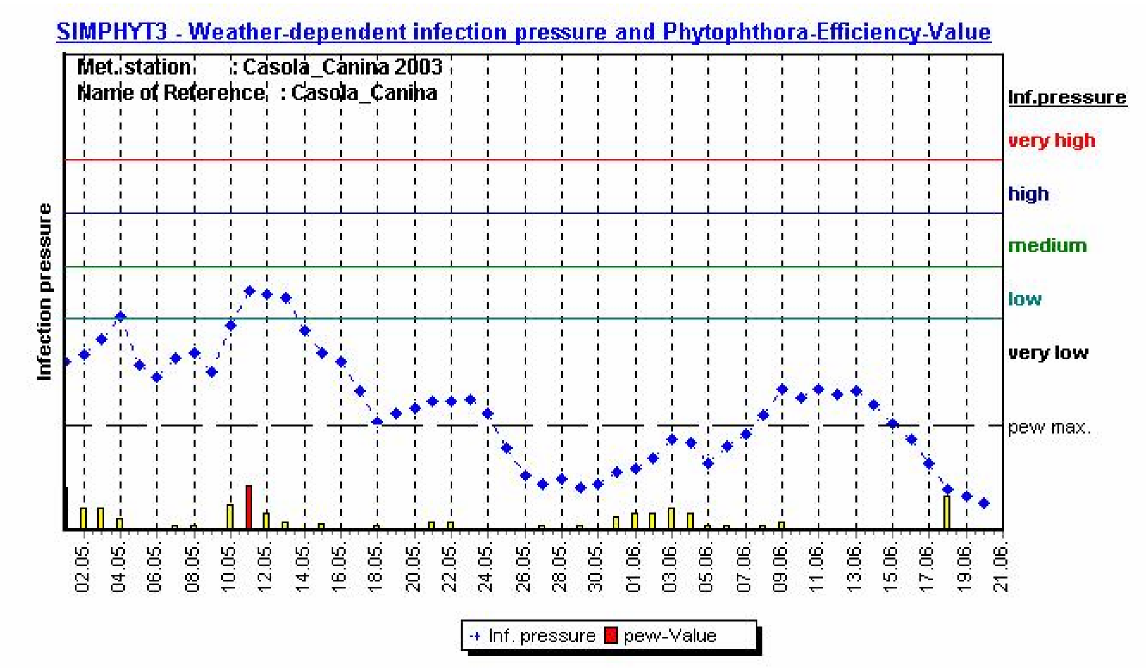

Fig. 9: Disease pressure and Infection efficiency values in 2003 as estimated by Simphyt III model

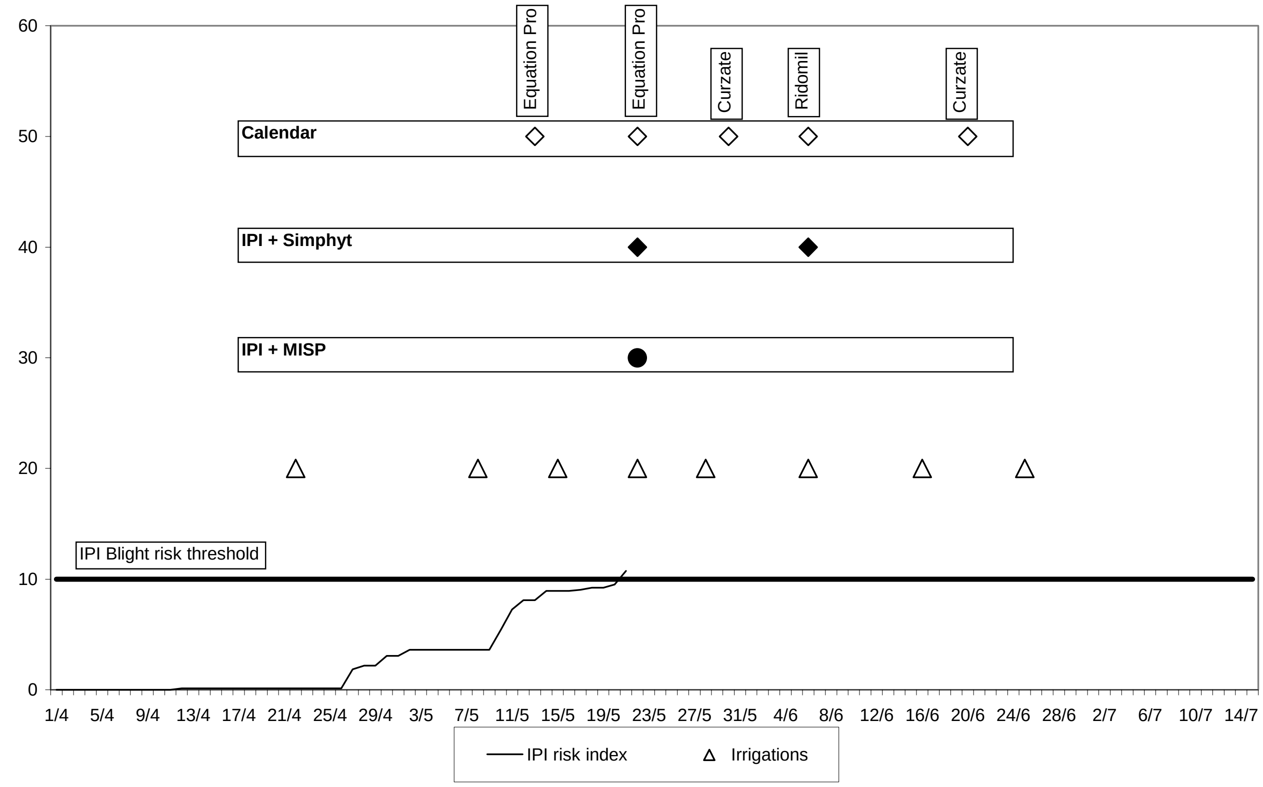

Fig. 10: Timing of fungicides and irrigations in validation trial in 2003

Conclusions

Results obtained during three years of field experiments (2001, 2002, 2003) which followed the first field experimental trial in 1999 (Bugiani R. *et al.*, 1999) showed that both MISP and Simphyt models are the most reliable for the determination of the infectious events during the potato growing season. In particular, Simphyt model proved to be the most effective during years with medium to high disease pressure, by reducing the number of chemical applications and still maintaining a good control of the disease similar to a routine strategy. MISP model seems to work better in years unfavourable for blight conditions, if the disease failed to occur, by reducing the number of chemical applications to a minimum extent. Fry model ranked at an intermediate level. It proved to be protective during years with medium disease pressure, but tend to overestimate the risk of blight infection. More information would be needed concerning the influence of sprinkler overhead irrigation on the first blight occurrence and its subsequent development. Observations over these three years seem to suggest that temperature, solar radiation and irrigation play an important role on the development of late blight. If *P. infestans* inoculum is not present in the field, irrigation has no influence on disease outbreak. On the contrary, if the inoculum is present, irrigation plays an important role in the epidemic spread. Implementation of the effect of irrigation on blight development in any DSS would be useful particularly in the Mediterranean countries where irrigations is frequently applied.

Table 3: Results of strategy efficacy in 2002. Data were arcsine transformed and statistically analysed by means of ANOVA. Mean comparisons were performed with S.N.K.'s test. Means with the same letter are not statistically different for p<=0.05

Strategy	N° of sprays	% of leaf area affected				Yield (t/ha)
		22/5	5/6	14/6	17/6	20/7
Unsprayed check	0	1.0 b	7.75 b	9.00 c	12.50 c	43.57
Calendar	5	0.0 a	3.00 a	4.75 a	6.50 a	49.20
IPI+MISP	1	0.0 a	3.75 a	6.25 b	8.50 b	43.81
IPI+FRY	4	0.0 a	3.00 a	5.00 ab	6.75 ab	46.11
IPI+Simphyt	3	0.0 a	3.00 a	4.50 a	6.50 a	48.18

Besides, Simphyt III showed a good reliability in determining the blight infection risk over the three years of experimentation and it seems to give valuable information to support the decisions in timing the chemical sprays.

Finally, testing the DSS in years with a higher disease pressure would be needed to conclude the validation.

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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

Influence of remoistening of leaves on efficacy of fungicides

J.G.N. WANDER[1], W. NUGTEREN[2], J.R. KALKDIJK[1], L.J. ESSELINK[1], H.T.A.M. SCHEPERS[1]

[1] Applied Plant Research, P.O. Box 430, 8200AK Lelystad, The Netherlands

[2] Opticrop B.V., P.O. Box 34, 2140AA Vijfhuizen, The Netherlands

Introduction

The DSS GEWIS (a Dutch acronym for crop protection and weather information system) provides weather-based recommendations for timing the application of agrochemicals (Bouma, 2003). Separate calculations are made for each active ingredient and are based on a total of 25 processes, e.g.: development of cuticle; uptake in leaf; humidification; transport in plant. The kind of chemical determines which processes are taken into account. Processes are based on weather and soil circumstances before, during and after the intended application time.

Of course to fill in the very large database about (importance of) processes for each agrochemical a lot of assumptions had to be made on which processes are involved in the efficacy of an agrochemical and on how processes work. For one, GEWIS assumes that remoistening does not positively affect the efficacy of (locally-) systemic agrochemicals. The uptake stops when the spraying fluid has completely dried. GEWIS assumes that the rest of the chemical which is still on the outside of the leaves, is influenced by solar radiation. Its chemical structure changes quickly, making it unsuitable for uptake later on.

In two trials this assumption was checked for the efficacy of fungicides to control *Phytophthora infestans*.

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Materials and methods

Trial 1

In trial 1 the fungicides cymoxanil (Cymoxanil 250 EC) and propamocarb (Previcur N SC) were sprayed prior to an inoculation two days later. Both fungicides were sprayed in a spraying chamber with 250 l/ha water in a low and a normal dose, for cymoxanil 63 and 125 g a.i./ha and for propamocarb 542 and 1083 g a.i./ha. Four hours after spraying the leaf wetness period was ended by strong ventilation with fans. During the following night plants were prevented from dew wetting by ventilating with fans. About 22 hours after spraying plants were placed in growth chambers with a high RH (remoistening) or a low RH (no remoistening) at a temperature of 20 °C. Remoistening was started by spraying 0.1 mm water with very small droplets. Inoculation was made by placing one droplet of 30 μl, containing about 300 spores of the *Phytophthora infestans* isolate 98014, on the centre of five leaflets per leaf for 4 leaves per plant. Prior to inoculation the full-grown leaves were detached from the plant and places in oasis. After inoculation the leaves were incubated for 24 hours in a growth chamber at 20 °C and a RH higher than 90%. One week after inoculation the number of lesions were counted. The trial was carried out in August 2002 with the cv. Bintje planted in 5 l pots with 16 pots per treatment.

Trial 2

In trial 2 the fungicides 'water' (control), cymoxanil (Cymoxanil 250EC), propamocarb (Previcur N SC) and metalaxyl-M (Ridomil Gold 480 EC) were sprayed one day after inoculation. The fungicides were sprayed in a spraying chamber with 250 l/ha water and a dose of 63 g a.i./ha cymoxanil, 542 a.i. propamocarb g/ha and 48 g a.i./ha metalaxyl-M at 10:00, 13:00 or 16:00 hours. During this period temperature was high (25 – 31 °C) and RH was low (48 – 31 %). At 19:00 plants were placed in growth chambers with a RH of 98% (remoistening) or a RH of 60% (no remoistening), both at 20 °C. Remoistening was started by spraying 0.1 mm water with very small droplets.

Inoculation was made by placing one droplet, containing about 300 spores of the *Phytophthora infestans* isolate 98014, on the centre of five leaflets per leaf for 4 leaves per plant. After inoculation the plants were incubated for 24 hours in a growth chamber at 20 °C and a RH higher than 90%. One week after inoculation the number of lesions were counted.

The trial was carried out in June 2003 with the cv. Bintje planted in 5 l pots for 4 pots per treatment. At spraying the plants were 15 to 20 cm high and sunny circumstances hardened the wax layer by growing the plants outside.

Statistics

Both experiments were set up as a randomised block design with four replications. In trial 1 a replication consisted of four pots, in trial 2 of one pot. The data of the calculated percentage lesions per pot were 3-factorial analysed with the GENSTAT 6.1 statement ANOVA using the factors fungicide, dose and remoistening in trial 1 and the factors fungicide, spraying moment and remoistening in trial 2.

Results

The results of trial 1 are shown in table 1. Only the effects of the separate factors were significant, interactions did not occur. The results indicate that remoistening contributed to the preventative efficacy of the two fungicides.

Table 1. Lesions (%) in trial 1; average of low and normal dose (F-prob.-fungicide 0.023, F-prob.-dose 0.020, F-prob.-remoistening 0.048).

	cymoxanil	propamocarb	average
no remoistening	10	20	15
remoistening	6	11	8
LSD	9		6

The results of trial 2 are shown in table 2. Major effects were caused by the factors 'fungicide' and 'remoistening' (F-prob. < 0.001). The factor 'spraying moment' and the two-factor interactions with 'spraying moment' were not significant (F-prob. > 0.1). The two-factor interaction of fungicide with remoistening was significant (F-prob. < 0.001) but minor to the effects of fungicide and remoistening. The three-factor interaction was not significant (F-prob 0.091).

The results indicate that remoistening after spraying with water (control) improved the 'efficacy' of water strongly. This phenomenon is not understood. Remoistening did not affect the efficacy of metalaxyl-M. For cymoxanil and propamocarb efficacy was strongly improved by remoistening.

Table 2. Lesions (%) in trial 2; average for 10:00, 13:00 and 16:00 hours.

	control (water)	cymoxanil	propamocarb	metalaxyl-M	average
no remoistening	54	28	17	7	27
remoistening	19	4	7	6	9
LSD			10		5

Discussion

In trial 1 remoistening after spraying reduced the percentage of lesions. The preventative and curative mode of action of cymoxanil is based on uptake by the plant (Howard *et al.*, 1996) and presumably not by cymoxanil that remains on the surface of the plant. Therefore a better uptake of cymoxanil by the leaf tissue will improve the preventative action. The same can be stated for propamocarb, although propamocarb has out of several modes of action also a protectant/contact mode of action (Anonymous). This means that the better efficacy of the sprayed fungicides after remoistening is caused by a better uptake thanks to remoistening.

In trial 2 timing of spraying was less important than remoistening. Therefore a wet night after spraying is more important for the efficacy of the investigated (locally-)systemic agrochemicals than circumstances during spraying.

Conclusion

Similar results of remoistening were found for insecticides. Therefore there are indications that remoistening can contribute to the efficacy of agrochemicals. A leaf wetness period in the night after spraying, in which the active ingredients can be taken up by the plant, is important for the efficacy of the investigated (locally-)systemic agrochemicals and can improve the efficacy.

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Evaluation of products for potato protection against late blight in order to replace copper based fungicides in organic farming

DAVID MICHELANTE AND DANIELE HAINE

CRA-W Centre wallon de Recherches agronomiques, Section Systèmes agricoles
Rue du Serpont, 100 B-6800 Libramont Belgique
Email : michelante@cra.wallonie.be

Summary

18 Substances liable to be allowed in organic farming were evaluated for their efficiency in foliage protection against late blight infection. The most efficient products were then characterized for their enduring (fungicide) activity, their rainfastness resistance and their close diffusing action. This preliminary evaluation permitted to determine the more efficient products. Those products were then studied in field trials realized during the 2003 season, in 4 sites including 2 in Wallonia (by CRA-W and CARAH), 1 in Flandria (by PCBT) and 1 in the Nord-Pas de Calais Region – France (by SRPV).

Keywords: Resistance inductor, antagonist, cultivar resistance, rainfastness, bioassay

Materials and methods

The protection efficiency is evaluated by the observation of the infection frequency after inoculation of detached leaves coming from treated plants. The same criterion is used to measure enduring activity, rainfastness resistance and close diffusing action of products. Enduring fungicide activity is evaluated by comparison of the infection frequency between inoculations realized at 2, 4 and 7 days after treatment. The rainfastness resistance is evaluated after the application of an 25 mm artificial rain. The diffusing action is evaluated by comparison of the infection frequency between inoculation realized on one untreated half-leaf and on the treated complementary half-leaf. 2 controls are used: one untreated object and one object treated with the « Bordeaux mixture » at a concentration of 10 g / litre of tap water.

Plant production

The plants used in these tests were of cultivar Bintje. In some of the tests, Ditta and Cara were also used. They all come from in-vitro seedlings transplanted into pots of enriched compost. They are grown for 6 to 8 weeks in a culture room maintained at a temperature of 18°C with a 16 hours day photoperiod. Two waterings at the pots feet are applied weekly at a rate of 0.2 litres of tap water per pot.

Tested products

This material was identified in the literature and by contacts with manufacturers and organic farmers. 18 products have been tested: 6 fungicides (different formulations of copper and H2O2), 8 resistance inductors (algae or plants extracts, clay minerals) and 4 biological products whose protecting action is based on antagonistic activity (strains of Bacillus subtillis, Trichoderma harzianum, complex non identified microorganisms mixtures). The table below presents the list of the tested products having demonstrated the best protection activity.

Table 1. List of tested products.

Name	Id	Manufacturers	Type of protection	Composition	Concentration of the mixture for pulverization
MYCO-SIN	SIN	Biofa Agrar GmbH	Resistance inductor	Aluminium silicate (clays) from selected rock and clay + sulfuric acid + extract of *Equisetum arvense*	1,50%
ULMASUD B	ULM	Biofa Agrar GmbH	Resistance inductor	Al (8,7%), S (11,8%), Si02 (13,7%), Ti (0,047%) from selected rock and clay + natural wetting agent	0,75%
KUBIG	KUBIG	BMS Micro-Nutrients	foliar fertilizer (also active as fungicide)	chelated copper 10%	0,25%
IRF 84	IRF (X)	SAMABIOL	Resistance inductor	ND	3%

Treatments

Each plant is individually treated by pulverization of 10 ml of protection mixture. The protection mixture is made by dilution of the product in tap water at a concentration determined by the supplier.

Inoculation

3 intermediate leaves – avoiding the lowest and highest leaves – composed of at least 5 developed leaflets are taken on each plant. The inoculation is carried out by the deposit of four 10µl droplets of inoculum on each leaflet (2 when the leaflets are too small). The inoculum is prepared starting from sporangia produced by an isolate conserved in a refrigerator at 6°C on rye-agar medium after revitalization by inoculation on leaves of cultivar Bintje. The concentration of the inoculum is 5.104 sporangia ml-1. Prior to inoculation, the suspension is conserved during 4 hours in the refrigerator to stimulate the release of zoospores. The inoculation is carried out 2 days after treatment for the tests of protection efficiency, diffusing action and rainfastness resistance; and after 2, 4 or 7 days for the enduring activity tests. The inoculated leaves are placed in a closed laboratory transparent humid box. The boxes are placed in an incubator at a temperature of 18°C and a 16 hours day photoperiod.

Observations

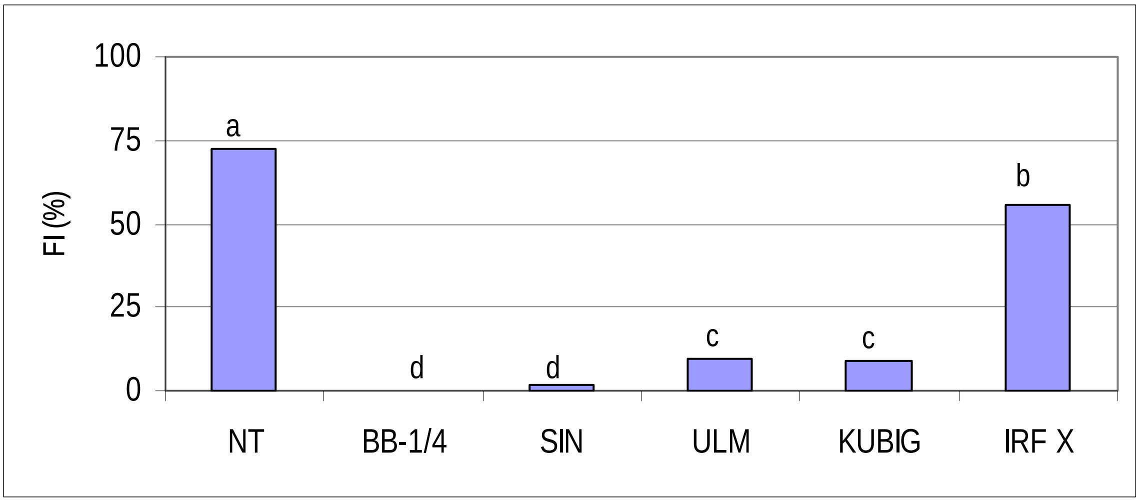
Successful infections are counted to calculate the infection frequency. Only the sporulating lesions are taken into account. The observations are carried out 6 days after inoculation. Experimental design was randomised complete blocs and results were statistically analyzed using ANOVA and Student-Newman-Keuls tests of SAS ($\alpha = 0.05$).

Results

The results that are presented only relate to the products having shown a satisfactory efficiency compared to the BB1/4 (1% Bordeaux mixture) control during the screening phase.

Protection efficiency

In most of the series of tests, the BB1/4 control offered a maximum protection whereas untreated control NT was totally infected. Among the 18 tested products, only Mycosin and Ulmasud showed, with a good regularity, a level of protection close to the control. The protection offered by KUBIG and IRF was low and more irregular. Regarding the other substances , they had no effect at all or their effect was very slight and irregular.

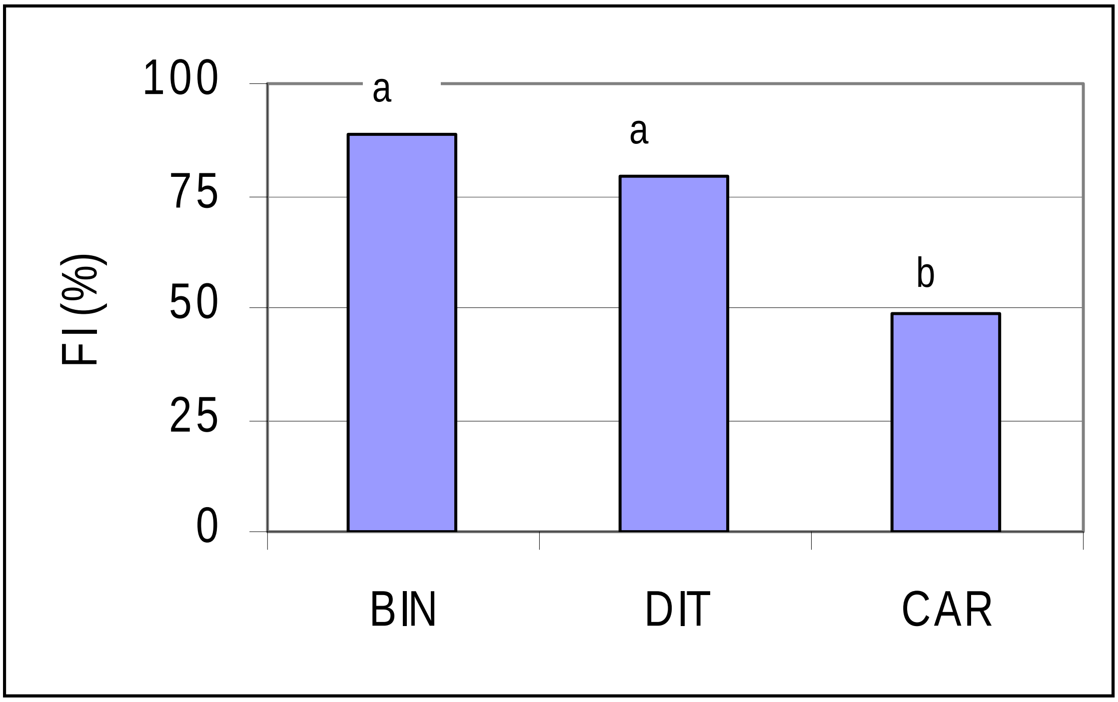


Means with the same letter are not significantly different
NT : untreated – BB-1/4 : Bordeaux mixture at one quarter of total dose – SIN: Mycosin – ULM: Ulmasud
FI : infection frequency

Figure 8. Protection efficiency of the products in term of infection frequency (FI). Average on the tests on 3 cultivars (Bintje, Ditta, Cara).

Varietal sensitivity

The tests highlighted the effect of the varietal resistance on the infection efficiency (Fig.2).



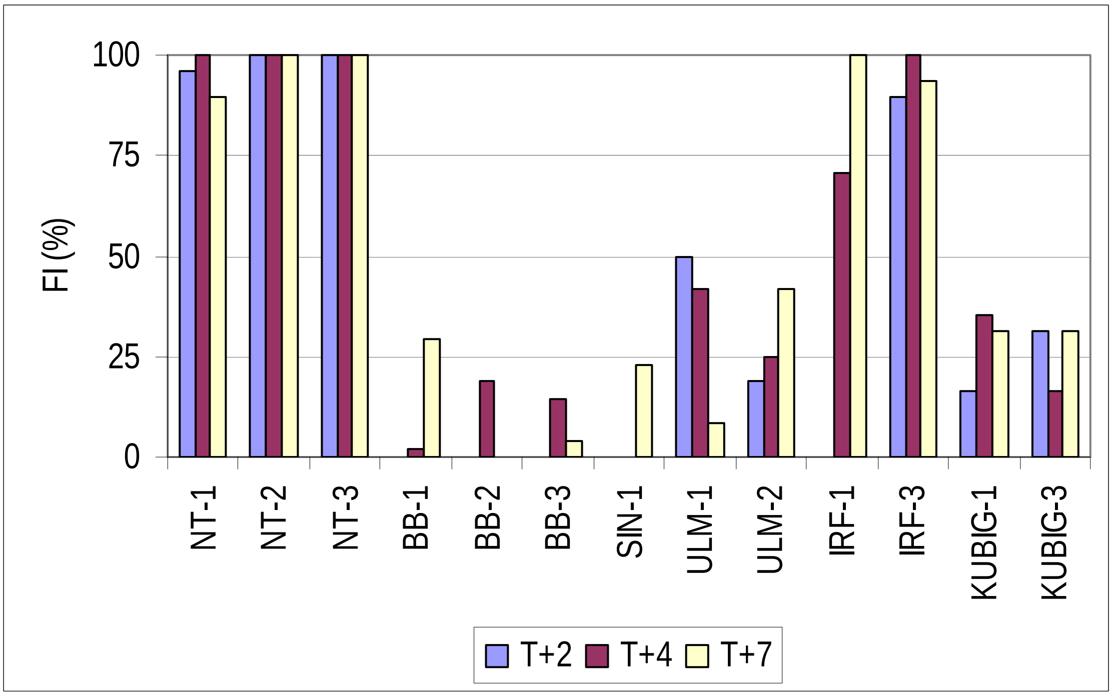
Means with the same letter are not significantly different
BIN: cv Bintje – DIT= cv.Ditta – CAR = cv. Cara

Figure 9. Effect of varietal sensitivity on the infection frequency (FI) on untreated plants

A synergy appeared between the effect of resistance and the protection activity of IRF (alga extract with resistance induction activity) for cultivar Cara with 51% of protection efficiency against, respectively, 13% and 16 % for Ditta and Bintje.

Enduring activity

Regarding to the efficiency of the substances tested, no significant differences were observed for artificial infections carried out 2, 4 or 7 days after pulverization (fig.3).

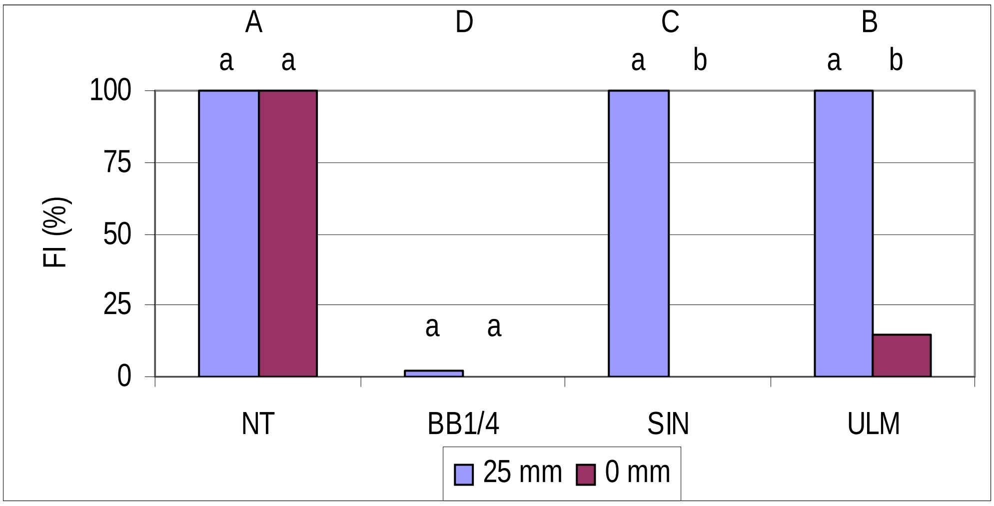


NT : untreated – BB: Bordeaux mixture at one quarter of total dose – SIN: Mycosin – ULM: Ulmasud
T+2, +4, +7: inoculation 2, 4 and 7 days after treatment
The number after the treatment (i.e. NT-1) is the identification code of the assay. There were 3 assays.

Figure 10. Effect of the type of protectants and of their enduring activity on the infection frequency (FI) – cv. Bintje

Rainfastness resistance

The test showed a very good rainfastness resistance of the BB1/4 control while Mycosin and Ulmasud lost all their protective activity after being subjected to a 25mm artificial rain.

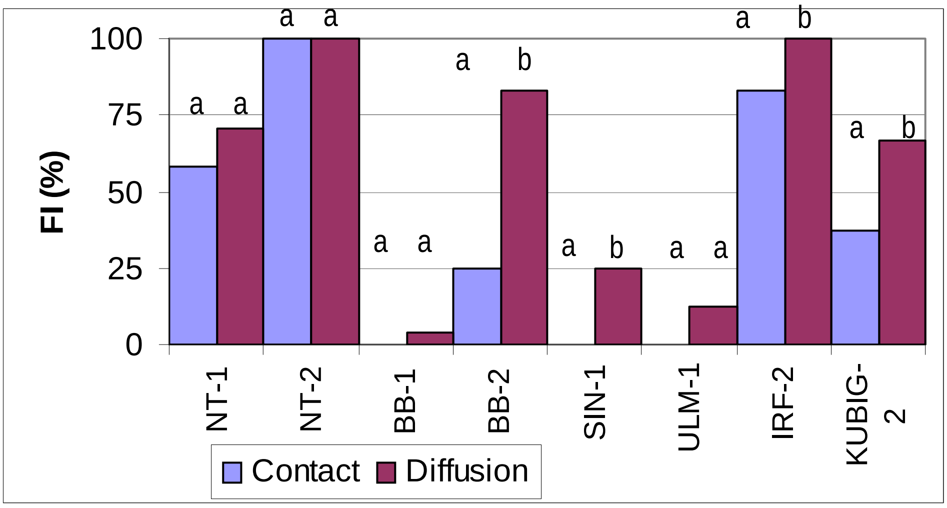


Means with the same letter are not significantly different
NT : untreated – BB-1/4 : Bordeaux mixture at one quarter of total dose – SIN: Mycosin – ULM: Ulmasud
Amount of artificial rainfall: 25 mm and no rain

Figure 11. Effect of products rainfastness on the infection frequency (FI)

Diffusing action

A very good diffusing action was observed for the BB1/4 control and, to a lesser extent, for Ulmasud, Mycosin and Kubig. IRF showed very slight direct activity (contact) and no diffusing activity at all.



NT : untreated – BB: Bordeaux mixture at one quarter of total dose – SIN: Mycosin – ULM: Ulmasud
The number after the treatment is the identification code of the assay. There were 3 assays.
Mode of action: contact = direct action – diffusion = action on the untreated part of the leaves

Figure 12. Effect of products diffusing activity on the infection frequency (FI)

Discussion

This test showed all its interest for the screening of protective substances having a moderate activity against infections by late blight: it is easy to set up and has a good repeatability. Field trials confirmed the results obtained in the laboratory. However, the results obtained by our partners on the four sites of experiment seem contrasting. It underlines the great sensitivity of the alternative substances to the climatic conditions and in particular to the precipitation measurements. This was explained by the results of the rainfastness tests.

Mycosin and Ulmasud have shown good protection levels, close to the Bordeaux mixture, with a rather good regularity and a normal enduring activity of 7 days. As does the BB1/4 control, they also have shown a good diffusing effect whose nature will have to be specified: acquired systemic resistance (SAR), vapour effect, surface diffusion, … ?

However, their great sensitivity to rainfastness will limit their efficiency in real conditions. It would be useful to study the possibilities of improving their rainfastness resistance by the adjunction of surfactants additives. In addition, their lack of efficiency after a rainfall seems to show that those products do no have an action on the stimulation of natural defences of the plants.

The field efficiency of the alternative products will have to be evaluated in order to determine the optimal conditions for their use: application at the beginning of the season, in regions with low inoculum pressure, during periods with low humidity, on less sensitive varieties, to support the efficiency of cupric products in high pressure periods, etc.

Conclusions

At the moment, no one of the tested products seems to offer a solution to replace the cupric products in the fight against late blight in potato field. Mycosin and Ulmasud present a good efficiency in terms of protection against infections but are very sensitive to rainfastness. Further experiments should be conducted in order to identify the conditions of use for the alternative products. The strategies based on the use of cupric products associated to the varietal resistance are, for the moment, the only efficient solutions for the control of late blight in organic farming.

Acknowledgements

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Activity of fluazinam on direct sporangia germination of *P. infestans* on potatoes

GERTRUDE KNAUF-BEITER[1] AND MICHEL PETIT[2]

[1]Syngenta Crop Protection AG, Disease Control, CH-4332 Stein;
[2] Syngenta Crop Protection, Syngenta Europe Marketing Services, 20 Rue Marat, F-78210 St. Cyr l´Ecole;
e-mail: gertrude.knauf-beiter@syngenta.com; michel.petit@syngenta.com

Summary

Activity of the fungicide fluazinam* (Shirlan®) against late blight most often underlines its strong inhibition of zoospores motility preventing infection from indirect germination of sporangia via zoospores At higher temperatures sporangia of *P. infestans* tend to germinate directly via formation of germ tubes. The question is raised whether fluazinam is able to inhibit direct germination. In vitro fluazinam suppressed direct germination at rates higher than 4 mg a.i./l. On potato leaves protective applications of fluazinam at 100 and 500 mg a.i./l inhibited sporangial direct germination and provided high levels of disease control..

Keywords: *P. infestans*; potatoes; direct germination; sporangia.

Introduction

The asexual reproduction in *Phytophthora* involves sporangia differentiation either directly by germ tube or indirectly by release of motile zoospores depending on external factors one of which is temperature (D.C Erwin *et al.*, 1983). *Phytophthora infestans* under Western European conditions is well-known to generally contaminate potato crops by means of zoospores on

* Active ingredient property of Ishihara Sangyo Kaisha Ltd
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foliage as well as on tubers at the end of the season. However during warm summer periods such as recorded in 2003, the question can be raised whether direct germination of sporangia could be involved in the infection process. Several fungicides used to control late blight, such as fluazinam, are described as being particularly active in inhibiting the motility of zoospores as primary source of infection but little is known about their ability to control direct germination. The present in vitro and in planta studies provide information on the control of late blight with fluazinam during the infection process via direct germination.

Materials and methods

In vitro:

P. infestans was cultivated on RDA for 14 d at 18°C in the dark. Sporangia were harvested in H_20 bidest. at room temperature, filtered through a copper grid and the suspension was finally adjusted to 20000 sporangia/ml. Mixtures with fungicide solutions were prepared at a 1:1 ratio reaching the final concentrations as indicated in the result tables. 5μl droplets (50 sporangia/ml) of the mixtures were placed on microscopic glass slides (prewashed with tap water), encircled with commercial petroleum jelly and covered with a cover slip. The slides were incubated for 4 days at 20°C in the dark until evaluation. % germination of the sporangia was determined in each droplet.

In planta:

Potato cuttings, cv. Bintje were grown in a climatic chamber in 4x4 cm pots in TKS-1 standard soil at 18 °C. After 2 weeks they were transplanted in 8 cm pots and further incubated in the climatic chamber at the same conditions for 2 weeks. They were then transferred to the greenhouse and used in the experiments after 1 week.

The compound was immediately applied in concentrations as indicated in the results table after being dissolved in water (bidest.). Treatments were carried out 1d protectively in a treatment tower with a rotary table.

Sporangia suspensions were prepared as described above and adjusted to 50,000 sporangia/ml. The lower leaf side of attached potato leaves were homogenously sprayed with the sporangia suspension and the inoculated plants were incubated at 25°C and 100% RH until evaluation (first 24 h in the dark). To determine germination leaf segments were prepared 48h after inoculation and stained directly with a drop of 0.2% Uvitex 2B for observation under an UV microscope with epifluorescence illumination (filter combination 390-420/FT 425/LP 450). 6 leaf segments were observed per treatment.

5 d after inoculation, the infected leaf area was determined on treated and untreated leaves and the results are expressed as % of untreated check.

Results

Zoospore release from sporangia is usually induced if the sporangia are incubated at low temperatures, i.e. 4°C followed by incubation at medium temperature of 18°C. In the present experiment the sporangia were only incubated at 20°C which suppressed indirect germination via zoospore release completely.

Table 1. Effect of fluazinam on sporangial germination of P. infestans in vitro (96 h after incubation)

Treatment	Rate(mg a.i./l)	% germination[1]
Fluazinam, SC 500	20	27
	4	21
	0.8	63
	0.16	66
	0.03	73

[1] % germination in untreated check 76%

Untreated sporangia differentiated germ tubes within 3 to 4 days if incubated at 20°C and resulted in 76% germination under the applied conditions. Fluazinam provided a clear dose effect on the direct germination of sporangia. If applied at 0.03 mg a.i./l fluazinam was ineffective while at rates between 0.16 and 0.8 mg a.i./l it suppressed the direct germination by approx. 15%. A significant reduction of 65% to 72% was achieved if fluazinam was applied at rates between 4 and 20 mg a.i./l.

At the applied conditions, the rate of direct germination was 28% on untreated potato leaves within 48h and did not increase over the time. During the course of the experiments no indications for zoospore release were found on the leaf samples.

Table 2. Effect of fluazinam on sporangial infections of potato leaves by *P. infestans*.

Treatment	Rate	Sporangia		% disease control[2]
	(mg a.i./l)	% nongerminated	% germinated[1]	
Fluazinam,	500	95	5	94
SC 500	100	95	5	91
	20	77	23	76
	4	77	23	25
	0.8	77	23	6

[1] *% germination on untreated check 28%*
[2] *% leaf attack on untreated check 73%*

In contrast to the in vitro experiments fluazinam did not provide a clear response on direct germination of sporangia on potato leaves. When applied between 100 and 500 mg a.i./l fluazinam reduced the germination rate to 5% compared to 28% on untreated plants which was well reflected in the activity to control disease symptoms.

Conclusion

In vitro fluazinam demonstrated the ability to inhibit direct germination by 65% to 72% at concentrations ≥ 4 mg a.i./l. In planta rates > 100 mg a.i./l provided a good disease control can be compared to the practical use rates (registration rate is 200 g a.i. /ha for mean water volumes of 200-800 l). The results indicate that this molecule has the potential to control infections based on direct germination. The role of this process in practice is unclear and has never been clearly demonstrated. Based on the knowledge of the conditions required for direct germination it can be speculated that within particular conditions of high temperatures and humidity both zoospores and direct germination can contribute to disease spreading.

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Status of *Phytophthora infestans* from 1993 to 2003: Mating type and resistance to fungicides

DELPHINE DETOURNE, SERGE DUVAUCHELLE AND LUDOVIC DUBOIS

SRPV Nord Pas-de-Calais

The populations of *Phytophthora infestans* from potato and tomato have greatly changed between 1976 and 1980. So the isolates are more aggressive and the epidemics are earlier.
The Services of Plant Protection carry out monitoring of populations since 1993 on two aspects:

- mating type
- resistance to several active ingredients

The isolates of *Phytophthora infestans* were collected from fields, private gardens, waste piles and volunteers. The resistance to metalaxyl was tested on each isolate with the determination of mating type. Other molecules were tested on some isolates.

Mating type

Mycelium plugs from tested isolates were confronted with reference strains A1 and A2 on V8 agar medium. The oospores formation requires the two opposite mating types.

Confrontation test on V8 agar medium

Since 1993, 846 isolates have been tested in North of France for mating type, 829 isolates were A1 and 17 isolates were A2. We have detected 11 isolates A2 in 1997 (from private gardens and fields), 6 isolates A2 and 1 isolate A1A2 in 2003 (from fields and waste piles).
From 1997 to 2000, 479 isolates have been tested in Brittany, only A1 were detected. In 2003, 2 isolates A2 were detected by INRA of Ploudaniel.

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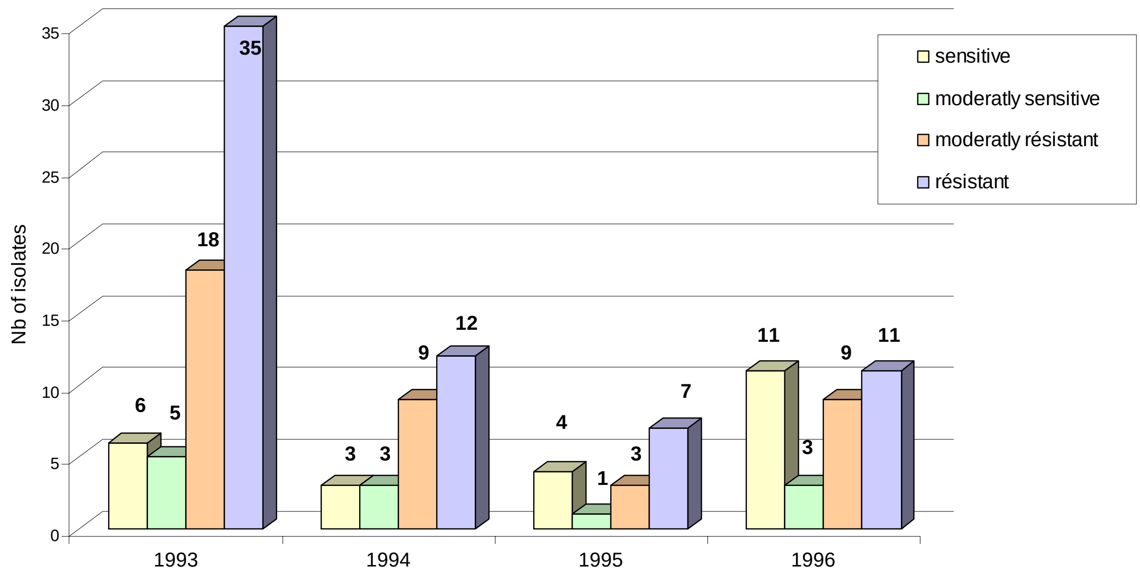
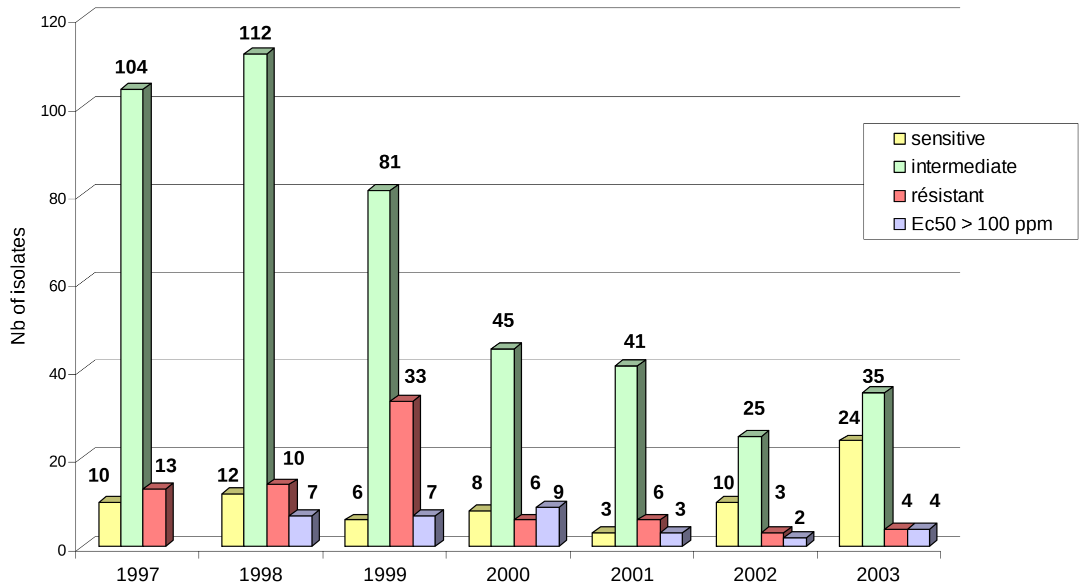
$$RF = \frac{Ec_{50}\ \text{tested isolate}}{Ec_{50}\ \text{the most sensitive isolate of the year}}$$

RF ≤ 5 : sensitive isolate
5< RF ≤ 10 : moderately sensitive
10 <RF≤ 100 : moderately resistant isolate
RF > 100 : resistant isolate

RESULTS TESTS METALAXYL
LRPV Nord Pas-de-Calais
1993 to 1996 (Total : 140 isolates)



RESULTS TESTS METALAXYL
LRPV Nord Pas-de-Calais
1997 to 2003 (Total : 627 isolates)



Resistance test to metalaxyl

North of France

1993 to 1996 : Method using the floating leaf discs

A range of concentrations between 0.01 and 100 ppm, Ec_{50} determined graphically for each tested isolate.

The isolates were classified according to RF (Resistance Factor):

1997 to 2003: The method to assess the resistance to metalaxyl is that one described by the FRAC using the floating leaf disc method (Sozzi *et al*, 1992).

A range of 6 doses was tested : 0.001-0.01-0.1-1-10 and 100 ppm.

Ec_{50} is determined graphically for each isolate

$Ec_{50} \leq 0.01$: sensitive isolate
$0.01 < Ec_{50} \leq 10$ ppm
$Ec_{50} > 10$ ppm : resistant isolate

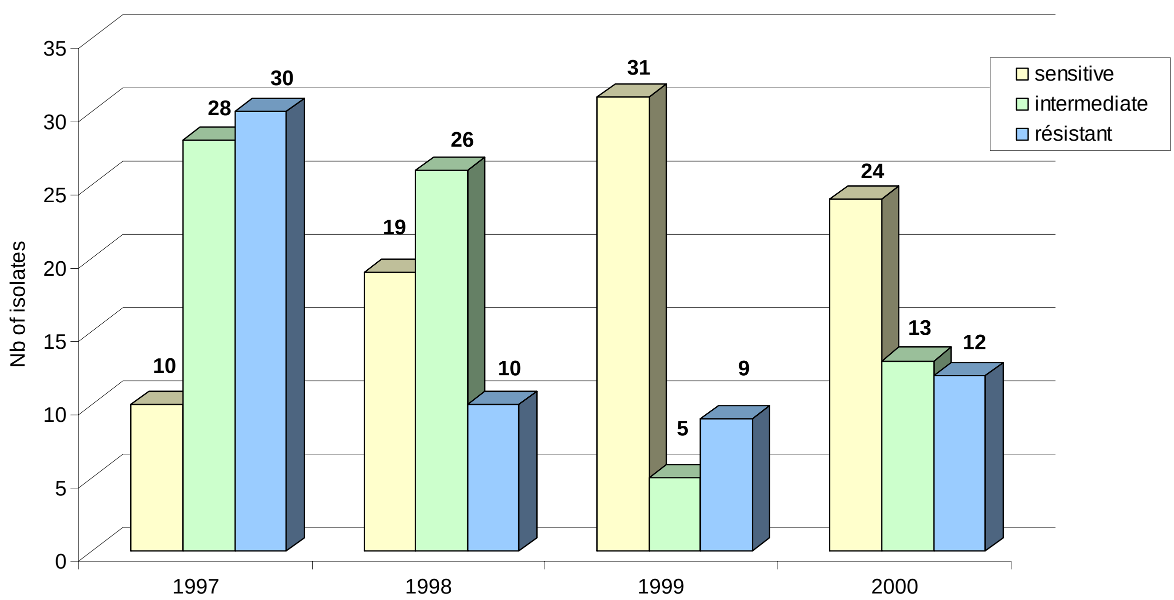
Brittany

Method using the floating leaf discs with 2 discriminating doses : 10 and 100 ppm..

Tested isolates were classified:

- sensitive if sporulation is observed only on untreated discs;
- intermediate if sporulation is observed on untreated and on 10 ppm;
- resistant if sporulation is observed on 10 and 100 ppm only.

RESULTS TESTS METALAXYL
LRPV BRETAGNE
1997 to 2000 (Total : 217 isolates)

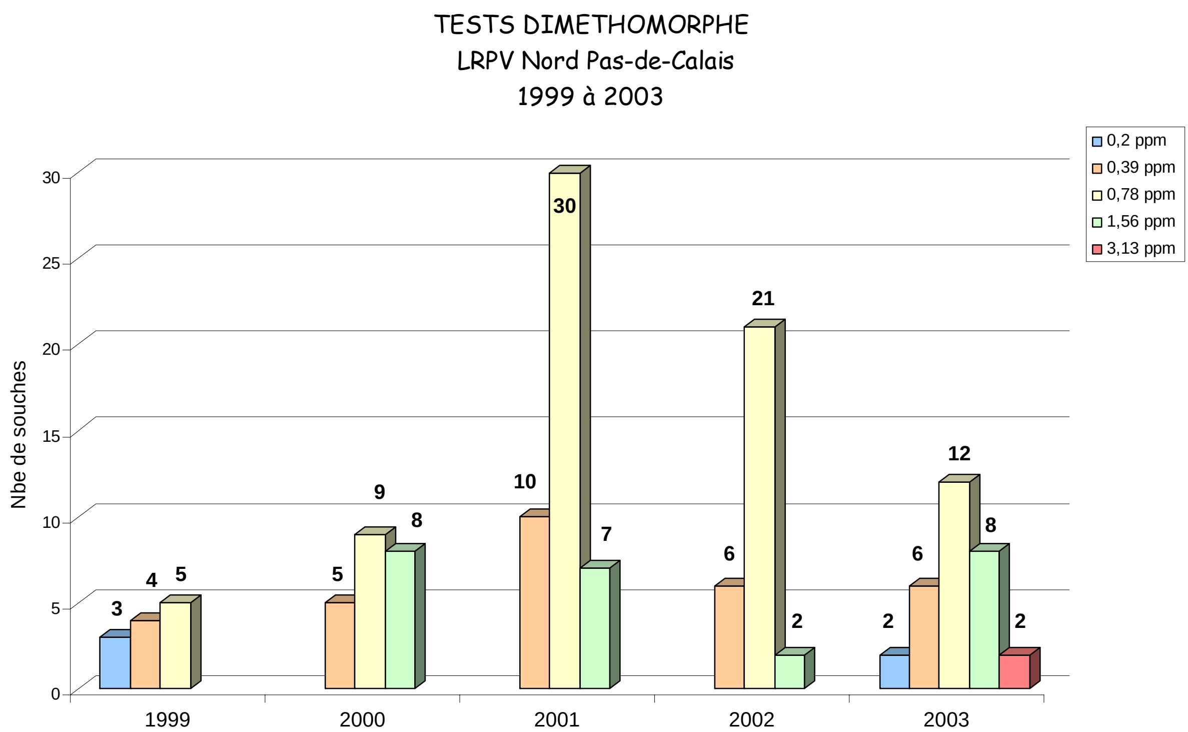


Conclusion

Resistant isolates to phenylamines are naturally present in low proportions. So the products with phenylamines can be used at the beginning of the season, but used preventively and not more than 3 times on the same field and the same year.

Resistance test to other fungicides

Dimethomorph is tested since 1999, cymoxanil since 2000 and propamocarb since 2002. They were tested on several isolates. Dimethomorph: 140 isolates between 1999 and 2003. Method using liquid V8 agar and determination of MIC (Minimum Inhibition Concentration)



Cymoxanil : 68 isolates between 2000 and 2003.

Method using agar medium and determination of Ec_{50}.

Propamocarb: 35 isolates from 2000 to 2003.

The isolates were inhibited to 200 ppm..

Year	Number tested isolates	mean Ec_{50} (range) Cymoxanil
2000	16	0.39 ppm (0.11-0.95)
2001	22	0.403 ppm (0.105-1)
2002	10	0.365 ppm (0.15-0.85)
2003	20	0.39 ppm (0.102-1.096)

Conclusion

These monitorings to cymoxanil, dimethomorph and propamocarb have not displayed any phenomenon of resistance on potato late blight.

Potato late blight in Sweden: Result of field trials 1998-2003

LARS WIIK

Swedish University of Agricultural Sciences, Unit of Applied Field Research,
Box 44, 230 53 Alnarp, Sweden. e-mail: lars.wiik@ffe.slu.se

Summary

Due to the use of potato cultivars more or less susceptible to the oomycete *Phytophthora infestans* repeated treatments with fungicides are necessary in conventional potato growing in Sweden. For the time being seven fungicide products, altogether with eight active ingredients, are approved to use against this disastrous plant disease. Usually, both late blight and tuber blight are controlled by fungicides. However, results from a few years including last year, reveal not as good control of late blight as usual and even less control of tuber blight. During 2003 both stem blight and top shoot blight were more common than normal and also more difficult to control than leaf blight.

Chemical treatments according to the decision support systems (DSS's) PLANT-Plus and NegFry gave as good control against late blight and tuber blight as conventional treatments, i.e. repeated treatments with the fungicide Shirlan once a week, in potato fields with starch and crisps varieties and during later years also in susceptible varieties as Bintje and King Edward VII. The DSS's often resulted in less number of applications than standard treatments.

Results from field trials with different fungicide strategies are outlined and discussed.

Keywords: *Phytophthora infestans*, tuber blight, stem blight, fungicides, control, efficacy, fungicide strategies, decision support systems, PLANT-Plus, NegFry

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Introduction

Potato late blight, caused by the fungus *Phytophthora infestans*, is one of the major diseases in Sweden. Most of the varieties grown are more or less susceptible to late blight and tuber blight. Repeated chemical control is therefore necessary in conventional potato growing. Fungicides used are 0.3-0.4 l/ha Shirlan (a.i. fluazinam 500 g/l, approval by The Swedish Chemicals Inspectorate, KemI March 1993), 0.4-0.5 l/ha Epok 600 EC (a.i. fluazinam 400 g/l and metalaxyl-M 200 g/l, approval by KemI January 2000), 1.5-2.0 kg/ha Acrobat WG (a.i. mancozeb 60 % by weight and dimetomorph 9 % by weight, approval by KemI February 1997), 2.0-4.0 l/ha Tattoo (a.i. mancozeb 302 g/l and propamocarb 248 g/l, approval by KemI March 1992), 0.2 l/ha Ranman + 0.15 additive (a.i. cyazofamid 34.8 % by weight, approval by KemI May 2003), 2.0 kg/ha Ridomil Gold MZ Pepite (a.i. mancozeb 64 % by weight and metalaxyl-M 3.88 % by weight, approval by KemI February 2004) and 0.7 kg/ha Tanos 50 WG (a.i. famoxadone 25 % by weight and cymoxanil 25 % by weight, approval by KemI April 2004). In the South of Sweden, where most of the potatoes are grown, fungicides are sprayed on average five to ten times during one season with the first treatment just before row closure, typically in the middle or late June. Results from Swedish field trials performed during 1998-2003 are outlined. The development of late blight and tuber blight has been followed during six years, both in the official fungicide testing programme and in projects studying if disease control can be maintained with a lower number of fungicide treatments by using decision support systems (DSS's).

Materials & Methods

Field trials, randomized in four complete blocks, were carried out during 1998-2003 in southern Sweden at agricultural field trial stations or in farmers´ fields. Normally the gross plots were about 30 square meters (five rows) and the net plots about 20 square meters (three rows). Sprayings were usually carried out once a week or in the decision support system trials as recommended by PLANT-Plus or NegFry. Conventional or experimental field sprayers and standard or experimental products from the chemical companies were used. Natural infection of late blight occurred in most of the trials and inoculation was not done. The untreated plots and untreated cover-rows (three rows in between the replications) promoted the spread of the disease in the trials. Late blight was assessed carefully several times and ended at haulm killing time. An attack of approximately one blotch per 50 plants was assessed as 0.01 per cent diseased leaf area, one blotch per plant as 0.10 per cent, ten blotches per plant as 1 per cent, 50 blotches per plant as 5 per cent up to 100 per cent when the haulm is totally destroyed. The attacks of stem blight and top shoot blight were estimated in relation to destroyed leaf area or per cent affected stems. Tuber blight was assessed on ten kilogram samples from each plot, both the number and the weight of tubers attacked. At harvest, potato yield was registered and tuber size graded. Tuber blight free yield was calculated.

The official fungicide testing field trials (tables 1a, 1b, 1c and 1d) were performed according to Good Experimental Practice (GEP) consistent with EU directive 93/71, KIFS 2004:4, STAFS 2001:1 and Standard Operative Procedures SLU 2004 and supervised by SWEDAC, Swedish Board for Accreditation and Conformity Assessment. Cultivars in the official fungicide testing trials were usually susceptible Bintje or King Edward VII.

Field trials with different fungicide treatment strategies including PLANT-Plus (Hadders, 1997 and Hadders, 2003) were carried out at the same time and mainly at the same locations as the official fungicide testing trials in the most southern part of Sweden, but not according to GEP, (table 2a, 2b and 2c). Different cultivars were used at different trial locations each year so as to reflect the use of varieties in that specific region. The cultivar (cv.) Bintje was used all years at trial location Borgeby Skåne, cv. Saturna at Lilla Böslid Halland and a starch variety at Trolle Ljungby Skåne (cv. Oleva 1999, cv. Florinj 2000, cv. Kardal 2001 and cv. Producent 2002). In 2003 the trials were extended to five but with fewer fungicide programmes; at Borgeby Skåne cv. Bintje, at Lilla Böslid Halland cv. Asterix, at Mosslunda Skåne cv. Kardal, at Bjäre Skåne cv. Provita and at Götala Västergötland cv. King Edward VII.

Field trials with different fungicide strategies including PLANT-Plus and NegFry (Hansen *et al.* 1995) were carried out during 2000 – 2002, particularly in the middle of Sweden (tables 3a, 3b and 3c). Different cultivars were used at different trial locations each year so as to reflect the use of varieties in that specific region. Cultivar Bintje was used all years at trial location Vreta Kloster Östergötland and cv. King Edward VII at Götala Västergötland and a starch variety in the Kalmar region Småland (cv. Meva 2000, cv. Seresta 2001 and cv. Seresta 2002).

SAS, GLM, Anova was used to test the result.

Results

In the official fungicide testing field trials results from only three fungicide treatments are included in table 1 due to the fact that these treatments were tested in all the field trials for most of the years now reported. The final attack of late blight was high at the end of the season in most of the field trials with the lowest average attack of 43 % in year 1998 at the final assessment. The three treatments with exclusively Shirlan, KP 481/Tanos and Shirlan, and Shirlan alternated by two treatments with fluazinam+metalaxyl-M (Epok) had fairly good effect against late blight (table 1a) although the effects during 2003 were poor for all the three treatments. In addition, the control of late blight was not as good in 1999 as in normal years, but not as bad as in 2003.

The effect against tuber blight was not as good as the effect against late blight (table 1b). The attack of tuber blight in untreated control was considerable most of the years with the exception of 2002 with only 0.2 % attack. Years with insufficient effect against late blight (2003 and 1999) resulted as expected in a great deal of tuber blight. However, during 2001 very good effect against late blight was achieved but nevertheless the outcome was quite a high attack of tuber blight.

Standard treatments with Shirlan once a week, on average nine to ten treatments each growing season, compared to untreated control gave an increase of tuber blight free yield close to 20 ton/ha as an average during 1998-2003 (7.9 to 35.4 ton/ha, table 1c). The average yield in these 20 field trials was in untreated control 36 ton/ha and with standard treatment 55 ton/ha.

Late blight is most often seen as blotches on the leaves in Sweden and usually leaf blight is the most common symptom. During 2003 we recorded more stem blight and top shoot blight than usually in the field trials. As can be seen in table 1d our assessment revealed as much top shoot blight as leaf blight and even more stem blight this year. The control of stem blight with all of the three fungicide programmes was not as good as the control of leaf blight.

Table 1a. Control of late blight, per cent, with three different fungicide programmes and late blight in untreated control at final assessment. Average results from the official fungicide testing during 1998-2003.

Fungicide programme	Per cent control of late blight					
	1998	1999	2000	2001	2002	2003
Shirlan, repeatedly	100.0	98.9	100.0	100.0	99.9	87.9
KP481 or Tanos and Shirlan, alternating	97.7	97.0	100.0	99.9	99.9	82.3
Shirlan and 2 x Metalaxyl-M, alternating	100.0	97.7	100.0	-	99.9	89.8
Untreated control	43	73	45	96	95	100
Average no. of application	8.8	8.8	10.5	10.3	10.3	10.3
Number of field trials	4	4	2	4	3	3

Table 1b. Control of tuber blight, per cent, with three different fungicide programmes and tuber blight in untreated control. Average results from the official fungicide testing during 1998-2003.

Fungicide programme	Per cent control of tuber blight					
	1998	1999	2000	2001	2002	2003
Shirlan, repeatedly	88.4	91.9	97.7	76.1	100.0	17.0
KP481 or Tanos and Shirlan, alternating	76.6	90.4	91.5	47.7	100.0	22.6
Shirlan and 2 x Metalaxyl-M, alternating	97.8	94.9	100.0	-	100.0	36.8
Untreated control	6.0	17.6	8.8	14.7	0.2	3.5
Average no. of application	8.8	8.8	10.5	10.3	10.3	10.3
Number of field trials	4	4	2	4	3	3

Table 1c. Tuber blight-free yields, ton per hectare, in three different fungicide programmes and in untreated control at final assessment. Average results from the official fungicide testing during 1998-2003.

Fungicide programme	Tuber blight-free yield, ton per hectare					
	1998	1999	2000	2001	2002	2003
Shirlan, repeatedly	58.5	58.0	61.1	55.2	52.4	44.5
KP481 or Tanos and Shirlan, alternating	57.9	58.3	59.5	50.2	55.7	42.6
Shirlan and 2 x Metalaxyl-M, alternating	61.1	57.5	62.1	-	55.1	46.3
Untreated control	50.6	35.6	25.7	37.3	40.3	19.6
Average no. of application	8.8	8.8	10.5	10.3	10.3	10.3
Number of field trials	4	4	2	4	3	3

Table 1d. Control of late blight, %, with three different fungicide programmes and late blight in untreated control at two assessments in the end of July and the beginning of August. Average results from the official fungicide testing 2003.

Fungicide programme	Per cent control of late blight 2003 on		
	leafs	top shoots	stems
Shirlan, repeatedly	99.0	95.6	75.6
KP481 or Tanos and Shirlan, alternating	97.9	95.2	66.6
Shirlan and 2 x Metalaxyl-M, alternating	98.8	98.0	80.9
Untreated control	24	23	34
Average no. of application	10.3	10.3	10.3
Number of field trials	3	3	3

The attack of late blight was high at the end of the season each year in most of the field trials in the most southern part of Sweden irrespective of fungicide strategy (table 2a). The lowest average attack was 34 % in year 2000 at the final assessment. More than 98 per cent control of late blight was achieved each year with the different fungicide strategies in totally 17 field trials except for 2003 when the control was poorer, but not as poor with PLANT-Plus as with the standard treatment. Recommendations by PLANT-Plus gave comparable control against late blight during 2000-2002 as standard treatment with Shirlan in spite of fewer applications. As an average during 2000-2003 standard treatments with Shirlan were carried out eleven times each growing season compared to nine treatments with PLANT-Plus.

In the fungicide testing field trials the effect against tuber blight was not as good as the effect against late blight (table 2b). Increasing dosages of Shirlan during the growing season (0.14 litre/ha the first, second and third application, 0.27 litre/ha fourth, fifth and sixth application and 0.40 litre/ha thereafter) did not give any obvious difference in disease control compared to standard treatment. Treatments with tank mixes, in this investigation tested with 2/3 of normal dose of 2/9 Shirlan + 2/9 Acrobat + 2/9 Tattoo, did not give a desirable result. Used preventative, as in these field trials, repeated sprayings with Shirlan alone gave better or as good result as Shirlan alternated by Epok twice. Delayed first treatment in field trials showed that it was possible to start the first treatment at least one week later than normal. In the susceptible cultivar Bintje it was difficult to give correct recommendations with PLANT-Plus during the first year of the project which resulted in a very high attack of tuber blight (20 % tuber blight) during year 2000 and totally a negative control of tuber blight (-275.2 %), thus more tuber blight in treatments according to PLANT-Plus than in untreated control. During 2001 and 2003 treatment according to PLANT-Plus gave comparable control against tuber blight as standard treatments with Shirlan once a week. No tuber blight was found 2002, not even in untreated control.

Standard treatment, Shirlan once a week with an average number of nine to ten treatments each growing season, resulted in increased tuber blight free yield of ~ 14 ton/ha as an average per year during 1999-2003 compared to untreated control (table 2c). The average yield in these 17 field trials was in untreated control 40 ton/ha and with a standard Shirlan treatment 54 ton/ha. The different strategies during 1999-2002 in three field trials per year were all comparable concerning yields, with an average tuber blight free yield increases of ~ 12 ton/ha compared to untreated control. Tuber blight free yield increase of 12 ton/ha was attained by PLANT-Plus compared to untreated, tested in 14 field trials during 2000-2003.

Table 2a. Control of late blight, per cent, with different fungicide programmes and late blight in untreated control at final assessment. Average results from the fungicide strategy field trials situated in the most southern part of Sweden, 1999-2003.

Fungicide programme	Per cent control of late blight				
	1999	2000	2001	2002	2003
Shirlan [1)]	99.9	99.8	100.0	99.0	84.8
Shirlan increasing dosage 0.14, 0.27, 0.40	99.8	99.7	100.0	98.9	-
2/3 Shirlan + 2/3 Acrobat + 2/3 Tattoo	99.9	98.9	100.0	98.5	-
Shirlan [1)] alternated by Epok twice	99.9	99.8	99.9	98.7	-
Shirlan [1)] but not the first treatment	99.9	99.8	99.9	98.5	-
Shirlan [1)] but not the two first treatments	99.9	99.8	100.0	98.7	-
PLANT-Plus	-	99.4	100.0	98.8	97.4
Untreated control	92	34	96	40	55
Average no. of application by conventional	11.0	11.0	11.3	12.3	10.8
Average no. of applications by PLANT-Plus	7.7	8.7	12.0	9.3	8
Number of field trials	3	3	3	3	5

[1)] *Shirlan treated repeatedly with 0.3-0.4 litres per hectare.*

Table 2b. Control of tuber blight, per cent, with different fungicide programmes and late blight in untreated control at the final assessment. Average results from the fungicide strategy field trials situated in the most southern part of Sweden, 1999-2003.

Fungicide programme	Per cent control of tuber blight				
	1999	2000	2001	2002	2003
Shirlan [1)]	100.0	83.1	91.4		100.0
Shirlan increasing dosage 0.14, 0.27, 0.40	98.8	100.0	87.2		-
2/3 Shirlan + 2/3 Acrobat + 2/3 Tattoo	98.7	41.8	54.6		-
Shirlan [1)] alternated by Epok twice	99.8	66.2	81.0		-
Shirlan [1)] but not the first treatment	100.0	100.0	93.2		-
Shirlan [1)] but not the two first treatments	99.7	75.6	92.8		-
PLANT-Plus	-	-275.2	93.0		97.1
Untreated control	8.7	1.8	16.7	0.0	1.0
Average no. of application by conventional	11.0	11.0	11.3	12.3	10.8
Average no. of applications by PLANT-Plus	7.7	8.7	12.0	9.3	8
Number of field trials	3	3	3	3	5

[1)] *Shirlan treated repeatedly with 0.3-0.4 litres per hectare.*

Table 2c. Tuber blight free yields, ton per hectare, with different fungicide programmes and late blight in untreated control at final assessment. Average results from the fungicide strategy field trials situated in the most southern part of Sweden, 1999-2003.

Fungicide programme	Tuber blight-free yields, ton/ha				
	1999	2000	2001	2002	2003
Shirlan 1)	64.5	61.8	53.2	57.1	42.8
Shirlan increasing dosage 0.14, 0.27, 0.40	62.1	60.7	52.9	55.8	-
2/3 Shirlan + 2/3 Acrobat + 2/3 Tattoo	64.9	61.1	49.9	57.2	-
Shirlan 1) alternated by Epok twice	62.9	60.7	51.5	53.7	-
Shirlan 1) but not the first treatment	62.6	58.3	52.2	56.5	-
Shirlan 1) but not the two first treatments	64.2	61.9	52.1	54.7	-
PLANT-Plus	-	54.7	53.0	54.4	45.0
Untreated control	49.5	47.5	36.1	48.4	28.4
Average no. of application by conventional	11.0	11.0	11.3	12.3	10.8
Average no. of applications by PLANT-Plus	7.7	8.7	12.0	9.3	8
Number of field trials	3	3	3	3	5

1) Shirlan treated repeatedly with 0.3-0.4 litres per hectare.

The attack of late blight was not as high in the fungicide strategy field trials in the middle of Sweden as in the most southern part of Sweden (table 3a). The highest average attack was 24 % in year 2001 at the final assessment. More than 99 per cent control of late blight was achieved during 2000-2001 in totally six field trials. In 2002 the control of late blight was poorer, 96 to 97 per cent. Recommendations by PLANT-Plus and NegFry gave comparable control against late blight as the standard treatment with Shirlan during 2000-2002 in spite of fewer applications. As an average during 2000-2002 standard treatments with Shirlan were carried out ten times each growing season compared to approximately seven treatments with PLANT-Plus and NegFry.

A large amount of tuber blight was found 2001 (table 3b). Tuber blight was not found at all in 2002 and only to a very small amount in 2000. This corresponds to the attack of late blight which was most severe 2001 (table 3a). In contrast with the result in the most southern part of Sweden repeated sprayings with Shirlan used alone did not give as good result as Shirlan alternated by Epok twice. Treatments according to the decision support systems PLANT-Plus and NegFry gave comparable control of tuber blight as treatments with Shirlan alternated by Epok twice.

Standard treatment, Shirlan once a week on average ten treatments each growing season, compared to untreated control gave an increase of tuber blight free yield of 4 ton/ha as an average during 2001-2002 (-2.1 to 9.8 ton/ha, table 3 c). The average yield in these six field trials was in untreated control 40 ton/ha and with the standard Shirlan treatment 44 ton/ha. As expected the different strategies including Shirlan, Shirlan alternated by Epok twice, PLANT-Plus and NegFry resulted in the largest yield increases, 10-12 ton/ha, during 2001 the year with the highest disease pressure. In 2002, a year with a low disease pressure, no yield increase was obtained.

Table 3a. Control of late blight, %, with different fungicide programmes and late blight in untreated control at final assessment. Average results from the fungicide strategy field trials mainly situated in the middle of Sweden, 2000-2002.

Fungicide programme	Per cent control of late blight		
	2000	2001	2002
Shirlan [1)]	100.0	100.0	96.9
Shirlan [1)] alternated by Epok twice	100.0	99.7	96.2
PLANT-Plus	100.0	99.6	96.9
NegFry	100.0	100.0	96.9
Untreated control	< 1	24	< 1
Average no. of application by conventional	10.0	9.7	10.0
Average no. of applications by PLANT-Plus	9.0	7.3	5.7
Average no. of applications by NegFry	6.7	7.0	6.3
Number of field trials	3	3	2

[1)] Shirlan treated repeatedly with 0.3-0.4 litres per hectare.

Table 3b. Control of tuber blight, % with different fungicide programmes and late blight in untreated control at final assessment. Average results from the fungicide strategy field trials mainly situated in the middle of Sweden, 2000-2002.

Fungicide programme	Per cent control of tuber blight		
	2000	2001	2002
Shirlan [1)]	41	82	
Shirlan [1)] alternated by Epok twice	100	97	
PLANT-Plus	100	98	
NegFry	100	100	
Untreated control	0.5	15.3	0.0
Average no. of application by conventional	10.0	9.7	10.0
Average no. of applications by PLANT-Plus	9.0	7.3	5.7
Average no. of applications by NegFry	6.7	7.0	6.3
Number of field trials	3	3	3

[1)] Shirlan treated repeatedly with 0.3-0.4 litres per hectare.

Table 3c. Tuber blight free yields, ton per hectare, with different fungicide programmes and late blight in untreated control at final assessment. Average results from the fungicide strategy field trials mainly situated in the middle of Sweden, 2000-2002.

Fungicide programme	Tuber blight-free yields, ton/ha		
	2000	2001	2002
Shirlan [1)]	44.6	47.6	39.6
Shirlan [1)] alternated by Epok twice	46.1	47.8	40.8
PLANT-Plus	46.2	49.1	41.6
NegFry	43.6	49.7	40.2
Untreated control	-	37.8	41.7
Average no. of application by conventional	10.0	9.7	10.0
Average no. of applications by PLANT-Plus	9.0	7.3	5.7
Average no. of applications by NegFry	6.7	7.0	6.3
Number of field trials	3	3	3

[1)] Shirlan treated repeatedly with 0.3-0.4 litres per hectare.

Discussion

Effectiveness of fungicides with respect to leaf blight, new growth, stem blight, tuber blight and other characteristics for the late blight fungicides are rated by experts participating in a European network for development of an integrated control strategy of potato late blight (Bradshaw, this report). As fungicides are used several times in a potato crop during a growing season and have different characteristics, the advantage of a specific fungicide should be emphasized in a fungicide programme and the risk of environmental side-effects and fungicide resistance should be minimized (se e.g. www.frac.info). Results from Swedish field trials do not fully give support and recommendations for how to use different fungicides, e.g. in a fungicide programme. Usually we get statistically significant differences between different fungicides and untreated control but seldom between different fungicide programmes. In any case, Swedish results and experience contribute to the recommendations given (Olofsson, 1987, Olofsson, 1989, Olofsson, 1991, Olofsson and Carlsson, 1994, Olofsson *et al.*, 1994, Wiik, 1996, Wiik, 2000, Wiik, 2002, Wiik and Olofsson, 1995) together with results and experience from other countries (e.g. Dowley and O´Sullivan, 1995 and Schepers, 2004). The importance of spraying just before spore infection was shown by Nielsen and Bødker (2002) which highlight a preventative use of all kind of fungicides, e.g. contact and systemic fungicides. Effects against oospores and stem blight could be among important fungicide characteristics. Kessel *et al.* (2002) found that fungicides could prevent oospore formation despite the fact that an epidemic was well underway. All seven fungicides tested had good effect against oospore formation *in Planta*. Geddens *et al.* (2002) found cymoxanil-containing fungicides, e.g. Tanos, to be effective against stem blight and thus a fungicide to be chosen early in the season against initial infections. The assessments reported here (table 1d) do not support Tanos to be better than e.g. Shirlan or Shirlan/Epok in this respect.

Bourke and Lamb (1993) showed that a sequence of weather events lead to the late blight epidemics during 1845 and 1846 but also other factors promoted the disease, e.g. the complete susceptibility of the varieties grown at that time. They also found that more favourable weather for the disease occurred after the great famine years but with a considerably more satisfactory outcome due to different reasons, e.g. the use of fungicides and cultivar resistance. Since the 1920s many different systems for predicting the initial occurrence of late blight based on the weather have been proposed, models based on the weather that already has occurred and models based on the weather to come, i.e. a prognosis (Harrison 1992). Many systems have been tested throughout the world but so far they have not become common in potato growing, nevertheless not so in Sweden. To optimize fungicide use will both meet the demands from the community and improve the economy of the farmers. Harrison (1992) seems to be in favour of simple and robust disease forecasting models but he concludes that significant improvements in disease forecasting are unlikely due to heterogeneity of the aerial environment within the haulm and the uncertainty of predicting the weather, particularly humidity conditions. Under Swedish circumstances Olofsson (1964) proposed that late blight warnings should be most useful for potato-growing regions where serious attacks of late blight are not so common and where routine spraying is not profitable in the long run which included regions in the north of Sweden. In regions where late blight appears every year, routine spraying should be continued and improved with a view to complete protection against late blight. In experiments with two forecasting models Fry *et al.* (1983) showed that less frequent applications of fungicide were required in resistant than in susceptible varieties. In one model the weather effects on fungicide distribution and amount were described and in the other host resistance and fungicide effects on *P. infestans*. By using decision support systems (DSS's) it has been shown that it is possible to reduce the use of fungicides still with full control of late blight. During 1993-1995 the NegFry model was validated in Scandinavia. Data from on-farm meteorological stations were compared with data from the national meteorological station net. The result indicated a reduction of the fungicide use, still with satisfactory disease control (Andersson, 1996). During 1994 the DSS NegFry recommended ~ 50 % lower number of applications than in a routine programme, in most cases due to a delay in the time of the first fungicide application (Hansen *et al.*, 1995). Hermansen and Amundsen (2003) evaluated the Førsund rules and the NegFry model in Norway during 1994-1999. These DSS's gave acceptable results, i.e. without causing significantly more disease, and the number of treatments was reduced by 25-50 % compared to routine treatments at fixed intervals (http://www.vips-landbruk.no). In Poland the NegFry model recommended 29-43 % less fungicide compared with a routine strategy, still with a late blight incidence at the same level or lower at the end of the season (Kapsa *et al.,* 2003). In the Lublin region of Poland the average number of applications was two to three per season. In 2001 DSS NegFry recommended more applications in this region, an increase shown to be economically justified (Rysak and Kozyra, 2003) as well as in Winna Góra during 2002 (Wójtowics, 2003). In Estonia, Latvia and Lithuania the Danish DSS NegFry was validated. Recommendations according to NegFry saved 1.6 applications, a reduction of 30 %, on an average, but the reduction of the number of applications was greater in more resistant varieties and during years with low disease pressure (Koppel *et al.,* 2003). In Belgium a DSS based on the Guntz-Divoux epidemiological model was validated for the susceptible cultivar Bintje and it was also confirmed that a further reduction of applications was possible in the less susceptible cv. Desiree. However if R genes are involved a rapid "erosion of resistance" may take place (Michelante *et al.* 2003). With the help of a foliar blight model Nærstad (2002) concluded that more fungicide could be saved at low disease pressure than at high. Moreover a reduction of dosage was of advantage to a longer application interval, especially at high disease pressure, also found by Wiik (1996). In Ireland a comparison between two DSS's, NegFry and Met Éiarann (MÉ), and routine fungicide applications with seven and ten days intervals were made in field experiments (Leonard *et al.,* 2001). A clear reduction of fungicide use was attained with both DSS's, especially with MÉ. NegFry resulted in significant better tuber blight control but with MÉ the disease control, yield and quality was inferior to routine fungicide programmes. During 2001 six different DSS's were tested in eleven field trials in seven European countries. Treatments with fungicides according to the DSS's reduced the fungicide input by 8-62 % compared to routine treatment, with as good as or better disease control (Hansen *et al.,* 2002). The Dutch DSS PLANT-Plus is a combination of empirical and fundamental submodels, including climatic calculations with the micro climate included, value of crop protection, e.g. unprotected part of the crop, and the fungus *Phytophthora infestans*, e.g. models for the spores above a field and the possibility of an infection. The system includes modules for data-communication, crop recording, weather data and crop advice (Hadders, 1997, Hadders, 2003). ALPHI (the Actual Local PHytophthora Information Line), an interactive voice response system based on PLANT-Plus recommendations triggered about 9-10 sprays where a standard weekly spraying regime resulted in 14 sprays (Bouwman and Raatjes, 2000). In starch potatoes the number of applications was reduced with ~ 50 %. In a few of the Swedish fungicide strategy trials in the most southern part of Sweden even more applications were recommended by PLANT-Plus than with the standard control, Shirlan once a week. During periods with strong plant growth and a high disease pressure this is consistent. In England and Wales the Smith Period scheme has been used since the 1970´s. This system was never intended to be field specific but is used for forcasting on a national scale. In an evaluation over five years 1998-2002 with a grid size of 2 x 2 km it was shown that the warnings according to the Smith Period scheme gave good warnings for seasons generally regarded as severe for late blight. However, warnings according to the Smith Period were not always correct, e.g. during a low severity year two thirds of the area received a warning too late and the Smith Period scheme worked less well for some regions (Taylor *et al.,* 2003). The authors propose to test other modern DSS's. Internet based systems are on its way as the BlightWatch a potato blight warning system – see www.potatocrop.com, www.eb-blight.net and www.ipm-baltic.dk (Barrie and Bradshaw, 2002, Hansen *et al.*, 2003, Koppel *et al.*, 2003).

Cultivar resistance is a key factor in the attempt to manage *Phytophthora infestans* epidemics. It has been shown that it is possible to reduce the amount of fungicides in cultivars with resistance against late blight. Fry (1975) showed that varieties with polygenic resistance could be quantified in terms of fungicide applications due to a reduction of the epidemic development (apparent infection rate) compared to the epidemic development in a susceptible variety. A variety with polygenic resistance was equivalent to ~ 0.5 kg fungicide active ingredient (zinc ion and maneb) per hectare applied weekly to a susceptible variety. In a later experiment Fry (1978) found that the effects of general resistance and fungicide were additive. The area under the disease progress curve (AUDPC) proved to be better than the apparent infection rate or the final disease ratings in quantifying effects of general resistance and fungicide. Fry (1978) found the difference between the most resistant and most susceptible variety in this experiment to be estimated to ~ 0.7 kg fungicide active ingredient (mancozeb) per hectare applied weekly. In American field trials late blight appeared in susceptible cultivars before it appeared in moderately resistant cultivars in most cases (Doster *et al.,* 1989). Clayton and Shattock (1995) showed it was possible to reduce the recommended dosage with 20 – 80 % in potato cultivars with high levels of polygenic resistance. Bus *et al.* (1995) reduced the fungicide dose with half of the recommended dose in varieties with a rating of ≥8 (according to the Netherlands descriptive list of cultivars; 2 = very susceptible and 9 = very resistant) for foliar late blight with sufficient control. Disease development was almost the same in susceptible (rating 3-5) and moderately susceptible (rating 5.5-7) cultivars. In English studies the intervals between applications of fungicides could be extended or the dosages reduced when using cultivars with improved resistance. Cultivar resistance made a partial substitute for fungicide. Cultivars with moderate resistance in combinations with lower fungicide rates appeared to be more robust than higher rates with low resistance (Gans *et al.*, 1996, Gans, 2003). In Poland the highly resistant cultivar Meduza could be left unprotected in some years with late appearance of late blight. Susceptible varieties as Karlena required full recommended fungicide amount each year. The recommended fungicide amount for medium resistant and medium susceptible varieties depended on the infection pressure in a given year. In years with low disease pressure the control was acceptable at 75 per cent reduced fungicide rate (Kapsa, 2002). In Danish field trials the fungicide input in cultivar Kuras with a high level of resistance was considerably reduced compared to routine strategies but it was proposed that information about both partial and race-specific resistance must be exploited and implemented in DSS's (Hansen *et al.*, 2002, http://www.web-blight.net). The ability of the oomycete *P. infestans* to adapt, an ability almost certainly more frequent today as this adaptability is increased by sexual reproduction, probably enhance the "erosion of resistance". Flier *et al.* (2003a) suggest a better understanding of the interaction between partial resistant cultivars and *P. infestans* in order to study the stability and durability of resistance including the stability of tuber resistance (Flier *et al.,* 2001). In the Netherlands Kessel *et al.* (2003) try to link cultivar specific resistance to a minimal fungicide rate with good control of late blight. Out of five components of resistance they indicate infection efficiency to be the most important in reducing the fungicide rates. They have found the actual list of resistance rating in the Dutch national variety list not to be suited as a base for recommending reduced dose rates. Therefore Kessel *et al.* (2003) is setting up a data base with information of all the five resistance components and field performance of potato cultivars.

The presence nowadays of two mating types in the European *P. infestans* populations brought about sexual reproduction and the consequence of a "new" blight will certainly lead to altered late blight management (Kadir and Umaerus, 1987, Umaerus, 1996, Fry and Smart, 1999, Flier *et al.,* 2002, Hannukala *et al.*, 2003, Hermansen and Amundsen, 2003). In addition the ratio of mating types A1 and A2 is approximately 50:50 in Sweden (Dahlberg *et al.,* 2002) which indicates bad odds.

Still basic knowledge is missing, both for the pathogen, e. g. in the life cycle of *P. infestans,* and for the host, e. g. in host resistance, resistance mechanisms and "erosion of resistance". Basic knowledge is certainly important in late blight management. Therefore some aspects of the biology of *P. infestans* need to be studied in detail. The initial source of the *P. infestans* inoculum and thus the potential start of an epidemic is often thought to be infected tubers but also oospores, e.g. in the Scandinavian countries (Andersson *et al.,* 1998, Lehtinen *et al.,* 2001, Dahlberg *et al.,* 2002, Hermansen *et al.*, 2002, Hermansen and Amundsen, 2003), potato dumps and ground keepers. Strömberg *et al.* (2001) showed that oospore formation differed between three intermediate-resistant varieties under controlled environmental conditions, with the lowest amount formed in cv. Asterix. In another study Turkensteen *et al.* (2000) found the highest amounts of oospores both in susceptible Bintje and resistant Pimpernel and the lowest amount in a variety with intermediate resistance. The same authors found oospores to remain infectious for 48 month in sandy soils and for 34 month in clay soils. More knowledge of the effect of climatic conditions of oospores, the oospores as a significant inoculum source, formation and survival of oospores, will probably be important in late blight management (e.g. Zwankhuisen and Zadoks, 2002). During the last years the first outbreaks of late blight in the Netherlands are supposed to be due to different reasons, no year was the same (Hadders, 2003). Kapsa (2003) proposed an improvement in DSS's concerning the primary source of inoculum. Geddens et al (2002) found that stem blight could serve as a focus of initial infection. The stem lesions sporulated longer than foliage lesions, especially at lower temperatures (< 18 °C) in a laboratory bioassay. Schlenzig *et al.*

(1999) showed that it was possible by using an indirect ELIZA to find *P. infestans* in potato sprouts without symptoms 39 days before disease outbreak in the field. The wind dispersal, spreading and viability of *P. infestans* spores are of the utmost interest due to organic potato growing (in Sweden a few per cent of the total acreage of potatoes), unprotected potato growing in home gardens and poorly protected conventional fields. Spore traps were placed in connection to the fungicide strategy field trials in the most southern part of Sweden. The results from these studies will be evaluated and presented in later reports. The epidemiological importance of a wider host range has been proposed (Flier *et al,*, 2003b). In Sweden severe attacks of *P. infestans* have been seen on *Solanum physalifolium* (Andersson *et al.,* 2003, Jönsson and Wuolo, 2003).

Conclusions

Normally the effect against late blight achieved in the Swedish official testing trials is very good. Usually 100 per cent is not achieved but often close to. In order to avoid tuber blight completely, 100 per cent effect against late blight is considered necessary. Some years as 1999 and 2003 the effects were not as good as desired.

Chemical treatments according to the decision support systems (DSS's) PLANT-Plus and NegFry gave as good control against late blight and tuber blight as conventional treatments, i.e. repeated treatments with the fungicide Shirlan once a week, in potato fields with starch and crisps varieties and during later years also so in susceptible varieties as Bintje and King Edward VII. In susceptible Bintje the model had some problems to give correct recommendations during the first two years of the project. The DSS's often resulted in a ~ 30 per cent reduction of applications than standard treatments.

Results from Swedish field trials show that the first attacks in untreated plots normally occur five to six weeks after the first routine treatment. Delayed first treatment in field trials 1999-2002 showed that it was possible to start the first treatment at least one week later than normal. Delayed first treatment is not recommended in practice in Sweden in spite of good results in field trials as the fungus most probably has changed during recent years and due to the risk of infection by soil borne oospores. First treatment is usually carried out before row closure.

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