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Proceedings of the Workshop on the European network for development of an integrated control strategy of potato late blight

Oostende, Belgium, 29 September – 2 October 1999

Huub Schepers (editor)

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Applied Research for Arable Farming and
Field Production of Vegetables

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European Network for development of an integrated control strategy of potato late blight (EU.NET.ICP)

H.T.A.M. Schepers

Fourth Workshop, Oostende, 1999

This report contains the papers and posters presented at the Third Workshop on the European network for development of an integrated control strategy of potato late blight held in Oostende, Belgium, 29 September – 2 October 1999. The Workshop was the last Workshop to be held as part of the activities in the Concerted Action EU.NET.ICP.

EU.NET.ICP

EU.NET.ICP is a network of 16 research groups from 10 European countries, all working on integrated control of late blight caused by the fungus *Phytophthora infestans* in potatoes. The network is funded by the European Commission as a Concerted action within the Programme for research, technological development and demonstration in the field of agriculture and fisheries 1994-1998.

With the establishment of a network for communication between scientists and research groups who work on control of late blight the following objectives are envisaged:

- To co-ordinate ongoing research in order to avoid duplication of efforts.
- Survey the state of the art on control of *Phytophthora infestans* and indicate information gaps to regards to integrating a Decision Support System.
- Development of European Integrated Control Strategy and a Decision Support System in which all available knowledge is integrated.
- By harmonising ongoing field trials an Integrated Control Strategy and a Decision Support System will be validated on a European level.
- Results will be diffused to extension officers and farmers.

The papers presented in the Proceedings give a survey of the state of the art in controlling *Phytophthora infestans* in potatoes in Europe. During the Workshop sub-groups discussed on the topics ëpidemiology”, “fungicides” and “Decision Support” Systems. Reports of these discussions are also included in this Proceedings.

For further information please contact the network secretariat where additional copies of this report and the newsletter can be ordered.

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Integrated Control Strategy of potato late blight
Oostende, Belgium, 29 September – 2 October 1999

The development and control of *Phytophthora infestans* in Europe in 1999

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Abstract

In most European countries the first recorded outbreak was at the same time or earlier than in 1998. The tendency that "late" blight is detected earlier in the season might be influenced by the weather conditions, the type of population and the increased awareness to look for late blight on dumps, volunteers and in covered crops (very) early in the season. Although blight became established in most countries in May and June, the hot and dry weather in July reduced the scale of the epidemic compared to 1998. In regions/countries with extremely high quantities of rain (SW-Sweden, Bavaria, Austria, Switzerland, Italy), epidemics were very difficult to control.

Introduction

From 29 September – 2 October 1999 a Workshop was held in the framework of a Concerted Action on control of *Phytophthora infestans*. Representatives from 16 European countries presented the development and control of late blight in their country in 1999. In this paper these presentations are summarised. The weather conditions of 1999, the disease progress and the input of fungicides are presented.

Weather conditions

In the EU.NET.ICP Late Blight Newsletter No. 7, published in July 1999, the late blight situation and weather conditions in spring 1999 (April-July) were already presented in 13 countries (http://www.agro.nl/pav/pavintp2.htm). The following information was not included in this Newsletter.

In the central and northern regions of **Italy** spring was extremely wet. Persistent rainfall in the last decade of April and last week of May increased the risk of blight in early potato and tomato crops. The control of the disease was extremely difficult and 8 to 10 sprays were carried out by farmers during the season. The first symptoms of the disease were recorded on 10 May on potato and 30 May on tomato. An A2 isolate was detected on tomato for the first time in Emilia-Romagna region. In most regions of **Spain** the summer was extremely dry followed by torrential rains early September. No blight developed in these areas because most potato crops were already harvested by that time. In Galicia and the Basque Country it rained in July and early August; blight was observed there at the end of June and up to 9 fungicide treatments were necessary to control blight. The average number of treatments was 4-5. In **Switzerland** the first blight attack was registered on 8 May in a polythene covered crop in the main potato growing region. From the beginning of May until the end of July, 31 high risk periods (MISP's) were observed. This high number of MISP's reflects a growing season in which control of late blight was very difficult. In the intensive production areas in the north and north east of **Austria** late blight occured very early between the 8-15 May at a plant hight of 20 – 25 cm.

There was no difference between cultivars of different levels of susceptibility. Most problems with late blight arose on ware potatoes with a long vegetation period, because (1) plants developed very early this year and (2) late blight appeared very early. During the vegetation period farmers all over Austria had to cope with unusually high precipitation. For example at the beginning of July it rained over 100 mm in 5 days. During nights leaf wetness was very high in consequence of relatively cold night temperatures. Due to the high infection pressure during the season farmers had to spray around 12 times. In the north east area many stem infections could be found. In seed potato production less problems occured in the main production area (Waldviertel and Leiser Berge). Because they were less developed in the critical time at May and they had already been desiccated when the second critical time with heavy rainfalls started in July. In Petzenkirchen in the western part of lower Austria where our trials are located the first appearance of late blight was on 14 July. This is on an average over the last 20 years. Due to favourable weather conditions staring from 8 July infection pressure rose until the end of August. In this period precipitation reached 207 mm. In Petzenkirchen no stem infections occured this year whereas the 3 years before stem infections could be found. In many regions of **Germany**, late blight appeared very late. In polythene covered crops blight appeared 28 April and in Bavaria blight appeared very early (1 June) compared to other years. The early and severe start of the epidemic in Bavaria was due to waterlogged soils over a longer period (high water of the Danube). In Baden-Württemberg the very high amounts of rain and many latent infected seed tubers probably played an important role in the early start of the epidemic. In **France** the first treatment according to the model Guntz-Divoux was given 28 May**.** Late blight occurred in fields early July. Significant rains in late August and early September caused problems with tuber blight. In **Belgium** the Guntz-Divoux model indicated the first critical period in the beginning of April and the second at the end of April. From June onwards numerous attacks were observed throughout the whole region including crops that were just emerging. The epidemic was slowed down in the dry month July, but the first half of August was again very wet which increased the disease pressure. However, with warnings from the Guntz-Divoux model blight could be controlled effectively. In **The Netherlands**, blight was widespread in June, but the warm and dry weather during the summer slowed down the epidemic. Rain in the end of August and beginning of September increased the occurrence of the disease once more, but serious problems with control of leaf and tuber blight did not occur. During 1999 blight became established in virtually all regions of **England & Wales** at some time during the season. During late July most of England & Wales experienced a period of very hot, dry weather. These conditions 'dried' up foliage lesions although the widespread occurrence of stem blight within crops allowed the disease to remain active. The dry weather also encouraged premature senescence particularly on lighter soils and in un-irrigated crops making identification of blight lesions more difficult. However, a return to wet weather during late August which continued into September stimulated a rapid development of foliar blight in some areas. In **Scotland** the disease pressure was high early on in the season. Inoculum was available early because of the exceptionally large number of volunteers from 1998. The disease pressure eased for the middle part of the growing season due to a dry spell of 3 weeks. In many cases foliar blight died out but stem infection remained until the end of the seson. High risk conditions returned in late August leading to further foliar blight development and an increased risk of tuber infection. In **Northern Ireland** 12 Full Smith periods were recorded, with the first on 18-20 June. Nine blight warnings were issued. It was noted that warm humid weather, particularly in South East coastal areas, where frequent seas mists occurred during June, increased the infection risk. During September rainfall has been very high with 138 mm recorded at Newforge (30 year mean is 92 mm). In **Ireland** temperatures during the growing season were average while humidity was higher than average. Rainfall was high in June, low in mid-season and high again in late August and September. Date of disease outbreak for maincrop varieties was normal (late July). Following disease outbreak, disease development was faster than average and reached 75% defoliation in unsprayed crops in 4 weeks. In the south part of **Poland**, blight was first reported on 27 May. In the beginning of June a high disease pressure was observed, it was remarkable that mainly stem blight was observed. Mid-June already some early potato crops were completely destroyed. The high temperatures in July slowed down the epidemic. In the north of Poland blight was observed one month later (26 June). The high temperatures and low humidity only allowed development of blight at a low level. In the South-West of **Finland** blight was observed but the extremely dry weather prevented an epidemic to develop. In the North and East of Finland rainfall was relatively normal and blight could develop in organic crops and home gardens. Production fields were well protected with fungicide sprays. In the South-West of **Sweden** serious infections were observed due to very high amounts of rain. It was estimated that 90% of the fields were infected by mid-July. The situation was considered worse than in 1998. A change in the weather in the last week of July saved the situation. In the eastern parts of South and Mid Sweden the weather was very dry and in these areas no problems with blight were observed. In polythene covered crops in the South of **Norway** blight was observed 2 weeks earlier than in 1998. In the main potato crops in this area, blight was also observed 1-3 weeks earlier than normal. The disease pressure was higher than normal, resulting in more infected fields. More stem blight was observed. In **Denmark** the general warning for risk of primary attack of blight was issued on 14 June. In the weeks following this warning, fields with blight were recorded all over the country. After this high infection in the beginning of the season the infection pressure decreased towards the end of the season.

Fungicide input

In **Italy** more dimethomorph-based fungicides were used compared to 1998. In **Spain** the most commonly used fungicides were: phenylamides, dimethomorph, cymoxanil, mancozeb and copper. The fungicide input of 80 PhytoPre participants in **Switzerland** was analysed. Contact fungicides were used in 39%, with fluazinam as the most important one. Locally systemic fungicides were used in 54% and systemic fungicides in 7%, with metalaxyl + fluazinam as the most important product. In **Austria** the most commonly used strategies consisted of 1-2 sprays with systemic fungicides (metalaxyl) followed by 2-4 sprays with contact fungicides (fluazinam, mancozeb). In **Germany**, fluazinam is more and more replacing the dithiocarbamates and fentin-fungicides. In **The Netherlands**, fluazinam is the most important contact fungicide. Fungicides with curative and eradicant properties, such as cymoxanil, dimethomorph, propamocarb and metalaxyl, are used in high risk periods. Although fluazinam is used in **France**, the dithiocarbamates are still the most important contact fungicides. Of the available (locally)-systemic fungicides, propamocarb was of lesser importance. In **Belgium** the fungicide input consisted approximately of 3 sprays with fentin, 6 sprays with locally systemics (cymoxanil, dimethomorph, propamocarb) and 1 spray with metalaxyl. Despite periods when weather conditions were extremely favourable for blight development and often difficult for spraying, the vast majority of growers in **England & Wales** were able to maintain effective spray schedules. This together with the hot, dry weather in July was a major factor in reducing the scale of blight epidemic in 1999. Phenylamide containing fungicides were most commonly used early in the season with many growers changing to translaminar materials (cymoxanil, dimethomorph) or protectant fungicides (fluazinam, mancozeb) as the season developed. In **Northern Ireland** growers had no problems obtaining first choice fungicides. Systemics were mostly used for the first 2 or 3 treatments with a lot of propamocarb, dimethomorph and cymoxanil used. Fluazinam and mancozeb were widely used with product cost remaining an important consideration. In **Ireland** the most common fungicides used were mancozeb, phenylamides and fentinhydroxide. Cymoxanil, fluazinam and dimethomorph were of lesser importance. In **Finland** fluazinam was the most widely used fungicide. Other fungicides used were mancozeb, propamocarb, dimethomorph and metalaxyl. In south **Sweden** metalaxyl was used because of many reports of infected fields. Insensitivity to metalaxyl was suspected in a number of fields with a low efficacy of metalaxyl. In **Norway** the use of fluazinam is increasing although mancozeb is still used. Propamocarb and dimethomorph were of lesser importance, whereas metalaxyl was not recommended in areas with high levels of resistance. In **Denmark** the input of fungicides was the same or higher than in 1998. Main fungicides used were maneb, mancozeb, fluazinam, propamocarb and metalaxyl.

Tuber blight

Only a few reports were available on the occuurrence of tuber blight. In late planted crops the very high rainfall in September might have an important effect on tuber blight levels (**Northern Ireland**). The high soil moisture contents at the end of the season could lead to high levels of tuber blight in store (**Ireland**). In ware potatoes problems with tuber blight were recorded (**Austria, The Netherlands**). In **Spain** some fields had blighted tubers, but not in an important amount. In **England & Wales** a return to wet weather during late August which continued into September stimulated a rapid development of foliar blight in some areas. This rainfall together with the presence of inoculum in the canopy and soils at field capacity provided an “ideal” scenario for tuber infection to occur. Although there have been reports of high levels of tuber blight, the scale and therefore impact on long term storage potential was not known at the time of writing.

Organic crops

In **Sweden** most organic farmers had little problems with late blight, only in the SW where high amounts of rain caused a serious disease pressure, a lot of damage in (organic) potato crops was observed. In **Northern Ireland** there has been an increase in organic crops; with two pre-packers contracted to supply the local multiple supermarket outlets; no serious problems with late blight were recorded. In **Switzerland** the disease pressure was already high in the beginning of the growing season which resulted in a very difficult situation for (organic) potato production. Although the highly resistant varieties Matilda, Appell and Naturella were not treated with fungicides, they remained green until the end of the season. In **Norway** the early and high disease pressure resulted in lower yields in organic crops and home gardens. In **Denmark** early and heavy attacks were observed in organic crops which led to low yields of 10-20 ton/ha. In **Belgium,** organic crops became infected at the end of June/beginning of July. After the first outbreak of the disease, 2-3 sprays with copper-based fungicides could only partially control blight in susceptible cultivars (Bintje, Charlotte) and moderately resistant cultivars (Sava).

Table 1. Weather conditions favourable for the development of late blight and dates of first recorded outbreaks of blight in potato in 1999 in relation to other years.

	May	June	July	August	September	First outbreak				
						1999	1998	1997	1996	1995
Austria	***	**	***	***	**	15 May	25 June	17 July		
Belgium										
* Flanders	**	***	*	**	**	29 April[1,2]	28 April[1]	15 May[1]	September	30 May[1]
* Wallonia	**	***	*	**	**	5 July	12 July			
Denmark	**	***	**	**		18 June	16 June	end June	begin July	20 June
Finland	**	**	*	*	*	2 June[1]	20 June	1 July	17 July	26 July
France (Champagne)	*	*	**	***		Early May[2]				
* Nord-Pas-de-Calais	**	*	***	**		Early April[2]	20 April[2]	23 May[2]	13 June[2]	1 April[2]
Germany	**	***	*	**	**	28 April[1]	5 June	30 May	12 June	19 June
Italy	***	***	**	*		10 May	No blight	No blight	19 May	30 May
Ireland	**	***	*	**	**	20 July	1 July	25 July	28 July	15 August
Netherlands	**	**	*	**	**	26 April[2]	Beginning May	2 June		
Norway	*	***	**	**	***	15 June[1]	20 June[1]	6 August	29 July	
Poland	**	***	*	*	**	27 May	Beginning June	end June		
Portugal										
Spain (North)	*	*	***	**	-	21 June	15 June	1-7 June		
Sweden	**	***	**	**	**	20 May[1]	15 May[1]	24 May[1]		
Switzerland	***	***	**	***	*(*)	8 May[1]	15 May[1]	16 May	23 May	29 April[1]
United Kingdom										
*Northern Ireland	*	**	***	***	***	16 June	8 June	30 May	27 June	20 June
*England/Wales	**	***	*	**	**	mid-May[1]	31 May[1]	29 May		
*Scotland	***	***	*	**	**	12 May[3]	25 June	3 July		

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

[1] polythene covered crop; [2] waste piles; [3] volunteers

Table 2. The estimated use[1] of fungicides to control P. infestans in 1996, 1997, 1998 and 1999.

	Average number sprays/season			
	1996	1997	1998	1999
Austria	4-6	5-6	?	4-12
Belgium	8-12	14-15	12-14	10
Denmark	6	7-10	4-12	4-13
Finland	3-4	4-5	3-8	2-6
France	9-11	11-14	?	15
Germany	5-6	7-9	3-10	4-5
Italy	6-8	6-8	4-5	8-10
Ireland	?	?	?	
Netherlands	5-12	7-15	7-15	7-16
Norway	2.9	4	5	5-6
Poland	1.6	1.7	1.7	2
Spain	3	5-6	3	4-5
Sweden	4-7	4-7	4-12	4-11
Switzerland	6-7	7-9	5-7	6-10
United Kingdom				
*Northern Ireland	2-10	3-15	4-16	4-14
*England/Wales	2-10	4-18	8-15	?
*Scotland	?	?	(1997)+2	?

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

Fourth Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Oostende, Belgium, 29 September – 2 October 1999

Report of the meeting of the Subgroup Epidemiology

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Participants: N. Adler, B. Andersson, D. Andrivon (chair), R. Bain, L. Bodker, C. Chatot, L. Cooke, R. Corbière, D. Emery, J. Hadders, A. Hermansen, M. Goemmine, G. Jamart, M. Maes, F. Niepold, M. Sandström, A. Schieder, A. Strömberg, T. Rantanen.

Summary

The fourth meeting of the subgroup on Epidemiology of *Phytophthora infestans* took place in Oostende, Belgium on October 1st, 1999. Since this was the final meeting of the subgroup within the frame of the Concerted Action, an agreement between the chairmen of all three Subgroups was made about an agenda in two points: 1) did we achieve the goals we had set up at the start of the CA, and 2) what prospects are emerging now for members of the subgroup in terms of joint projects.

Did we achieve our goals?

The first question that was debated was: which were those goals? The purpose of the concerted action was to provide a structure for a better interactions between groups pursuing similar or complementary objectives, so as to foster synergies and avoid duplication of research efforts. Therefore, the goals we set to achieve were of three distinct kinds: providing suitable answers to the DSS builders, making new research questions emerge, and sharing information within the network.

Answering the requests of the DSS builders

The group had a hard time with this objective, as shown by the successive reports of the DSS subgroup. In retrospect, our inability to deliver the useful information to the DSS people arose from two main reasons:

- first, we could not identify precise questions to develop research the well-focused research programmes necessary to come up with adequate answers within the time span of the concerted action. One major reason for this is that the DSS and epidemiology people usually did not know each other before the CA started; it took us about the course of the CA to learn each other's jargon and vocabulary, and to be able to interact.
- second, even on topics that were clearly identified as gaps in the available knowledge (such as the climatic requirements of the new isolates of P. infestans in comparison with 'older' ones), we were not able to obtain all the relevant data because no research programme was running at the time on these aspects. Since the CA did not provide any money to perform the research itself, launching such programmes needed to set up the proposals, find the funding, and then perform the experiments. Some research was done (mainly in the Nordic countries and in the Netherlands), however, in the course of the CA (see previous reports).

Making new questions emerge

Many new topics emerged during discussions within the subgroup. Some were directly related to the improvement of DSSs (ie monitoring and modelling of inoculum sources, including oospores; inclusion of data from population studies and/or cultivar resistance into the DSSs). Others (such as the incidence of crop husbandry and nitrogen supply on late blight development, the role of latent infection in early outbreaks, or the prediction of tuber blight incidence) were not necessarily foreseen as 'hot' issues, but turned out as important questions in the discussions.

Sharing information and networking

All participants felt that this objective was very satisfactorily achieved. They welcomed the opportunity that was provided by the meetings and subgroups to present their own data and thoughts, and to confront different opinions. Among the very positive comments emerging from the group, should be highlighted:

- the fact that the subgroup structure and informal discussion atmosphere made easy the inclusion of 'newcomers', who were not included in the initial consortium but joined in during the course of the CA. These newcomers were either confirmed scientists or graduate students, who derived ideas for new experiments for their Ph.D. project from discussions in the subgroup;
- the inclusion of various groups from the same geographic area strengthened the links between these groups; this was reported in the UK, Germany and the Nordic countries, but also applies to other parts of Europe, such as France;
- the opportunity provided by the workshops for an early dissemination of the results of the various groups helped create a useful network, which might serve as a basis for developing a European linkage group within the framework of the Global Initiative for Late Blight (GILB).

Where are we heading next?

Various research projects have been already set-up by members of the subgroup. They deal mainly with host resistance (breeding for and use of), oospore biology, and early outbreaks (role of latent infection, soil type, etc…). Some of these projects are submitted to national funding bodies (e.g., the epidemiology items in the Masterplan Phytophthora in the Netherlands, or the project on primary infection sources in tyhe Nordic countries), while others are operated at the EU level (eg the project ECOPAPA, launched in 1998 within the INCO-DC programme). Most of these projects associate several members of the Concerted Action, which in itself is proof of the quality of the networking achieved during EU-NET-ICP.

Several other projects are on the works, but did not start yet because of lack of funding. One is dedicated to the forecasting of tuber blight, using climatic sequences and historical data. Another is the maintenance of a structure for networking and interacting on DSS-related topics. EU-NET-ICP showed that bringing together people from diverse backgrounds but sharing a common goal of improving the DSS and control strategies available against late blight was a difficult, long-term, but achievable task; we would be reluctant to let the effort made during the four years of the CA to understand each other and define joint research objectives down, simply for want of a (light) structure facilitating the exchanges. The aforementioned GILB linkage group might serve as such a structure, but will require some financial input to be fully operative.

We consider that EU-NET-ICP was a great opportunity to start the interaction between scientists and extension specialists to achieve better late blight management. Now seems the time to set up integrative research projects, covering all three areas tackled within this CA (as well as a fourth dedicated to the plant itself), and building on the now rather precise research priorities defined in each of the subgroups. As far as the Epidemiology subgroup is concerned, these topics would certainly include 1) the identification of primary inoculum sources, as well as the development of tools/models to quantitatively predict their respective contribution to early outbreaks, 2) the definition of criteria to include cultivar susceptibility in DSS models, and 3) the development of models to predict the risk of tuber infections.

Before concluding this report, I would like to seize this opportunity to thank all the members of the Subgroup Epidemiology for their active involvement in the discussions (in and out of the Subgroup) that took place during the past four years, and their constant support to me as a Chairman.

Report of the Sub-Group Discussions on the practical characteristics of Potato Late Blight fungicides

Participants: Nick Bradshaw (Chairman, UK), Gilbert Ampe (Belgium), Jan Bouwman (The Netherlands), Leslie Dowley (Ireland), Johann Habermeyer (Germany), Asko Hannukkala (Finland), Howard Hinds (UK), Josefa Kapsa (Poland), Albert Koops (The Netherlands), George Little (UK), Raquel Marquinez (Spain), Huub Schepers (The Netherlands), Peter Taylor (UK), Geert de Wever (NL)

Objective

The main objective of the sub-group discussion was to review the progress made during the period of the Concerted Action. In particular (i) to review the ratings given to the fungicide characteristics (PAV-Special Report No 5, pp 20-22), and (ii) to identify possibilities and funding sources for further work on fungicides with a special emphasis on their integration within a Decision Support System.

Whilst there was continued general agreement for the ratings previously given in relation to the effectiveness and mode of action of late blight fungicides, following discussions with the company representatives it was clear that the table required some revision. The ratings are intended as a guide for the development of new. Decision Support Systems or the improvement of existing ones. A revised table of ratings is given below.

The effect of the most important fungicide active ingredients used for the control of P infestans in Europe

Opinion of the fungicides sub-group at the Oostende workshop, 1999.

Active ingredient		**Effectiveness**				**Action mode**				
	spray interval	leaf blight	new growing point	stem blight	tuber blight	protectant	curative	eradicant	rainfastness	mobility
propamocarb-HCl	7	++(+)	+(+)	++	++	++(+)	++	++	+++	systemic
fluazinam	7	+++	0	+	++(+)	+++	0	0	++(+)	contact
cymoxanil	7	++(+)	0	+(+)	0	++(+)	++	+	++	translaminar
fentin hydroxide	7	++	0	+	++(+)	++	0	0	++	contact
fentin acetate	7	++	0	+	++(+)	++	0	0	++	contact
mancozeb or maneb	7	++	0	+	0	++	0	0	+(+)	contact
dimethomorph	7	++(+)	0	+(+)	++	++(+)	+(+)	++	++(+)	translaminar
metalaxyl*	10	++(+)	++	++	N/A	++(+)	++(+)	++(+)	+++	systemic
oxadixyl*	10	++(+)	++	++	N/A	++(+)	++(+)	++(+)	+++	systemic
copper	7	+	0	+	+	+(+)	0	0	+	contact
chlorothalonil	7	++	0	(+)	0	++	0	0	++(+)	contact

* = See text for comment on phenylamide resistance.

Key to ratings : 0 = no effect ; + = reasonable effect ; ++ = good effect ; +++ very good effect. ; N/A = not recommended for control of tuber blight.

N.B. The ratings given in the table assume a phenylamide-sensitive population. Strains of blight 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

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 ie 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 mid/late season post infection fungicide application and has 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 post tuber initiation 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 scientists in countries participating in EU.NET.ICP. While 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 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 and available for use within one or more EU countries.

The application intervals indicated in the Table are not intended as a guide as to how frequently a particular fungicide should be used. Where disease pressure is low, intervals *between 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.*

Further Research

It was agreed that fungicides remain a vital component in the effective control of late blight across Europe. As such, investigations into their effectiveness and other attributes should form an integral part of research proposals aimed at the development of Decision Support Systems. The sub-group were concerned that research proposals made to the EU investigating the effects of blight fungicides would not be accepted as they would be considered as being production oriented and not satisfying the stated objectives of the 5th Framework Programme. The sub-group agreed that the interaction between fungicide dose, interval between application and cultivar resistance should be investigated as a matter of urgency as the results generated would form an integral part of a DSS.

Fourth workshop of an European Network for development of an
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Report of the discussions of the Subgroup DSS

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Participants

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Subject areas

In the frame of the EU.NET.ICP concerted action, four late blight decision support systems (DSS) were validated in field trials in six different countries in 1999 (Kleinhenz & Jörg, 2000). Participants responsible for the validation trials and the model builders met Thursday evening to discuss the results obtained in the trials. At the official DSS subgroup meeting next morning, the overall results and major discussion points were presented. It was decided that Benno and Erich should compile and publish the results of the DSS validations in the next workshop proceeding (Kleinhenz & Jörg, 2000). The subgroup was then divided into smaller groups to discuss:

- What were the major achievements and results in the frame of the subgroup DSS during the concerted action.
- Recommendations on important issues dealt with during the concerted action.

- Proposals for EU.NET.ICP follow-up activities.

This paper reports the results of the discussions.

Achievements, results and major discussion points in subgroup DSS

Surveys and reports produced by the group

The following survey reports and reports on harmonisation of methods were produced by the group during the four year working period:

- Compilation of questionnaires on availability of meteorological data for late blight warning in operational use (Bouma & Sigvald, 1999)
- Overview of standard descriptions of Phytophthora decision support systems (Bouma & Hansen, 1999)
- Proposal for the validation of late blight DSS in field trials (Jörg & Kleinhenz, 1999)

Four reports were produced on DSS validation using historical data:

- Validation of NegFry, a PC-program for scheduling the chemical control of potato late blight (J.G. Hansen, 1997)
- Validation of NegFry, a PC-program for scheduling the chemical control of potato late blight (J.G. Hansen, 1998)
- Model output of the Prophy advice system on the European weather data sets. (Wim Nugteren, 1997)
- Prophy output of European weather datasets 1997/98 (Wim Nugteren, 1998)

One unique EU decision support system?

One of the objectives in the EU.NET.ICP concerted action was to develop "a European Integrated control strategy and a DSS in which all available knowledge is integrated". We did not reach this goal, and it was discussed if this is achievable. It might be achievable, but it has to taken into account that the conditions for late blight development and late blight control are different between countries, such as:

  - Climate conditions – do *Phytophthora infestans* populations adapt to the different climate conditions in EU? Can we use the same basic models in e.g. Norway and Italy?
  - Cultural practises.

- Grower attitude to use DSS´s.
- Fungicide use.
- National policies for pesticide use.

Therefore, it was decided all ready on the first workshop that we should concentrate on:

- Compare and discuss whole systems as well as sub-models of several existing late blight DSS systems.
- Validate some of these DSS´s using historical data.
- If possible validate DSS´s of special interest in field trials.

In Oostende it was discussed if it was possible in the future to exchange and adapt DSS components instead of whole systems, see Hansen et al., 2000 for further information.

DSS validation

Four late blight decision support systems were validated in field trials in six EU countries in 1999 (Kleinhenz & Jörg, 2000). This work has:

- Highlighted advantages and constraints in each system.
- Improved the links between model builders and the users of the DSS´s
- Produced a standard protocol for DSS validation.
- Stimulated and improved research on national level.
- Stimulated countries external of the validation group to start validation trials (France, England and Wales)

Weather data

The availability and the quality of weather data are one of the major constraints in the practical use of late blight decision support systems. In many countries there exists no agrometeorological network and ordinary weather stations are located along cost lines and in mountain areas, primarily aimed at weather forecasting. How close should meteorological stations be to the potato field? Is it better to use in-crop data (microclimate) than data from above the crop (macroclimate)? These questions are asked again and again, and there seems not to be any clear answers. It depends on the local topography, shelters, distance to cost lines and rivers, the type of model used etc.

Although more of the DSS´s use weather forecasting data, the quality of forecasting data seems to be questionable. "Having a good weather forecast gives more possibilities" (*for right timing and choose of fungicide type and dosage*), one of the model builders concluded. The survey on availability and quality of weather data has stimulated participants to go into detailed discussions with national meteorological offices about weather information for the agricultural sector in general. One way to take into account the uncertainty in the weather forecast will be to include this uncertainty also in the output of the DSS.

Harmonisation of research programs and methods

The standard protocol for the validation of DSS´s has worked very well. It should be further improved and used in future validation trials. Standard protocols for experiments related to the development and the validation of decision support components and -systems are needed, but it was stressed by several of the participants, that the lack of funding has inhibited progress in this area. New projects in the area of development and validation of DSS´s have been initiated stimulated by the activities in the frame of the concerted action.

Implementation on farm-level and transfer of knowledge to extension offices and farmers

There exists no unique European approach for the implementation of late blight DSS´s on farm-level. Different countries have different approach. A survey report about implementation of DSS´s and dissemination to extension offices and farmers was published earlier (Bouma & Sigvald, 1999). It was recommended by more of the participants, that the information in this paper should be updated via a follow-up questionnaire. A few late blight DSS´s have become commercial during the last five years (Bouma & Hansen, 1999), but more work is needed in the area of validation and adaptation before they can be widely promoted in other countries, e.g. NegFry in Sweden and Plant-Plus in England.

It was recommend by the group to make a list of all publications in farmers journals, scientific papers etc. regarding validation, demonstration and implementation activities produced in the frame of the concerted action.

Technology transfer (Software and tools for general use etc.)

The concerted action has stimulated the development of different software tools and Internet applications for general use such as:

- ClimateDataInterface (CDI) for the import and quality control of weather data (Lassen & Hansen; 1999)
- Internet based monitoring system for potato late blight (Hansen, 1999)
- The field trial guideline for the validation of late blight DSS´s (Jörg & Kleinhenz, 1999) has been adapted and implemented as a PC-software integrated with Internet. This application was used in a project aimed at validation of NegFry in the Baltic countries (Hansen, 2000).

These and other similar activities have stimulated members of the group in developing and using Internet applications in their work.

Recommendations and follow-up activities

Fungicides

More work is needed in the area of:

- Adaptation of DSS´s for different national policies and restrictions in the use of fungicides to control late blight.
- Implementation of economy and price of chemical products in DSS´s.

Epidemiology

More work is needed to quantify:

- Weather requirements for the processes in the disease cycle, e.g. sporulation and infection for the "new *P. infestans* population" in Europe.
- Importance of different inoculum sources for primary attacks (local infected tubers, waste potatoes, volunteers, potatoes under plastic, oospores in the soil etc.).
- Risk of tuber infections during crop growth and at harvest.

Implementation of DSS´s by advisors and farmers including demonstration activities

More field validations and demonstration trials should document and demonstrate the potential in the use of late blight DSS´s for the end-users. Methods and strategies for implementation on farm-level should be discussed on EU level including methods for evaluation of the success of implementation.

EU harmonisation's, management and information

An EU organisation/institution could collect, analyse and disseminate via Internet late blight information with general interest for EU countries. This information could be:

- Distribution of mating types and population characteristics of P. infestans in EU in time and space. (maps, graphics and interpretations).
- The time of epidemic development of *P. infestans* in different regions of EU
- Results of fungicide trials testing new fungicides.
- Test and quantification of crop variety resistance components under different EU conditions (medium/long term project)

Follow-up project

A follow-up project should focus on improvements and adaptations to local conditions of existing and new late blight DSS´s in Europe. Recommendations and results from the EU.NET.ICP concerted action should be implemented as part of the aims and tasks in the project.

Existing and new late blight DSS components (sub-models) should be evaluated, and based on this evaluation, new components should be developed as open and documented components that easily can be modified and used in any DSS shell based on PC and /or Internet applications. It has to be taken into account that different DSS´s may have different aims

A database with high quality data from several countries in EU, including weather data and field and biological data could be available for the development, adaptation and validation of whole systems and sub-models. Therefore, a strong link between model builders and epidemiologist are required.

In many EU countries a major problem is availability and quality of weather data for operation of weather based DSS. This was concluded in EU.NET.ICP survey report Bouma & Sigvald, 1999). A new project could take the initiative to develop a prototype of an EU agrometeorological network, develop standard protocols and tools for weather data transmittance, transformations and quality control, that can be used on EU level in any modern DSS that requires weather data as input. Stations in this network could be established at localities where validation trials, specific field experiments and demonstration trials should be carried out in the project.

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Up-Date on the Potato Blight Population in Northern Ireland – fungicide resistance and mating type

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Summary

Annual surveys of the incidence of phenylamide-resistant *Phytophthora infestans* in Northern Ireland showed that the percentage of isolates containing resistant strains was relatively stable during the years 1997-99 at 42-48%. Although this was greater than in 1996 (27%), there was no evidence of a trend of increasing resistance over these years. Four 1999 isolates (of 39 tested) were of intermediate resistance. The incidence of resistant strains was greater on crops treated with formulations containing phenylamides than on crops not so treated. Most growers who used phenylamides applied them not more than three times within a season. Isolates were also tested for mating type in each year; all proved to be A1. In 1999, up to 25 single-lesion isolates were collected from each of three crops and tested for phenylamide resistance, mating type and *glucose 6-phosphate isomerase* (*Gpi*) genotype. Isolates were homogeneous for mating type (all A1) and *Gpi* genotype (all *100/100*), but heterogeneous for phenylamide resistance both within and between crops.

Key words: *Phytophthora infestans*, late blight, fungicide resistance, phenylamide, mating type, *Gpi* genotype.

Introduction

At the end of the 1996 season, Cooke, Little & Carlisle (1997) concluded that phenylamide fungicides continued to have a useful role in the control of late blight on potato crops in Northern Ireland. Most growers who used products containing this type of fungicide were following DANI (Department of Agriculture for Northern Ireland) advice and making not more than three applications in the early part of their spray programmes before switching to fungicides from other groups. The proportion of isolates containing phenylamide-resistant strains had declined from a peak of 90% in 1988 to 27% in 1996.

In the succeeding years 1997-98, there was high rainfall in Northern Ireland in the June-August period resulting in conditions very conducive to late blight (Table 1). This had the potential to enhance selection for phenylamide resistance, by increasing the size of the *P. infestans* population and by encouraging growers to use phenylamide fungicides. It was therefore considered important to continue to monitor the incidence of phenylamide-resistant *P. infestans* and also to take the opportunity to investigate the status of the A2 mating type within the current Northern Ireland population.

The first Northern Ireland A2 mating type isolate of *P. infestans* was obtained in 1987, but A2 mating types were found very infrequently among *P. infestans* isolates tested in the years 1988-1995 (Cooke *et al*., 1995). However, in some other European countries the A2 mating type is now common. During 1996-1999, isolates from the phenylamide resistance survey were also tested for mating type. Shaw *et al*. (1998) recently showed that detailed sampling within crops may reveal a greater incidence of the A2 mating type than is found by coarse-grain sampling. Therefore, single-lesion isolates obtained from selected crops in 1998 and 1999 were tested for mating type and also, in 1999, for phenylamide resistance and for *Gpi* genotype to provide information about within crop variation in the pathogen population.

Table 1. Summer rainfall data, Newforge Lane, Belfast, 1996-1999 and 30-year mean.

Year	Rainfall (mm)			
	June	July	August	Total (June-August)
1996	25	46	65	136
1997	92	94	59	245
1998	111	107	70	288
1999	48	46	89	183
30-y mean	65	59	85	209

Materials & Methods

Sampling of potato crops and isolation of Phytophthora infestans

Samples of infected potato foliage together with data on sample site, potato cultivar, fungicide usage and disease incidence were obtained (mainly from seed crops) by members of the Department of Agriculture's Potato Inspection Service, as previously described (Cooke *et al*., 1997). Isolates were derived by bulking together the sporangia obtained from all foliage samples within a single crop and initially maintained on detached glasshouse-grown potato leaflets (Cooke, 1986). After phenylamide resistance testing, isolates were transferred into axenic culture by plating leaf pieces onto rye agar (Caten & Jinks, 1968 as modified by Carlisle, 1999) supplemented with rifampicin (25 mg l^{-1}) and natamycin (25 mg l^{-1}). Mating type was then determined. At the end of each season, Inspectors provided estimates of fungicide usage for all seed potato crops in their areas.

Detailed sampling of selected potato crops, 1998-99

On 20 August 1998, 20 leaves with single lesions were collected from a crop of the maincrop cv. Kerr's Pink with *c*. 1% foliage blight infection growing at Eglinton, Co. Londonderry.

In 1999, 25 leaves with single lesions were collected from each of three crops, as follows:

Crop 1:	cv. Pentland Dell, Killough. Co. Down, treated with mancozeb, sampled 28 July, *c*. 1% foliage infection
Crop 2:	cv. Désirée, Kilkeel, Co. Down, treated with mancozeb and propamocarb + chlorothalonil, sampled 23 July, *c*. 25% foliage infection

Crop 3: cv. British Queen, Ballymena, Co. Antrim, treated with mancozeb and dimethomorph + mancozeb, sampled 26 July, *c*. 50% foliage infection

Isolates derived from lesions were initially maintained on detached glasshouse-grown potato leaflets (Cooke, 1986). At this stage, isolates from the three 1999 crops were tested for phenylamide resistance (the 1998 single-lesion isolates were tested only for mating type). Subsequently, isolates were transferred into axenic culture as above.

Tests for phenylamide resistance

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

Mating type determination

Mating types were determined by pairing an agar culture of each isolate with reference A1 and A2 isolates on either clarified rye agar (after Caten & Jinks, 1968) or carrot agar (Erselius & Shaw, 1982). Paired cultures were incubated in the dark at 15-20°C for 7-21 days and checked microscopically for the presence of oospores in the contact zones between the unknown and reference isolates.

Glucose-6-phosphate isomerase allozyme genotype determination

Gpi genotype was determined by cellulose acetate electrophoresis (Goodwin *et al*., 1995) using tissue extracts prepared from fungal mycelium grown on antibiotic pea or rye agar plates (Carlisle, 1999).

Results

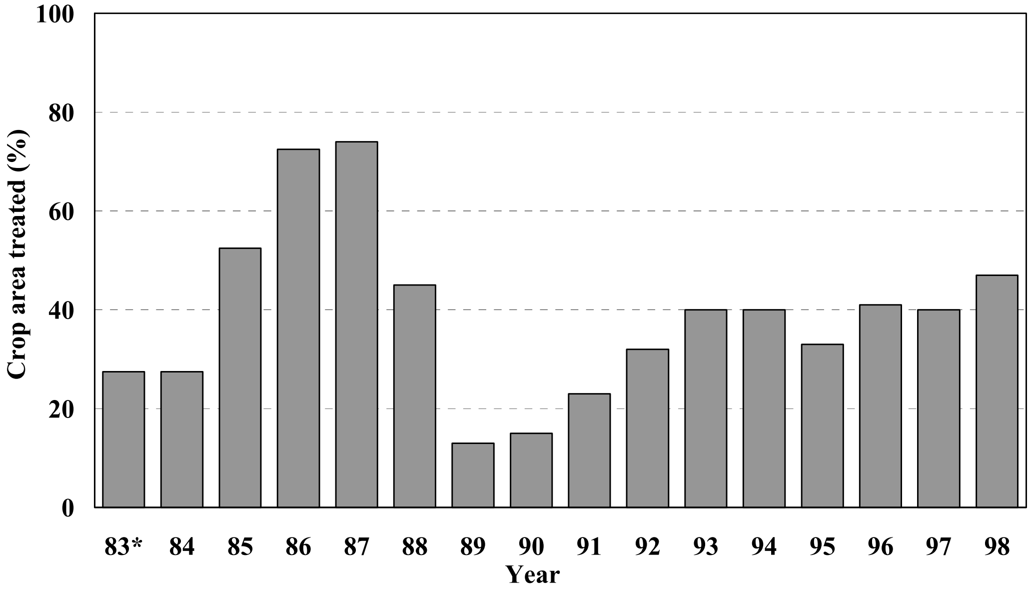
Fungicide usage on seed potato crops

Potato Inspectors' estimates of the types of fungicide formulation applied for most of the season on seed potato crops for 1996-98 are shown in Table 2 (1999 figures not yet available). In 1996 and 1997 over 60% of crops received mancozeb alone, but the proportion was lower in 1998 (the year most favourable to blight) with a concomitant increase in those phenylamide-treated. Fluazinam and dimethomorph, which were only introduced commercially in the UK in 1994, were both being applied to a significant proportion of the crop area by 1998.

Considering crops which had received phenylamide treatments at any time during the spray programme, 40-50% have been so treated in recent years (Fig. 1; 1999 data not yet available). However, most of these crops received only one or two phenylamide applications (Table 3).

Table 2. Fungicide usage on seed potato crops for most of the season.

Fungicide type		Year	
	1996	1997	1998
mancozeb alone	61	60	47
phenylamide	14	12	20
dimethomorph	6	8	14
fluazinam	16	19	16
other	3	1	3



* no data available for 1981, 1982

Figure 1. The proportion of Northern Ireland seed potato crops treated with phenylamides, 1983-1998.

Table 3. Number of applications used by seed potato growers applying phenylamides, 1996-1998.

Number of phenylamide applications	Of growers using phenylamides (%) 1996	1997	1998
one	17	22	17
two	36	44	42
three	24	15	22
four	9	8	10
five +	14	11	9
% growers using phenylamides	50	60	74

Incidence of phenylamide resistance

The overall proportion of isolates containing phenylamide-resistant strains of *P. infestans* for the years 1981-1999 is shown in Fig. 2. From 1989 to 1996 the proportion declined in every year (except 1992) reaching 27% in 1996. In 1997, the proportion increased to 47%, but for the last three years it has remained relatively stable at between 44 and 49% despite conditions very favourable to blight. In each year, a greater percentage of phenylamide-resistant isolates was obtained from the northern Counties (Antrim, Londonderry and Tyrone) than from Co. Down (data not presented). In 1999, in contrast to previous years, four isolates with intermediate sensitivity to phenylamides were detected. These were re-tested on several occasions and consistently grew on 2 mg, but not on 100 mg metalaxyl l^{-1}-treated discs.

As before, when product usage on sampled crops was examined, those which had received phenylamide applications tended to yield a greater proportion of isolates containing resistant strains, but even crops where no phenylamide had been applied often yielded resistant strains (Table 4). Blight samples were obtained from phenylamide-treated crops rather less frequently than would have been expected on the basis of the crop area treated with these products (Figure 1).

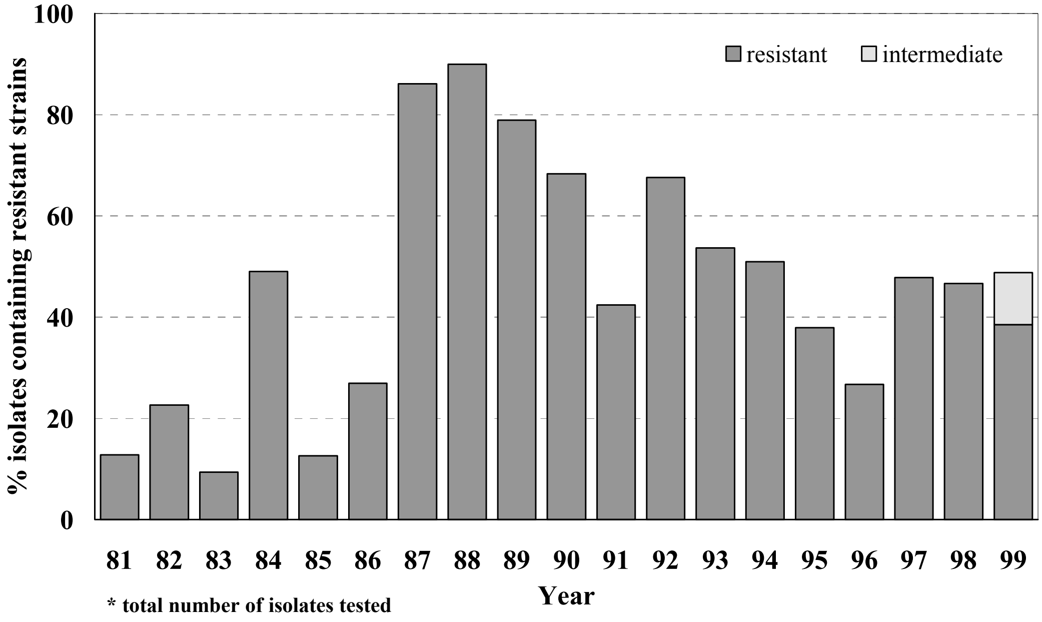


Figure 2. The proportion of Northern Ireland Phytophthora infestans isolates containing phenylamide-resistant strains, 1981-1999.

Table 4. Fungicide usage on potato crops sampled for phenylamide resistance survey, 1997-1999.

Crop treatment	% crops with resistant strains (number of crops)		
	1997	1998	1999
phenylamide	69 (13)	67 (18)	83 (12)
no phenylamide	39 (31)	39 (38)	31 (26)
all crops*	47 (46)	44 (58)	49 (39)

* includes crops where fungicide usage is not known

Although none of the three crops sampled in detail in 1999 had been treated with a phenylamide fungicide (see Materials & Methods), all of the 25 single-lesion isolates obtained from Crop 1 proved to be phenylamide-resistant. From Crop 2, 24 single-lesion isolates were established, of these 23 were phenylamide-sensitive and one was phenylamide-resistant (4% phenylamide-resistant). Crop 3 yielded 22 isolates and all of these were phenylamide-sensitive.

Mating type and Gpi genotype

Mating type was determined for 143 multiple-lesion *P. infestans* isolates collected for the phenylamide resistance survey during the period 1996-1999. All of these isolates proved to be of the A1 mating type (Table 5). Nineteen isolates were obtained from the 20 single-lesion samples collected from one crop of cv. Kerr's Pink in 1998. These were also all of the A1 mating type.

Some 46 of the 71 isolates obtained from the three crops sampled in detail in 1999 were successfully isolated into axenic culture and tested for mating type. The phenylamide-resistant isolates from Crop 1 proved reluctant to grow on agar media even when supplemented with metalaxyl. Eight isolates were successfully tested from Crop 1, 19 from Crop 2 and 19 from Crop 3. All proved to be of the A1 mating type.

Gpi genotype was determined for the single-lesion isolates collected in 1999. Eight isolates from Crop 1, 24 isolates from Crop 2 and 18 isolates from Crop 3 were all found to be *Gpi 100/100*.

Table 5. Mating type of multiple and single lesion isolates, 1996-1999.

Year	Number of isolates			
	multiple lesion		single lesion	
	A1	A2	A1	A2
1996	42	0	0	0
1997	19	0	0	0
1998	44	0	19	0
1999	38	0	46	0
Total	143	0	65	0

Discussion

Despite several seasons conducive to late blight and continuing usage of phenylamide fungicides, the percentage of Northern Ireland isolates of *P. infestans* containing resistant strains has remained under 50%. Although the percentage of resistant isolates obtained from phenylamide-treated crops was greater, phenylamide-treated crops were proportionately under-represented in the survey suggesting that blight was often well-controlled in such crops. The pattern of phenylamide usage (three or fewer applications per season early in the spray programme) helps to limit the build-up of resistant strains, but many growers also now make extensive use of non-phenylamide fungicides such as dimethomorph and fluazinam. The identification of four phenylamide-intermediate isolates in 1999 was unexpected, since intermediates have rarely been found among Northern Ireland *P. infestans* isolates. These isolates could be mixtures of resistant and sensitive strains, they could be heterozygous for resistance or they might carry a different mutation from that conferring high level resistance.

Significant levels of sexual recombination are unlikely within the present Northern Ireland *P. infestans* population, since no A2 isolates were detected. In addition, to the 143 multiple-lesion and 65 single-lesion isolates reported here, a further 143 single-lesion isolates collected in 1996 as part of a population study were also all A1 (Carlisle, 1999). Indeed, no A2 mating type isolates have been found in Northern Ireland since 1995 when a single A2 isolate was found. If the A2 mating type is still present, it must be at a very low level and very detailed sampling would be needed to detect it. As well as being homogeneous for mating type, the 50 single lesion isolates tested in 1999 also proved to be homogeneous for *Gpi* genotype (all *100/100*). These observations tend to support the view that the present *P. infestans* population in Northern Ireland is relatively stable.

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Structure of *Phytophthora infestans* populations orginating from potato leaves and stems

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Summary

In some region of Poland changes in the occurence of late blight symptoms have been noted. Observations of potato crops showed that occurence of the first potato late blight symptoms is sometimes on stems instead on leaves. In laboratory conditions 10 pairs of 1-spore of *Phytophthora infestans* isolates orginating from leaves and stems from different potato cultivars were compared for for phenotypic and genotypic diversity. Potato late blight starting on leaves and stems is caused by the same species Phytophthora infestans although similarities of phenotipic characteristics (race complexity, nutrive, temperature and light requirements, mating types, phenyloamide sensivity) and better adaptation of stem isolates to unfavourable conditions confirm that leaf and stem populations belong to different physiological races.

Keywords: *Phytophthora infestans,* stem and leaf form of late blight

Introduction

Late bligh, caused by the fungus *Phytophthora infestans*, is an important disease of potato and tomato. Today, late blight is found in nearly all areas of the world where potatoes are grown. The 1970s migration indicated that significant changes were occuring within P.infestans populations in Europe. Analyses indicated that the lineage of P.infestans present in Europe prior to the migrations was being displaced by new immigrant genotypes (Spielman et al.1991; Sujkowski et al.1994). The results of changes are: early infections of late blight, higher disease severity in seasons, more frequent breakdown of potato and tomato cultivar resistance, presence of more aggressive and virulent pathotypes of the fungus, appearance of untypical symptoms on plants.

The fungus infects leaves, stems and tubers of the potato throughout the growing season. The first symptoms of the disease are generally observed on the leaflets and the petioles. In humidity conditions late blight develops very intensivly, destroying leaves, later stems and at last whole plants. Dry and hot air temperature during growing season, stops very often development of typical late blight generally.

In some regions of Poland a change in the occurrence of the first potato late blight symptoms has been noted. The first symptoms of the disease were confined to stems. Infections of leaves is the next step of the disease development. Stem lesions appear as oily, brown areas that later turn black. In case of this form of late blight there was not observed general inhibition of the disease at higher air temperatures but only stopping it temporarily (Clayson, Robertson 1956). When weather conditions became better for the disease, late blight develops again epidemic (Bain et al. 1996).

Material and methods

Isolates of *Phytophthora infestans* were collected from potato crops at Bonin during the growing season 1996. Isolates were obtained from ten different potato cultivars: Aldona, Atol, Frezja, Gloria, Jaśmin, Mila, Morene, Ponto, Tarpan and Van Gogh. They were orginated from leaf lesions (L-isolates) and stem lesions (S-isolates). Infected leaf tissue and infected stem pieces were placed under a thin slice of potato tubers. The fungus grew through the potato to the surface and sporangia were removed and placed onto rye extract agar plates. In laboratory conditions, 10 pairs of 1-spore leaf and stem isolates, orginating from the same cultivars, were characterized and compared for virulence race composition, mating type, metalaxyl sensivity, nutritive, temperature, light requirements and genetic diversity.

1. Comparision of race structure and diversity in leaf and stem populations

Virulence and race composition was determined using a host set of 11 potato line differentials. Each line contained one of the R_1 to R_{11} race specific resistance genes (except R_9) against *Ph.infestans* and cv. Bintje as r genotype (Black et al.1953).

Identification of races was made according to the phenotypic reaction of artificially-inoculated leaflets of differential plants. After 6 days, virulence reactions were scored. Race diversity was estimated using Gleason index, calculated as:

$$H_G = (N_p - 1) / \ln N_i$$

where: N_i - number of isolates in the sample, N_p - is the number of races identified among these isolates, (Groth, Roelfs 1987). The Gleason index is particulary sensitive to the richness aspect of diversity (*i.e.*, the number of different races in the sample).

2. Mating types

Mating type was determined by inoculating a mycelial plug (5 mm diam.) of the appropriate test isolate on a Petri dish containing rye agar, equidistant a similar plugs of a reference A1 and A2 isolates (Caten, Links 1968). Cultures were incubated at 15^0C and checked microscopically after two weeks for the presence of oospores in the zone of contact between the two colonies.

3. Phenylamide sensivity

Phenyloamide sensivity of *Ph.infestans* isolates was tested using a floating leaf disc methods (Davidse et al.1981). After 7 days the sporulation was rated visually as % infected leaf area compared to the control and the disease severity index was calculated for scoring reaction.

4. Nutrive, temperature and light requirements

Two pairs of single sporangia leaf and stem isolates were cultured in Petri dishes on two different media: rye extract agar and potato-glucose agar, at three temperatures: 10, 17 and 25^0C to give an information about their nutrive and temperature requirements. Additionally, the isolates kept at 17^0C were maintained in the darkness or under a 12 h light/dark regime on rye extract agar. Mycelium growth of colonies was measured each 3 days, giving information about rate of the isolate developments. To compare the isolate pairs, radial growth of mycelium and sporulation density for each isolate were measured after 21 days.

5. Genotypic diversity

Preliminary studies of genotypic diversity were carried out using molecular PCR method. DNA was prepared from Ph.infestans isolates using the CTAB method (Trout C.L. et al.1997). Twelve leaf and stem isolates were analysed using intermicrosatellite amplification with two 5'-anchored repeat primers **AC** and **AG** (AC - 5' GCG CAC ACA CAC ACA CAC AC; AG - 5' CCG GAG AGA GAG AGA GAG AG). These anchored primers were chosen because of their good possibility to differential potential (Provan J. et al.1996).

Results and discussion

1. Comparision of race structure and diversity in leaf and stem populations.

Eight different physiological races were identified among 20 leaf and stem isolates of Ph.infestans (tab.1). All races were rather complex races, having 5-10 virulence genes. Comparison of race structure in leaf and stem populations showed that complex races were more common among both compared populations. Five pairs of tested isolates (from cultivars Atol, Frezja, Gloria, Mila and Morene) posessed the same virulence characteristics. The rest of pairs differed varied by 1-3 virulence genes.

Table 1. Race structure and diversity of *Phytophthora infestans* isolates orginating from leaves (L) and stems (S) of various potato cultivars.

Lp.	Isolate orginating	Race composition	Number of virulence genes per isolate	Mating type
1.	**L** $_{\text{Aldona}}$	1.2.3.4.5.6.7.8.10.11	10	**A** $_1$
	L $_{\text{Aldona}}$	1.2.3.4.6.7.8.10.11	9	**A** $_1$
2.	**L** $_{\text{Atol}}$	1.3.4.7.10.11	6	**A** $_1$
	L $_{\text{Atol}}$	1.3.4.7.10.11	6	**A** $_1$
3.	**L** $_{\text{Frezja}}$	1.2.3.4.5.6.7.8.10.11	10	**A** $_1$
	L $_{\text{Frezja}}$	1.2.3.4.5.6.7.8.10.11	10	**A** $_1$
4.	**L** $_{\text{Gloria}}$	1.2.3.4.5.6.7.8.10.11	10	**A** $_2$
	L $_{\text{Gloria}}$	1.2.3.4.5.6.7.8.10.11	10	**A** $_2$
5.	**L** $_{\text{Jaśmin}}$	1.2.3.4.5.6.7.10.11	9	**A** $_1$
	L $_{\text{Jaśmin}}$	1.3.4.7.10.11	6	**A** $_1$
6.	**L** $_{\text{Mila}}$	1.2.3.4.6.7.8.10.11	9	**A** $_2$
	L $_{\text{Mila}}$	1.2.3.4.6.7.8.10.11	9	**A** $_2$
7.	**L** $_{\text{Morene}}$	1.2.3.4.5.7.11	7	**A** $_2$
	L $_{\text{Morene}}$	1.2.3.4.5.7.11	7	**A** $_2$
8.	**L** $_{\text{Ponto}}$	1.3.4.6.10.11	6	**A** $_1$
	L $_{\text{Ponto}}$	1.3.4.7.8.10.11	7	**A** $_1$
9.	**L** $_{\text{Tarpan}}$	3.4.8.10.11	5	**A** $_1$
	L $_{\text{Tarpan}}$	1.3.4.7.10.11	6	**A** $_1$
10.	**L** $_{\text{V.Gogh}}$	1.3.4.7.8.10.11	7	**A** $_1$
	L $_{\text{V.Gogh}}$	1.2.3.4.6.7.8.10.11	9	**A** $_1$

Virulence genes 3, 4 and 11 were the most common in both isolate populations and 5 and 6 the least common. Genes 9 was absent in all isolates.

Race diversity was estimated using Gleason index. There was found higher race diversity among leaf isolates compared to isolates orginating from stems: H_G for leaf isolates was -3,04 and for stem isolates was -1,74.

2. Mating types

All pairs of the isolates from the same cultivar were of the same mating type. Seven of them were A1 and three were A2 (tab.1). A2 mating type isolates were detected in Poland each year since 80s (Sujkowski et al. 1994) but their frequancy varied in years (Zarzycka, Sobkowiak 1997a, 1997b).

3. Phenylamide sensivity

All tested leaf and stem isolates were sensitive to phenylamides (metalaxyl). The isolate obtained from stem of cultivars VanGogh showed tendency to lower sensivity to metalaksyl, but finally it was joined to sensitive group of isolates also. Among twenty tested isolates there was not any resistant one.

4. Nutrive, temperature and light requirements

For both kinds of isolates (from leaves and stems) rye agar medium was more favourable for growth and sporulation intensity. Mycelium of both groups of isolates grew most rapidly at 17^0C, more slowly at 10^0C and growth rate was lowest at 25^0C (tab.2). There were not observed any significant growth differences between leaf and stem isolates.

Isolates of both groups sporulated most intensively at 17^0C and very fine at 10^0C (tab.2). Sporulation of leaf isolates was stopped at 25^0C completly. At this temperature we observed sporulation of stem isolates. It gave information about better adaptation of stem isolates to unfavourable conditions.

Table 2. Influence of various medium and temperatures on the development of leaf and stem isolates of *Ph. infestans*.

Criterion of isolate development	Orginating of isolates	Rye extract agar			Potato-glucose agar		
		25^0	**17^0**	**10^0**	**25^0**	**17^0**	**10^0**
Radial growth of mycelium	L $_{\text{Tarpan}}$	30,7	68,5	61,9	19,1	31,6	48,1
	S $_{\text{Tarpan}}$	32,7	77,3	65,2	19,8	45,9	39,4
after 21 days (mm)	L $_{\text{V.Gogh}}$	27,3	75,7	66,4	24,0	16,3	23,3
	S $_{\text{V.Gogh}}$	33,0	78,1	68,3	26,7	23,9	11,1
Mean for:	**Leaf isol.**	**29,0**	**72,1**	**64,2**	**21,6**	**24,0**	**35,7**
	Stem isol.	**32,9**	**77,7**	**66,8**	**23,3**	**34,9**	**25,3**
	L $_{\text{Tarpan}}$	0,71	2,28	0,71	0,71	1,22	0,71
Sporulation density	S $_{\text{Tarpan}}$	2,00	5,51	1,18	0,89	4,14	0,71
(transformation of data	L $_{\text{V.Gogh}}$	0,71	5,15	1,00	0,71	4,53	0,95
$y= x+0,5$)	S $_{\text{V.Gogh}}$	2,39	6,37	1,18	0,71	4,79	0,71
Mean for:	**Leaf isol.**	**0,71**	**3,72**	**0,86**	**0,71**	**2,88**	**0,83**
	Stem isol.	**2,20**	**5,94**	**1,18**	**0,80**	**4,47**	**0,71**

In laboratory condition, we observed that present or absence of light did not influent significantly on sporulation density of both groups of isolates and on linear mycelium growth of leaf isolates (tab.3). Stem isolates grew significantly better at darkness. It showed again better adaptation of them to natural conditions.

Table 3. Effect of illumination on linear mycelium growth and sporulation density (Rye extract agar, temperature 17^0C).

Isolate	Light conditions	Mycelium diameter /mm/	Sporulation density (transformation of data $y= x+0,5$)
leaf isolates	light	68,1	11,89
	darkness	75,2	10,97
stem isolates	light	66,6	9,26
	darkness	81,1	8,44
LSD		9,1	no significant

5. Genotypic diversity

Using the two primers described above, a total of 6 polymorphic bands were obtained, differing of their lenghtways. Presence-absence of a band was taken as differential criterion also.

The DNA banding patterns produced from the thirteen Ph.infestans isolates showed a high level of polymorphisms between leaf and stem isolates in pairs. Only pair of isolates obtained from cultivar Van Gogh showed the same DNA banding pattern. The same polymorphis among leaf isolates and stem isolates orginating from various cultivars was observed . It showed genetic diversity between isolates in pairs but also among isolates from the same plant organs. This information need confirming in the next studies.

Conclusions

1. After microscope studies species *Phytophthora infestans* (Mont.) de Bary had been identified as the cause of late blight started on potato leaves and stems. Isolates of *Ph.infestans* from leaves and stems had not been different morphologically.
2. On base of observed polymorphisms between leaf and stem isolates in pairs, the same polymorphis among leaf isolates and stem isolates orginating from various cultivars and similarities of their phenotipic characteristics we can concluded most probably, that population of *Ph.infestans* is not composed of „stem" and „leaf" genotypes.
3. Similarities of phenotipic characteristics (race complexity, nutrive, temperature and light requirements, mating types, phenylamide sensivity) and better adaptation of stem isolates to unfavourable conditions confirm that leaf and stem populations belong to different physiological races.

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Genetic structure of the late blight population in Belgium

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Abstract

Isolates of *Phytophthora infestans* were collected randomly from blighted potato plants in the Flanders during the summer of 1998. The Belgian population consisted of both mating types A1 and A2. The fact that metalaxyl-resistance is a selectable marker, strongly affected by fungicide use, was clear in this collection. Metalaxyl-resistant isolates accounted for 65 % of the individuals tested. For the allozyme *Gpi* only the 100/100 genotype was observed, and the dominating banding pattern for *Pep* was 100/100. DNA fingerprinting patterns revealed high genetic diversity: among 33 isolates tested 9 genotypes were distinguished. The present study indicated that some genotypes (39 %) were distributed to several locations, whereas others (15 %) may be unique to a single site.

Key words: late blight, *Phytophthora infestans*, mating type, metalaxyl-resistance, *Gpi*, *Pep*, DNA fingerprints

Introduction

The last years, there is a high rate of blight infection in Western Europe. The disease is becoming more aggressive and therefore the application of good control measures is very important. Spraying fungicides alone is not sufficient, but fungicides still play a very important part in controlling the disease. Another important aspect of the struggle against late blight is choosing the right potato varieties. Different varieties are susceptible to late blight to different extents. To establish the most effective control strategy for late blight, we need to know much more about dispersal and genetic variation in local populations of

Phytophthora infestans. In recent years also in Belgium high infection rates were already observed at the beginning of the potato growth season. This was partly due to the wheather conditions: wet springs and mild winters, but it was also due to the more aggressive behaviour of the fungus. The warning systems have to be adjusted to a fitter population of *Phytophthora infestans*. Due to a fitter population the disease can develop more quickly in time. Furthermore, the fungus can produce more spores so there is a greater risk of spreading the disease more quickly. Besides the spores are more effective which implies more efficient infection. For all these reasons, we started in 1998 with the investigation of the genetic variation in local populations of *Phytophthora infestans* at our institute. The characterization of isolates relied on a series of phenotypic and genetic markers: determination of the mating type, investigation of metalaxyl-resistance, identification of the allozyme alleles of *Gpi* and *Pep*, and studying DNA fingerprinting patterns.

Material and Methods

Blighted plant material was collected randomly in the Flanders from July till September in 1998. Not all isolates were analyzed for all markers, so sample sizes differ for each marker.

Isolations were carried out from typical lesions on leaves, stems and tubers onto selective pea broth agar amended wit 500 ppm ampicillin, 10 ppm rifampicin and 10 ppm pimaricin. After isolation into pure culture, isolates were kept on pea broth agar at 18 °C in the dark and routinely maintained.

Mating type was determined by pairing the Belgian isolates individually with isolates of known mating type on separate 90 mm plates of 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 was determined by inoculating a hyphal plug of *Pythophthora infestans* isolates onto pea broth agar amended with 0.1, 1, 10 and 100 ppm metalaxyl (Ridomil 5G, 7217/B). Plates were incubated at 18 °C in the dark and after 5 to 10 days colony diameters were measured.

Isolates were analyzed with DNA probe RG57 as described by Goodwin et al. (1992). Total genomic DNA was digested with the restriction enzyme *Eco*RI and probed with digoxygenin-labelled RG57. Polymorphism in the restriction patterns was revealed using either colorimetric and chemiluminescent detection. Probe RG57 which hybridizes to 25 different nuclear DNA fragments, represents a moderately repetitive nuclear sequence of 1.2 kb. Each fragment was assumed to represent a single genetic locus and of the hybridizing fragments, 13 are known to segregate indepently. Each DNA fingerprint locus was scored for either the presence or absence of a band. When comparing fingerprint patterns among isolates, band 4 was omitted for genotype identification because the band was inconsistent.

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 unkown isolates were determined by compairing their banding patterns with those of proper controls.

Results and Discussion

Both A1 and A2 mating types were present among the Belgian isolates: 83 % of the isolates was characterized as A1 and 17 % as A2 (n = 48). A comparable proportion of A1/A2 was also found in the Netherlands (Fry et al. 1991) and Poland (Sujkowski et al. 1994). In France only 3 % of the isolates represented the mating type A2 in 1996 (Lebreton et al. 1998) and in 1998 no A2 mating type was found. The two mating types did not occur in a 1:1 ratio but this observation does not exclude the possibility of sexual reproduction. Sexual reproduction results in the formation of oospores which can survive in the soil for a considerable length of time, without any potato tubers being present. This is a major difference with respect to the past. When the fungus reproduced vegetatively it needed refuse heaps or blighted seed potatoes to survive. Oospores may be a source of inoculum. But at the moment we don’t have answers to the questions: when are oospores produced? or what are the conditions for germination and infection?

Metalaxyl-resistant isolates accounted for 65 % of the individuals tested (n = 40). The high amount of metalaxyl-resistant isolates can be explained by the moment of collecting the blighted plant material. This was rather late in the season and the potato plants were already treated several times with metalaxyl. However, the proportion of metalaxyl-resistant isolates was similar in commercial fields compared to private gardens. In most cases the proportion of metalaxyl- resistant isolates is higher in commercial fields, where the fungicide is widely used. Also in France and in the Netherlands metalaxyl-resistant isolates were found (Lebreton et al. 1998, Fry et al. 1991). Isolates exhibiting an intermediate response to metalaxyl were also detected: they accounted for 8 %. Furthermore, we observed an association between the A1 mating type and metalaxyl-resistance. A similar correlation has been reported in Poland (Ritch et al. 1991) and Eastern Germany (Daggett et al. 1993). A possible explanation for this observation may be that the resistance allele existed in the old population and that more judicious use of metalaxyl since the reported occurence of resistance at the beginning of the 1980s, has limited an increase of the resistance allele among A2 isolates.

All the 31 isolates tested, showed allozyme genotype 100/100 for *Gpi*. For *Pep* 3 alleles were found: 83, 96 and 100. But the widely appearing allozyme genotype for *Pep* was 100/100. For *Gpi* 2 alleles were identified in France (Lebreton et al. 1998) and in the Netherlands (Fry et al. 1991): 90 and 100. And in Poland even 3 alleles were distinuished: 86, 90 and 100 (Sujkowski et al. 1994). For *Pep* 2 alleles were identified in France (Lebreton et al. 1998) and in the Netherlands (Fry et al. 1991): 83 and 100. And in Poland even 5 alleles were identified: 83, 92, 96 and 100 (Sujkowski et al. 1994).

Nine different RG57 fingerprints were observed among 33 Belgian isolates differing from one another by 4 to 11 RFLP loci. DNA fingerprinting patterns revealed more diversity than the other markers tested. However allozyme uniformity does not necessarily imply lack of genetic diversity. 39 % of the isolates had the most widely distributed genotype and 15 % of the samples which had a unique genotype was detected at only one location. In France 9 genotypes were identified among 74 isolates (Lebreton et al. 1998). In the Netherlands 35 genotypes were distinguished among 153 isolates (Fry et al. 1991) and in Poland 62 genotypes were identified among 189 isolates (Sujkowski et al. 1994). The most widely distributed DNA patterns in Belgium, the Netherlands and Poland differed from one another by only 3 to 4 RFLP loci.

Combining all the markers of the tested Belgian isolates (n=19) revealed the appearance of 11 unique genotypes indicating the high genetic diversity of *Phytophthora infestans* populations in Belgium.

Conclusion

Since the beginning of the 1980s a new population of *Phytophthora infestans* has been introduced and displaced the original population not only in Belgium and Europe but world-wide. A comparable proportion of A1/A2 was found in Belgian as well as in the Netherlands, on the contrary only few isolates were characterized as A2 in France. Furthermore, metalaxyl-resistant isolates were found in these three countries. However, the Belgian population differed from the French and Dutch population in allozyme profile: among Belgian isolates only the 100/100 genotype was found for both *Gpi* and *Pep* whereas in the Netherlands and France 2 alleles were identified for both *Gpi* and *Pep*, respectively 90, 100 and 83, 100. DNA fingerprinting patterns revealed high genetic diversity: an average variation of 25 % was observed in Belgian and in the Netherlands, however in France this was only 12 %.

Now that both mating types are present sexual reproduction can occur and the *Phytophthora infestans* population becomes increasingly fitter. Oospore formation is probably the most important change in the disease epidemiology. Sexual reproduction increases the genetic variation in population and oospores themselves provide a new soil born source of inoculum.To establish the most effective control strategy for late blight cultivar resistances and fungicides effective against the old population should be evaluated against the new more aggressive population. And also good agricultural practices, such as covering refuse heaps and spraying volunteer plants grown from tubers left in the soil after harvest, can help to control the disease.

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Prophy advice system (PC-Fax-Internet): Backgrounds and present situation

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Summary

ProPhy is an advice system for Phytophthora control, developed and dedicated for on-farm use. The main component concerns the weather conditions: micro-climate measurements by weatherstations and a regional weather forecasts. Submodels are incorporated to calculate daily Phytophthora danger and disease pressure. A second component calculates the protection status of the previous spraying by taking all relevant circumstances in account, e.g. chemical type, dosage, susceptibility of the variety, disease pressure, wash off by rain or irrigation, crop growth and development. The combination of infectious weather and an unprotected crop leads to the spraying advice: whether to apply a spraying or not, chemical type, dosage. The article describes the ProPhy system in its different forms (PC program, fax and Internet program) and gives some results of deskresearch on the influence of weather forecasts and spraying conditions.

Key words: *Phytophthora infestans*, Potato late blight, ProPhy, Internet, Decision support system

Introduction

The ProPhy advice system had its initial development about 10 years ago. Years of research, field trials and practical experience have made the ProPhy system into a complete, reliable and user-friendly instrument for controlling *Phytophthora infestans*.

Almost 1500 farmers in The Netherlands use ProPhy by means of the PC-program, by fax or through Internet.

ProPhy model

The underlying model has 4 main components:

- Weather
- Protection
- Advice
- Explanation & backgrounds

Weather

Obviously, the main component of ProPhy is the module that predicts Phytophthora development from the weather conditions. The model uses weatherstation measurements (hourly data) as well as the weather forecast (if available). In The Netherlands there is now an “Open Meteo Network” in which over 120 agrometeorological weatherstations are included. The network enables each Dutch potato grower to use a local weatherstation at a maximum distance of 10-15 km..Opticrop records all data hourly into a central database. Datafiles holding weatherstation and forecast data are distributed to the farmers by electronic mailboxes or through an Internet fileserver. Whenever a ProPhy PC-program is consulted, the weatherdata is updated by modem. This way, the farmers always have access to up-to-date measurements (max. 1 hour delay) and the latest regional weatherforecast. The standard fee for farmers using weatherstation data from the network is Dfl. 175,= per year per weatherstation.

Three different organisations in The Netherlands each offer an agricultural weatherforecast for 20-40 regions in the country with 3-hourly data for up to 5 days ahead. The farmers pay around Dfl. 200,= per year for these data including radar pictures of rainfall.

ProPhy uses the weatherdata to calculate:

- Phytophthora danger per day (yes or no)

- Daily Phytophthora index (0-100), representing daily degree of danger
- Phytophthora disease pressure (0-100), as a rolling average over the last 10 days
- Wash-off
- Spraying conditions

Protection

The model makes a field-specific calculation of the protection period of the last spraying:

Standard protection of the last used chemical(s)

+	Dosage factor	dosage
+	Variety factor	susceptibility of varieties
+	Disease pressure factor	disease pressure
+	Wash off factor	wash off by rain and/or irrigation
+	Crop factor	foliage growth and development

The result is the protection period in days: “the number of days this particular field is sufficiently protected by the last spraying given the present situation of crop, weather and disease”. All factors are expressed in days (+/-), to offer the farmer a clear insight in the model.

Advice

Although the advice model is quite complicated, the general basis for the advice is simple: a spraying is recommended as soon as dangerous weather conditions (will) occur on a non-protected crop. An advice always consists of the following components:

- Advice title (for example: “apply the next preventive spraying as soon as possible”)
- Textual explanation of the advice (situation and backgrounds)
- Calculation of the protection period including all factors
- Weather conditions (danger, disease pressure, rainfall, temperatures)
- Information on chemical types
- Dosage indication

The chemical type (preventive, translaminar, systemic) is advised to fit the present situation.

Even if the advice is to postpone treatment, a dosage indication is given. With this facility farmers can adjust the dosage to disease pressure and/or susceptibility of the variety, rather than adjusting the spraying interval. This strategy is quite common in seed potatoes where Phytophthora control is combined with weekly application of insecticides, on large farms where a spraying takes a couple of days, or when crops are regularly irrigated.

Besides regular treatments, the ProPhy model also has rules to advise for:

- First treatment
- Phytophthora control when there is visible infection in the field itself
- Timing of haulm killing or harvest in relation to infection degree

Explanation & backgrounds

For real adaptation by farmers, it is not enough just to provide them with the right advice. It is essential that the system also gives explanation why the advice is given, and how it can be interpreted. This adds educational value to the system, and makes it easier for the farmer to include his own experience and feelings in coming to a final decision.

On the other hand, an advice system should not give an overload of information and data. In ProPhy this is solved by offering advice/information in layers. On top there is the straight forward advice. If the user wants more information, step by step one can go deeper into the explanation facilities onto the basic weatherdata itself.

Products (PC – Fax – Internet)

Different products have been developed to meet different demands. The main product is the ProPhy PC-program, offering the most information, facilities and detailed advices. It is a modern and user-friendly program with a pleasant Windows interface.

Farmers can also subscribe to a fax information service, based on the ProPhy model. The fax information is generated automatically and sent daily to the farmers at around 7 AM. On the fax page there is an overview of the weather conditions (10 days back, 2 days ahead), an advice table and the weather forecast (text). The table lists all advices for combinations of variety group (susceptibility) and period since last spraying. Influencing factors like growth rate and infection sources are not included on the fax itself, but defined centrally for each location and updated weekly.

Since 1999, the ProPhy advice can also be consulted through Internet. Looking at the facilities, it is a mixture between PC program and fax. On one hand the Internet application gives the same information as the fax service: weather conditions, advice table and forecast. Extra functions are added like selecting your own varieties, and background calculations for each cell in the advice table. On the other hand, there is a module in which the user can define his own situation (variety, growth rate, regional infection situation and time since last spraying) for which the program will calculate the advice.

Research activities

Opticrop is conducting ongoing research to improve and expand the ProPhy system:

- Contacts with national and international experts
- Field trials
- Eu.net.icp workshops

Model studies

Since 1992 lots of data has been collected to use for model study or desk research. Figure 1 shows a multi-year overview of the Phytophthora weather situation in The Netherlands. The daily disease index is accumulated from May 1st onwards. The graph is an average of 12 weatherstations in 1992 to 60 weatherstations in 1999. It gives a clear distinguish between years with very high disease pressure (1997, 1998), low disease pressure (1992, 1994, 1995) and “average” years (1993, 1996, 1999).

An important topic in research concerns the weather forecast. Since Phytophthora contral mainly means preventive treatments, it is a major advantage to have a reasonably priced, detailed, and regional forecast. However, the weather is never 100% predictable, and for that reason a lot of research has been done to minimise errors in using the forecast. Data of the 3 Eu.net.icp trial locations in 1999 were used for this study. For 75% of the days the forecast (1 day ahead) was right in comparison with the model output on measured weatherdata. On 13% of the days the forecast showed dangerous conditions, where it did not turn out to be (making the advice too “cautious”).

On another 13% of the days a “critical” error occurs: a dangerous day is not forecasted. If the crop is unprotected, this situation causes an advice to postpone treatment the day before, followed by a spraying advice on the day itself. If disease pressure is high or immediate spraying is not possible, this could mean a translaminar product (Cymoxanil).

Another aspect of research are the spraying conditions predicted from the weather forecast. If bad spraying conditions (wind, rain etc.) are expected, ProPhy can give an earlier spraying advice than strictly necessary when looking at the disease situation. On the other hand, when a number of consecutive days with bad spraying conditions occur, the farmer might not be able to follow the advice. Depending on the disease situation, this can lead to the recommendation of translaminar or systemic products. For the study, "suitable" conditions for spraying were defined as:

- Windspeed < 5 m/s (at 2 m. height)
- Dry crop
- Rain on day of spraying < 5 mm.
- Rain on day before spraying < 10 mm.
- Minimum of 4 suitable hours per day from 7 AM to 22 PM

Average results for 1998 and 1999

1999

Number of weatherstations	35	56
Length of season (days)	152	139
Days unsuitable for spraying	55	41

Percentage of days unsuitable for spraying

Total	36%	30%
Rainfall	26%	17%
Leafwetness	12%	7%
Windspeed	4%	7%

In these years 36% and 30% respectively were judged as unsuitable for spraying. In most cases, rainfall was the problematic factor. The overall result (1 out of 3 days is unsuitable for spraying) is quite important when looking at advice systems, and it means that spraying conditions is something the advice systems should incorporate.

International use of ProPhy

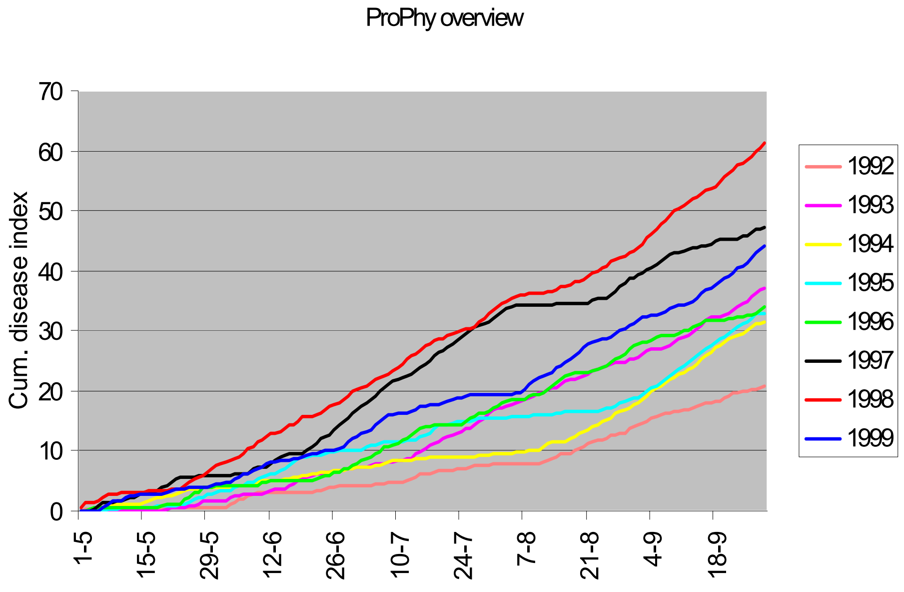
The main use of ProPhy is in The Netherlands. For trials, the system has been “translated” to other countries: language translation, national list of admitted chemicals and national list of varieties. These trials have been done within the Eu.net.icp project, but also other projects have been started. All these trials show very promising results, and prove that the ProPhy model is well able to control Phytophthora under very different circumstances. As might be expected, performance is best when conditions are similar to The Netherlands: humid climate and high disease pressure. In really dry and low-risk locations, the advice tends to be somewhat on the cautious side. Real adaption to other climates means not only translation and replacing lists, but also fitting the decision rules to the local situation.

Future developments

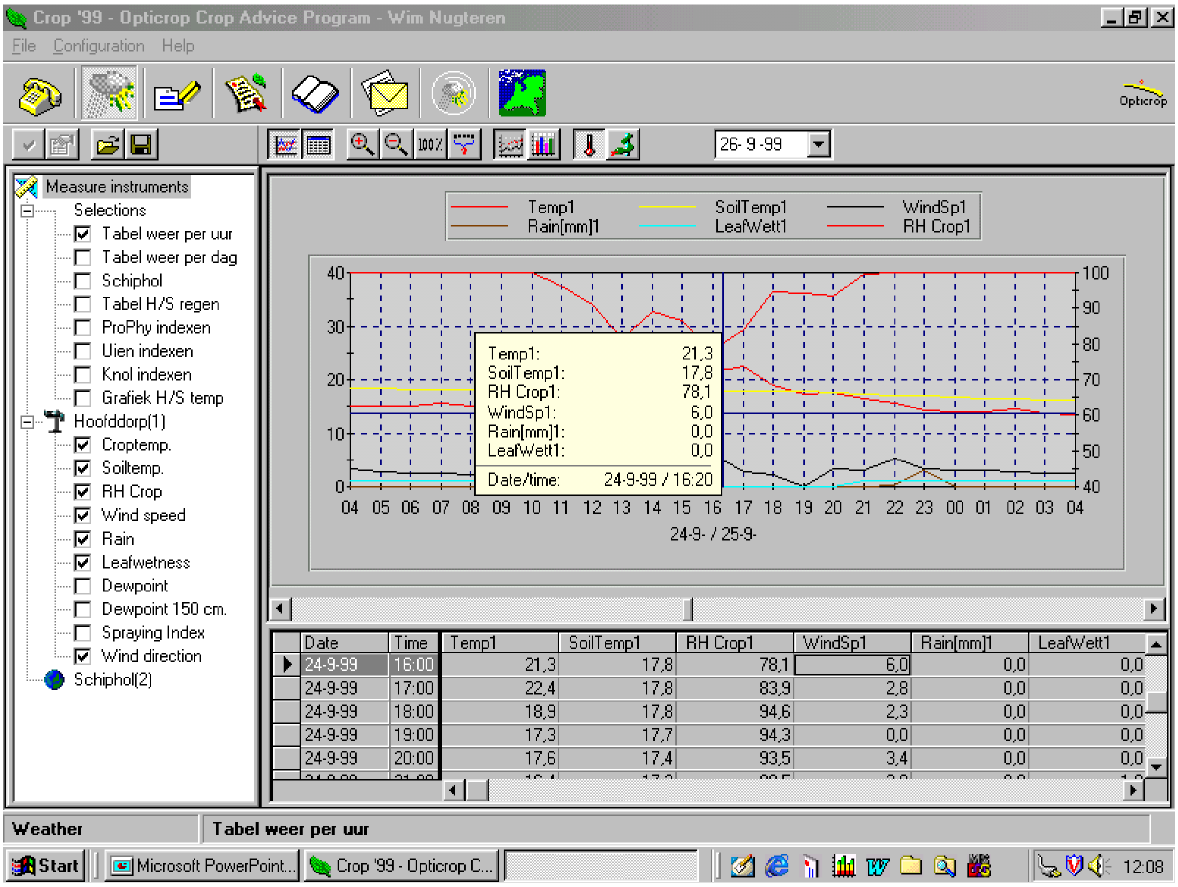
The basic model in ProPhy has proved itself and has been quite stable for years now. Farmers recognize it as a very good tool for controlling Phytophthora. However, continous research and adaptations will remain necessary. For example:

- Introduction of new chemicals and ending admission of other chemicals
- Official regulations on maximum number of sprays or maximum use of a.i.
- New resistant varieties and improved screening of present varieties
- Oospores

Technically, developments will concentrate on ProPhy through Internet. More and more functions from the PC-program will be added to the Internet application, so that it developes into a very sophisticated tool for detailed and field-specific recommendations.



1-2-00 Opticrop B.V. 1



Measure instruments
Selections
- ☑ Tabel weer per uur
- ☐ Tabel weer per dag
- ☐ Schiphol
- ☐ Tabel H/S regen
- ☐ ProPhy indexen
- ☐ Uien indexen
- ☐ Knol indexen
- ☐ Grafiek H/S temp

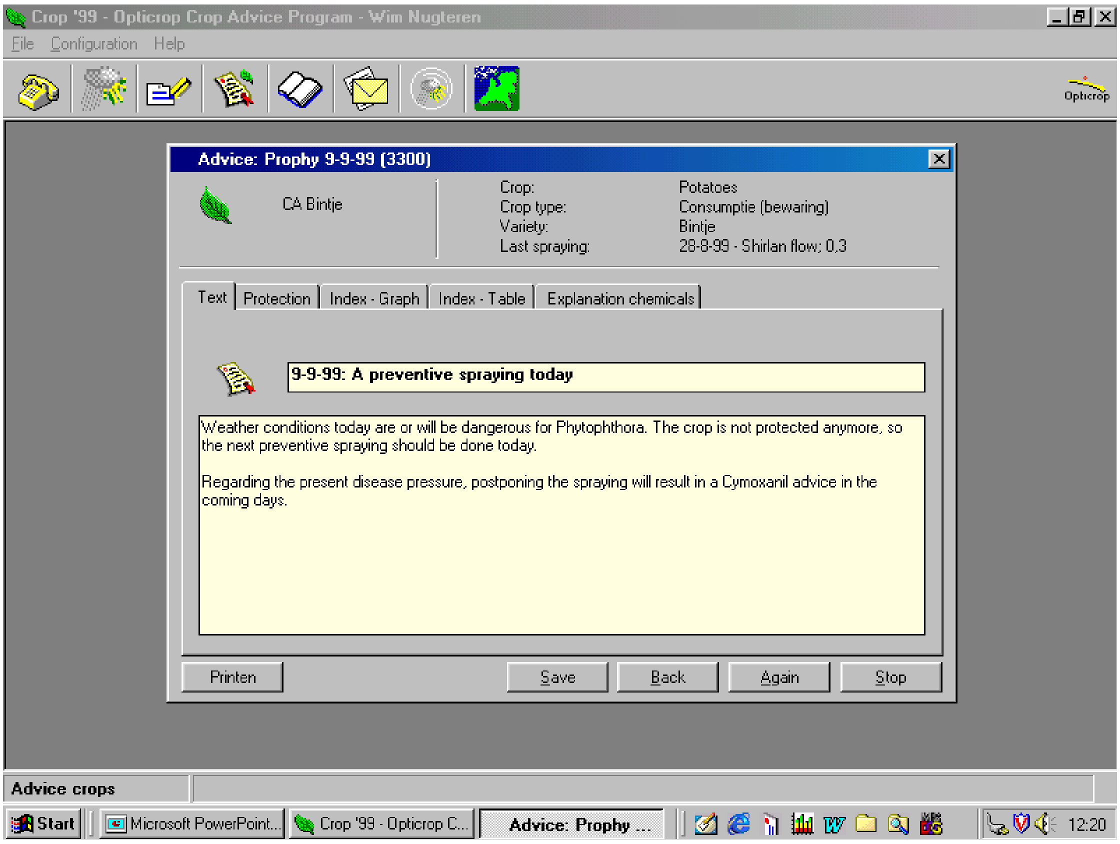
Hoofddorp(1)
- ☑ Croptemp.
- ☑ Soiltemp.
- ☑ RH Crop
- ☑ Wind speed
- ☑ Rain
- ☑ Leafwetness
- ☐ Dewpoint
- ☐ Dewpoint 150 cm.
- ☐ Spraying Index
- ☑ Wind direction

Schiphol(2)

Temp1: 21,3
SoilTemp1: 17,8
RH Crop1: 78,1
WindSp1: 6,0
Rain[mm]1: 0,0
LeafWett1: 0,0
Date/time: 24-9-99 / 16:20

Date	Time	Temp1	SoilTemp1	RH Crop1	WindSp1	Rain[mm]1	LeafWett1
24-9-99	16:00	21,3	17,8	78,1	6,0	0,0	0,0
24-9-99	17:00	22,4	17,8	83,9	2,8	0,0	0,0
24-9-99	18:00	18,9	17,8	94,6	2,3	0,0	0,0
24-9-99	19:00	17,3	17,7	94,3	0,0	0,0	0,0
24-9-99	20:00	17,6	17,4	93,5	3,4	0,0	0,0

Weather
Tabel weer per uur



Advice: Prophy 9-9-99 (3300)

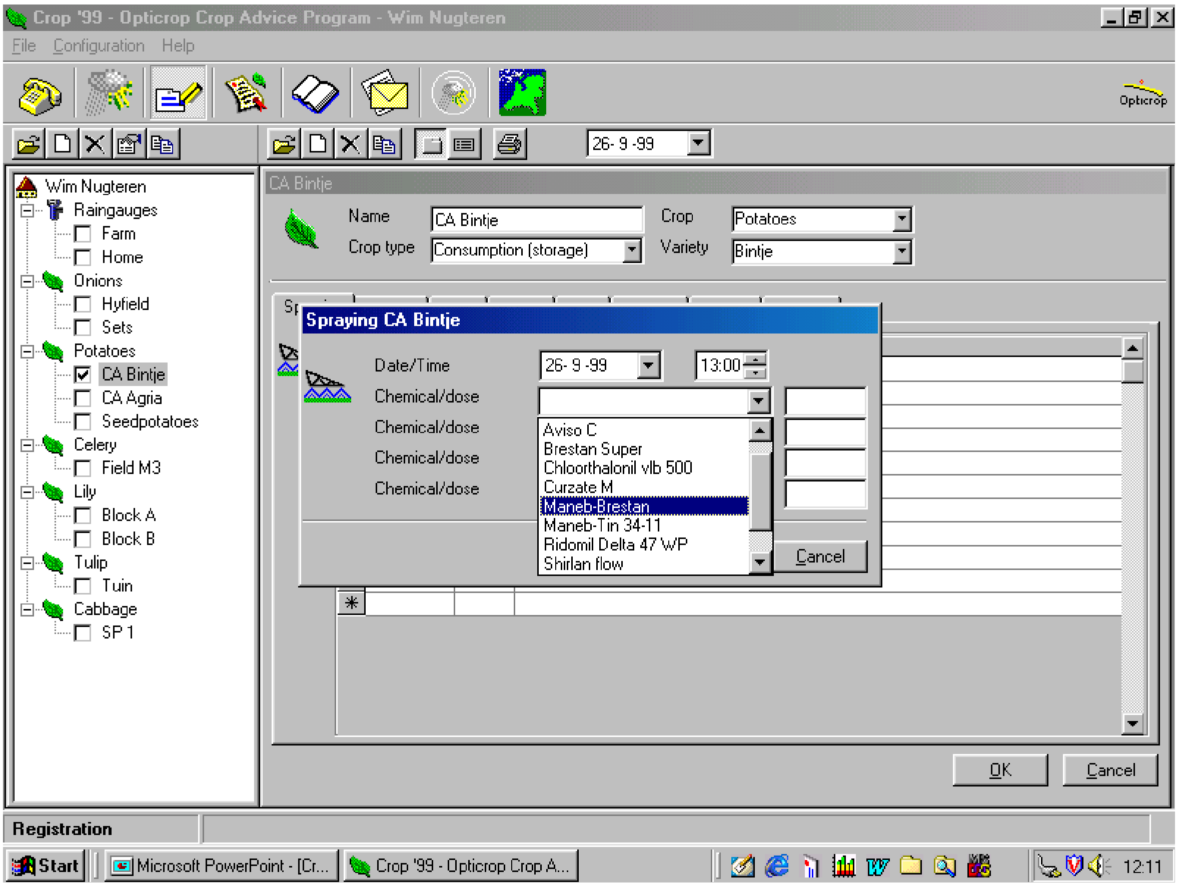
CA Bintje

Crop: Potatoes
Crop type: Consumptie (bewaring)
Variety: Bintje
Last spraying: 28-8-99 - Shirlan flow; 0,3

9-9-99: A preventive spraying today

Weather conditions today are or will be dangerous for Phytophthora. The crop is not protected anymore, so the next preventive spraying should be done today.

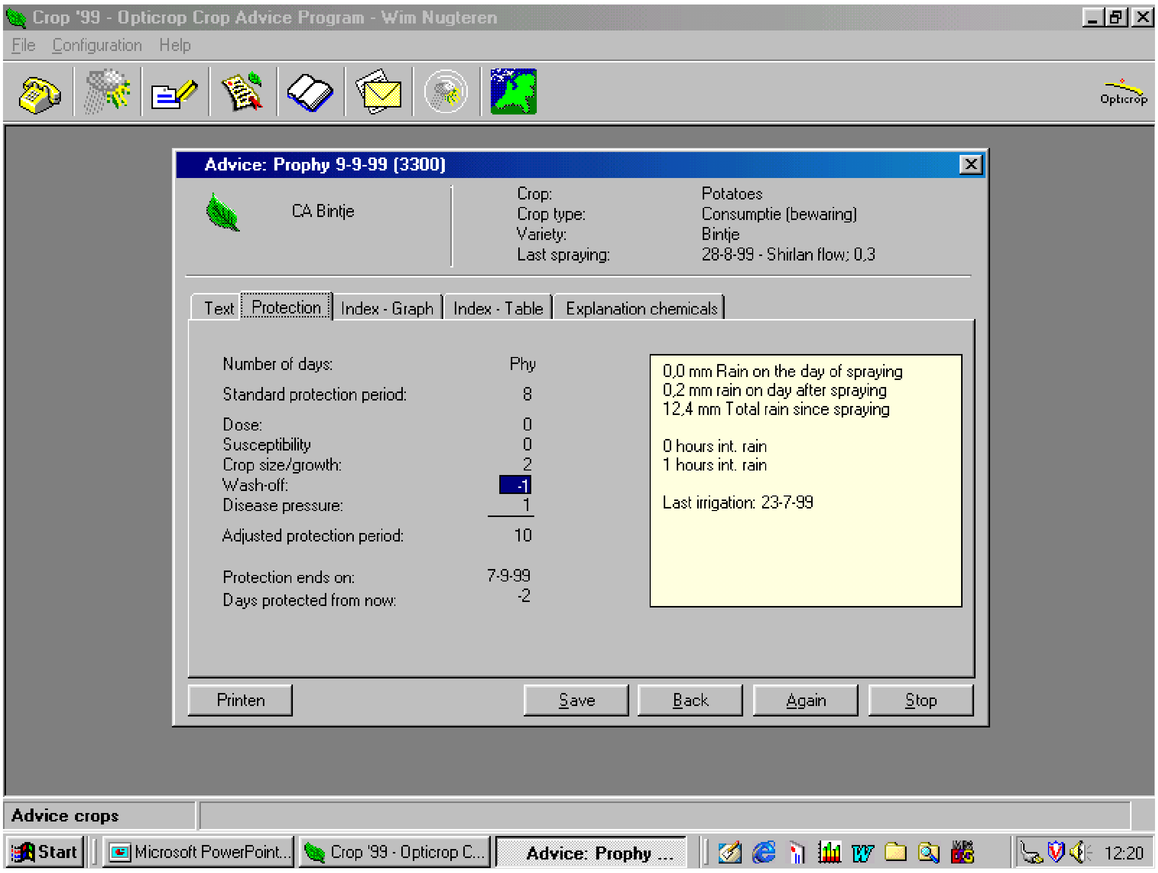
Regarding the present disease pressure, postponing the spraying will result in a Cymoxanil advice in the coming days.



Name: CA Bintje
Crop: Potatoes
Crop type: Consumption (storage)
Variety: Bintje

Spraying CA Bintje

Date/Time: 26- 9 -99 13:00
Chemical/dose
Chemical/dose
Chemical/dose
Chemical/dose



CA Bintje

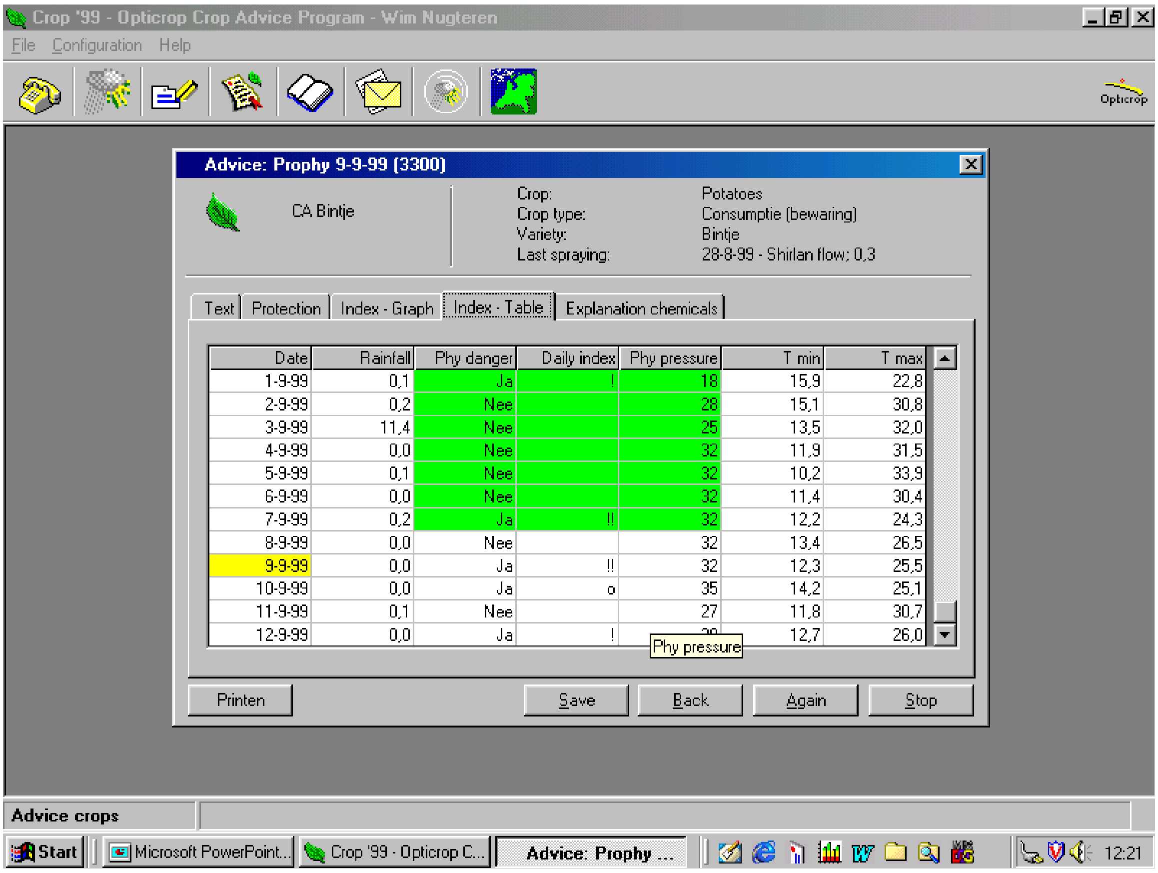
Crop: Potatoes
Crop type: Consumptie (bewaring)
Variety: Bintje
Last spraying: 28-8-99 - Shirlan flow; 0,3

Number of days:	Phy
Standard protection period:	8
Dose:	0
Susceptibility	0
Crop size/growth:	2
Wash-off:	-1
Disease pressure:	1
Adjusted protection period:	10
Protection ends on:	7-9-99
Days protected from now:	-2

0,0 mm Rain on the day of spraying
0,2 mm rain on day after spraying
12,4 mm Total rain since spraying

0 hours int. rain
1 hours int. rain

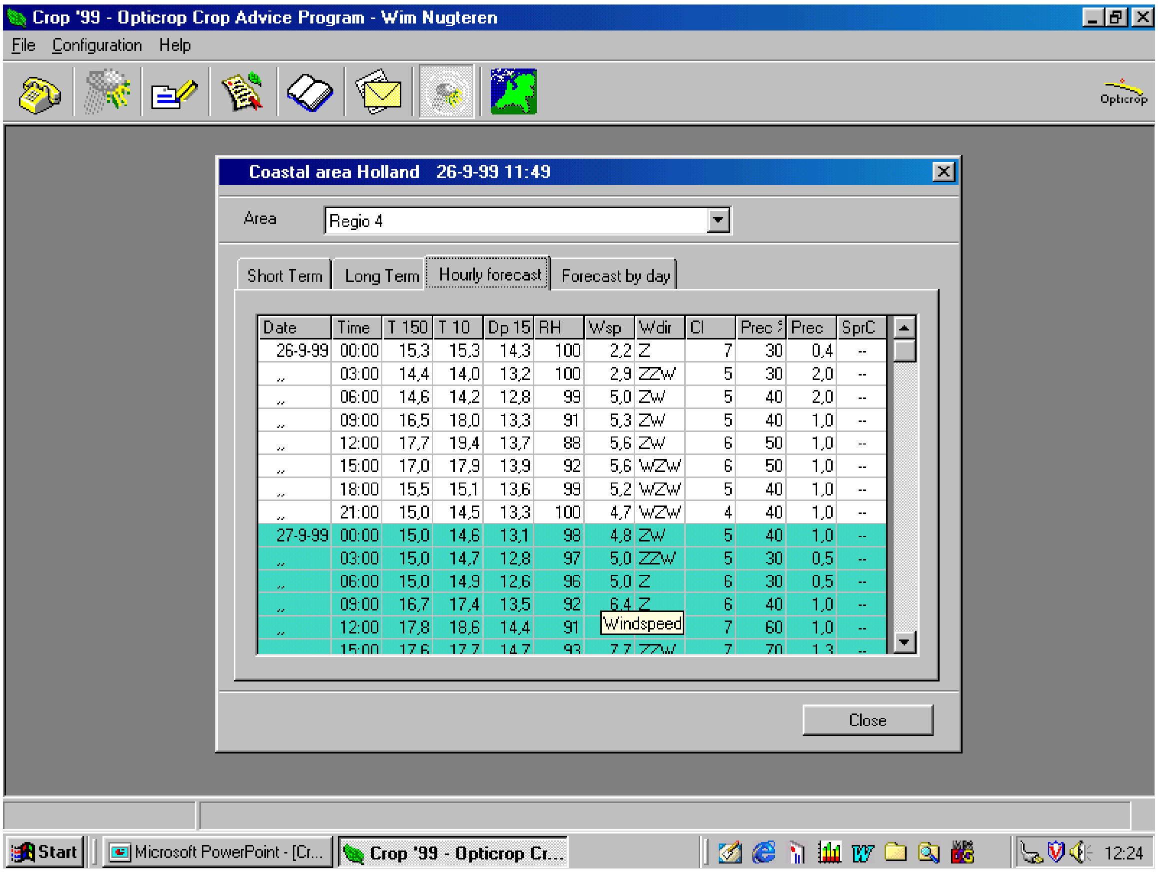
Last irrigation: 23-7-99



CA Bintje

Crop: Potatoes
Crop type: Consumptie (bewaring)
Variety: Bintje
Last spraying: 28-8-99 - Shirlan flow; 0,3

Date	Rainfall	Phy danger	Daily index	Phy pressure	T min	T max
1-9-99	0,1	Ja	!	18	15,9	22,8
2-9-99	0,2	Nee		28	15,1	30,8
3-9-99	11,4	Nee		25	13,5	32,0
4-9-99	0,0	Nee		32	11,9	31,5
5-9-99	0,1	Nee		32	10,2	33,9
6-9-99	0,0	Nee		32	11,4	30,4
7-9-99	0,2	Ja	!!	32	12,2	24,3
8-9-99	0,0	Nee		32	13,4	26,5
9-9-99	0,0	Ja	!!	32	12,3	25,5
10-9-99	0,0	Ja	o	35	14,2	25,1
11-9-99	0,1	Nee		27	11,8	30,7
12-9-99	0,0	Ja	!	[illegible]	12,7	26,0

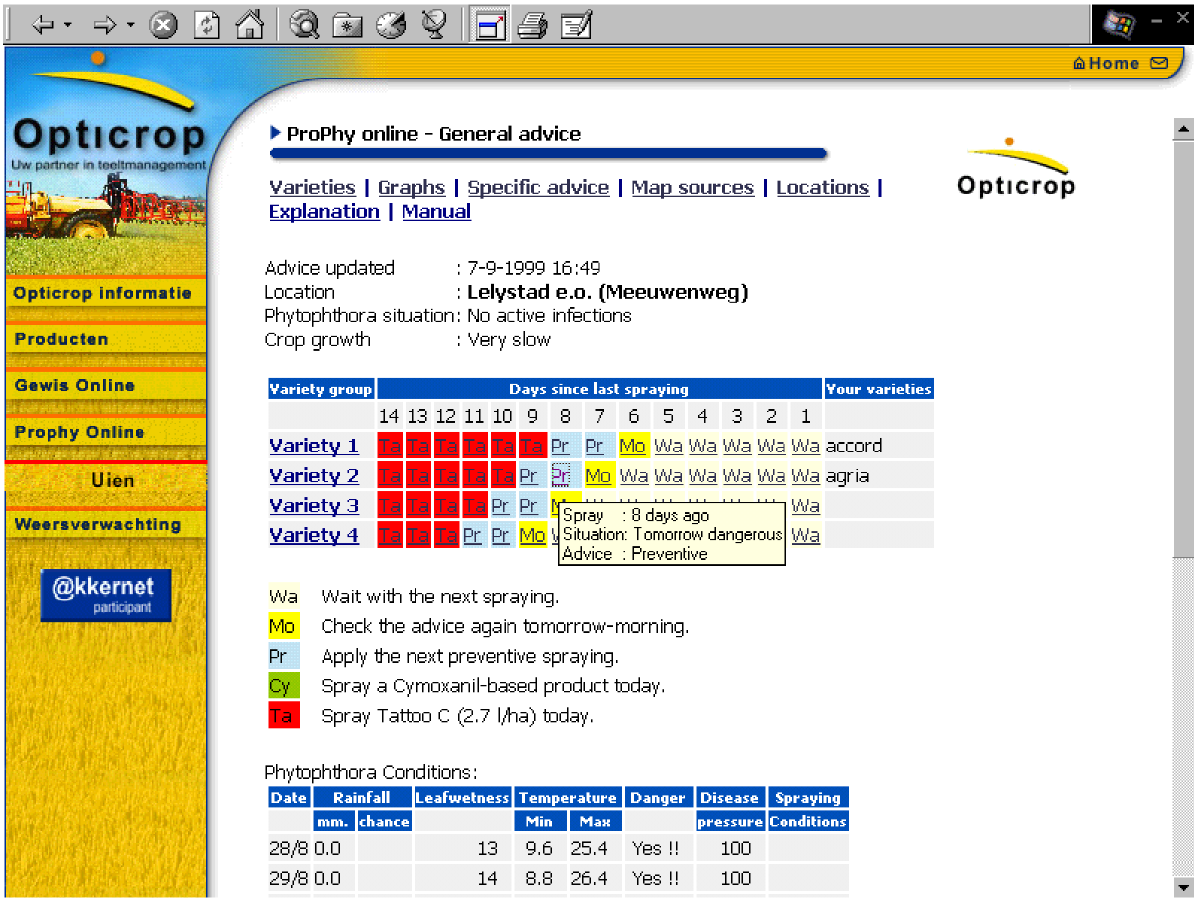


Area: Regio 4

Date	Time	T 150	T 10	Dp 15	RH	Wsp	Wdir	Cl	Prec ?	Prec	SprC
26-9-99	00:00	15,3	15,3	14,3	100	2,2	Z	7	30	0,4	--
,,	03:00	14,4	14,0	13,2	100	2,9	ZZW	5	30	2,0	--
,,	06:00	14,6	14,2	12,8	99	5,0	ZW	5	40	2,0	--
,,	09:00	16,5	18,0	13,3	91	5,3	ZW	5	40	1,0	--
,,	12:00	17,7	19,4	13,7	88	5,6	ZW	6	50	1,0	--
,,	15:00	17,0	17,9	13,9	92	5,6	WZW	6	50	1,0	--
,,	18:00	15,5	15,1	13,6	99	5,2	WZW	5	40	1,0	--
,,	21:00	15,0	14,5	13,3	100	4,7	WZW	4	40	1,0	--
27-9-99	00:00	15,0	14,6	13,1	98	4,8	ZW	5	40	1,0	--
,,	03:00	15,0	14,7	12,8	97	5,0	ZZW	5	30	0,5	--
,,	06:00	15,0	14,9	12,6	96	5,0	Z	6	30	0,5	--
,,	09:00	16,7	17,4	13,5	92	6,4	Z	6	40	1,0	--
,,	12:00	17,8	18,6	14,4	91			7	60	1,0	--
	15:00	17,6	17,7	14,7	93	7,7	ZZW	7	70	1,3	--

```
PHYTOPHTHORA INFO (PROPHY)                        Update:  9/ 8/99 16:32
------------------------------------------------------------------------
WEATHER CONDITIONS                           Area: Hoekse Waard (Westmaas)

Date  Rainfall  Hours   Temperature  Dangerous    Disease    Spraying
                  wet   Min    Max   Phytophthora pressure   conditions
------------------------------------------------------------------------
30/ 7   0.0         3   13.8   35.0    No   -         4
31/ 7   0.0         6   14.6   34.3    No   -         4
 1/ 8   0.0         5   13.6   35.9    No   -         2
 2/ 8   0.0         5   13.3   36.2    No   -         0
 3/ 8   0.0         0   15.1   28.1    No   -         0
 4/ 8   0.0         8   16.7   34.0    No   -         0
 5/ 8   2.4        13   15.6   23.9    Yes  !!        0
 6/ 8   0.0        10   12.8   32.0    No   -         0
 7/ 8   5.2        15   15.9   22.5    Yes  !!        0
 8/ 8   3.0        24   13.6   21.6    Yes  !!!      13

 9/ 8   0.9 (70%) 21    14.9   22.9    Yes  !!!      13          -
10/ 8   9.5 (70%) 22    13.8   20.6    Yes  !!!      26          -
11/ 8   0.0 (30%)  6    12.8   21.6    Yes  !        50          ++
```

```
SPRAYING ADVICE

Variety group               Number of days since last spraying
                      1   2   3   4   5   6   7   8   9  10  11  12  13  14
-----------------------------------------------------------------------------
   1                  -   -   -   -   -   M   P   P   C   C   C   T   T   T
   2                  -   -   -   -   -   -   M   P   P   C   C   C   T   T
   3                  -   -   -   -   -   -   -   M   P   P   C   C   C   T
   4                  -   -   -   -   -   -   -   -   M   P   P   C   C   C

Rain after spraying:  4   9   9  12  12  12  12  12  12  12  12  12  12  12
Wash off factor:      0   0  -1   0   0   0   0   0   0   0   0   0   0   0
Protection period:    8   8   7   8   8   8   8   8   8   8   8   8   8   8
Protection left:      7   6   4   4   3   2   1   0  -1  -2  -3  -4  -5  -6

Advice based on: No active infections in the area, Normal crop growth

Explanation:      -=Wait M=Tomorrow P=Preventive C=Cymoxanil T=Tattoo 2.7

Dosage advice variety group:   1) 100%     2) 100%     3) 100%     4) 100%
```



ProPhy online - General advice

Varieties | Graphs | Specific advice | Map sources | Locations | Explanation | Manual

Advice updated : 7-9-1999 16:49
Location : **Lelystad e.o. (Meeuwenweg)**
Phytophthora situation: No active infections
Crop growth : Very slow

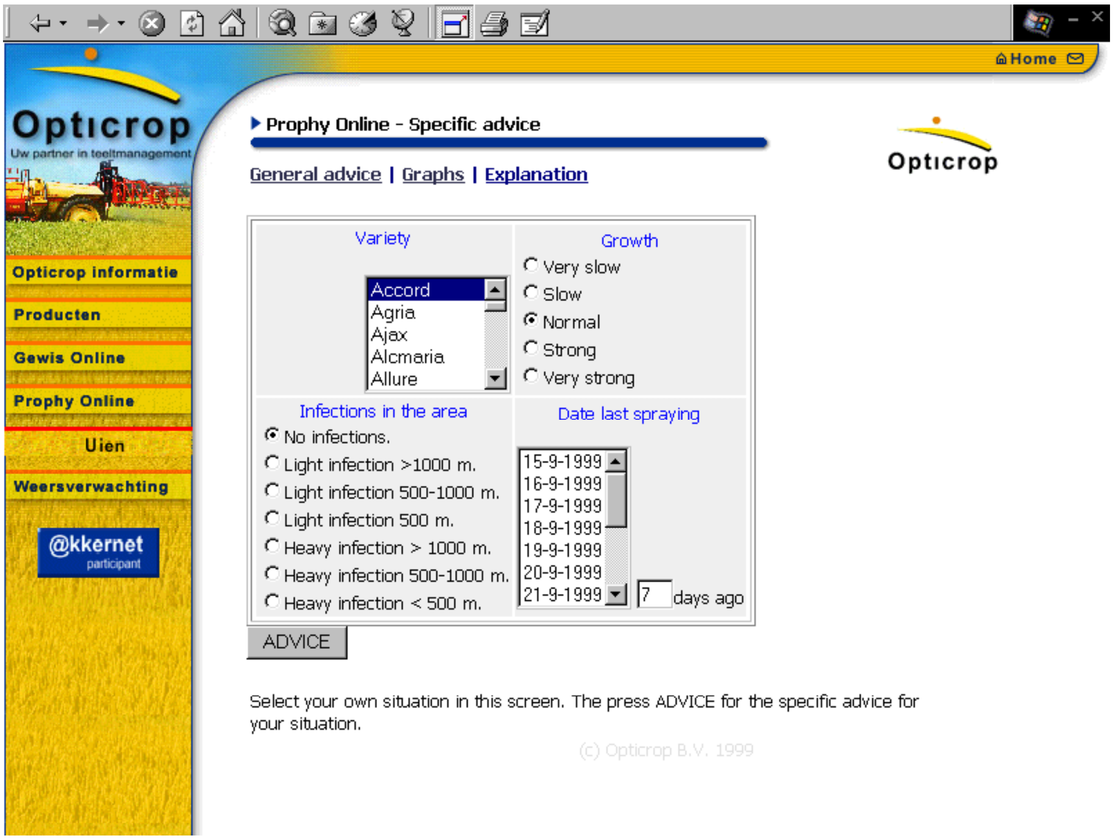
Variety group	Days since last spraying														Your varieties
	14	13	12	11	10	9	8	7	6	5	4	3	2	1	
Variety 1	Ta	Ta	Ta	Ta	Ta	Ta	Pr	Pr	Mo	Wa	Wa	Wa	Wa	Wa	accord
Variety 2	Ta	Ta	Ta	Ta	Ta	Pr	Pr	Mo	Wa	Wa	Wa	Wa	Wa	Wa	agria
Variety 3	Ta	Ta	Ta	Ta	Pr	Pr	M							Wa	
Variety 4	Ta	Ta	Ta	Pr	Pr	Mo	W							Wa	

Spray : 8 days ago
Situation: Tomorrow dangerous
Advice : Preventive

Wa	Wait with the next spraying.
Mo	Check the advice again tomorrow-morning.
Pr	Apply the next preventive spraying.
Cy	Spray a Cymoxanil-based product today.
Ta	Spray Tattoo C (2.7 l/ha) today.

Phytophthora Conditions:

Date	Rainfall		Leafwetness	Temperature		Danger	Disease	Spraying
	mm.	chance		Min	Max		pressure	Conditions
28/8	0.0		13	9.6	25.4	Yes !!	100	
29/8	0.0		14	8.8	26.4	Yes !!	100	



Prophy Online - Specific advice

General advice | Graphs | Explanation

Variety	Growth
Accord Agria Ajax Alcmaria Allure	○ Very slow ○ Slow ● Normal ○ Strong ○ Very strong
Infections in the area	**Date last spraying**
● No infections. ○ Light infection >1000 m. ○ Light infection 500-1000 m. ○ Light infection 500 m. ○ Heavy infection > 1000 m. ○ Heavy infection 500-1000 m. ○ Heavy infection < 500 m.	15-9-1999 16-9-1999 17-9-1999 18-9-1999 19-9-1999 20-9-1999 21-9-1999 7 days ago

ADVICE

Select your own situation in this screen. The press ADVICE for the specific advice for your situation.

(c) Opticrop B.V. 1999

Fourth Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Oostende, Belgium, 29 September – 2 October 1999

Further experience with DSS for the control of potato late blight in Bavaria

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Abstract

In Bavaria, as in the rest of Germany, the agricultural headlines are dominated by the "integrated" idea. The aim is to produce food and agriculture products for industry according to the principles of integrated production.

Late blight is the most dangerous disease in potatoes in this region. For several years there have been some efforts to improve a warning service of potato late blight.

Since 1997 the Phytophthora model Weihenstephan, a DSS for the integrated control is established in Bavaria. The experiences and the results of the years 1997-1999 are presented and discussed here.

Key words: DSS, *Phytophthora infestans*, SIMPHYT, warning system

Introduction

In Bavaria, potatoes are grown on an area of 60.000 hectares. This area has been very stable for several years.

Potato late blight is the disease most feared by Bavarian potato growers. Farmers usually apply many fungicides, both preventive and curative, with the aim of avoiding any risk of a *Phytophthora*-epidemic.

The use of a forecasting model within a regional warning service seems to be the best way to optimize the fungicide applications against the disease and to reduce the chemical input. The aim is to maintain the quality and the yield of the crop with the necessary input of chemical fungicides.

In 1997, a warning service of potato late blight was introduced in Bavaria, providing advice throughout the growing season on the optimal spraying interval and on the type of fungicides to be used.
The following is an overview of the experience with a DDS for the control of potato late blight this year.

Materials & Methods
The main idea of the Phytophthora model Weihenstephan is the useful integration of two components (Figure 1):

- Weather-based prognosis
- Actually disease observation in the field

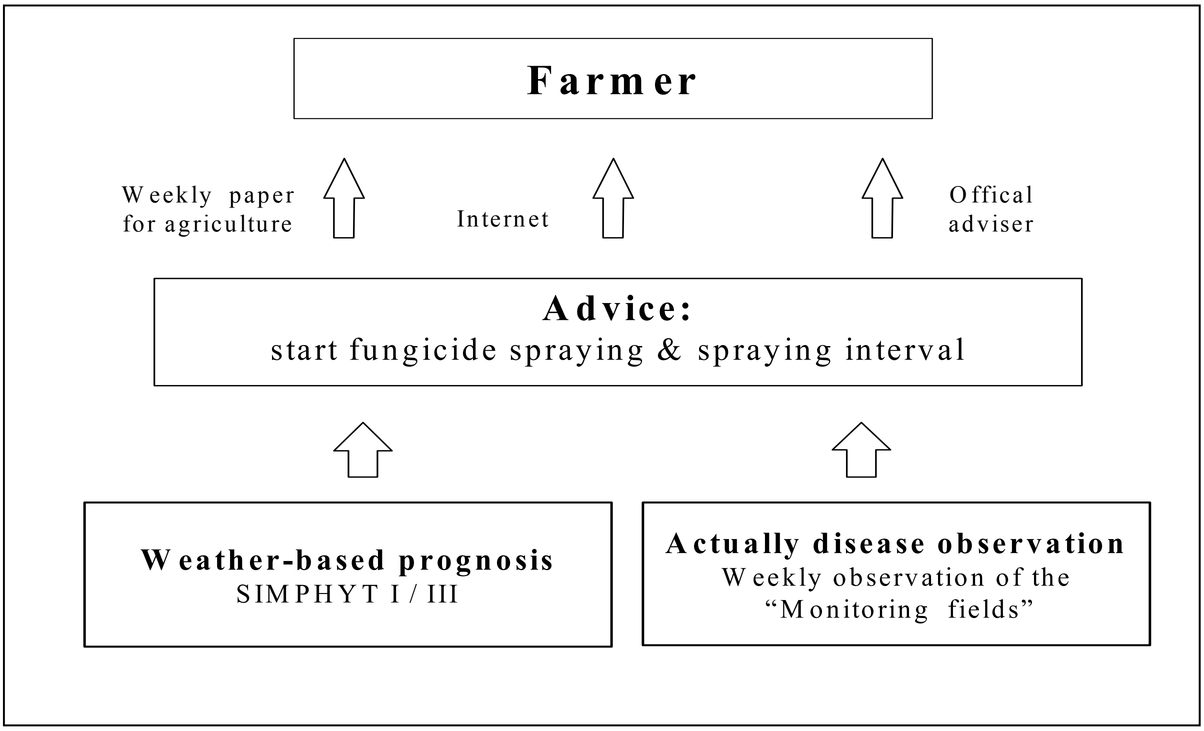

Figure 1. Scheme of the Phytophthora model Weihenstephan.

Prognosis

The decision support system SIMPHYT developed by the Federal Biological Research Centre for Agriculture and Forestry (Gutsche et al.) consists originally of two modules: SIMPHYT I and SIMPHYT II. In 1998 the sub-model SIMPHYT II was further developed and modified and the program SIMPHYT III was available. Therefore the prognosis since 1998 is based on SIMPHYT I and III.

SIMPHYT I predicts the date of the first fungicide spraying for eight different crop emergence-date classes and two risk levels. The program requires the input of temperature, relative humidity, and precipitation.

SIMPHYT III provides information on epidemic pressure and dry periods. Additionally information about the efficiency of the development of *Phytophthora infestans* on a single day are given. The model itself does not recommend a fungicide strategy, but from the calculated epidemic pressure under consideration of the factors of foliage growth, cultivar resistance, blight situation in the field, and fungicide usage, a spraying interval is derived.

In practice: Hourly meteorological data on temperature, relative humidity and rainfall are provided automatically by weather stations (see figure 2: network of the weather station used in the warning system). Such weather stations have their sensors placed 2 m above the ground. The local weather data are transferred online to a server. The data quality is controlled and the data are transformed to be calculated by the program SIMPHYT. The programs run twice a week by the Bavarian State Institute of Agronomy and Crop Protection.

Disease observation

The second component of the model – field assessment - is carried out weekly. The observed fields called "monitoring fields" are sown with cultivars most frequently grown in the region. These fields, which belong to farmers, also contain an untreated control plot of about 100qm. No fungicide applications are carried out on this plot until the occurrence of the first symptoms of *Phytophthora infestans*. The fungicide treated fields were monitored weekly by counting leaf and stem symptoms. There are two or three monitoring-fields in the vicinity of each weather station.

Data processing

Both types of information - disease observation and the output of the computer-based model (SIMPHYT) - were evaluated and interpreted and then conclusion for fungicide applications is drawn.

A summary of the information is published in a weekly newspaper for agriculture called „Landwirtschaftliches Wochenblatt“ which is subscribed to by nearly all of the Bavarian farmers. Thus, many farmer can access the information. For more successful control of the fungus *Phytophthora infestans*, it is necessary to inform the farmer with the latest data. Using the latest technology for efficient dissemination of information the Phytophthora warning system has also been available via World Wide Web since 1998. The information from the Phytophthora model Weihenstephan is updated twice a week and is available over the Internet: http://www.weihenstephan.de/pp or http://www.lbp.bayern.de.

The third way to inform farmers is for official advisers to take the information out of the Internet, record it on an answering machine, or send a fax to the potato growers.

So the internet is a very fast way to give information to a lot of persons who needs actual information about the *Phytophthora* situation.

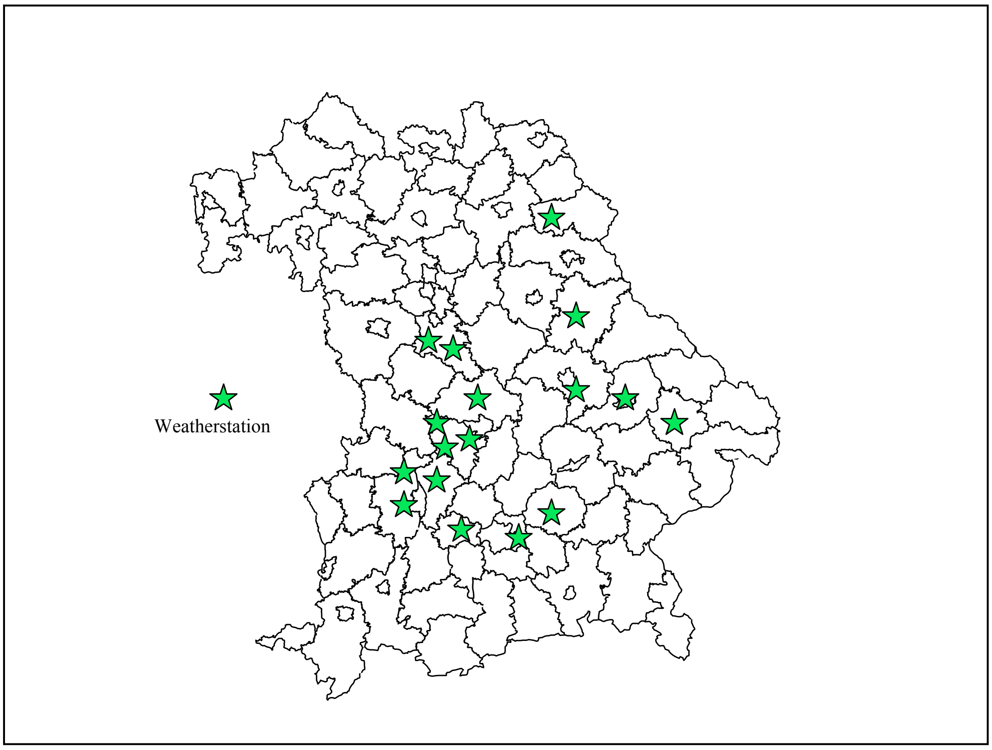

Figure 2. Network of the weatherstations used in the Phytophthora advisory service 1999.

Results and Discussion

The climatic conditions in May were very conducive to the development of *Phytophthora* late blight. In the second and third weeks of May heavy rainfall was measured - in some regions there was more than 50mm precipitation in one day. The consequence of this rain period was a high soil water content.

In 1999, late blight was first detected at the end of May in the field. In the beginning of June, more diseases were recorded. This is an unusually early outbreak in the Bavarian region. Normally the first blight is recorded 3-4 weeks later. This year especially, stem blight was recorded at this time.

The weather conditions in June were not very favourable for the development of late blight. Consequently, late blight spread very slowly at most sites. The high temperatures between 2-5 July (more than 35 ^{o}C) stopped the epidemic. However, a rain period from 6 July onwards increased the late blight pressure. In some regions the farmers could not get in the field for several days. So in these cases, late blight occurred. Most of the untreated haulm had been killed by this time by *Phytophthora*.

In the end of July there was nearly no precipitation for three weeks. As a result, potato late blight was halted and most of the potato foliage were infected by early blight (*Alternaria solani*).

First fungicide treatment

The prognosis for the first fungicide treatment is calculated by the sub-model SIMPHYT I. On the other hand there is the information about the appearance of late blight in a region (monitoring-fields, practice fields, dumps, etc). Because of the recorded late blight at the end of May, the recommendation for the first fungicide spray were given to the farmers on 1 June, even before SIMPHYT I prescribed the start of spraying.

SIMPHYT I gave good results in the year 1997 and 1998 (Hausladen et al., 1999). But the overall results of the program this year were not satisfactory. Figure 2 indicates the time between the first treatment and the late blight outbreak in the untreated plot at 16 different sites.

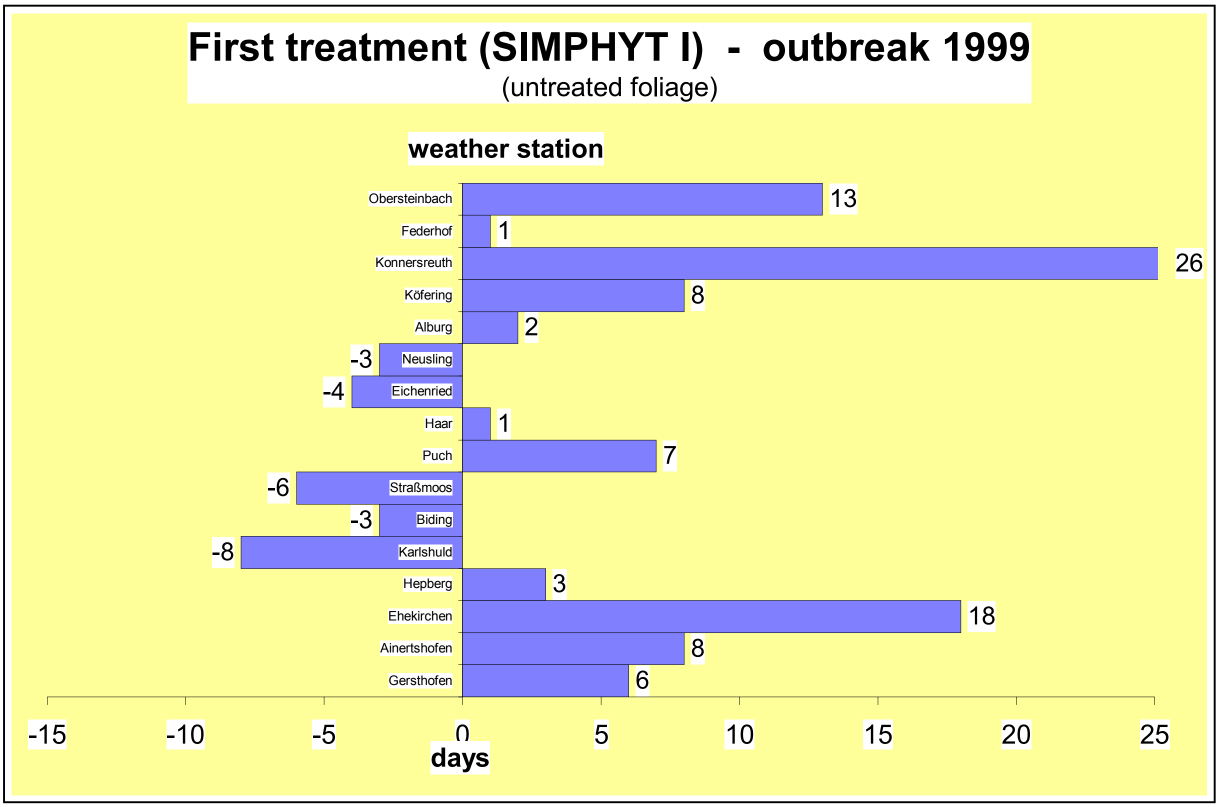

Figure 2. Time between the first fungicide treatment (SIMPHYT I) and outbreak.

The results demonstrate that frequent heavy rainfall and high soil moisture after planting can provide optimal conditions for a early *Phytophthora* infection. It was especially apparent since these conditions were prevalent this year in nearly all of the Bavarian regions. This result confirms the results obtained in 1997 in the northern part of Germany (Gutsche, 1998).

Spraying program

The following sprayings were recommended in reference to SIMPHYT III. The idea is to reduce the spraying interval during periods of high epidemic pressure and to extend the interval during low infection periods under consideration of the factors shown in Figure 3. Figure 4 is an example of how to utilize this information for a spraying interval. The time of application is marked by an arrow.

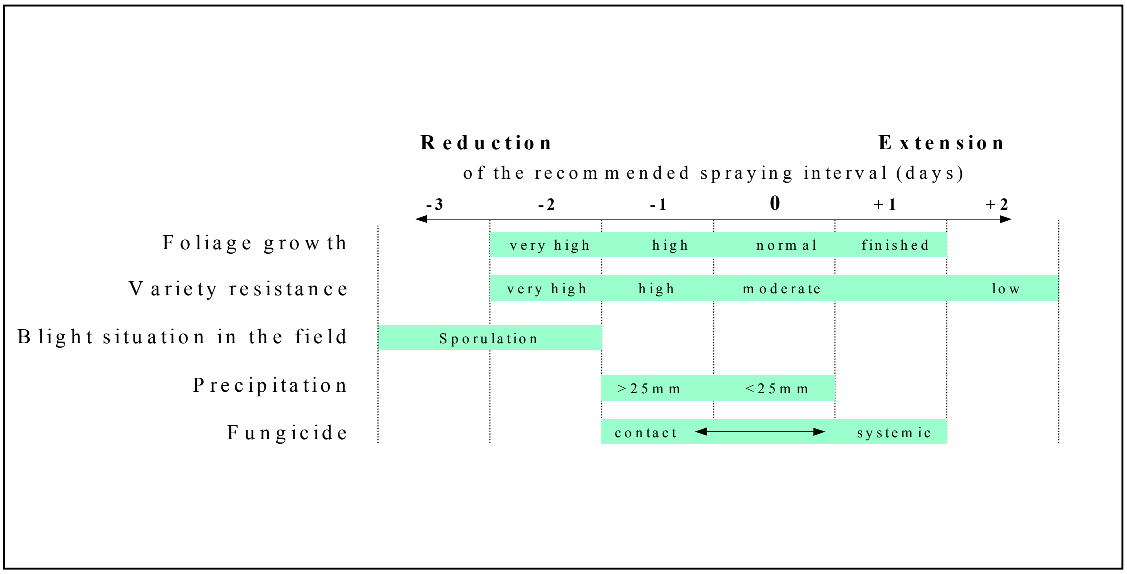

Figure 3. Scheme for the individual spraying interval.

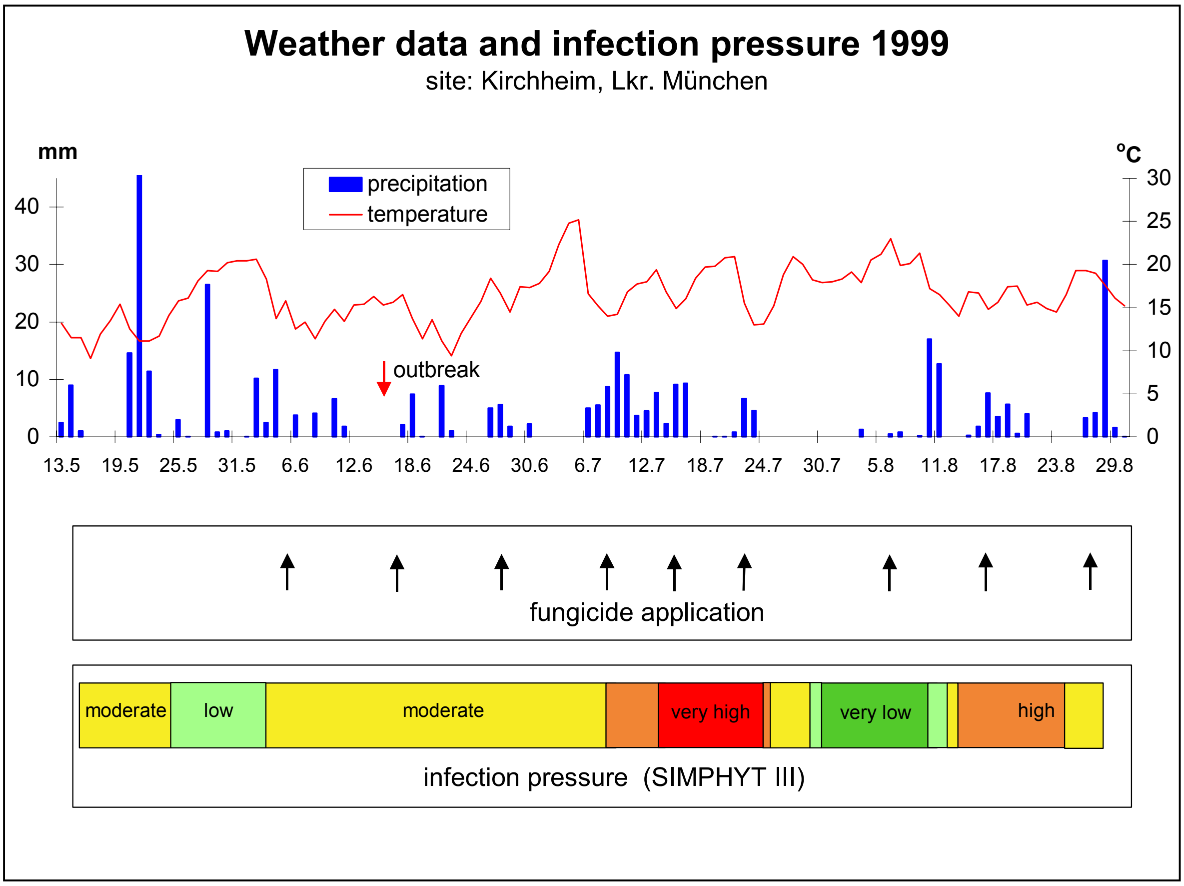

Figure 4. Weather conditions and infection pressure 1999 at Kirchheim , Lkr. München.

The arrow in the weather chart marks the first observation of *Phytophthora infestans* in the untreated plot.

Conclusions

The year 1999 was marked by an unusually early blight attack. The good results of the sub-model SIMPHYT I for the start of fungicide spraying obtained in the years 1997 and 1998 were not confirmed in 1999. SIMPHYT I was in the most cases too late. But with the monitoring part within the concept "Phytophthora model Weihenstephan" it successfully warned the farmers in time. The result indicates that it is useful to have two components - monitoring and prognosis - in a functional integrated Phytophthora-concept.

Acknowledgement

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Using disease forecasting to reduce fungicide input for potato blight in the UK

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Summary

A disease forecasting service using the *PLANT - Plus* model for late blight was carried in the East Midlands for the second year. This commercial service was adopted by 9 growers, and included 18 different crops. A comparison with normal practice was made between 4 conventionally treated crops and 4 nearby model crops with similar emergence dates. Varieties were matched with three of the crops.

The season was medium in blight risk, with high pressure in June and early August and relatively low pressure in July and late August. There was no significant blight infection in any crops being monitored.

The number of sprays saved by adopting forecast practice using the model was between 2 and 3, and generated from extended spray intervals in July and late August. The widest spray interval in a model crop was 30 days.

The average fungicide cost saving in the model crops compared to the conventional crops was £44/ha. This benefit was relatively consistent irrespective of crop emergence or variety. The reduction in cost input was also influenced by greater use of contact products with model crops.

Key Words; Commercial Service, Medium Risk, Extended Intervals, Cost Saving

Introduction

Fungicide sprays for late blight are a significant cost input in UK potato production. Normal practice is to start spraying when crops have met along the rows and to continue at 7 to 10 day intervals until the crop is ready for harvest or desiccation. Professional growers will apply 10 to 14 sprays in most seasons that cost between £130-200/ha for the fungicide depending on product choice. A recent UK survey (Garthwaite 1999) showed that 12.3 separate products were applied by large potato holdings (80 to 120ha) in 1998.The pressure from consumers and retailers is to reduce pesticide inputs and justify when they are applied. Add to this the growers desire to lower costs, in an ever more hostile trading environment, then the case for reducing inputs is overwhelming.

Decision Support Systems such as Dacom PLANT *Plus* have the potential to reduce cost inputs by increasing spray intervals when disease risk is low. By timing sprays closer to infection periods they can also lead to the use of cheaper products and so can reduce the cost of programmes even if the number of applications is high.

In 1998 DMA Crop Consultants carried out the UK's first commercial service for late blight forecasting on a field specific basis, using the *PLANT - Plus* model (*Hinds 1998*). The season turned out to be severe for late blight infection. Results from 7 commercial users of the service showed that, although few sprays were saved, improvements in disease control were observed between their crops and those of surrounding growers who were using normal practice treatments. This validation of the model gave the growers confidence to implement advice from model recommendations. It was clear from the pattern of spraying that they had moved away from the traditional prophylactic approach. Importantly the service worked on practical level for both advisor and grower. The only question mark left in the grower's mind, after such a bad disease year, was could such a service save money by reducing inputs?

In 1999 use of the service in the East Midlands increased to 9 growers. The service was also expanded to other areas including East Anglia, West Midlands, South West England, Northern Ireland and Portugal. The second year of results, from the East Midlands network is discussed.

Operation of the Service

The change from 1998 was that one grower dropped out of the group due to a decrease in his growing area, however 3 new growers came into the network, making a total of 9. Significantly, all grow over 50ha of potatoes, with 4 growing over 200ha in the area.

The service was still based on 20ha of crop for new users, however some of the year 2 growers increased the area of forecast practice to 50ha of crop. Last year it was difficult to get a comparison of model treatments to normal practice, because the model influenced decisions on the control area. This year two growers managed to run control programmes without influence by the model advice.

Crops

The predominant variety was again Saturna, a processing potato with moderate resistance to blight. This year saw the introduction of more blight susceptible varieties such as Hermes, Saxon, Santana and Lady Rosetta. In all 18 separate crops were run on *PLANT – Plus*, including an organic crop.

Weather Data and Data Transfer

The network of 8 Adcon weather stations transmitted real-time data by telemetry to a DMA central receiver and PC data server. Three synoptic stations in the area were used to generate local five-day weather forecasts. The local weather data was sent 4 times a day via an Internet connection to Dacom NL where it was integrated with the synoptic weather forecast for each site. The complete data file was then called at regular intervals from Dacom NL by DMA advisors and locally processed through the *PLANT - Plus* software. Software support and administration was provided by Dacom Systems UK Ltd.

Crop Recording and Advice

Crops were visited weekly to make recordings of crop growth and density. Crops and dumps were also scouted on a regular basis to record any sources of infection in the area. This data was then input into the *PLANT - Plus* software by DMA.

Interpretation by the advisor involved an assessment of the recent and projected infection risk as generated by the model. If a treatment was required, communication was established with the grower. During this communication spray timing and product choice was advised.

Results of the Service

Disease Pressure

The growing season provided contrasts in disease pressure from one month to the next. May was dry and cool with low risk, June however was wet and blight pressure increased. July started humid but got hotter and less humid as time went on. By the end of July a period of drought had set in. The beginning of August, however, saw a return to wet weather and produced the most sustained period of high blight pressure of the whole summer. Late August and early September were dry and disease pressure eased off. Overall the season can be classified as a medium blight pressure year.

Field Infection

Blight was found on 3 dumps in the area in early May before crops had emerged. No blight infection was recorded in any of the *PLANT - Plus* fields, except P16 (ref. table 1) where stem blight was observed in mid July. The blight originated from the seed and infection was contained to just a few stems with limited spread to leaves. Conventional fields used as comparisons were also blight-free.

PLANT - Plus sprays

Growers applied an average of 9.1 sprays (Table 1) for the season using *PLANT - Plus*. Shortest spray intervals occurred in June. The widest spray intervals occurred in July and August, with most growers achieving one interval wider than 20 days. One grower (P5) reached a 30-day interval during July. In comparison conventional fields (Table 2) averaged over 2 sprays more for the season. The shortest conventional spray intervals occurred in July.

Table 1. Number of sprays per month for each using *PLANT - Plus* site, in order of crop emergence.

Site	Emergence Date	**Variety**	May	June	July	Aug	Sept	Total
P1	27 April	Saturna	1	3	3	3		10
P2	28 April	Premiere	2	3	3	1		9
P3	30 April	Saturna	2	4	3	2		11
P5	4 May	Saturna	1	3	2	2	1	9

P6	4 May	Saxon	2	4	2	1		9
P7	4 May	Lady Rosetta	1	4	1	3	1	10
P8	5 May	Saturna	1	4	2	3	1	11
P9	5 May	Lady Rosetta	2	4	1	3	1	11
P10	5 May	Lady Rosetta	1	4	2	2		9
P11	8 May	Maris Piper	1	4	2	3	1	11
P12	10 May	Navan organic		3	1			4
P13	12 May	Saturna		4	3	2	1	10
P14	15 May	Saturna		4	2	3	1	10
P15	20 May	Saturna		4	3	2	1	10
P16	24 May	Estima		2	3	3	1	9
P17	2 June	Santana		1	3	2	1	7
P18	7 June	Hermes		2	3	3	2	10
		Average	**0.8**	**3.2**	**2.2**	**2.2**	**0.7**	**9.1**

Conventional Sprays

Table 2. Number of sprays per month for normal practice fields.

Site	Emergence Date	Variety	May	June	July	Aug	Sept	Total
C3	30 April	Saturna	1	3	4	5		13
C14	15 May	King Edward		4	5	3	1	13
C16	24 May	Estima		2	5	3	1	11
C18	7 June	Hermes		2	3	3	4	12
		Average	**0.3**	**2.8**	**4.3**	**3.5**	**1.5**	**12.3**

Fungicide Use and Cost

The *PLANT - Plus* programs were predominantly based on the use of 3 products, dimethomorph + mancozeb, cymoxanil + mancozeb and fluazinam. Generally the translaminar products were used in around 60% of cases and contact products in 40% of applications. Normal practice programs used more systemic products in the case of C3 & 18 than *PLANT - Plus* programs and C14 & 16 used less contacts, than the *PLANT - Plus* programs.

Table 3. Fungicide use and costs for *PLANT - Plus* and Conventional comparison fields.

Site	Prop + Chlor	Met + Mcb	Dim + Mcb	Cym + Mcb	Fluaz	Mcb	Tin	Total Sprays	*Total Cost £/ha
	systemic		translaminar			contact			
P3			4	4	2		1	11	138

P14			2	4	3		1	10	118
P16			2	2	4	1		9	99
P18			2	3	4		1	10	116
C3	2	1	1	2	5		2	13	177
C14			5	6	1		1	13	167
C16			5	5			1	11	145
C18	1	2	1	1	5		2	12	158

* Costs based on Propamicarb + Chlorothalonil @ £25/ha, Metalaxyl + Mancozeb @ £18/ha, Dimethomorph + Mancozeb @ £15/ha, Cymoxanil + Mancozeb @ £12/ha, Fluazinam @ £10/ha, Mancozeb @ £ 5/ha, Tin @ £10/ha.

Cost Reduction

The average cost reduction made by *PLANT - Plus* forecasting compared to conventional use was £44 /ha. This benefit was relatively consistent irrespective of crop emergence date or variety.

Table 4. Cost reduction by *PLANT - Plus* compared to Normal Practice.

Crop Emergence Date	Comparison Fields	Sprays Saved	Spray Cost Reduction £
30th April	P3 – C3	2	39
15th May	P14 – C14	3	49
24th May	P16 – C16	2	46
7th June	P18 – C18	2	42

Cost benefit

It is always difficult to estimate cost benefits from using a decision support system because the use of a proactive model such as *PLANT - Plus* invariably influences ‘normal practice’, therefore any comparison can be invalid. However, this season 2 producers did implement normal practice treatments for comparison purposes.

Despite the fact that normal practice for each grower differed in product selection, the trend was the same, in that normal practice programs tended to use more sprays than necessary in periods of low risk and use expensive products when they were not required.

The savings arising from the use of *PLANT - Plus* were mostly made in the two low risk periods of the summer, which occurred in July and in late August/early September. During these periods spray intervals were extended well beyond the normal intervals. Growers found themselves using spray intervals of 14 days, then 21 days and even to 28 days. One grower sprayed just once in the whole of July.

What surprised many was, just how receptive the growers were to stretch intervals, even though this was alien to their instincts which are based upon conventional thinking. Sceptics of modelling are quick to point out the dangers of extending intervals. However, the growers using this system have now built up enough confidence in it to know it will control blight when the risk is severe, and they now know when the risk is low, they do not need to spray.

Grower enthusiasm for using a disease forecasting service is at present driven by the need to reduce costs and, to lesser extent, to justify inputs. In high-risk years the cost savings are likely be marginal but become significant in low risk years. If the savings made this year represent an average benefit over a number of years then it is possible to determine the value of the service.

The basic costs of *PLANT – Plus* including software, data transfer and weather forecast start from around £1000 per customer. DMA advice costs are around £500 and local weather data a further £500. In an average year the smaller scale grower will need to be using the system on at least 40ha of potatoes to generate sufficient savings in chemical costs to break even. Above this area the costs rise but the cost per ha is reduced and the grower will be able to realise a considerable cost saving whilst retaining the benefit of sound crop protection.

Smaller scale growers can take advantage of this system by sharing a weatherstation providing the data is representative of the area in which they grow their crops. Another way to reduce costs is for the grower or one of his staff to record their own crops and send the data to the advisor.

The one cost benefit, which has not been discussed, is that of producing blight free potatoes. Potentially this is cost benefit that will far exceed any savings in fungicides. In low to medium risk years it is aspect this is sometimes forgotten by growers. The *PLANT-Plus* model has demonstrated, however, when blight pressure is high that it will give better protection against blight, through improved timing and product choice, than traditional methods. Even if this cost benefit is spread over a number of years the economics of using an insurance tool, like *PLANT-Plus*, must add up irrespective of savings on fungicides.

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Fourth Workshop of an European Network for development of an
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Oostende, Belgium, 29 September – 2 October 1999

ALPHI: Actual Local PHytophthora Information line based on PLANT-Plus

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Summary

The Dutch Farmers' Association (LTO-Nederland) has made up an agreement with the Dutch government to control input of chemicals in the period 1990 - 2000: The Long Term Crop Protection Plan. The aims of this project are to reduce input of active ingredient and to reduce the dependency of agriculture on chemicals. On the other hand a broad spectrum of chemicals need to be available and the continuity of agriculture may never be in danger. Overall the agreement has shown good results. By regulating the soil fumigants the proposed reduction towards input of active ingredient was reached. Fungicide input however still is a problem. Both 1997 and 1998 have shown increase in active ingredient, caused by bad weather conditions. Concluding we can say that instead of the proposed reduction of 36 % in 2000 we saw an increase of 29 % in 1998. However it is fair to say that in that period the evironmental pressure was reduced with 43 % due to new registrered compounds to control P. infestans.The biggest share (2/3) of the fungicide input is used for the control of Phytophthora infestans in potatoes. Besides this increase farmers still are to much depending on chemicals. Although there were a lot of plausible reasons for the increase over the last years, like bad weather conditions and a more aggressive pathotype, the government has put a lot of pressure on the agribusiness to reduce chemical input one way or the other. That is why the LTO has started the 'MASTERPLAN Phytophthora'.

Masterplan initiative

The project will take three years and has started in 1999. The project bundles a number of regulations like removing dumps and volunteer plants. A lot of groups are involved, like growers, processing industry, chemical companies, crop consultants, plant protection services and research institutes. The Masterplan aims for a reduction of active ingredient by 20 % in 2001 (reference years 1996/1997). To reach this goal the use of decision support systems is mentioned as vital for the coming years to justify the input of chemicals to prevent and control the disease. All weather stations are united in a national network and growers who use a forecasting system are subsidised.

Zeneca Agro in the Netherlands felt obliged to offer the possibility, free of charge, to all potato growers to get information on their local Phytophthora situation, together with a spraying recommendation. The project was started in april 1999. DACOM built a system, based on PLANT-Plus, called ALPHI: the Actual Local PHytophthora Information line.

Implementation

ALPHI works as an interactive voice response system. The farmers call a free of charge phone number and have to answer the next questions by typing on the telephone keypad:

Enter the four digits of your postal code

Enter the number of days since the last treatment

Enter your crop's variety resistance. You can find this figure in the variety list.

Enter the estimated crop growth. Three for rapid growth, two for medium growing speed and one for little growth.

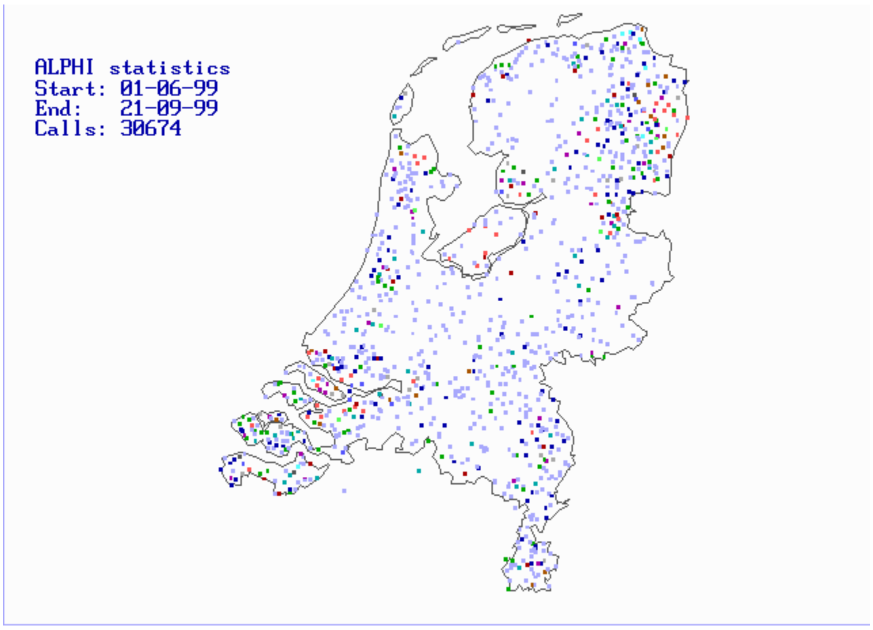
After the farmer has entered his postal code the system knows where he lives and can compile the first part of the output: the latest regional information. While the farmer listens to this first part the system calculates the recent crop recommendation, based on the other answers. The regional information consists of the number of reported outbreaks in the area, the forecasted rainfall figures and the forecasted wind speed.

The outbreaks are recorded in the PLANT-Plus system as part of a project in the Masterplan that is coordinated by the Plant Protection Service. Scouts in the field observe and record any attack in fields, hobby gardens and volunteers. The figure indicates for the farmer the current status of the epidemic in his area. The forecasted figures for rainfall probability and wind speed are part of the five day regional weather forecast that is provided by Holland Weather Services. Both rainfall and wind speed are important for the spraying conditions the next days.

The crop recommendation is based on the nearest weather station in the national network. The regional forecast is also used to project the infection conditions for the coming days. The data the farmer enters are fed into the PLANT-Plus model that calculates the recent conditions. The output first summarises the farmer's data that was used to calculate like the weather station's name, the last spraying date, growing speed and variety resistance. Following the farmer will hear the actual recommendation, based on the infection possibilities in the last and coming days. This recommendation is divided into four categories, based on the period the infection occured in relation to the time of the phone call: no spray, or a spray with a contact, translaminar or systemic fungicide. In the last three categories a level of necessity is included: a spray is to be considered or definitely necessary.

Results

In the 1999 growing season ALPHI was consulted over 30.000 times between June 1st and October 1st. These calls were made by approximately 2.500 different callers. The peak arose to about 1.000 calls per day after a mailing was sent out to the farmers in the first week of June, declining towards the end of the season. The next map shows the geographic location of the users.



The category of the recommendations were analysed. The results are shown in the next table. The different categories of positive recommendations add up above 100 %, because they sometimes come in the same advice when there are not only infections expected to arrive in the next days, but also were found in the last days.

No spraying needed	55 %	
Spraying recommended	45 %	
- contact fungicide		80 %
- translaminar fungicide		50 %
- systemic fungicide		15 %

The next graph shows the occurence of the recommendations over the season. Where the lines drop down in the different categories this means that a recommendation is triggered. Both the levels consideration and definitely are shown. The vertical lines show the major infection events in the 1999 season. This indicates that ALPHI triggered about 10 sprays. We can also see that a contact warning always comes before a translaminar or systemic warning. This indicates that regular callers can always spray with an environmentally friendly contact product.

There is also a strong correlation between the negative advices and the spraying interval of the callers. In the periods with a lot of ‘no sprays’ the farmers have stretched the interval to an average of 12 days.

Conclusion

ALPHI has shown to be an easy to use, low barrier advice system that has been used over 30.000 times the first year in the field. The recommendations were mainly based on contact products. The users have stretched to interval to over 12 days on average. Over the season ALPHI has in general triggered about 9-10 sprays where a standard, weekly spraying regime would have resulted in 14 sprays. We can clearly state that ALPHI has contributed to reduce the input of chemicals.

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Integration of SimCast and resistant cultivars to manage potato late blight in the Toluca valley

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Summary

In 1997, 1998 and 1999 we evaluated host resistance and fungicide forecasting as components of integrated management in the Toluca Valley of central Mexico. Potato cultivars Rosita and Norteña showed high levels of resistance (20% and 4% final disease severity, respectively) in the no-spray controls, whereas the susceptible cultivar, Alpha was completely defoliated well before the end of the season. Disease on Alpha was well managed with a weekly spray of chlorothalonil. Here we report a field evaluation in 1999 with a modified version of SimCast adapted for Mexican varieties with very high levels of resistance to Potato Late Blight. SimCast accurately predicted fungicide applications for the three cultivars Alpha, Rosita and Norteña and under experimental conditions resulted in considerable reductions in numbers of sprays compared to current grower practice. SimCast was implemented in Visual Basic for Applications in Microsoft Excel and will be made available to interested users on the Internet.

Keywords: SimCast, DSS, Forecasting system, *Phytophthora infestans*, Toluca Valley, Mexico.

Introduction

The Highlands of central Mexico are considered to be the center of origin of the Potato Late Blight fungus (*Phytophthora infestans (*Mont.) de Bary based on DNA fingerprinting, isozyme analysis, mating type frequency, the presence of major genes for resistance to Potato Late Blight in *S. demissum* and *S. stoloniferum* among several other characters (7, 8, 17). Most research on *P. infestans* in central Mexico has been conducted in the Toluca Valley. The

Toluca Valley offers a tropical highland climate due to the latitude (19º14'N; 99º 34' E) and altitude of the area (2640 m above sea level). This valley is characterized by monthly average temperatures in the range of 12-17º C and a yearly rainfall around 800-900 mm. The winter is dry and mild followed by a rainy and cool summer. Potatoes (*Solanum tuberosum* L.) are grown during the summer months, which are characterized by cool (daily average temperature: 15-16ºC) and wet weather.

Under normal circumstances growers in the Toluca valley use 16-24 applications of fungicides per crop with cultivars Alpha or Atlantic, both of which are susceptible, but comprise more than 50% of the potato acreage (18). Integration of host resistance and forecasting could considerably reduce the current production costs (5, 9).

The Mexican national breeding program has produced several varieties with high levels of field resistance (3, 11, 14). These cultivars can be grown without a single fungicide application resulting in about 4% and 20% disease severity for Norteña and Rosita, respectively, while Alpha is completely defoliated (11).

A good disease management program should integrate the effects of host resistance, weather and fungicide. Forecasting systems such as BLITECAST (16) and calendar spray schedules have been used with success in temperate climates to control Late Blight. To the best of our knowledge of the existing forecasting systems only TOM-CAST has been used successfully in Northern Mexico (R. Felix-Castellum, *personal communication*). Forecasting systems such as BLITECAST (15) and TOM-CAST (10) did not work well in the Toluca Valley (11, 12, 13, 14). SimCast (6) explicitly includes levels of resistance and degree of fungicide weathering in the decision rules. In 1998, SimCast resulted in 10 applications for Rosita and 8 for Norteña. Since these cultivars can be grown with less fungicide applications we adapted SimCast to include two new levels of resistance: resistant and highly resistant. We here report performance of the modified SimCast. Our objective was to evaluate SimCast with three varieties considered to be susceptible (cv. Alpha), resistant (cv. Rosita) and highly resistant (cv. Norteña) to Potato Late Blight in the Toluca Valley.

Materials and Methods

Cultural procedures. A field experiment was conducted at the INIFAP (Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias) field station in Metepec, Toluca Valley, in 1999. Whole tubers of cultivar Alpha, Rosita and Norteña were planted on June 15th. Treatments were randomized in complete blocks with 4 replications. Plots were separated from each other by 4 m.

Fertilization and non-experimental pesticide applications were applied according to standard grower practice in the region. Fertilizer was applied at time of planting (120 kg N/ha; 180 kg P/ha; 120 kg K/ha; 20 kg Ca and Mg/ha) together with the granulated insecticide terbufos (Counter FZ-15; 1.05 kg a.i./ha). The fungicide chlorothalonil (Bravo 720) was applied at a rate of 1.15 kg a.i./ha with a hand-sprayer. The herbicide metribuzin (Lexone) was applied at a rate of 525 g a.i./ha when needed. Several insecticides were applied weekly in rotation as needed (Methamidophos, Dimethoate, Oxamyl, Monocrotophon, Methomyl, Endosulfan). A second fertilizer application (60 kg N) was applied at hilling on July 26 and 27.

Fungicide spray forecasting. We used a new version of SimCast (Table 2, 3, 4), in combination with three potato varieties in the factorial treatment combinations presented in Table 1. SimCast was developed using weather data from 1997 and 1998 (14) and running simulations of different management scenarios with the Cornell Late Blight simulator (1, 2).

Weather data. Canopy air temperature and humidity were measured at 0.5m height inside the canopy of cultivar Alpha in a plot corresponding to the SimCast treatment. Rainfall was measured with an automated TE525 tipping bucket rain gage (Texas Instruments, Dallas, TX) located at approximately 100m distance at a fully automated weather station. All sensor signals were sampled in 5-min intervals, and 60-min averages were calculated to enable daily forecasting. Weather data were downloaded daily to produce forecasts.

Disease estimates. Disease severity (%) was assessed on a plot basis and was estimated visually as described previously (4). Assessments were made every 3-5 days starting July 5th. Scouting for disease was initiated at emergence of the crop so that onset could be determined accurately.

Results

Although Alpha is very susceptible, a weekly calendar spray effectively suppressed late blight resulting in 10 applications (Table 5; Figure 1A). Disease severity and RAUDPC at the end of the growing season were highest in the 0-S treatment, followed by SIM-MS, and finally the 1-S and SIM-S fungicide application treatments (Figure 1A, Table 5). SIM-S suppressed disease as well as a weekly application and resulted in 11 fungicide applications on a 5-d schedule. SIM-S did not perform as well, resulting in 9 applications and a significantly higher RAUDPC value ($P < 0.05$; Fisher's protected LSD) as compared to a weekly application of chlorothalonil.

Disease progressed much more slowly in the two resistant cultivars Rosita and Norteña than in Alpha. In the case of Rosita the 10d-S treatment received 8 applications, while Norteña received 6 applications in the 14-S treatment (Table 5). Both varieties showed a good degree of resistance to Late Blight (Figure 1 B, C). In the absence of any fungicide Rosita had a final disease severity of 12-25%, while all other treatments had between 0.1 and 2% disease (Figure 1 B). For Norteña, there was only 1-7% final disease severity in the absence of fungicide (Figure 1 C), and there were no significant differences among treatments that had received fungicides. SimCast worked well with both varieties resulting in the same or less applications of fungicide (Table 5). No significant differences were observed between the SimCast treatments and the 10-d application in the case of Rosita or the 14-d application in the case of Norteña.

Discussion

SimCast performed as well or better than a scheduled fungicide application. With increasing level of resistance (from Alpha, to Rosita and Norteña) the number of fungicide applications declined. Compared to the standard grower practice of 16-24 applications (18), SimCast forecast 9-11 applications in the case of Alpha, 6-7 in the case of Rosita and 4-6 in the case of Norteña (Table 5).

SimCast has been implemented in Visual Basic for Applications (MS Excel) and will be made available for downloading from the Internet. Weather data consists of date, average temperature (C) during hours of high relative humidity ($RH \geq 90\%$), the number of hours of high relative humidity, and cumulative precipitation (mm) between 13:00 hrs. of the previous day and 12:00 of the day in question.

The varieties Rosita and Norteña showed a high level of resistance to Potato Late Blight. Both varieties had less than 25% disease at the end of the field season without a single fungicide application. Rosita was released in 1971 (release #: PA-4/71) and Norteña in 1992 (release #: PAP-080592-011). Rosita and Norteña are currently grown on 18% (18) and approximately 5% (INIFAP National Potato Program, *pers. comm.*) of the national acreage. Our results correspond well to informal reports by the national potato program (INIFAP). Rosita has been grown commercially for 27 years and it's resistance to Late Blight does not seem to break down (O. A. Rubio-Covarrubias, *pers. comm.*).

Potato Late Blight on the susceptible cultivar Alpha was well suppressed with one application of chlorothalonil per week confirming our results from 1997 and 98 (11, 12, 13, 14). Based on our results from three field seasons, it appears that a weekly, scheduled fungicide application is optimal. This result will have to be validated in larger field trials, due to the fact that our results are based on 4 × 4m plots and applications with hand-sprayers.

Epidemics of Late Blight in the Toluca Valley seem to begin shortly after the rain season starts. Thus, potatoes are grown when conditions are most conducive to blight. Use of varieties with high levels of field resistance such as Rosita and Norteña in combination with a properly adapted fungicide forecasting system like SimCast show promise for use in the Toluca Valley. Varieties such as Alpha are best managed with weekly or 5-day calendar spray applications.

Conclusions

SimCast accurately predicted fungicide applications for the susceptible variety Alpha, the moderately resistant to resistant variety Rosita and the resistant to highly resistant variety Norteña. Under experimental conditions SimCast predicted considerably lower numbers of sprays than are currently applied by growers. Integration of host resistance with SimCast shows promise for use in the Toluca Valley.

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Table 1. Definition of abbreviations for treatments applied to experiments conducted at the Experimental Field Station of the Mexican National Potato Program of INIFAP in the Toluca Valley in 1999.

	Definition		
Abbreviation	**Cultivar**	**Fungicide Treatment**	**Description**
0-AL	Alpha	none	No-spray control
7d-AL	Alpha	weekly	Calendar spray
SIM-S-AL	Alpha	SimCast: susceptible	Forecast
SIM-MS-AL	Alpha	Simcast: moderately susceptible.	Forecast
0-RO	Rosita	none	No-spray control
10d-RO	Rosita	every 10-d	Calendar spray
SIM-MR-RO	Rosita	SimCast: moderately resistant	Forecast
SIM-R-RO	Rosita	SimCast: resistant	Forecast
0-NO	Norteña	none	No-spray control
14d-NO	Norteña	every 14-d	Calendar spray
SIM-R-NO	Norteña	SimCast: resistant	Forecast
SIM-HR-NO	Norteña	SimCast: highly resistant	Forecast

Table 2. SimCast blight units as determined by temperature and periods of high relative humidity (RH ≥ 90%). Blight units are estimated during a 24-hour period starting at 1300 hrs. to 1200 hrs. of the following day. These rules were modified from Fry et al. (6) to work for Mexican cultivars under tropical highland conditions (Grünwald and Fry, unpublished).

Average temperature (C)[1]	Cultivar resistance[2]	Consecutive hours of relative humidity ≥ 90% that should result in Blight units of:							
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
>27	S	24	…	…	…	…	…	…	…
	MS	24	…	…	…	…	…	…	…
	MR/R/HR	24	…	…	…	…	…	…	…
23-27	S	6	7-9	10-12	13-15	16-18	19-24	…	…
	MS	9	10-18	19-24	…	…	…	…	…
	MR/R/HR	15	16-24	…	…	…	…	…	…
13-22	S	6	…	…	…	…	7-9	10-12	13-24
	MS	6	7	8	9	10	11-12	13-24	…
	MR/R/HR	6	7	8	9	10-12	13-24	…	…
8-12	S	6	7	8-9	10	11-12	13-15	16-24	…
	MS	6	7-9	10-12	13-15	16-18	19-24	…	…
	MR/R/HR	9	10-12	13-15	16-24	…	…	…	…
3-7	S	9	10-12	13-15	16-18	19-24	…	…	…
	MS	12	13-24	…	…	…	…	…	…
	MR/R/HR	18	19-24	…	…	…	…	…	…
<3	S	24	…	…	…	…	…	…	…
	MS	24	…	…	…	…	…	…	…
	MR/R/HR	24	…	…	…	…	…	…	…

1. Average temperature during hours of high relative humidity (RH ≥ 90%).
2. Level of resistance of a potato cultivar to Late Blight: S = susceptibe, MS = moderately susceptible, MR = moderately resistant, R = resistant, HR = highly resistant.

Table 3. Fungicide units (for chlorothalonil) for SimCast as determined by rainfall and the number of days since the last fungicide application. These rules were modified from Fry et al. (6) to work for Mexican cultivars under tropical highland conditions (Grünwald and Fry, unpublished).

Time (days) since fungicide application	Daily rainfall amounts (mm) that result in fungicide units of						
	1	2	3	4	5	6	7
1	< 1	…	…	1-1.4	1.5-3.4	3.5-6	> 6
2	< 1	…	1-1.4	1.5-4.4	4.5-8	> 8	…
3	< 1	…	1-2.4	2.5-5	> 5	…	…
4-5	< 1	…	1-2.4	2.5-8	> 8	…	…
6-9	< 1	…	1-4	> 4	…	…	…
10-14	< 1	1-1.4	1.5-8	> 8	…	…	…
> 14	< 1	1-8	> 8	…	…	…	…

Table 4. SimCast decision rules. These rules were modified from Fry et al. (6) to work for Mexican cultivars under tropical highland conditions (Grünwald and Fry, unpublished).

Logic statements	Cultivar resistance				
	Susceptible (S)	Moderately susceptible (MS)	Moderately resistant (MR)	Resistant (R)	Highly resistant (HR)
Fungicide should be applied if fungicide has not been applied within 5 days					
AND cumulative blight units since last spray exceed:	30	35	40	45	50
OR cumulative fungicide units since last spray exceed:	15	20	25	30	35

Table 5. Evaluation of different fungicide application treatments with three levels of host resistance in terms of numbers of fungicide applications, and relative area under the disease progress curve (RAUDPC; %-days (n = 4; SD = standard deviation).

Treatment[a]	**# Fungicide applications**	**RAUDPC (Mean ± SD) (%-days)**
0-S-AL	0	46.32 ± 6.8
1-S-AL	10	0.23 ± 0.20
SIM-S-AL	11	0.10 ± 0.16
SIM-MS-AL	9	2.05 ± 1.75
0-S-RO	0	2.30 ± 0.36
10-S-RO	8	0.01 ± 0.01
SIM-MR-RO	7	0.14 ± 0.14
SIM-R-RO	6	0.05 ± 0.04
0-S-NO	0	0.53 ± 0.24
14-S-NO	6	0.02 ± 0.01
SIM-R-NO	6	0.02 ± 0.01
SIM-HR-NO	4	0.03 ± 0.04

1. See table 1 for definition of abbreviations.

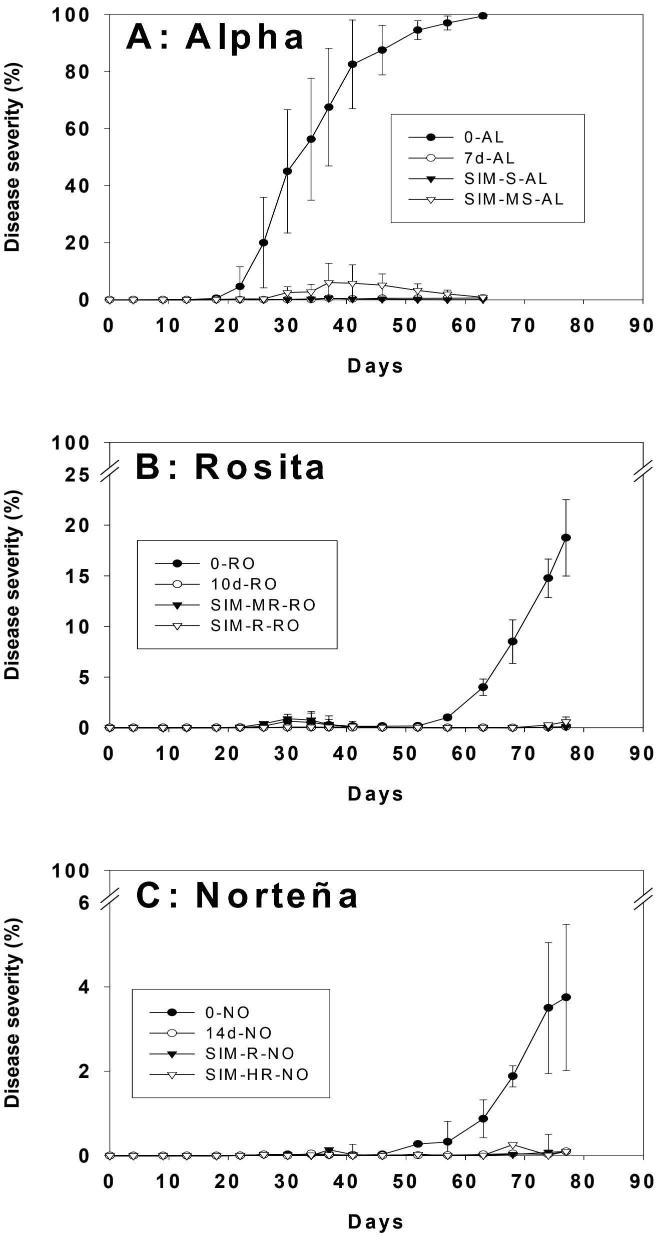

*Figure 1. Disease progress curves of Potato Late Blight on cultivars **(A)** Alpha, **(B)** Rosita, and **(C)** Norteña. See Table 1 for description of treatments.*

Fourth Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Oostende, Belgium, 29 September - 2 October 1999

Supervising the control against the potato late blight using the model MILSOL combined with the varietal resistance : a synthesis of 5 trials carried out in Northern France

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Introduction

With the view to controlling the potato late blight, the SRPV uses 2 models :
MILSOL and GUNTZ-DIVOUX, they are both epidemiological models which describe late blight epidemics. These can predict the risk periods so as to act preventively in the fields.

The model GUNTZ-DIVOUX is a qualitative model that forecasts the occurrences of necroses due to late blight. It gives the seriousness level of attacks.

GUNTZ-DIVOUX is currently used as an indispensable tool by the warning service.

GUNTZ-DIVOUX is able to determine the treatment dates before the late blight occurs. This model is especially used to decide the first treatment before the occurrence of the third generation. However, we realised that GUNTZ-DIVOUX over-assesses the number of fungicides applications, that’s why the SRPV has been working on the validation of another model since 1992, the model MILSOL.

MILSOL is a quantitative model based on temperature and hygrometry that predicts and quantifies attacks of late blight.

The targets of MILSOL is to supervise the control against late blight by reducing the number of treatments. MILSOL is already used by the staff of the SRPV to complete the results provided by GUNTZ-DIVOUX.

MILSOL describes daily the epidemic of late blight by giving the values of 3 variables :

- Weigh = number of spores having contaminated
- Spospo = potential sporulation, number of spores that might be yielded if the weather conditions become favourable.
- Sporul = real sporulation, number of available spores that could be contaminating as soon as the first rain occurs.

Some trials have shown that :

- there is a contamination when the weigh>1
- there is a sporulation when Spospo>3 and Sporul>2

Trials 1998

In 1998, trials for MILSOL validation were set up with the view to reducing the number of treatments by combining the use of MILSOL and the varietal resistances.

3 fungicide protection strategies were tested :

- In the strategy 1, the treatments are carried out according to the agricultural warnings. The two other strategies consist in triggering the treatments according to the risks given by MILSOL.
- Strategy 2 : treatment when the risks are high
- Strategy 3 : treatment when the risks are very high

3 varieties are tested :
Bintje, susceptible variety to late blight
Saturna, quite resistant variety
Samba, resistant variety
2 trials are set up :
One in Nord Pas-de-Calais where the pressure of disease was very high.
Another one in Picardy where the pressure of disease was high.

On Bintje, the untreated plots were 85% destroyed in Nord Pas-de-Calais and 60% in Picardy (cf. table).

The treatments according to the agricultural warnings provided good results in the epidemic control. On the other hand, the strategies 2 and 3 for which the number of treatments was reduced, the treatment efficacy was insufficient.

On Saturna, the control plot was 53% destroyed in Nord Pas-de-Calais and 30% in Picardy. In general, the 3 strategies controlled quite good the epidemic, however, the results for the strategy 3 in Picardy was not as good as the others.

On Samba, the control plot was 37% destroyed in Nord Pas-de-Calais and 12% in Picardy. Good control on the 3 strategies.

The trials in 1998 proved that the varietal resistance plays an important role in the late blight control.
Concerning the susceptible varieties to late blight, such as Bintje, the treatment programme according to the agricultural warnings should be maintained.

As regards the varieties more resistant, such as Samba and Saturna, a reduction in the number of treatments can be planned thanks to the model MILSOL.
Nevertheless, the decisions to treat or not according to MILSOL are only made according to the variables weigh, Spospo and Sporul, and with no precise criteria. That’s why validation trials of MILSOL have been set up this current year in order to define the decision criteria for triggering fungicide treatments by testing the strategy consisting in treating when Spospo>3 and Sporul>2 and to adapt these criteria to the susceptibility of each variety.

Experimentation 1999 programme
5 trials were set up :

- 1 in Auchy les Mines (Nord pas-de-calais)
- 1 in Herlies (Nord pas-de-calais)
- 1 in Paraclay (Picardie)
- 1 in Rethel 5Champagne Ardenne)
- 1 in Albert (Nord pas-de-calais)

3 conditions are tested :

- Condition 1 : treatment according to the recommendations given by the agricultural warnings. Taking a minimum of risk.
- Condition 2 : treatment when Spospo>3 and Sporul>2, with no putting back to zero of the model. Taking high risks.
- Condition 3 : treatment when Spospo>3 and Sporul>2, with a putting back to zero of the model. Taking very high risk.

These conditions are tested on varieties possessing a different susceptibility to late blight :

- Bintje
- Saturna
- Samba

A treatment programme with 3 fungicides :

- DITHANE DG
- SAGITERRE
- ACROBAT M

We consider that the persistence of these products is 7 days.

Design : Each trial has 4 replication with plots 4 rows by 8 meters.
Contaminating rows are planted between the plots so as to have an homogeneous presence of late blight and one implanted row is along each experimental plot.

Results :
A counting is done at least once a week, first in number of necroses, then in percentage of destruction when the pressure becomes high.
-On the figures that show the evolution in the number of late blight impacts over the untreated controls in Auchy les Mines and Herlies we can notice that : the first symptoms of late blight were observed on Bintje on 17 June in Herlies, and later around 28 June in Auchy les Mines.
Then a rise in the pressure of disease is observed over both trials together with significant occurrences of necroses between 5 and 16 July, with a higher pressure in Herlies.
From 19 July onwards, the risks goes down further to the heavy heats that dried up the late blight.

The figure shows that Bintje is very susceptible, affected early by late blight.

The varieties Samba and Saturna are affected later and have shown a similar resistance whereas we expected that Samba was more resistant. The unique difference is Saturna was a little bit affected earlier than Samba.

On the figure that displays the percentage of destruction by late blight, end of July, on Bintje in Herlies, we can see that the treated plots according to the conditions 2 and 3 are more affected by late blight than those treated according to the recommendations given by the agricultural warnings.

On the varieties Saturna and Samba in Herlies, no difference in efficacy was noticed and the treated plots according to the 3 conditions are at the same level.

The results in Auchy les Mines are similar to those in Herlies, Bintje is more affected under the conditions 2 and 3 than under the condition agricultural warning.

No difference have been noticed under the 3 conditions on Saturna and Samba in Auchy les Mines.

At the treatment number level, MILSOL strategies permitted to reduce the number of sprays compared with the condition agricultural warnings under which 11 treatments in Herlies and 9 treatments in Auchy les Mines were carried out.

Under the condition 2, MILSOL with no putting back to zero saved up 6 treatments by carrying out 5 treatments in Herlies and 3 treatments in Auchy les Mines.

Under the condition 3, MILSOL with a putting back to zero saved up 7 treatments by carrying out 4 treatments in Herlies and 2 treatments in Auchy les Mines.

-On the trials in Champagne Ardenne, the pressure of disease was very low, reductions in the number of treatments are obtained 1 to 2 treatments lesser compared with the agricultural warnings. On Bintje, the late blight control was very good under the condition agricultural warnings. The conditions 2 and 3 are a little bit less effective.

The late blight control was very good on Samba and Saturna whatever the condition.

- On the trial set up in Picardy (Paraclay), the pressure of disease was very high, the untreated control plot is entirely destroyed at the end of the trial. On Bintje, the condition agricultural warnings provided a good control with 9 treatments.

Under the conditions 2 (6 treatments) and 3 (5 treatments), the late blight control was good. On Saturna and Samba, the control was very good whatever the condition and 4 or 5 treatments could have been saved up compared with the agricultural warnings.

- On the trial in Albert where the pressure was very high, 12 treatments were carried out under the condition agricultural warnings, the control of the disease was very good. Under the conditions 2 (10 treatments) and 3 (7 treatments), the disease control was not entirely satisfying.

The accurate monitoring of the product rainfastness could not be carried out because of the information lack about the real rainfastness on the plot. In addition, the weather station located at 10 kms from the trial could have missed a contamination period.

Conclusion

The notion of varietal resistance is to be taken into account in the strategies of fungicide protection. According to the varietal resistance, the decision criteria for treating are not the same, the sprays can be done in periods of high risks for the varieties more resistant.

The strategy Spospo>3 and Sporul>2 with a putting back to zero seems to be effective in the supervised control against late blight for varieties.

The criteria for triggering treatments on susceptible varieties should still more be refined so as to get better results.

A new validation in the field is required next season to confirm and specify these results and to attempt distinguishing the strategies with and without putting back to zero.

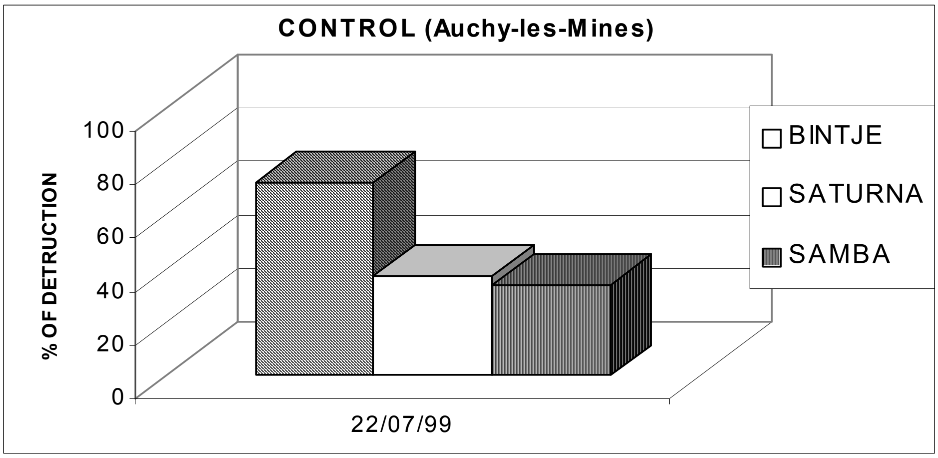
RESULTS SYNTHESIS

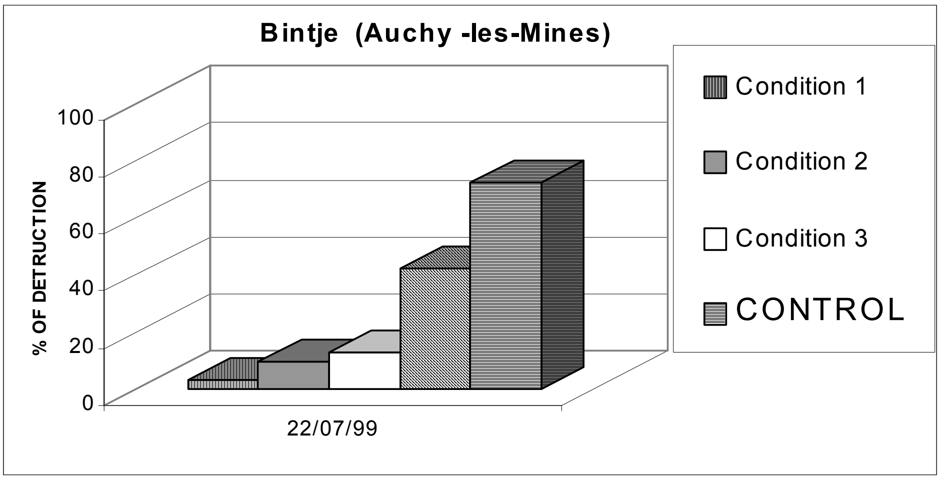
		Bintje				**Saturna**				**Samba**			
TRIALS	**Disease pressure**	**C**	**1**	**2**	**3**	**C**	**1**	**2**	**3**	**C**	**1**	**2**	**3**
HERLIE **late August**	High	99.50%	11 G b	5 I a	4 I a	75%	11 VG -	5 G -	4 G -	82%	11 VG -	5 G -	4 G -
AUCHY **late July**	Average	72%	9 V G b	3 M a	2 M a	37%	9 VG b	3 G a	2 G a	35%	9 VG -	3 VG -	2 VG -
RETHEL **Early August**	Very very low	Impact plants	6 V G	5 VG	5 VG	~0%	5 VG	3 VG	3 VG	~0%	5 VG	3 VG	3 VG
PICARDY **Paraclay** **late July**	High	96%	9 VG	6 I	5 I	41.95%	9 VG	5 VG	5 VG	16.62%	9 VG	4 VG	4 VG
ALBERT	Very high	100%	12VG	10 G	7 I								

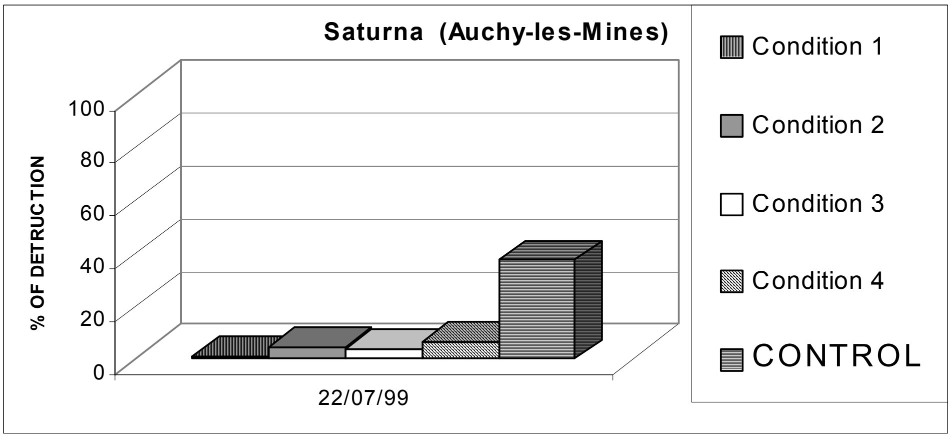
C : disease in the control at the end of the trial / % of destruction

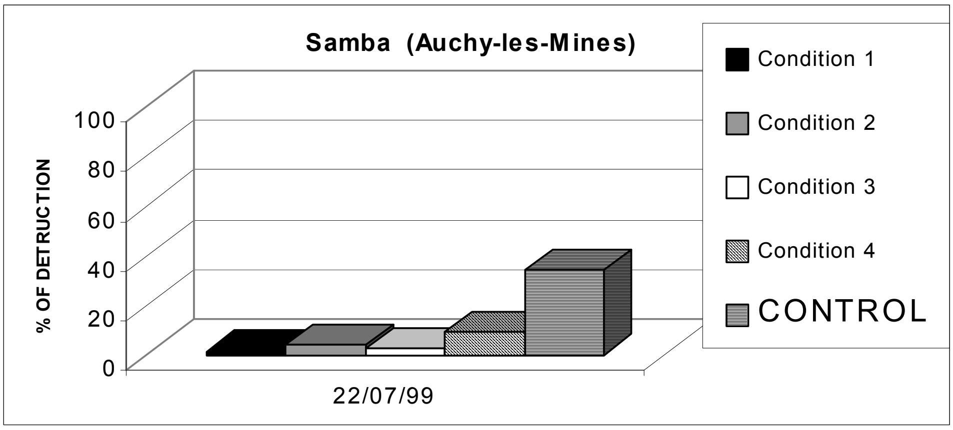
Number of treatments

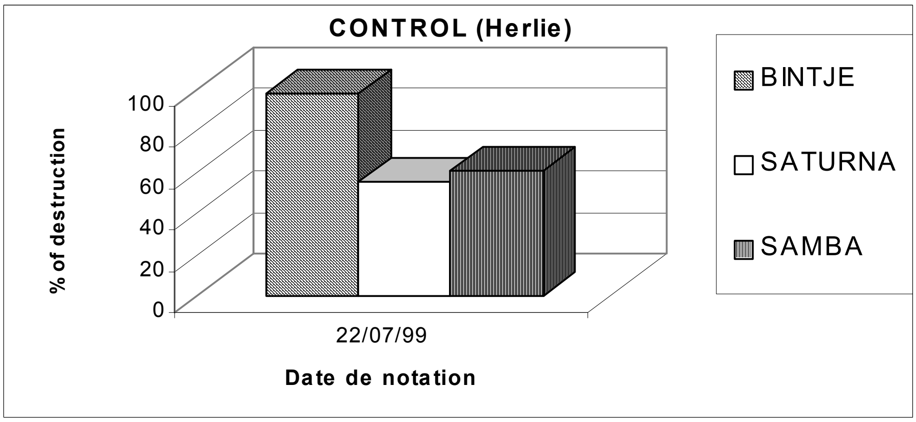
Efficacy VG (very good) G (good-average) I (Insufficient)

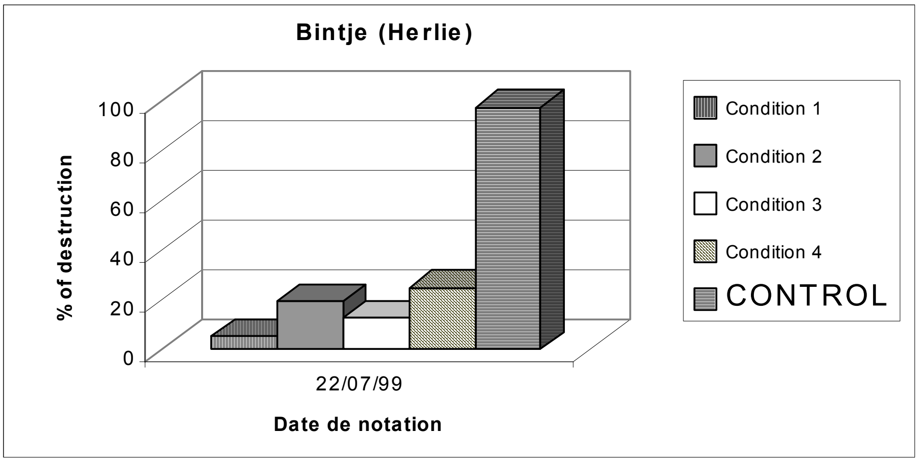

CONTROL (Auchy-les-Mines)
% OF DETRUCTION
100
80
60
40
20
0
22/07/99
BINTJE
SATURNA
SAMBA


Bintje (Auchy -les-Mines)
% OF DETRUCTION
100
80
60
40
20
0
22/07/99
Condition 1
Condition 2
Condition 3
CONTROL


Saturna (Auchy-les-Mines)
% OF DETRUCTION
100
80
60
40
20
0
22/07/99
Condition 1
Condition 2
Condition 3
Condition 4
CONTROL


Samba (Auchy-les-Mines)
% OF DETRUCTION
100
80
60
40
20
0
22/07/99
Condition 1
Condition 2
Condition 3
Condition 4
CONTROL


CONTROL (Herlie)
% of destruction
100
80
60
40
20
0
22/07/99
Date de notation
BINTJE
SATURNA
SAMBA


Bintje (Herlie)
% of destruction
100
80
60
40
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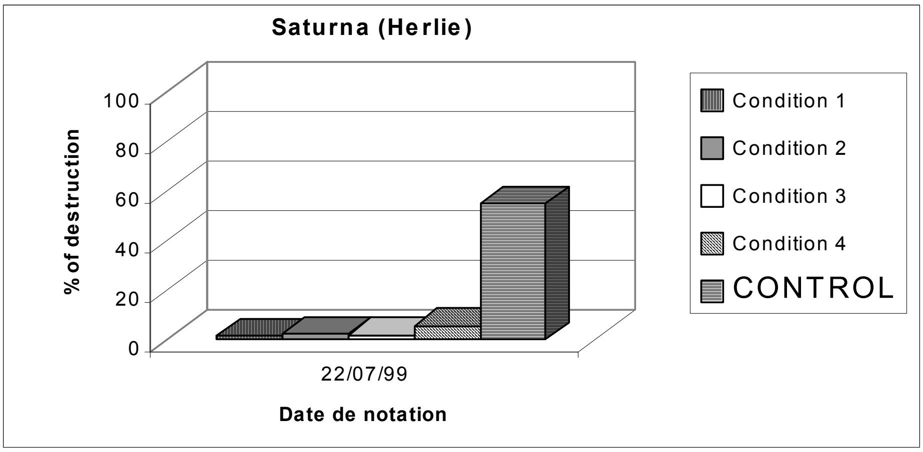
22/07/99
Date de notation
Condition 1
Condition 2
Condition 3
Condition 4
CONTROL


Saturna (Herlie)
% of destruction
100
80
60
40
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0
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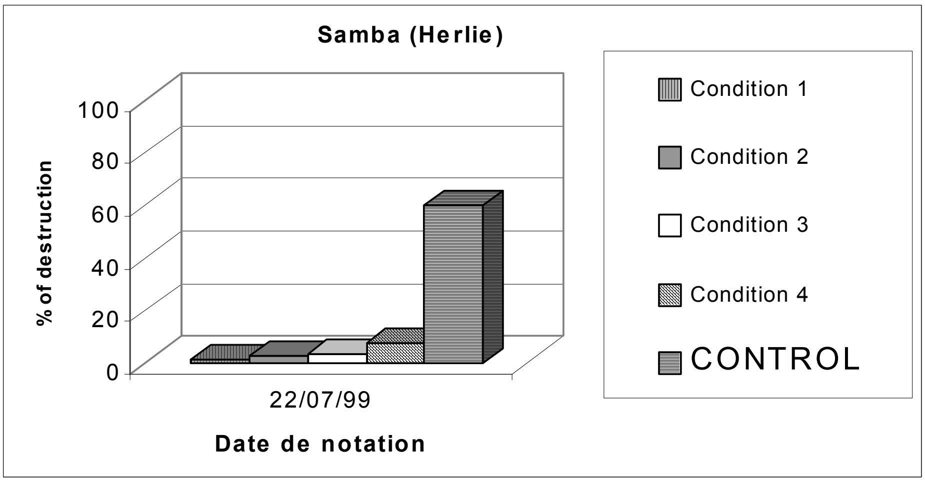
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Fourth workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
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Validation and implementation of a Danish decision support system for the control of potato late blight in the Baltic countries

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Summary

One major task in the European Network for development of an Integrated Control Strategy of potato late blight (EU.NET.ICP) was to discuss the possibilities of exportation and adaptation of existing late blight decision support systems (DSS) between countries to avoid duplication of efforts. Two Danish systems aimed at information and decision support for the control of potato late blight (PC-NegFry and Pl@nteInfo) are currently under implementation in Estonia, Latvia and Lithuania. This paper describes methods, preliminary results and problems in the implementation of these systems in the three Baltic countries in 1999.

Keywords: Potato late blight, decision support system, Baltic countries, Internet, NegFry, Pl@nteInfo

Introduction

In the Baltic countries (Lithuania, Estonia and Latvia), late blight caused by Phytophthora infestans (Mont.) de Bary, is the most serious problem in the potato production. Pesticides are relatively expensive and the average number of fungicide applications is 2-4, although the need probably is in the area of 4-10, depending on seasonal weather conditions. Most used fungicides are products based on Maneb/Mancozeb and the products Ridomil, Acrobat and Tattoo. The quality of seed potatoes is generally low, and there are indications that a new P. infestans population is established and acts more aggressively than in former time. Farmers start their spraying strategies at the time of row closing, alternatively based on local disease recordings. Weather based forecasting systems do not exist, as ordinary weather data are not available for the agricultural sector, or data are too expensive to buy from the meteorological offices.

Only 10-15 % of the farmers are now able to produce potatoes based on Western European standards and input levels (Schepers, 1999), and the use of pesticides is relatively low at present. However, as the general economical situation improves it is likely that the consumption will increase. By adapting and implementing existing DSS´S for plant protection, this can be a help to avoid an excessive use of pesticides in the future.

In Denmark decision support for the control of potato late blight is available both as a PC-based software, NegFry (Hansen et al., 1995; Hansen, 1998) and as a part of the Internet based information and decision support system called Pl@nteInfo (Jensen et al, 2000). PC-NegFry was developed for use on field level to forecast the time of primary attack (initial spray) and to recommend subsequent fungicide applications during the season. NegFry operates with weather data from local weather stations (Hardi metpole), alternatively with interpolated weather data from the Danish Meteorological Institute (Lassen & Hansen, 1999). The disease forecast has been implemented in Pl@nteInfo, calculating the regional risk of primary attacks based on weather data from the Danish network of ordinary meteorological stations (Hansen, 1997). This information compliments the use of PC-NegFry on field level. In 1999 comprehensive information and decision support were available through Pl@nteInfo, such as late blight forecasting based on NegFry, monitoring of early attacks of late blight, information about late blight biology and fungicides, weather radar films to predict precipitation during the coming hours, potato variety information etc. (Hansen et al., 1999)

PC-NegFry and part of the Danish Pl@nteInfo system are now under implementation in the Baltic countries. These activities are part of a much wider project titled "Development of a Decision Support System for Integrated Pest Management in the Baltic countries" (http://www.ipm-baltic.dk), supported by the Danish Ministry of Food, Agriculture and Fisheries. All past and future activities have the common objective to support the development of environmentally friendly and sustainable agriculture in the partner countries.

This paper describes results of the validation of PC-NegFry in Estonia, Latvia and Lithuania in 1999. It also includes a short description and a discussion of the approach used for the implementation of Danish DSS components into Baltic Internet based information and decision support systems.

Validation of NegFry

Materials and methods

NegFry was validated in Lithuania in 6 small plot trials, 3 at Voké and 3 at Dotnuva. In Estonia three small plot trials were conducted at Jõgava. In Latvia 6 small plot trials and 3 demonstration trials were conducted at Priekuli, Saldus, Vecauce (2), Stende (Talsi), Skriveri (2), Bauska and Carnikava. In total 18 trials were carried out in the three Baltic countries in 1999. Crop varieties used in the validation trials are given in Table 1. The date of crop emergence in the trials varied between late May to early June.

The methods for validation of NegFry were based on the field trial guideline defined for validation of late blight DSS´s in EU.NET.ICP in 1999 (Jörg & Kleinhenz, 1999). Treatments in field trials: untreated, standard (routine), "Local practice" (only in Lithuania) and according to NegFry. In most trials the first two treatments were carried out with systemic fungicides, (Tattoo or Ridomil) or translaminar fungicides (Acrobat). The contact fungicide, Dithane, was used subsequently. This was valid for both standard treatment and treatment according to NegFry. Standard treatment was defined as treatment at 8-12 days fixed intervals depending on the fungicides used.

Local Hardi metpoles were used as the weather data source. In 1999 there were 3 metpoles in Estonia, 11 in Latvia and 17 in Lithuania. Translation of software, conduction of a computer class and a workshop before the season facilitated high quality of the results of the validation trials.

Results

The 1999 growing season in the Baltic countries was not very favourable for late blight development. According to NegFry, risk of primary attacks occurred during the period June 29- July 6 in Latvia and in Lithuania. At Jõgava in Estonia this was a little bit later

(July 15) (Figure 1). Late blight was found in the area at the same time or shortly after that, but often 2-3 weeks later in the field trials in Latvia. In Lithuania and Estonia late blight was not found in the field trials, but only in fields or home gardens in the area (Figure 1 and Table 1). The results indicate that weather conditions favoured establishment of primary attacks in early July, but a change to very hot and dry weather stopped or delayed the disease development from primary infected mother plants at some of the locations until late July or early August e.g. at Dotnuva, Priekuli and Saldus.

In Latvia and in Estonia the Standard fungicide strategy was initiated at the time of row closing, mid to late June. In Lithuania the Standard fungicide strategy was initiated when late blight was recorded in the region, June 29 at Voke and July 24 at Dotnuva (Figure 2 and Table 1). The times of first and last fungicide applications in the trials are given in Table 1. The crop was desiccated with Reglone in most cases during the period late July to mid August. This was a little bit earlier than normal, caused by the dry and hot weather and the fact that the trials were not irrigated. The number of fungicide applications according to standard treatment varied between 3 and 7. In some cases the fixed intervals were prolonged because of the very dry weather. The number of fungicide applications according to NegFry varied between 2 and 4.

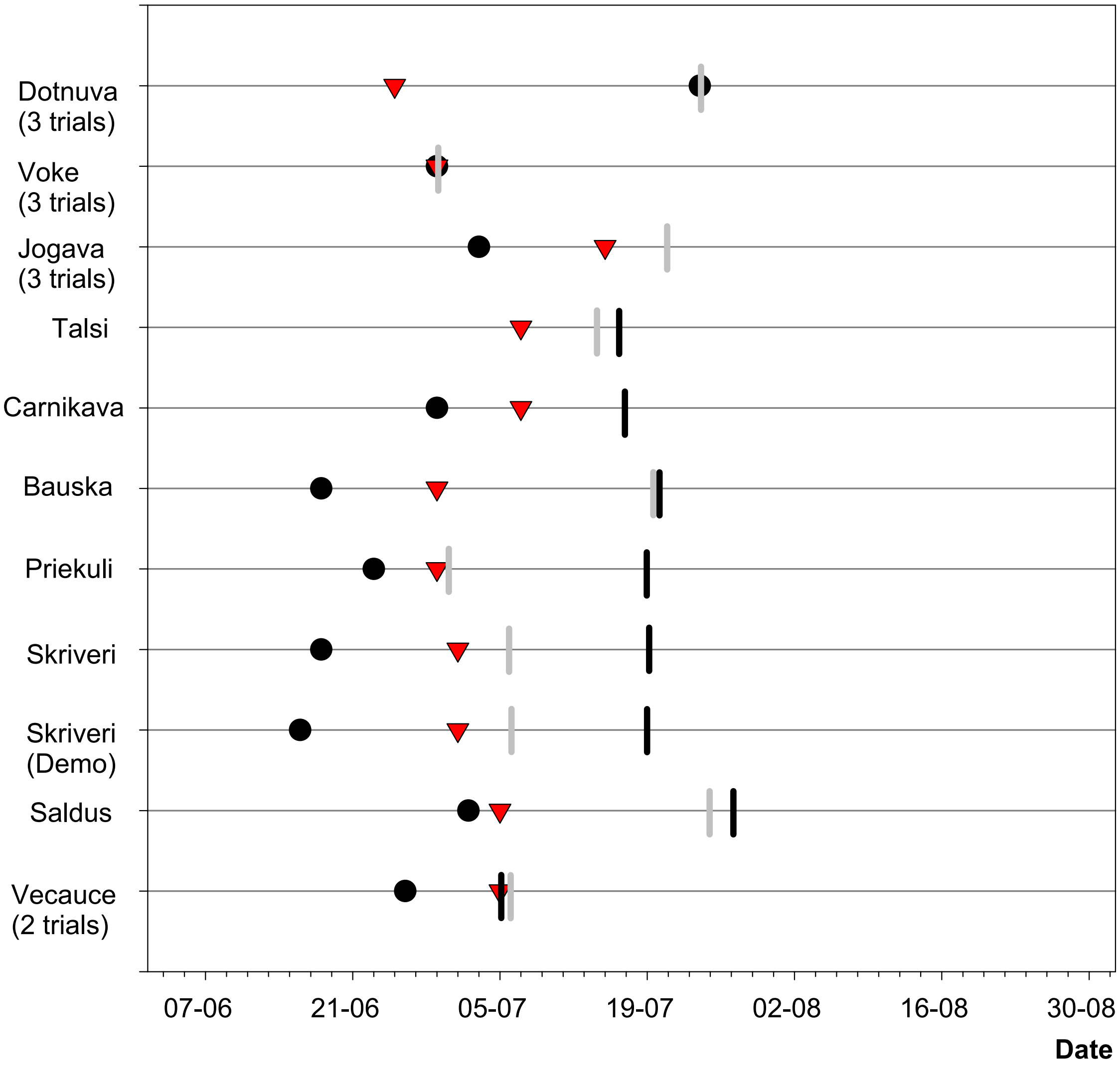

Figure 1. First time late blight was recorded in validation trials/area and time of first applications recommended by NegFry in the Baltic countries, 1999. Grey bars indicate late blight observed in the area. Black bars indicate late blight recorded in the field trial. Dots indicate date of the initial spray according to standard treatment. Triangles indicate the date of first fungicide application recommended by NegFry.

Table 1. Results from validation of NegFry in the Baltic countries in 1999. Figures in brackets after crop variety names indicate the variety susceptibility to late blight, Susceptible (1), Moderate susceptible (2) and moderate resistant (3). For the trials in Latvia, disease end of season in untreated indicates the disease level at the time of crop desiccation. This was zero days (Vecauce) and up to two month (Skriveri) before the last disease assessment in standard and NegFry treatments.

Country and Station name	**Variety name**	**First – last fungicide application (date)**		**No. of fungicide applications**		**Disease end of season (%)**			**Tuber blight (%)**	
		Standard	**NegFry**	**Standard**	**NegFry**	**Untreated**	**Standard**	**NegFry**	**Standard**	**NegFry**
Latvia										
Vecauce	Mutagen. (1)	06.26-07.30	07.05-07.29	4	3	>0.1	0,00	0,00	0,00	0,00
Vecauce	Sante (3)	06.26-08.17	07.06-08.26	6	3	>1.0	0,25	0,25	0,00	0,00
Saldus	Sante (3)	07.02-08.13	07.05-07.27	4	2	>1.6	1,00	0,50	0,00	0,00
Skriveri	Sante (3)	06.16-08.19	07.01-08.19	6	3	>25.0	1,40	1,40	0,00	0,00
Skriveri	Sante (3)	06.18-08.19	07.01-08.19	6	3	>25.0	1,50	1,40	-	-
Priekuli	Sante (3)	06.23-08.09	06.29-08.09	5	3	>8.0	1,00	1,00	0,00	0,00
Bauska	Sante (3)	06.18-08.09	06.29-08.02	6	3	>0.1	0,75	2,00	0,00	0,00
Carnikava	Asteriks (2)	06.29-08.09	07.07-08.06	4	4	>1.0	0,40	0,50	0,00	0,00
Talsi	Sante (3)	07.03-08.18	07.09-08.16	4	3	>1.6	1,00	0,50	0,00	0,00
Estonia										
Jogava	Anti (3)	07.03-09.08	07.15-09.08	6	3	0,00	0,00	0,00	0,00	0,00
Jogava	Ants (2)	07.03-08.24	07.15-08.28	5	3	0,00	0,00	0,00	0,00	0,00
Jogava	Adora (1)	07.03-08.24	07.15-08.24	5	3	0,00	0,00	0,00	0,00	0,00
Lithuania										
Voke	Venta (2)	06.30-07.21	06.29-08.12	4	2	0,00	0,00	0,00	0.00	0.00
Voke	Mirta (2)	06.30-08.03	06.29-08.12	7	2	0,00	0,00	0,00	0.00	0.00
Voke	Aistes (2)	06.30-08.12	06.29-08.15	7	2	0,00	0,00	0,00	0,00	0,00
Dotnuva	Venta (2)	07.26-08.16	06.25-07.15	3	2	0,00	0,00	0,00	0,00	0,00
Dotnuva	Mirta (2)	07.26-08.16	06.28-08.16	3	3	0,00	0,00	0,00	0,00	0,00
Dotnuva	Aistes (3)	07.26-08.16	06.28-08.16	3	3	0,00	0,00	0,00	0.00	0.00

As late blight did not appear in the field trials in Estonia and Lithuania, the second part of the NegFry system could only be evaluated based on the results from Latvia. In the nine trials from Latvia, up to 25 % attack of late blight was recorded in untreated plots at crop desiccation. Most of the untreated plots were desiccated at disease levels of 0.1-10 % according to the field trial guideline. In the two trials at Skriveri the untreated plots were desiccated on July 27 and July 29 respectively. The last disease assessments in the Standard and NegFry plots were made on September 26 in both trials. Late blight was recorded in treatments according to both Standard and NegFry in all the trials in Latvia but at very low levels, 0 to 2 % (Table 1).

The difference in disease level at the end of the season between Standard and NegFry was not significant according to a T-test. In the NegFry treated plots the disease level at the end of the season was the same (Vecauce, Skriveri, Priekuli and Carnikava) or a little bit lower (Saldus and Talsi) compared to Standard treatment although the use of fungicides was 25-50 % lower. Only at Bauska a higher disease level was recorded in the plots sprayed according to NegFry (2 %) compared to Standard treatment (0.75%) (Table 1).

Because late blight in most cases appeared relatively late in the trials (mid July) and the weather conditions were relatively unfavourable for disease development, it is not possible to make clear conclusions about the potential of NegFry. Probably the system can be used in dry seasons with success, but more validations are needed including seasons with more humid weather conditions favourable for disease development.

Discussion

When fungicides are cheap and there are no restrictions in their use, most farmers will claim that the criteria for success of using a DSS should be 100 % control at the end of the season. In field trials the inoculum pressure from untreated plots and/or infection rows is often much higher than in practice. Therefore, in field trials it is more relevant to compare control strategies than to focus on the exact disease level at the end of season applying the DSS. In the comparison of control strategies, the reference is often routine (standard) defined as approximately weekly fungicide applications or “local practice” strategies.

In attempt to minimise the use of pesticides in a DSS strategy, there will in general be an increase in the level of risk taken and in the importance of the uncertainty of biological and physical input variables used for running the DSS. Therefore the balance between fungicide use and the control effect applying the DSS has to be discussed.

The results from Latvia are shown in Figure 2 as the reduction in fungicide use when applying NegFry (x-axis) versus the difference in disease level [%] at the end of the season - standard minus NegFry (y-axis). Assuming that the goal is to minimise the fungicide use compared to a reference treatment, the validation of the DSS will be successful if results are in window A (reduction of fungicide use and higher control effect than standard treatment). If results are in window B, the DSS strategy uses more fungicides than the standard treatment, but have higher or the same control effect than the standard treatment. Results in window C are not successful as the DSS strategy use more fungicides and have lower control effect than the standard treatment. Results in window D at first view seems not to be successful as the DSS strategy has a lower control effect than the standard treatment. If a minimisation of the fungicide use becomes important or a must because of political restrictions, maybe a certain low level of disease can be accepted in a validation of the DSS. Depending on the situation, the reference lines for relative control effect and goals for reduction in fungicide use can be changed, and thereby the criteria of success for validation of the DSS (Figure 2).

In the Baltic countries the goal is to minimise the use of fungicides and to keep the control level as high as possible. Assuming that the goal for fungicide use is about 20 % lower than standard treatment and it is accepted that the control effect using the DSS is up to 1 % lower than standard treatment, the reference lines defining success can be changed as shown in Figure 2. Based on this criteria of success, in Latvia 7 of the 9 validation trials were successful, and two were not. Further discussions will be needed about the definitions of standard treatment (routine) and conventional treatment (local practice). In Figure 2 the reference treatment was chosen as the standard treatment. In the same way the validation of the DSS can be compared to conventional treatment (local practice).

Conclusions about validation of NegFry

NegFry was validated in Estonia, Latvia and Lithuania in 18 field trials in 1999. The use of fungicide was significantly lower in plots treated according to NegFry compared to standard treatment (25-50%). Only in Latvia late blight appeared in the trials. In the plots treated with fungicides (standard and NegFry), the disease levels at the end of season were relatively low (0-2 % severity) and not significantly different. Because the weather conditions were relatively unfavourable for disease development, only preliminary conclusions could be drawn about the potential of using NegFry in the Baltic countries. More validation trials are needed in growing seasons with more humid conditions when the challenges for test of a DSS are different than in a dry season like the one in 1999.

After evaluation of the NegFry system in Denmark, it is now decided to develop new components to support decisions of the time, dosage and fungicide type of subsequent fungicide applications during the season. This component will be a substitution for the calculation of blight units in NegFry. A major task will be to include the use of a weather forecast including uncertainty in the DSS output. The Baltic countries will participate in the development of new sub-models.

After validation and adaptation of NegFry sub-models, these will be implemented on the Internet, in the Danish Pl@nteInfo system as well as in similar systems in the Baltic countries.

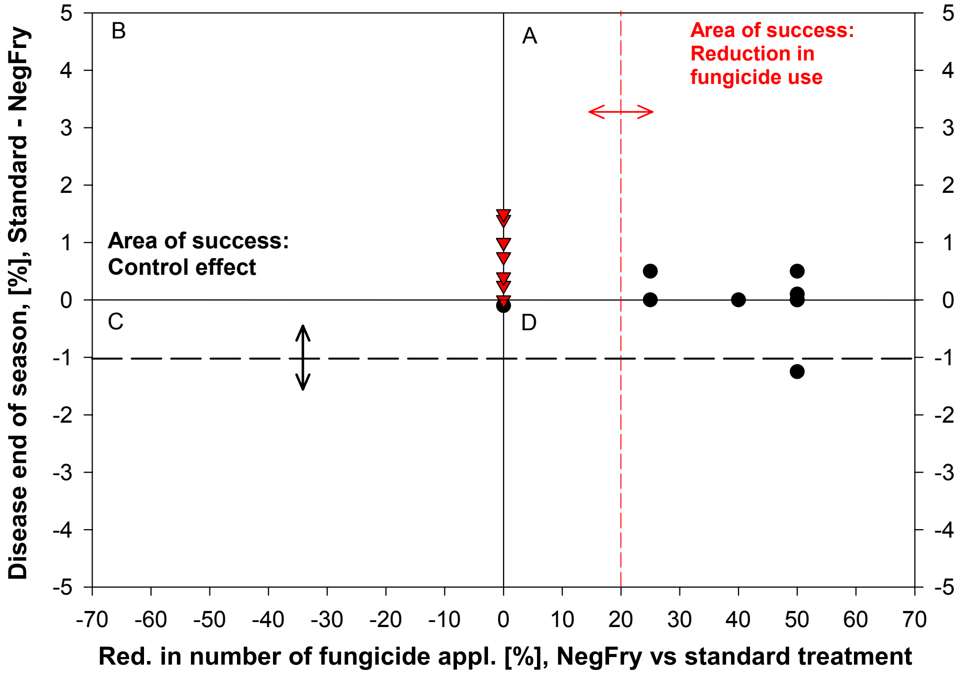

Figure 2. Results from test of NegFry in nine field trials in Latvia in 1999. X-axis: Reduction in the use of fungicides [%] when applying NegFry. Y-axis: Standard minus NegFry disease [%] at the end of the season (dots). The triangles show the level of disease [%] at the end of season in standard treated plots in the nine field trials. This indicates the level of disease in the reference control strategy. The number of fungicide applications in standard treated plots was between 4 and 6 (Table 1).

Implementation of the Danish Pl@nteInfo in the Baltic countries

General approach for the exportation of DSS components

The Danish Pl@nteInfo system is based on the SAS System (SAS, 1989). The advantage of using this system, is that all applications, databases and documents can be programmed and managed by the same system. But, on the other hand the SAS license is relatively expensive and the programming and management of the system are quite complicated. In the partner institutions in the Baltic countries the experiences in using SAS as well as Internet technologies were limited. Therefore, the general approach in this project was to convert the SAS applications into web applications using techniques like HTML, XML, Java, ASP/JSP and SQL databases.

The advantages of this approach are:

- Java components are independent of platform.
- Object oriented components are easy to adapt, modify and reuse.
- The components can easily be implemented and integrated in existing systems.
- A Java server including license is much cheaper than using SAS IntrNet.

PC-NegFry and PC-Plant Protection (cereal diseases, pests and weeds) are now reconstructed in a similar way. Those methods and components relevant for Baltic partner countries will be adapted and implemented in existing or new DSS shells made by the partner countries themselves (Figure 3).

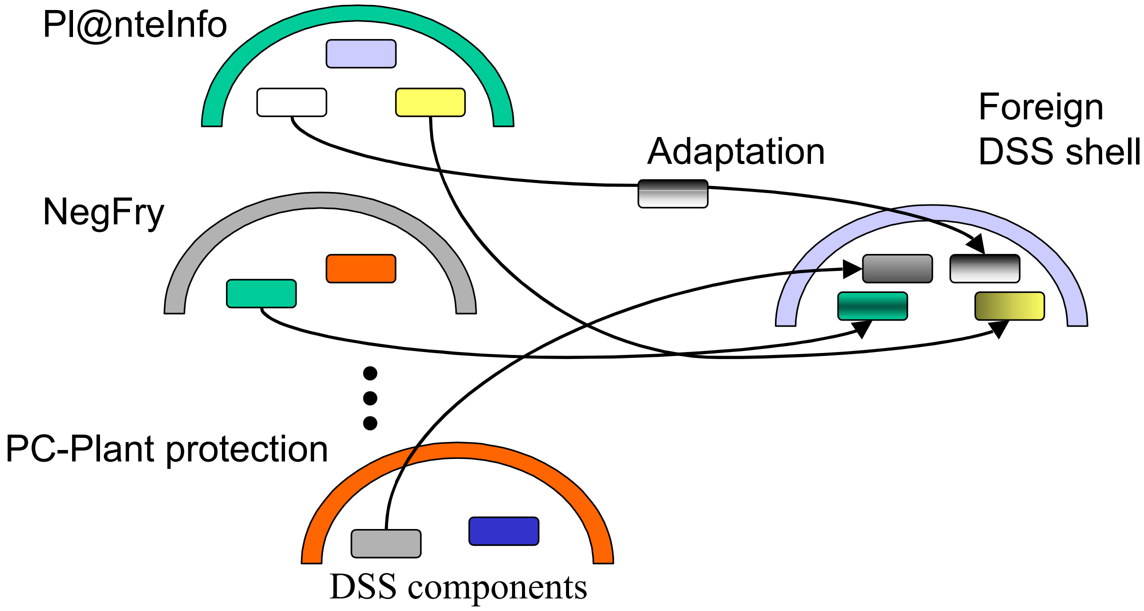

Figure 3. General approach for the exportation of three Danish decision support systems. Sub-models and methods are validated and adapted for local conditions. Sub-models and methods are then programmed as Java-components and implemented into the foreign DSS shell (Internet or PC) developed by the individual partner countries.

Using the Pl@nteInfo server as host in 1999

In 1999 Internet based information systems for Estonia, Latvia and Lithuania were developed on the Pl@nteInfo server based on existing SAS technology (www.planteinfo.dk/ee, www.-planteinfo.-dk/lv, www.planteinfo.dk/lt) (Figure 4).

Information available in 1999 was:

- News service in local language including general information, advice and interpretations of current information concerning plant protection.
- Maps and time series with daily updated weather information for temperature, relative humidity and rainfall based on measurements with Hardi metpoles.
- Maps and time series with daily updated accumulated and daily risk values according to the NegFry system
- Monitoring data for early attacks of potato late blight (only Lithuania).

Based on subscription number, a user can be allowed to upload information into the Pl@nteInfo system. This existing application was used for the Baltic news services. Existing applications were slightly adapted and reused for drawing maps and figures and for calculation of late blight risk indices. For monitoring via Internet, the existing Danish system was used directly. A new application had to be developed to transfer the local Hardi metpole data to the Pl@nteInfo server, and a language database was built to administer the three different Baltic languages (Figure 4).

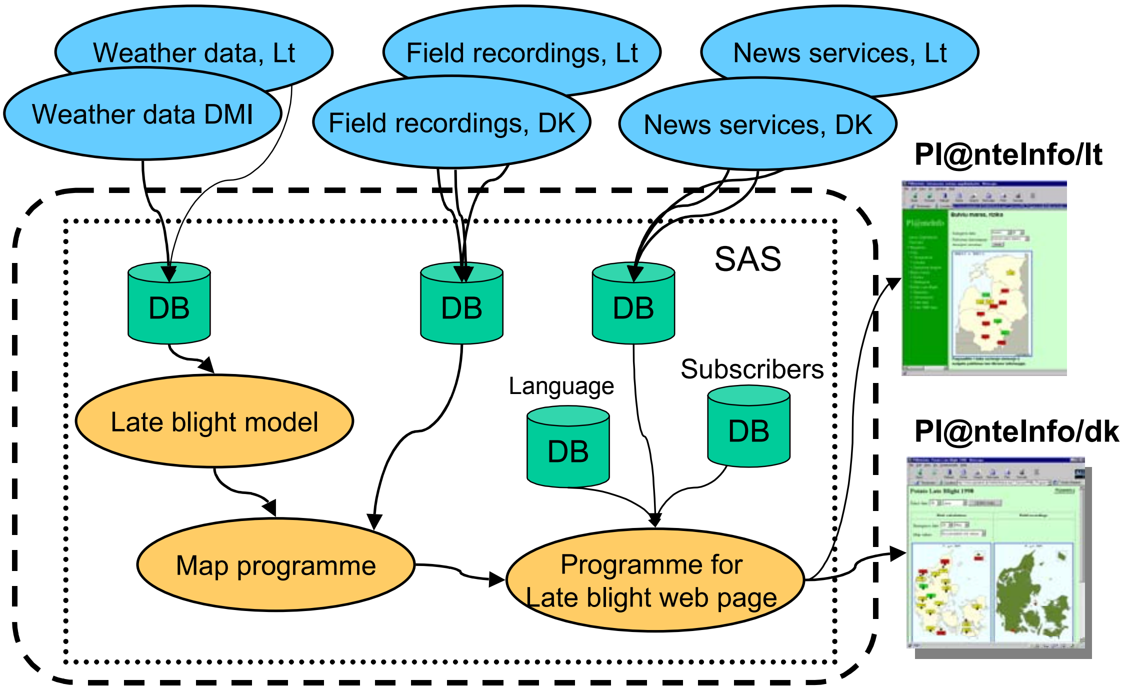

Figure 4. Components necessary for the production of late blight forecasting and monitoring in Pl@nteInfo, using the Danish and the Lithuania versions as an example. Weather data from Lithuania are based on Hardi metpoles. Weather data from Denmark are based on ordinary meteorological stations from the Danish Meteorological Institute (DMI). Field recordings of late blight are entered via the same Internet based monitoring system. Data from all partner countries are standardised and stored in the same SAS databases (DB).

In 1999 the forecast of primary attacks in NegFry was converted from a C++ based component to a Java component. This component was implemented on a Lithuanian server and integrated with a component for the transfer and import of weather data from the local metpoles. Another Java component was developed to produce a Lithuania map with late blight risk indices. This was the first successful step in the development of a local information and decision support system based on DSS components from Denmark.

Discussion and conclusions about implementation of Internet based DSS

After only one year, the results and the experiences from the current project clearly show the potential of using Internet and web applications for the transfer of a DSS from one country to another. In only three months, it was possible to make a first running version of an Internet based information and decision support system for Estonia, Latvia and Lithuania including news service, local weather information, late blight disease forecasting and monitoring. Although this first version is using the Danish Pl@nteInfo server as host, this is not recognised by the users of the system in partner countries as all texts are in local language and the news service is managed totally by the partners.

From year 2000 the first version of a local hosted system will be available in Lithuania. This will not be based on SAS but on a combination of Java components, Active Server Pages, Java server pages, HTML, XML and SQL databases. The experiences from Lithuania as well as web components developed for Lithuania will be used to develop similar systems in Latvia and Estonia in year 2001 and 2002.

We believe that the shells of DSS´s should be developed by the individual countries, and in the current project only stand alone models and methods are adapted and exported from Denmark to the Baltic countries. Before implementation on the Internet, the components are reconstructed into Java and web based components in collaboration with the partners, so that they can maintain these components and build new ones after the project has ended. In this way the chance of sustainability is much higher than if the total system was exported, and partners only were trained in the use of the system.

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Integrated Control Strategy of potato late blight
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The Masterplan Phytophthora
A nationwide approach to late blight

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Introduction

The climatic conditions in The Netherlands, are usually favourable for the development of late blight. This together with the intensive growing of (susceptible) potato varieties and the more aggressive population of *Phytophthora infestans* leads to control strategies with 10-15 fungicide sprays in a growing season. The control of late blight accounts for a major part of the total fungicide input in agricultural crops (Table 1 & 2). In 1990 the Dutch government launched the Multi-Year Crop Protection Plan (MYCPP) which aimed at a reduction of fungicide input of 25% in 2000. Mainly due to intensive spraying in orchards to control scab, in flower bulbs to control Botrytis and in potatoes to control late blight this reduction target has not been achieved. In order to safeguard the continuity of growing potatoes in The Netherlands and achieving a reduction of fungicides used to control late blight, a nationwide Masterplan Phytophthora was launched by the Agricultural and Horticultural Organisation in The Netherlands (LTO-Nederland) in 1999.

Table 1. Estimated use of fungicides (in kg active ingredient x 10^3) in The Netherlands (sources: Nefyto, CBS).

	All sectors	Arable Farming	Potatoes	Late blight
1984-1988	4,039	2,162		
1991	4,281			
1992	4,192	2,262	1,973	1,837
1993	4,007			
1994	3,883			
1995	3,990	1,719		
1996	3,624			
1997	4,356			
1998	5,179		1,940	1,847

Table 2. Estimated use of active ingredients used to control late blight (in kg active ingredient x 10^3) in The Netherlands (source: CBS).

Active ingredient	1992[1]	1998[2]
Maneb/mancozeb/metriram	1,570	1,132
Chlorothalonil + propamocarb	0	352
Fentinacetate	212	90
Fluazinam	0	192
Dimethomorph	0	21
Cymoxanil	0	40
Total use	1,783	1,829

[1] 187,000 ha potatoes grown in 1992

[2] 179,000 ha potatoes grown in 1998

Masterplan Phytophthora

The Masterplan Phytophthora is a coordination of all activities of potato growers, chemical industries, applied and fundamental research institutes, breeders, environ-mental organisations, packagers, potato processors, biological growers, government and extension services to tackle the late blight problem in The Netherlands. Activities of all participants are discussed, agreed upon and integrated in the Masterplan. Special attention is being given to the communication of results to all participants and growers. The impact of the Masterplan will also be monitored.

The main general objectives of the Masterplan are (a) safeguarding the continuity of growing potatoes and (b) reducing environmental side-effects by decreasing fungicide input. The Masterplan aims at a reduction of environmental side-effects of 35% in 2001 and 50% in 2005 compared to the years 1996-1998. This leads to the following concrete objectives:

Short term objectives

1. The growers have to anticipate on factors they cannot influence
    1.1 Evaluate and optimise the Decision Support Systems Prophy and Plant-Plus
    1.2 Update epidemiological parameters to be included in these DSS's
    1.3 Setup of a nationwide network of weather stations
2. Everybody controls (initial) infection sources
    2.1 Develop and implement measures to prevent initial sources (dumps)
    2.2 Setup a nationwide network of scouts
    2.3 Communication to home gardeners
    2.4 Investigate the rôle of polythene covered crops as an initial infection source
3. Investigate rôle and control of oospores
    3.1 Investigate conditions in which oospores are formed and how they can infect
    3.2 Relation between resistance and oospore formation
    3.3 Influence of fungicides on formation and germination of oospores
4. Growers realise the impact of an infection and know how to prevent it
    4.1 A harmonised control strategy is developed
    4.2 Develop a biological system to grow potatoes with minimal risk for late blight

Medium-term objectives

1. Ensure the availability of enough biological and chemical fungicides
    1.1 Clarify the registration status in the near future of late blight fungicides
    1.2 Support the biological development and registration of the biological fungicides (eg. Citrex = Vi-Care)

Long term objectives

1. Commercially interesting varieties should be late blight resistant
    1.1 Revision of protocol to test late blight resistance and testing all important varieties with this protocol
    1.2 Develop a plan to promote the use of resistant varieties by growers, contracters and processing industry.
    1.3 Coordinate activities of breeders to promote the exchange of resistant lines in order to accelerate the development of resistant varieties.

Structure of the Masterplan

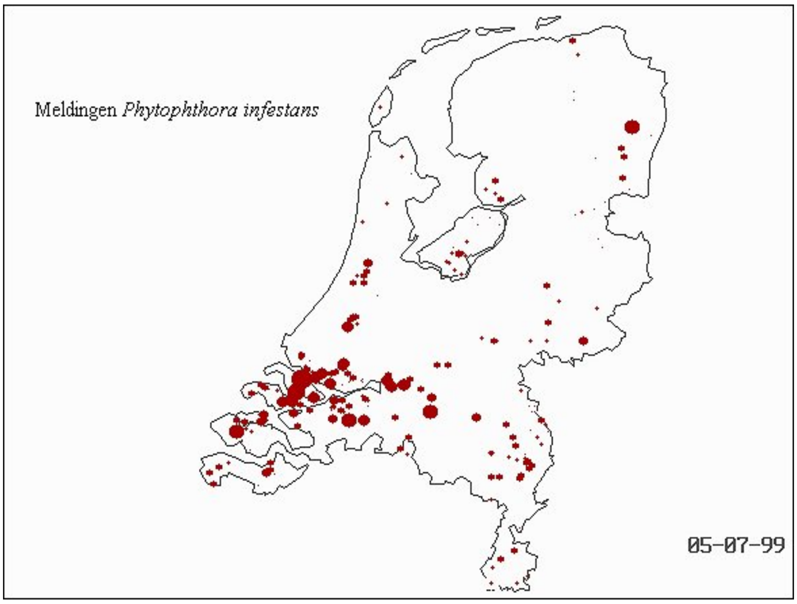
The Masterplan is coordinated by the Agricultural and Horticultural Organisation in The Netherlands (LTO-Nederland). Together with representatives from the Main Board for Arable Products (HPA), the MYCPP and the DLV Advisory Service, activities are planned, discussed and coordinated. All activities in the Masterplan (research, communication & monitoring) are collectively financed by the Dutch farmers through paying a specific Masterplan levy of DFL 10,- per hectare of potatoes. In this way DFL 10 million becomes available in 1999-2001 to tackle the late blight problem in The Netherlands.

Research projects

A lot of projects started in 1999. Results from only a number of projects are mentioned here:

- *Evaluation of DSS*: 12 Plant-Plus and 9 Prophy users were visited regularly throughout the growing season. In these visits, the experiences of the farmer with the systems were discussed and late blight and the growth of the crop were monitored. Most of the users started to spray earlier than the recommendations of the DSS. The following applications were timed for 70-80% according to the DSS, although the amount of curative fungicides was higher than the DSS recommended. The users could reduce their number of sprays with 3 compared to a weekly spray programme. A number of recommendations was given for improvement of the DSS.
- *Measures to prevent inoculum sources*: A nationwide regulation to cover dumps before 15 April was intensively communicated to farmers through a publicity campaign. Everybody was invited to report uncovered dumps to the Plant Protection Service who in its turn sent the farmer a yellow (warning) card. When after three days the dump was not covered, the farmer received a red card together with a money fine. In 1999, 77 yellow cards and 12 red cards were issued. The project positively contributed to a higher awareness of the importance of dumps as a primary infection source.
- *Setup a nationwide network of scouts:* This project was setup to generate information on regional infection pressure. Control strategies could be tuned accordingly. The scouts reported 558 infected field/dumps. These foci were reported on the Internet (http://www.plant-net.com/barometer) and in agricultural newspapers and journals. The foci were also used to generate recommendations in Plant-Plus, Prophy and Alphi

(Figure 1). Alphi is an interactive voice response system based on Plant-Plus that provides users with spray recommendations (Bouwman & Raatjes, 2000)



- *Development of a harmonised control strategy:* A reduction of fungicide input can be achieved when the choice of fungicides, dose rate and timing are adapted to the infection pressure and weather conditions. DSS provide such a strategy but the objective of this project was to develop guidelines for a Good Plant Protection Practice (GPP) when DSS are not used. As a starting point for the discussions, in which 6 agrochemical companies participated, the EPPO guideline for GPP was chosen. A draft of this Dutch Guideline is still being discussed.
- *Investigate the rôle of polythene covered crops as an initial infection source:* In 1999, 39 crops were inspected immediately after the polythene had been removed. In 3 crops in which late blight was present, growers applied curative fungicides to control the disease. Almost all growers treated their crop preventively within one week after removal of the polythene. Circumstantial evidence made it plausible that infected tubers caused the primary infection and not oospores. Tests in the spray cabine showed that spraydroplets penetrated plastic and acryl in such an extent that is is worthwile to test the biological efficacy of such sprays in the field.

Communication and monitoring

Information already available on control of late blight and new information that is being generated is transferred to participants in The Masterplan and to farmers and homegardeners by newsletters, leaflets and articles in agricultural newspapers and journals. Also 56 study groups have been formed in which approximately 600 farmers and advisors regularly discuss late blight. The Masterplan is also presented on farmers meetings and Conferences. In order to measures whether the aims set, will be achieved, indicators are being formulated and measured such as fungicide input, date of first spray, number of sprays, environmental side-effects and risk perception of farmers.

References

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Field evaluation or four decision support systems for potato late blight in The Netherlands

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Abstract

In 1999, three field trials were carried out in the Netherlands to evaluate four weather-based decision support systems for potato late blight control: Plant-Plus, Prophy, Simphyt and NegFry. The four models were compared with a weekly spraying schedule with protective fungicides. The models succeeded in decreasing the number of sprays. The recommended number of curative sprays varied both between models and between trials. In all three trials, NegFry did not control potato late blight sufficiently under Dutch potato growing conditions. Simphyt started spraying too late in a trial with a late planted, susceptible crop, resulting in an insufficient disease control. Prophy and Plant-Plus managed to control the disease to an acceptable level in all trials.

Introduction

In the Netherlands, two weather based decision support systems for late blight control in potatoes are commercially available, Plant-Plus (Hadders, 1998) en Prophy (Nugteren, 1995). A DSS is considered as an important tool to optimise fungicide sprays and thus restrict the amount of chemicals to a minimum. Individually, Plant-Plus and Prophy have been compared to weekly spraying schedules in field evaluation trials (Hadders, 1998; Ridder et al., 1995). However, a joint field evaluation of both DSS's has not been carried out. In 1999 a research project was set up to compare both DSS's both with each other and with a weekly spraying schedule. This comparison is expected to produce information that can be used to further improve the systems. Following the 1998 workshop at Uppsala where it was decided to carry out validation trials in several European countries (Hansen, 1998), two more DSS's were incorporated in the Dutch research project, NegFry (Hansen, 1995) and Simphyt (Kleinhenz & Jörg, 1998). This paper describes the results of three trials carried out in the Netherlands in 1999.

Materials and Methods

A proposal regarding the set-up of trials to validate the Phytophthora DSS's was produced in Uppsala (Jörg & Kleinhenz, 1998). This proposal was further discussed and elaborated at a follow-up meeting in Lelystad on 13 and 14 April 1999. Wherever possible, the 1999 trials carried out in the Netherlands were carried out in accordance with this proposal and its elaboration agreed upon in Lelystad.

Trial sites, weather data and experimental set-up

Trials were set up in Lelystad (loamy soil), Valthermond and Vredepeel (both sandy soils) with the cultivars Bintje (susceptible), Karakter (medium susceptible) and Oscar (medium susceptible). The potatoes were planted on ridges 75 cm apart on May 14, May 6 and April 15 respectively at 4.0, 5.3 and 4.2 tubers m^{-2}. Fields were 10,5 by 17 m, 6 by 12 m and 8.25 by 13 m respectively. Observations were made in net fields measuring 4.5 by 15 m, 3.75 by 10 m and 4.5 by 10 m. Potatoes emerged on June 3, May 29 and May 17.

On all three locations automatic weather stations were situated within 1 km from the trial site, measuring hourly values of air temperature, rain, relative humidity, leaf wetness, wind direction and wind speed at 150 cm height. Hourly data on crop temperature and relative humidity were measured in Lelystad on the trial site and in Valthermond in a crop within 2 km distance of the trial site. Crop data were not available in Vredepeel. Prophy and Plant-Plus both used 3-hourly regional weather forecasts for five consecutive days. All trials included the four DSS's Prophy, Plant-Plus, NegFry and Simphyt and weekly-sprayed plots. In Lelystad, untreated plots were incorporated in the experimental set-up. All experiments were set up as randomised block treatments with four replications. In Valthermond and Vredepeel 16 and 8 planted strips respectively were present on the trial site and situated between plots. The strips measured 9 by 7 m in Valthermond and 8.25 by 7 m in Vredepeel. At any one time a maximum of four strips were untreated. When disease pressure in these strips became unacceptably high, the crops on these strips were killed with diquat and four other strips (weekly treated until that time) were left untreated.

Observations

On 11, 9 and 9 occasions disease severity was observed in Lelystad (between June 9 and August 18), Valthermond (between June 18 and September 21) and Vredepeel (between June 16 and September 6) respectively. Disease was assessed by counting the number of diseased leaflets, petioles and stems on the net fields in the beginning of an epidemic and by estimating the amount of disease according to the so-called PD-scale when diseased leaflets became uncountable. The counts were used to calculate an index as follows:

$$index = \frac{100 \times (leaf + 10 \times petioles + 25 \times stems)}{36 \times plants} \qquad (1)$$

where:

leaf = number of diseased leaflets on the net field;
petioles = number of diseased petioles on the net field;
stems = number of diseased stems on the net field;
plants = number of tubers planted on the net field.

The weight factors 1, 10 and 25 for leaflets, petioles and stems represented the higher severity of a stem attack and petiole attack relative to a leaflet attack. The PD-scale used to estimate the Phytophthora severity is indicated in Table 1. First appearance of Phytophthora on the trial site was observed on July 7, July 13 and July 8 in Lelystad, Valthermond and Vredepeel respectively.

Table 1. PD-Scale to estimate Phytophthora disease severity.

scale	description
10	no disease
9.5	<5% of plants with diseased leaflet
9	5 to 10% of plants with 1-5 diseased leaflets per plant
8	10-20% of plants with 5 diseased leaflets per plant
7	>20% of plants with 10 diseased leaflet per plant
6	many plants attacked with 10% diseased leaflets per plant
5	almost every plant and leaflet attacked; crop still looks green
4	every plant attacked, half the foliage necrotic; crop green-brown
3	about 75% of the foliage necrotic
2	some green leaflets left but stems are still green
1	almost every leaflet dead; stems are dead or brown
0	crop completely dead; leaflets and stems desiccated

Use of the DSS's

The systems were asked for advice daily except on weekend days. This implied the risk of more curative sprays being carried out in the DSS plots relative to the weekly-sprayed plots. The weekly-sprayed plots were treated with fluazinam (500 g l^{-1}) at a rate of 0.3 or 0.4 l ha^{-1}. The first treatment on these plots was carried out according to a decision of the farm manager. The first treatment on other plots was done according to the DSS's (see further). On all plots of the trials, the last treatment was applied when ageing of the crop had progressed to the extent that disease observations were no longer possible.

NegFry – NegFry 99 version 5.11 was used in the trials. Sprayings were carried out with fluazinam (500 g l^{-1}) 0,3 or 0,4 l ha^{-1} when an application was carried out on the day of advise and with cymoxanil/mancozeb (4,5/68%) 2,5 kg ha^{-1} or chlorothalonil/propamocarb (375/375 g l^{-1}) 2,7 l ha^{-1} when the application had to be postponed by 1-2 and 3-5 days respectively. A spray was carried out following an advice or when an advise was likely to pass the threshold value the next day. In Vredepeel four sprays were applied in advance of an advise. In Valthermond, this situation occurred only once.

Simphyt – The model version PASO 99.1 for Windows was used in the trials. First sprays were carried out as soon as the model forecasted a date for Risk Level I. Consequently, the date of first spray was 4-7 days too early depending on the location. Abusively, on several occasions at each the trial, other fungicides were sprayed than were advised. In

Lelystad, cymoxanil/mancozeb (4,5/68%) at 2.5 kg ha^{-1} was applied on July 20 in stead of a fungicide that contained metalaxyl. Metalaxyl has a more curative and eradicant action compared to cymoxanil (Bradshaw, 1998). Nevertheless, after July 20 the disease did not increase until August 12. Additionally, on August 4 fluazinam (500 g l^{-1}) 0,4 l ha^{-1} was applied following an advice to spray mancozeb or zineb. This change has no adverse effect on Phytophthora control, because fluazinam has a better preventive effect than mancozeb or zineb (Bradshaw, 1998). In Valthermond, on three occasions (July 1, 9 and 19) fluazinam (500 g l^{-1}) 0,4 l ha^{-1} was sprayed where a metalaxyl containing fungicide was advised. Compared to metalaxyl, fluazinam lacks a curative or eradicant action (Bradshaw, 1998). However, it must be stressed that Phytophthora was not found in Simphyt plots until August 11. In Vredepeel, on June 22 and July 2 fluazinam (500 g l^{-1}) 0.3 and 0.4 l ha^{-1} respectively was applied in stead of a metalaxyl containing fungicide. The first Phytophthora attack in Simphyt plots was sighted on July 8. On July 8, cymoxanil/mancozeb (4,5/68%) 2.5 kg ha^{-1} was applied where metalaxyl was advised. This change resulted in less curative and eradicant effects on the Phytophthora population present. Finally, on August 8 fluazinam (500 g l^{-1}) 0,4 l ha^{-1} was applied following an advice to spray mancozeb or zineb.

Additional to the fungicide application changes, the appearance of Phytophthora in the Simphyt plots on August 11 in Valthermond was not acknowledged to the program. Probably, this influenced the subsequent fungicide recommendations. Phytophthora appearance in the region was acknowledged to the program on July 7, July 15 and June 11 in Lelystad, Valthermond and Vredepeel respectively. Phytophthora appearance in the Simphyt plots in Lelystad and Vredepeel was registered at July 7 and July 8 respectively.

Prophy – During the trials, the 1999 version of Prophy (CROP '99) was used. Preferentially, Prophy uses crop weather data on temperature and RH. In Valthermond and Lelystad, these data were available. In Vredepeel, Prophy had to use climatic data registered at standard height. The program can account for this change in weather data origin. In Lelystad, crop growth was set at average throughout the season. In Vredepeel, crop growth was estimated as strong from May 25, as very strong on June 1 and set to average at July 5. In Valthermond, crop growth was found to be average on May 28, strong at June 14, moderate at July 13 and September 2 and weak on September 14. A crop height of 15 cm was observed in Lelystad, Valthermond and Vredepeel on June 15, June 14 and May 24 respectively. On these three trials, closure of crop canopy was registered to have taken place on June 30, July 2 and June 5. Crop canopy volume was estimated to be average on all three trials. Phytopthora infections were acknowledged to the program according to Table 2. Disease appearance in the Prophy plots on August 23 in Vredepeel and on August 30 in Valthermond was not acknowledged to the program. Overhead irrigation was applied in Vredepeel on June 17 and on July 1, 13 and 31 (25 mm each) and registered accordingly.

Plant-Plus – Version 5 of the Plant-Plus model was used in the trials. Crop and disease observations were acknowledged to the program as summarised in Table 3. Overhead irrigation was registered as previously indicated. Regarding Phytophthora observations it should be stressed that, in the Netherlands, the Plant-Plus system makes use of a Phytophthora monitoring network. Data from these activities are incorporated in advises given by the program which is supplied with the geographical trial site co-ordinates (Hadders, 1996). Sprayings were carried out whenever calculated infections passed a threshold value of 200.

Table 2. Phytophthora infection within or nearby Prophy fields, as acknowledged to the program during the 1999 growing season.

Trial site	date	description
Lelystad	June 11	no infections in or near the plots
	June 22	no infections in or near the plots
	July 7	PD-scale 9.5 in Prophy plots
	July 13	PD-scale 9 in Prophy plots
	July 23	PD-scale 9.5 in Prophy plots
	July 30	slight infections within 500 m
Valthermond	May 28	no infections in or near the plots
	June 18	no infections in or near the plots
	July 13	slight infections within 500 m
Vredepeel	May 25	no infections in or near the plots
	June 7	slight infections within 500 m
	June 16	heavy infections within 500-1000 m
	June 22	slight infections within 500 m
	June 28	slight infections within 500-1000 m
	July 7	slight infections within 500 m
	August 2	slight infections within 500 m

Statistics

Statistic analyses were carried out using the statistical package Genstat 5, release 3 (Genstat 5 Committee, 1993). Results were transformed before analysis whenever necessary.

Table 3. Observations acknowledged to the Plant-Plus program.

observation type	trial site		
	Lelystad	Valthermond	Vredepeel
Crop growth rate	7/6: 2 leaves per week	2/6: 1 leaf per week	5/6: 3.5 leaves per week
	22/6: 2 leaves per week	11/6: 1.5 leaves per week	30/6: 1 leaf per week
	1/7: 4 leaves per week	20/6: 3 leaves per week	
	7/7: 3.5 leaves per week	3/7: 3.5 leaves per week	
		20/7: 3.5 leaves per week	
		19/8: 2.5 leaves per week	
		13/9: 0.5 leaves per week	
Crop growth stage	3/6: 100% emergence	2/6: ground cover 12.5%	17/5: 100% emergence
	7/6: 25% ground cover	11/6: ground cover 37.5%	5/6: heavy and lodged crop
	30/6: upright stems; ground cover 100%	18/6: ground cover 50%	16/6: heavy, still upright canopy
	7/7: heavy canopy, still upright	20/6: ground cover 50%	25/6: heavy canopy, starting to lodge
	30/7: heavy canopy starting to lodge	3/7: ground cover 100% recently reached	
		19/8: heavy canopy starting to lodge	
Disease pressure	30/6: Phytophthora in neighbouring field	20/7: Phytophthora in neighbouring field	16/6: Phytophthora in neighbouring field
	7/7: PD-scale 9.5 in the field		15/7: PD-scale 9.5 in the field
	30/7: Phytophthora in neighbouring field		11/8: PD-scale 8 in the field

Results

Sprays and advises

According to Table 4, using a DSS decreased the number of applications. However, it should be noted that all the NegFry plots in Lelystad and all the NegFry and Simphyt plots in Vredepeel were prematurely killed (with diquat) on July 13, August 20 and August 24 respectively following unacceptable high disease severity.

Table 4. Number of applications, longest spraying interval, amount of active ingredients and date of first spray depending on DSS (weekly treatments included) and trial.

Trial		weekly	Prophy	Plant-Plus	NegFry	Simphyt
Lelystad	total number of sprays	13	10	9	1	8
	- curative sprays	0	4	2	1	5
	longest interval	8	12	19	-	14
	kg a.i. ha^{-1}	2.6	7.4	5.4	2.0	8.0
	date first treatment	16/6	24/6	30/6	6/7	30/6
Valthermond	total number of sprays	14	9	11	9	9
	- curative sprays	0	4	5	4	1
	longest interval	12	13	14	21	15
	kg a.i. ha^{-1}	2.2	8.4	10.4	8.2	2.8
	date first treatment	16/6	22/6	29/6	11/6	11/6
Vredepeel	total number of sprays	14	14	11	7	9
	- curative sprays	0	5	1	0	5
	longest interval	14	14	16	16	17
	kg a.i. ha^{-1}	2.1	10.4	3.3	1.3	8.3
	date first treatment	28/5	28/5	5/6	11/6	11/6

In the weekly-sprayed plots no curative fungicides were used. The number of curative treatments in the DSS plots varied between the trial sites and DSS's. The high number of curative sprays using Plant-Plus in Valthermond (5), relative to Lelystad and Vredepeel, were in four occasions caused by the fact that advises were not asked during the weekends. In Valthermond, on three occasions, the Prophy advises for a preventive spray could not be followed due to unfavourable weather conditions. Consequently, curative sprays had to be applied. The relative low number of curative sprays using Simphyt on this trials site, has already been mentioned in the Materials and Methods section.

The long spraying intervals on the weekly-sprayed plots in Vredepeel and Valthermond followed a long dry period during which sprays were not considered necessary. Therefore, the number of applications saved by the DSS's on these trials were in fact higher than apparent from Table 4. The amount of active ingredients applied was very low for the weekly-sprayed plots due to the usage of fluazinam, which is sprayed at a low rate. A higher number of curative sprays inevitably results in a higher amount of active ingredients. The importance of the timing of the first spray was illustrated in the NegFry plots in Lelystad, which suffered from a heavy attack within one week after the first application. The data in Table 4 show few consistent differences between treatments. In all trials the weekly-sprayed plots were the earliest sprayed. Furthermore, a consistent difference seemed apparent between Prophy and Plant-Plus, Prophy advising earlier than Plant-Plus. However, in Valthermond the first Plant-Plus advise was already issued on June 12, but a spray was not carried out because the crop only showed about 40% ground cover at that time.

Disease severity

Results on disease severity are listed in Tables 5 (indexes) and 6 (PD-scale).

Lelystad – On July 7 the disease appeared on a high level in both the untreated crop (index of 7.6) and the NegFry and in two of the Simphyt plots. According to NegFry, weather conditions were stimulating Phytophthora attack in the period between June 29 and July 3 (high daily risk values). Plant-Plus calculated a high infection probability on June 30, while Prophy calculated a high Phytophthora index from June 28 to July 1. The first spray on the NegFry plots was applied on July 6 with the curative fungicide chlorothalonil/propamocarb. It was decided to apply a curative fungicide because the NegFry threshold for the first spray was reached on July 3 (a Saturday) and due to adverse weather conditions, a spray on July 5 could not be carried out. Clearly, the first NegFry spray was timed too late to control Phytophthora sufficiently. Until July 7, only one spray (with fluazinam) was applied on the Simphyt plots on June 30. It could be concluded that, besides the NegFry plots, also the Simphyt plots were sprayed too late for the first time. However, Plant-Plus advised for the first spray on the same day (June 30) and, contrary to two of the four Simphyt plots, Plant-Plus plots were not heavily infested on July 7. The only difference between both DSS's was that on July 6 a second treatment with fluazinam was applied on the Plant-Plus plots. In view of the lack of curative activity of fluazinam (Bradshaw, 1998), it is highly unlikely that this treatment could have caused the observed disease severity difference between both DSS's.

Table 5. Disease severity according to a calculated index (equation 1).

trial	date	weekly-sprayed		Prophy		Plant-Plus		NegFry		Simphyt	
Lelystad	7/7	0.0	a	0.2	a[5]	0.6	a	7.1	b	9.0	b
	13/7	0.5	a	9.6	bc	3.7	b	43.5	d	22.9	cd
	22/7	0.8	a	6.2	b	3.6	b	-[1]	-	6.3[2]	b
	18/8	0.8	a	4.7	a	2.7	a	-[1]	-	3.6[2]	a
Valthermond	30/8	2.6	a	0.1	b	0.0	b	2.5	a	0.2	b
	7/9	4.7	a	0.5	b	0.1	b	-[3]	-	0.5	b
Vredepeel	8/7	0.0	a	0.0	a	0.0	a	2.3	b	2.3	b
	15/7	0.4	a	0.1	a	1.1	a	10.8	b	2.0	a
	26/7	0.2	a	0.0	a	1.9	a	12.7	b	0.8	a
	12/8	0.8	b	0.0	a	2.7[4]	c	11.2[4]	c	0.5	b
	23/8	9.5	b	1.6	a	7.2	ab	-[1]	-	-[3]	-

1. plots killed prematurely
2. based on only two plots; the other two plots of the treatment were killed on July 13
3. lesions too numerous to count
4. results based on only two plots: on the other plots, lesions were uncountable
5. for each trial location, values in columns followed by the same letter are not significantly different at the 5%-level

On July 13, disease severity appeared to have increased considerably in all the NegFry plots and in two of the Simphyt plots (the same that were heavily infected on July 7). It was decided to kill these plots prematurely directly following the disease observation. Between July 7 and July 13 NegFry advised no further spray, while Simphyt advised on two emergency treatments with a combination of fluazinam plus chlorothalonil/-propamocarb on July 8 and 12. These treatments restricted increase of the disease only in the two plots that were less infected on July 7. Possibly, the disease increase observed on July 13 had already been realised shortly after July 7 and was part of the same sporulation-infection period. NegFry did not calculate a high daily risk value between July 7 and 12. In addition, Prophy indicated no danger of Phytophthora outbreak in this period as well. After July 13, a further increase of disease severity could not be observed.

Table 6. Disease severity according to the PD-scale (see Table 1).

trial	date	weekly sprayed		Prophy		Plant-Plus		NegFry		Simphyt	
Valthermond	7/9	8.6	b[2]	9.6	a	9.5	a	7.6	c	9.6	a
	15/9	8.4	b	9.5	a	9.4	a	6.3	c	9.6	a

Vredepeel	12/8	9.4 a	10.0 a	7.6 bc	6.9 c	9.1 ab
	23/8	8.3 b	9.3 a	8.6 b	-[1] -	5.6 c
	3/9	6.2 b	6.7 ab	7.2 a	-[1] -	-[1] -

1. plots killed prematurely
2. for each trial location, values in columns followed by the same letter are not significantly different at the 5%-level

Valthermond – The first attack of Phytophthora was visible in one of the four untreated strips on July 13. On July 20 the disease had spread to other untreated strips and disease severity appeared to have further increased on July 28. After this date, the four untreated strips were killed and four other strips were left untreated. On one of these strips, the disease appeared at a low level on August 25. By August 30 the disease had spread to the other untreated strips and had increased considerably in the strip that was attacked in the first place. A further increase in the disease was observed on September 7.

Although a single diseased leaflet could occasionally be found in some of the trial plots before August 30, a spread of the disease over the whole trial area did not occur before that time. Table 5 shows that on August 30, the weekly-sprayed plots and the NegFry plots had a significantly higher disease severity than the other treatments. The last spray on the NegFry plots before August 30 was applied on August 10 (cymoxanil/mancozeb) and on the weekly-sprayed plots on August 21 (fluazinam). On the Prophy plots the last treatment before August 30 was also applied on August 21, but with cymoxanil/-mancozeb. In view of the good curative effect of cymoxanil (Bradshaw, 1998) and the absence of such an effect with fluazinam, it is likely that an infection had taken place in the few days prior to August 21, for example on August 19 or 20. Probably, the observation on August 25 was too early for disease expression following an infection on one of those days. Possibly, the fluazinam application at a rate of 0.3 l ha^{-1} on the weekly-sprayed plots on August 13 had not offered enough protection against an infection on August 19 or 20. However, on the Simphyt plots, where only very few diseased leaflets were found on August 30, sprays were carried out on August 12 with fluazinam at a rate of 0.4 l ha^{-1} and on August 26 with cymoxanil/mancozeb. Therefore, a protection from the infection on August 19 or 20 could have been realised by the fluazinam treatment. The application was one day earlier than that on the weekly-sprayed plots, but at a higher rate. This can only be explained by assuming that the higher rate had realised a longer protective period.

On September 7 the disease had increased considerably on the NegFry plots where lesions became uncountable, but was slowed down on the weekly-sprayed plots (Tables 5 and 6). On the NegFry plots the only treatment applied in the period that the infection, that caused this increase, could have taken place, was on August 30 (cymoxanil/-mancozeb). On the weekly-sprayed plots fluazinam was applied on August 12 and on September 2. It is unlikely that the disease increase observed on September 7 followed an infection after August 30, because both fluazinam en cymoxanil/mancozeb have good protective abilities (Bradshaw, 1998). Possibly, the infection took place before August 30 while symptoms were not yet visible on August 30. Consequently, the fluazinam treatment on the weekly-sprayed plots on August 21 gave some protection against an infection at the end of August.

Vredepeel – On July 8 both the NegFry and the Simphyt plots showed a disease severity that was higher than that of the other treatments. Last sprays were applied on NegFry and Simphyt plots on July 5 and July 2 respectively (both fluazinam) and before that the plots were protected by a fluazinam treatment on June 22. This means that the infection must have taken place before July 2 but long enough after June 22 for the fluazinam treatment to have lost sufficient protective activity. On the Plant-Plus plots, sprays were applied on June 21 and June 30, both with fluazinam. These data suggest that the infection observed on July 8 had taken place between the June 30 treatment of Plant-Plus and the July 2 treatment of Simphyt. A treatment of the Simphyt plots on July 2 with metalaxyl as was advised, in stead of fluazinam, could have prevented the disease increase observed on July 8.

On July 15 an increase in disease level was recorded on the NegFry plots. The last spray before that time was applied on July 5. Considering an incubation period of 4-5 days and assuming a protective period by fluazinam of at least 5 days, it must be concluded that the infection responsible for the observed disease increase took place before the fungicide application on July 5. Probably, the infection took place on July 5, considering the high daily risk value calculated by NegFry on July 5 (36.4) and the high calculated Phytophthora index calculated for that day by Prophy (93). In the morning of July 5, NegFry only calculated a daily risk value of 8.2. The spray was not carried out until 15:30 hours. An increase of disease level was not observed on the Simphyt plots. After disease had been observed on July 5, three treatments were applied on these plots.

On August 12 disease had increased on the NegFry, Plant-Plus and weekly-sprayed plots. This is not clear from the figures in Table 5 as results from August 12 for these treatments were only based on two of the four plots. The reason for this is that lesions on the other plots became uncountable. However, from Table 6 it is clear that both the NegFry and the Plant-Plus plots suffered from a higher disease severity than the other treatments. The last NegFry spray was on July 27 (fluazinam), while on the Plant-Plus plots sprays were carried out on July 23 and August 5 and 8 (all fluazinam). The infection must have occurred after the fluazinam treatment on July 27 on the NegFry plots had lost its protective activity, but before the August 5 spray on the Plant-Plus plots. Possibly, the infection took place on August 4 or 5. NegFry calculated moderate risk values for these dates (8.6 and 6.7) while Prophy calculated a high Phytophthora index on August 5 (36) but not at August 4. The fluazinam treatment of the Plant-Plus plots was not applied until 13:00 hours, leaving opportunities for infections during morning hours on August 5.

On August 23 the disease had increased on the weekly-sprayed, the Prophy and the Simphyt plots, but not on the Plant-Plus plots (Table 6). By that time, the Negfry plots were prematurely killed due to unacceptable high Phytophthora levels. The apparent recovery of the Plant-Plus plots resulted from the necrosis of attacked leaflets as observed on August 12 in the lower parts of the crop canopy. From the disease increase on the weekly-sprayed plots, it becomes apparent that a weekly schedule (with 0.3 l ha^{-1} fluazinam) can be insufficient under high disease pressure. The very strong disease increase on the Simphyt plots followed a 10-day interval between the treatments on August 9 (fluazinam at a rate of 0.3 l ha^{-1}) and 19 (metalaxyl/fentin-acetate/maneb). The Phytophthora index, calculated by Prophy, was continuously high from August 7 to 21 (a period with cool weather and high relative humidity). NegFry calculated high daily risk values in the period between August 7 and August 14.

Discussion

The results described in this paper, can only be discussed considering the changes made while using the different systems. However, using the models, more curative sprays were carried out in comparison to the weekly-sprayed plots. On the latter plots, the preventively applied, low rate fungicide fluazinam was used, resulting in a low total amount of active ingredients. Curative sprays on the DSS plots were applied either following the fungicide strategy of the model (Prophy and Simphyt), following unfavourable weather conditions on days when a preventive treatment was recommended (Plant-Plus, NegFry and Prophy) or following the non consulting of the models during the weekend (Plant-Plus, Prophy and NegFry). Consequently, the amount of active ingredients applied while using the models was sometimes considerably higher. Additionally, some remarks can be made regarding the different decision support systems.

NegFry – On all three trials the NegFry plots suffered from the earliest and heaviest infestations by potato late blight. Clearly the timing of the first spray in Lelystad was too late and spray intervals were too long on the other two trials. Probably, the late timing in Lelystad is due to the late planting date of the crop relative to crops in the region. The cumulation of daily risk values that starts at emergence of the crop does not account for weather conditions before that time to which neighbouring crops were exposed. Therefore, it is suggested that the risk value cumulates from the average emergence date for crops in the region and not from the emergence date of a relative late planted crop. Furthermore, it should be considered to adapt the blight unit thresholds to Dutch conditions with relatively high Phytophthora disease pressure due to the high intensity of potato growing. Results from the Vredepeel and Valthermond trials have shown that some intervals were too long.

Simphyt – Discussions on the effectiveness of Simphyt to control late blight can have been influenced by the changes made in fungicide choice and the too early first treatments. However, the trial in Lelystad showed that if the first Simphyt spray would have been postponed until July 5 according to the advise on June 28, the plots would have been infected as heavy as the NegFry and the untreated plots. The fungicide changes in Valthermond did not result in heavy potato late blight attacks. In this trial Simphyt realised a good protection against Phytophthora in spite of the fact that a low Phytophthora attack in one of the plots was abusively not acknowledged to the model. Moreover, the number of sprays was reduced relative to the weekly-sprayed treatment. In Vredepeel the replacement of a metalaxyl treatment on July 2 by a fluazinam spray could well have prevented disease attack on July 8 due to the curative effect of metalaxyl. However, the sudden disease increase observed on August 23 was due to a too long spraying interval (10 days) and was not caused by the replacement on August 9 of mancozeb by fluazinam, which even has better protective activity (Bradshaw, 1998).

Prophy – Prophy managed to control disease to acceptable levels in all three trials. Only on July 13 in Lelystad, a rapid increase in disease severity could be observed. As has been argued in the result section, the corresponding infection already took place before July 7, the first observation date. Both NegFry and Prophy calculated high Phytophthora risk on July 5. Possibly, the curative Prophy spray with chlorothalonil/propamocarb on July 7 did not completely control this infection. Prophy managed to decrease the number of sprays relative to the weekly-sprayed treatment in Valthermond and Lelystad, but not in Vredepeel. Possibly, this is associated with the use of standard height weather data in stead of crop weather data as preferred by the program. The interpretation of the possible characterisations of crop growth rate in the program was found to be difficult. The characterisations are relative concepts like 'moderate' or 'average' and can therefore be misinterpreted. Possibly, a simple crop growth model based on temperature and global radiation (Spitters, 1990) could replace the manual registration of crop growth rate.

Plant-Plus – Plant-Plus controlled the disease sufficiently in Lelystad and Valthermond, while saving 3-4 sprays. The first spray in Lelystad on June 30 appeared to have been timed on exactly the right moment. A postponement of one day could well have resulted in a severe Phytophthora outbreak. Plant-Plus could not completely control an increase of Phytophthora in Vredepeel as observed on August 12. Probably, the spray advice submitted on August 5 was one day too late. It can also be argued that the spray was carried out too late (13:00 hours) to be sufficiently effective. On August 4, the program calculated an infection probability of 91, which is well below the threshold value of 200. After August 12, the disease was controlled at an acceptable level relative to the weekly-sprayed treatment. In Lelystad and Vredepeel, leaf growth was not observed correctly during the second half of the season. In Lelystad, leaf growth was not lowered towards the end of the season, thus minimising spray intervals and resulting in one or more unnecessary sprays. In Vredepeel, leaf growth rate was 1 from June 30 onwards. Possibly, this was too low for at least a part of the remaining season. The Phytophthora outbreak of August 12 could have been related to this error. However, an automatic leaf growth calculation on the basis of a simple crop growth model (Spitters, 1990) could improve user-friendliness of the program.

In the described research, we use a disease observation method that deviated from the commonly used method of expressing the disease severity as a percentage of the leaf area attacked. By counting the number of diseased leaflets, unlike estimation of the percentage of the leaf area blighted or defoliated, it is possible to distinguish between plots at low disease level. Additionally, an estimation of blighted leaf area does not account for stem blight, which occurred frequently in the 1999 trials. By using the index according to equation (1) and counting the number of stem lesions, the presence of the disease in the crop is accounted for even when diseased leaflets are no longer visible.

The trials will be continued in 2000 and 2001.

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Fourth Workshop of an European Network for development of an
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Late blight warning in Hainaut: advising and application of potato varieties sensitivity

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Introduction

The late blight warning service in Hainaut was created in 1986. It is based on the Guntz - Divoux model. With a network of 10 fully automatic weather stations we are able to send warning messages during the crop season to our 700 subscribers covering more than 12000 ha of the total 13293 ha potatoes in Hainaut in 1999. Beside the most cultivated variety ‘Bintje’ we observe a lot of interest from the growers for other varieties with a different Phytophtora sensitivity. In 1999 we have tried to apply the sentivity differences and adapt accordingly the warning messages in practice.

It is necessary to consider also the field situation (emergency date, environnement, présence of early cultivated fields in the region, inoculum sources in the surrounding,...).

Keywords: Phytophtora infestans, Late blight, Potato, variety sentivity, warning service.

Results

The first problem was to determine the sensitivity of different varieties in practical field conditions. The observation fields wich were visited once or twice a week through the whole season brought a lot of informations.

More informations were obtained through our frequent contacts with the farmers: their observations completed ours, and provided to locate very early late blight infections in the season.

Typical of 1999 was the very wide range of planting dates. It was finally necessary to consider four periods of emergency day: before May 17th, between May 18th and 30th, between May 31th and June 3th and after June 4th.

Table 1. Number of sprayings during the season in normal conditions and varieties sensitivity from late blight.

	Emergency day			
	before May 17th	May 18th to 30th	May31 to June3	after June 4
very sensitive var.	12	11	12	12
fairly sensitive var.	10 (+2)	9 (+2)	9 (+3)	9 (+3)
sensitive var.	9 (+2)	8 (+3)	8 (+3)	9 (+3)
moderately sens var	5	4	5	7
slightly sensit. var.	4	3	5	6
very early crop *	4 (+1)	-	-	-

* very early crop, grown under cover.

( ) additional spayings recommanded in danderous situations or near inoculum sources.

In 1999, early planted crops were advised less sprayings than late planted crop. While in september the risk of infection was to high to reduce the number of spayings. Late blight was spotted in every region and some observations indicate that a number of varieties suffered late blight on leaves. Thirty varieties covering more than 99,5 % of the potato area in our province were concerned by the warning messages.

Conclusions

For the first time in 1999 we had the oppotunity to work in a whole region with the warning service according to the variety sensitivity and it was a success:

- farmers showed great interest;

- the protection of the different varieties appeared sufficient;
- the number of sprayings could be reduced by 6 or even 8 times for some varieties;

But we faced some difficulties:

- the regular control of the different varieties in practical fields conditions took a lot of
- time for experienced staff to fit to the evolution of the late blight population;
- the sensitivity of each variety was found not independant of some environment or
- cropping parameters (rotation, proximity of contamined fields, seeds sanitary status);
- farmers are looking for regular and frequent contacs which are also heavily time consuming.

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Production and potato late blight situation in North-West of Portugal

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Abstract

In Portugal where the area of potato amounts to 84 457 ha and produces average more than 1 273 574 ton., the potato late blight represents the most dangerous diseases.

Epidemiological surveys confirmed that diseases occur every year in the main regions of potatoes production, observed regularly 8-10 treatments per growing seasons by farmers, without taking into consideration the real blight risk.

In spite of such intensive treatments, some plots are still found to be infected.

In view of increasing the efficiency of late blight control, it is absolutely necessary to know in what conditions the diseases comes about and which moments are the most convenient for spraying.

The Crop Protection Division in Entre Douro e Minho Region, started in 1997 the preliminary evaluation the Guntz-Divoux model, and their practical implementation are presented and discussed in this paper.

Introduction

The potato crop takes a very important role in the agricultural activities of Portugal leading its production to 1 273574 ton, for an area of 84 457 ha. (INE/1997)

Nowadays due to the growing of marketing offers, as well, to the new products which are given by the distribution companies, the farming area has been decreasing, leading a very significant growing of medium production per area.

Growing all over our country, the greatest production is found in Beira Litoral, Ribatejo Oeste, Entre Douro e Minho, Trás os Montes and Beira Litoral regions, having as main aim the self-consumption, Industry, Seed and Exportation.

In these different regions; there are three plantation times: late, early and summer growing. (Annexe 1-Geographical distribution of the main production areas in the Continent)

In Entre Douro e Minho Region potato crop cover roughly 176 575 ha and produces an average of more than 18 000 tons of tubers. (INE/1997)

In spite of the existence of potato production in whole region, the western part is without any doubt the region, which has the most important potentialities.

This region is characterised by the existence of mild temperatures, rainy springs and dampness, lead to the late blight disease that provokes the most serious damages, every destroying about 50-100 % of the potato production. So, it's urgent to take special Warning Services in this region to minimise all the damage.

Objectives

This preliminary evaluation the Guntz-Divoux model, already in practice in two regions of Portugal (Beira Litoral and Trás os Montes Region), as main goal, the installations in of Warning Service for the fight of potato late blight in Entre Douro e Minho Region, allowing a more efficiency in treatments, by the opportunity of its application and consequently a bigger rationalisation of sprayings, what leads to a better reestablishment of biological balance and the same time minimises the negative impact on the environment.

Methodologie

During these past three years, the responsibility of these essays belongs to the Protection Crops Division.

Due to the wide extension, to the big geographical diversity of the region and to the technical and human limitations, the Warning Service covered only a part of the Western Entre Douro e Minho Region.

All the localities were chosen because of their strategical position within some important growing areas.

The validation of forecasting model for the prediction of potato late blight was carried out over three years, from 1997-1999 in four farmers.

The service was moved from using four manually operated thermohigrographers.

Recording are taken each morning by participating farmers and sent by mail to the analysing and decision-making centre in Oporto.

The elements taken are: temperature, hygrometry, pluviometry and plant phenology.

Then all parameters are plotted on graphs and occurrence of infections is made out on the basis of the Guntz-Divoux scale. The daily incubation units are defined on the basis of the average daily T^a (Max.Min/2).

Treatment recommendations are sent by mail to the subscriber farmers.

Since then some of the leading principles of Warning System may be summed up as follows:

- From the time of general emergence of all crops in a given area the Service lays down the possible infections and their incubation periods after gathering data on weather parameters.
- The first recommendation for treatments is generally given at the end of incubation, generally of the second serious infection cycle. Such a recommendation could however be diffused as soon as at the end of the first serious infection cycle when conditions are very favourable to the disease (mild winter, earlier infection, high pluviometry, dampness and precociousness of lots of plantation and favourable conditions to contamination of the first cycle. In fact what really happens by us, is permanent existence of what’s mentioned above.

- Given the continuous development of news leaves until the stage of tuberization, the treatments should be repeated at the end of the next possible very serious, serious or even moderate infection.
- The recomended of treatment, had in account the wheather forecasting for the following the weekend and banc holidays

Results

The results are exposed in following tables (Annexe 2/3 - Place1 and Place2 – Potato Late Blight–cycles of multiplication – Model Guntz-Divoux)

> The place 1 - represents the farmers who made the plantation in April and took the place in a farm which belong to the Division.
>
> The place 2 - represents the farmers who made the plantation in February and Mars and took the place in a farm which belong to the participating farmers.

In 1997, in place one, the first treatment was recommended before the end of second serious infection cycle. In the following years, having been checked the permanent favourable conditions of the diseases, the recommendation ware always before the end of the first serious infection cycle.

The recommended treatments had in account the weather forecasting for the weekend and bank holiday.

In 1999 we had initiate experimentally the transmission of the warning for the potato late blight for 350 subscriber farmers.

Conclusions

- The late blight is really the most serious disease in the Region.
- April, May and June are the months where the most serious and systematic infections occur; as a result the farmers loose control of the situation.

- On average, 4-6 treatments are recommended to the farmers who followed the warning services. On the other hand during the same period, the number of systematic treatments was estimated at 8 to 10 to those who didn't follow the Warning Services.

- Some main restrains:
- It's difficult to find volunteers to do the recordings. So, the farmers themselves put their duties at the first place forgetting the responsibility of sending the weather information recordings.

- The slow transmission of information to the decision-making centre and, in return, the slow transmission of treatment recommendation to the farmers. As a matter of fact there is no mail delivery in weekends and bank holidays and most of the time, even or the weekdays the mail service is deficient. This complicates the Work of experts who have to foresee possible delays with respect to the availability of information and the transmission of recommendations.
- The manually operated thermohigrographers are too fragile, so they are in systematic out of operation. As a consequence the recording registers are not available to be evaluated.
- There is nobody specialised in this model to help the experts to solve the doubts, which are appearing systematically.

In short:

- It's necessary and urgent to know other new methods and technics adaptable to our regions, in order to make the expert work easier and overcome the difficulties of everybody involved in this process.

So, in our opinion, our participation here is something like a contributed, and opportunity of interchange.

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The Impact of seed tuber treatments on *Phytophthora infestans*-infected potatoes

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Summary

The impact of seed tuber treatments on *Phytophthora infestans*-infected Potatoes was studied with two fungicides. For this purpose seed tubers were inoculated with zoospores of the Phenylamid-resistant strain S41 and dressed with a fungicide solution. The latent infection was proved with PCR (polymerase chain reaction).

Keywords

Phytophthora infestans, late blight, fungicide, tuber dressing, Metalaxyl

Introduction

To reduce fungicide application against *Phytophthora infestans*, several strategies were propagated. But up to now no suitable way of precautional treatment is introduced into practice to avoid primary symptoms of late blight yet, although VAN DER ZAAG (1956) presumed that *Phytophthora infestans* causes stem lesions out of latent infected tubers. In connection with good motility of systemic fungicides in all kind of plant tissue and their properties as "multi-site inhibitors" in fungal cyclus, it is to assume, that there may be some kind of impact on the occurrence of primary symptoms, which can easily be used for integrated control.

Material and Methods

a) Inoculation:

1550 Tubers of the susceptible cultivar Christa have been inoculated with an amount of 100-200 zoospores. The solution of zoospores was gained out of sporangia, washed off from Agar-plates and cooled for 1h at 4°C in a refrigerator. Then the solution was diluted down to a concentration of 1000 zoospores/ml. The inoculation itself was made with a syringe: tubers were broached 1.5cm beside the next-neighboured eyespot. Then zoospore-solution was injected into the tuber during the needle was pulled out of tissue. With this method about 100-200 zoospores remain in the tuber [SCHLENZIG, 1997]. Big tubers have been inoculated twice or three times to raise infection rate at almost the same level in all tubers.

b) dressing:

Four days later tubers have been dressed in fungicide solutions with a concentration of active ingredient: 2 g/l by dipping into it. About 450 tubers of every variant were planted in 1.31 pots. The soil used for planting was sprayed with the remaining dressing solution to simulate conditions like common dressing technique in practice is managed. So total amount of applicated active ingredient per pot was 2.5 mg.

c) Glasshouse conditions

The three variants have been cultivated in an extra glasshouse chamber at the same conditions: 20°C temperature, >90% humidity and 14 hours supplementary light per day.

d) Sampling

Samples were taken at three different stadiums of potato-growth in glasshouse. In sample I all sprouts were mixed to a probe, whereas in sample II and III only 1cm long parts of all stems in a height of 1.5 cm respectively 8 cm have been used. Additional to this, light sprouts of unplanted tubers were sampled before.

Table 1. Experimental design and sampling.

Date		**Action**	**Code**	U	M (Metalaxyl)	C (comp.)	Annotations
9.11.1998		inoculation		Isolate: S41 (PA. resistant)			

13.11.1998		dressing		untreated	Ridomil	comp. agent	wet dressing
	amount a. i.			-	120 g/ha	120 g/ha	
2.12.1998	light sprouts	sample (PCR)	1.	50	50	45	
18./19./20. 11.1998		planting		500	450	450	
27./28./30. 11.1998	sprouts	sample (PCR)	I.	125	115	115	
7./8./9. 12.1998		sample (PCR)	II.	125	115	115	
21./22./24. 12.1998		sample (PCR)	III	125	115	115	changing experimental design
21.01.1999		harvest	IV/1	54	45	50	
2.02.1999		harvest	IV/2	50	48	49	

In Table 1 the dates of the experimental setup and the time of sampling is pointed out.

e) DNA-extraction

DNA was extracted out of stems with the commercial extraction Kit (Qiagen DNeasy Plant tissue kit®; Hilden, Germany). Though this kit originally was developed for extraction of plant-DNA it allows to isolate suitable yields of fungal-DNA out of stem-samples.

f) PCR-proof

The proof of *Phytophthora infestans* was made with primers coding for "internal transcribed spacer region" **ITS 5** and complementary computer-designed primer **PIN FX** [TROUT ET AL., 1997]. They determine an amplicon-size of 600 bp. The protocol for parameters of thermocycling derives from ADLER [1998] (Table 2). The multiplied DNA was blotted on Agar gel-electrophoresis. The DNA-probes were marked with Ethidiumbromide and visualized in a fluorescence chamber with a computer linked camera-system (Biorad).

Table2. PCR-parameter.

Program-name in thermocycler		Adler 1	
primername		ITS 3 / PIN FX and ITS 5 /PIN F2	
		temperature	time
	start	94°C	3 min
Cyclus	denaturation	94°C	30 s
	annealing	55°C	30 s
	extension	72°C	45 s
Number of cycles		35	

final extension	72°C	10 min
cooling	4°C	forever

Results

a) Macroscopic Results

During every time of sampling the number of pots with not-emerged shoots were counted (figure 1). In the untreated variant from 11.5% of the tubers, no sprout emerged at all. Metalaxyl showed intermediate emergence rates but no significant statistical differences neither to the untreated nor to the comparative agent (Bonferroni, p= 0.05). Between the untreated plot and the comp. agent the differences can be ensured at this value.

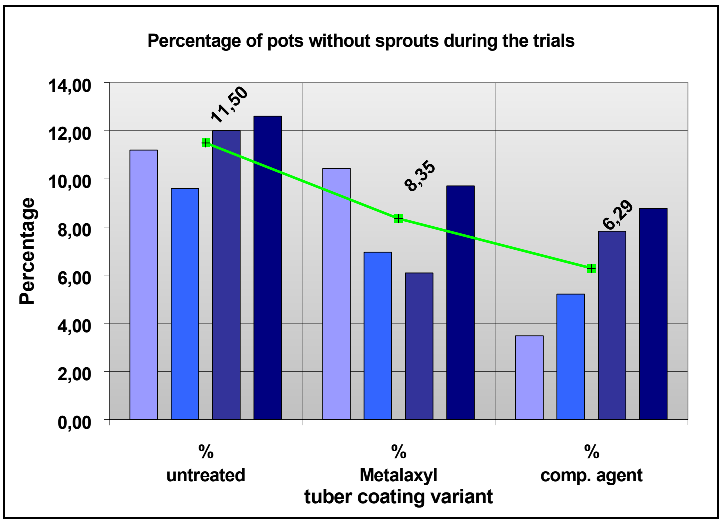


Figure 1. Rate of not-emerged sprouts.

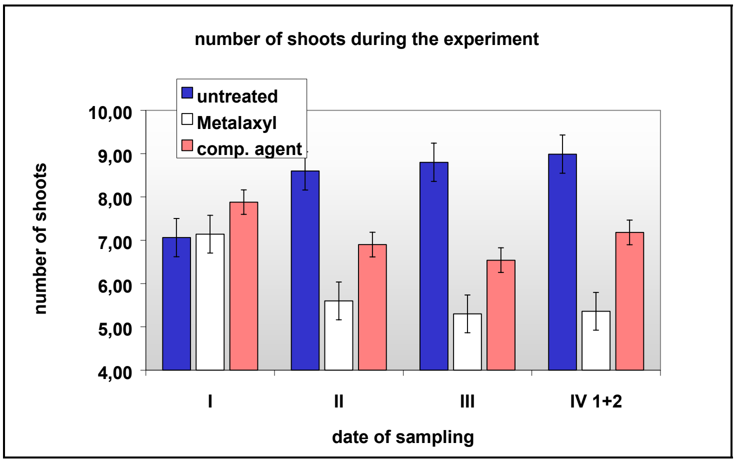


Figure 2. shoots per plant

At the time of emergence-assessments the number of stems have been counted (figure 2). At the beginning the three plots showed similar numbers of sprouts. After emergence the number of shoots increased in the untreated variant and decreased with Metalaxyl. The

plot dressed with the comparative agent stayed at the same level.
(Annotation: The average weight of the planted tubers in each plot was equal.)

At sample III first small lesions of *Phytophthora infestans* were detected on stems. Within three days almost every plant showed symptoms. Fifty days after planting, the number of diseased stems were counted, but no differences neither in severity and size of symptoms occurred (table 3).

Table 3. Percentage of stems with lesions.

treatment	untreated	comp.agent	Metalaxyl	**total**
number of plants	54	50	45	**149**
% stems with symptom	97,19	95, 34	91,53	**94,86**

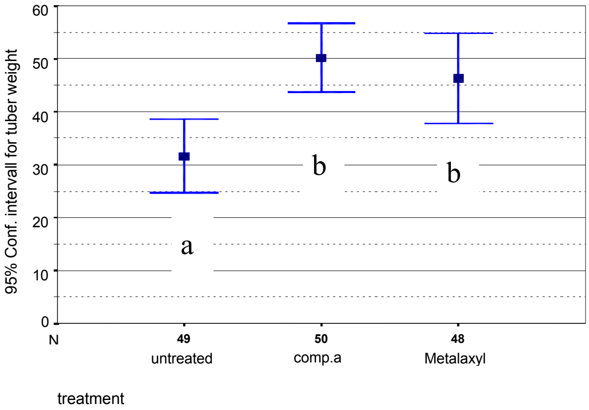


Figure 3. average tuber yield [g/pot] at the end of trial

At the end of the trials the three different plots were harvested and yield was weighed. Only tubers with a mean size >10 mm have been evaluated. In figure 3 the differences of yield are shown: Both coated variants have brought significantly higher yield. In relation to the untreated plot, yield in the Metalaxyl-dressed variant increased for 47%. The compared fungicide (=compared agent) enhanced the harvest-result for 59%.

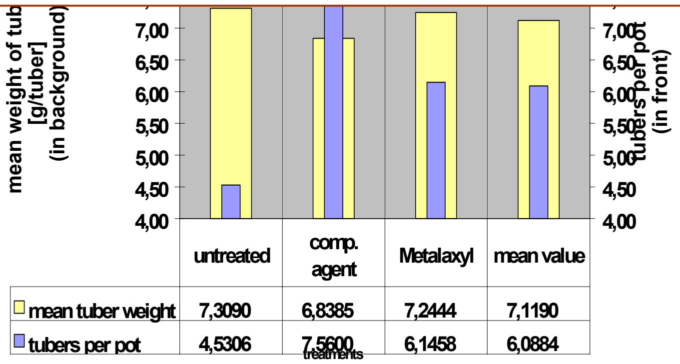
In figure 4 the parameters are drawn, on which the differences in yield depend on. The average tuber mass stayed at least at the same level over all treatments while the number of tubers increased from the untreated plot over Metalaxyl up to the plot treated with the comparative agent.

b) Results of *Phytophthora infestans*-proof with PCR

From every plant one mixed stem-sample was tested. The samples were amplified in thermocycler in two tubes for getting more exact results. Therefore two slots in gel-electrophoresis have been filled with one sample. The problem was, that often results were not clear. Sometimes a signal appeared only in one of the two slots or even only blurred bands has been detected.

Figure 5. PCR-Detection of Phytophthora infestans

*Data not complete in this column: Failure of PCR-amplification



	untreated	comp. agent	Metalaxyl	mean value
mean tuber weight	7,3090	6,8385	7,2444	7,1190
tubers per pot	4,5306	7,5600	6,1458	6,0884

Figure 4. Yield parameters

Discussion

First of all it is important to remind all possible methodical problems of the experimental design. Beside common difficulties of regulating glasshouse climate (variance of temperature, humidity and light exposure) the inoculation of tubers cause troubles. The level of infection is influenced by several factors of fungus and tuber, whose settings cannot be determined exactly That means that the physiological age of tubers, the “fitness” of the *Phytophthora* isolate, the kind of inoculum and the way of inoculation are hard to control and therefore the resulting level of tuber-infection is not clear.

The impact on the number of sprouts and the improved rate of emergence are indications for the possibility, that dressing with both fungicides has an influence on the hormonal retail of plant. As a sign for this, the reduction of shoots in the Metalaxyl variant and the constant number of stems of those plants, dressed with the comparative agent, can be taken. Trials with tomatoes have shown similar effects on growth of shoots. [ARP, 1987]. On the other hand the nearly equal number of stems where *Phytophthora*-lesions occurred indicates, that the direct impact on the pathogen was not strong enough to suppress the formation of symptoms.

Obviously infection of tubers was so successful that dressing could have no more appreciable effect on the occurrence of symptoms. The facts mentioned here are considerations, that dressing with systemic fungicides has great impact on potato plant physiology and plant-pathogen interaction. For this thesis also it speaks, that yield rose enormous in the two treated variants. The difference in the variants can only be traced back to the effect of tuber dressing (on account of the experimental design after "ceteris paribus"-principles).

The detection of *Phytophthora infestans* in light sprouts with the PCR-proof is the explicit evidence for the theory VAN DER ZAAG 1956 (and others before him) presumed, that the fungus is able to cause latent stem-infection directly from tubers.

Lower detection rate in light sprouts in comparison to the rate in long dark sprouts shows, that the amount of fungal material in sprout increases, when stem-growing begins.

Generally the decreasing number of positive PCR-proofs in further course of the trial - although later symptoms occurred - is a hint, that concentration of mycelium is diluted during stem growth. So the signals of common PCR contain also a quantitative information in a sense. On account to the low concentration of mycelium, the detection limit of PCR is fallen below. This fact matches with results of ADLER,1999: In her examination of stems with ELISA and PCR on latent infection she concluded, that the pathogen is not detectable in every part of the plant if dilution is too low. But PCR-assay shows higher performance because it refines the proof for 10^2-fold. If this fact is included to the results then it is to suppose, that the place where stem samples have been taken here in this trial, were not optimal. Within the stem higher concentration of mycelium is located at the bottom and the place where symptoms break out.

Some indications of the trials brought auspicious results to introduce a seed tuber dressing against *Phytophthora infestans* in practice. Higher yield in the treated variants justifies the effort of examine tuber dressing also in field trials.

Especially when formulation of the agent would be adapted to dressing requests, it could be combined easily with common tuber treatments against *Rhizoctonia solani*.

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Fourth Workshop of an European Network for development of an
Integrated Control Stategy of potato late blight
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Sources of initial inoculum; relative importance, timing and implications for late blight epidemics

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With the recent global migration of more aggressive *Phytophthora infestans* strains and populations [1, 2], late blight epidemics have become less predictable and at the same time less controllable in potato producing areas. This paper aims to gain some insight in the possible changes in the appearance of late blight that take place when a surveyable and stable late blight situation changes into a less predictable one.

When a regional clonal reproducing population of *P. infestans* is being displaced by more aggressive late blight strains, the speed of the epidemic will increase dramatically. Further, increased yield losses due to tuber blight attack are to be expected due to increased aggressiveness towards tubers [3]. The pathogen will be totally dependent on overseasoning in infected tubers for its survival during the crop free period. When no overlap from one growing season to the next and no alternative host plants are available. Aggressive isolates, which cause extensive tuber rot in storage, can have a selective disadvantage in such situations [4]. However, since aggressiveness towards tubers and the foliage does not appear to be correlated [5], directional selection against isolates with high levels aggressiveness to tubers will not automatically lead to decreased levels of foliar aggressiveness in asexually reproducing populations of *P. infestans*.

However, if functional oospores are present in the field, *P. infestans* is no longer dependent on hibernation in infected tubers. Potato cultivars with intermediate levels of host resistance facilitate the production of oospores. In the Netherlands, oospores are commonly found to be present in leaflets of volunteer potato plants with multiple lesions per leaflet. Oospores were abundantly formed in partially resistant cultivars (Table 1). In

1998 up to 87 % of the collected leaflets with two or more lesions contained oospores, indicating that volunteer potato plants do not only cause a direct threat to neighboring potato fields (asexual spore production) but they can also serve as an important source of oospore inoculum.

Table 1. The presence of oospores of *Phytophthora infestans* in leaflets with multiple lesions sampled from volunteer potato plants in 6 farmers' fields in the starch potato region of the Netherlands in 1998.

Locality	Sampling date	Crop	Potato cultivar (volunteers)	Total number of leaflets	% leaflets with oospores present
Muntendam A	July 29	Winter wheat	Karnico	101	35.6
Muntendam B	August 4	Winter wheat	Karnico	54	35.2
Velingerveen	August 4	Winter wheat	Kartel	15	33.3
Hooghalen	September 10	Flax	Elkana	109	68.8
Kooyenburg	September 10	Sugar beet	Florijn	106	76.4
Rolde	September 10	Sugar beet	Florijn	77	87.0

Until the present day, limited information is gathered about the maximal survival time of oospores[6]. Oospores of *P. infestans* buried in a sandy soil and a light clay soil were exposed to Dutch weather conditions and regularly checked for their infection potential for six years. The soils were found infectious for 48 and 30 months respectively (Figure 1).

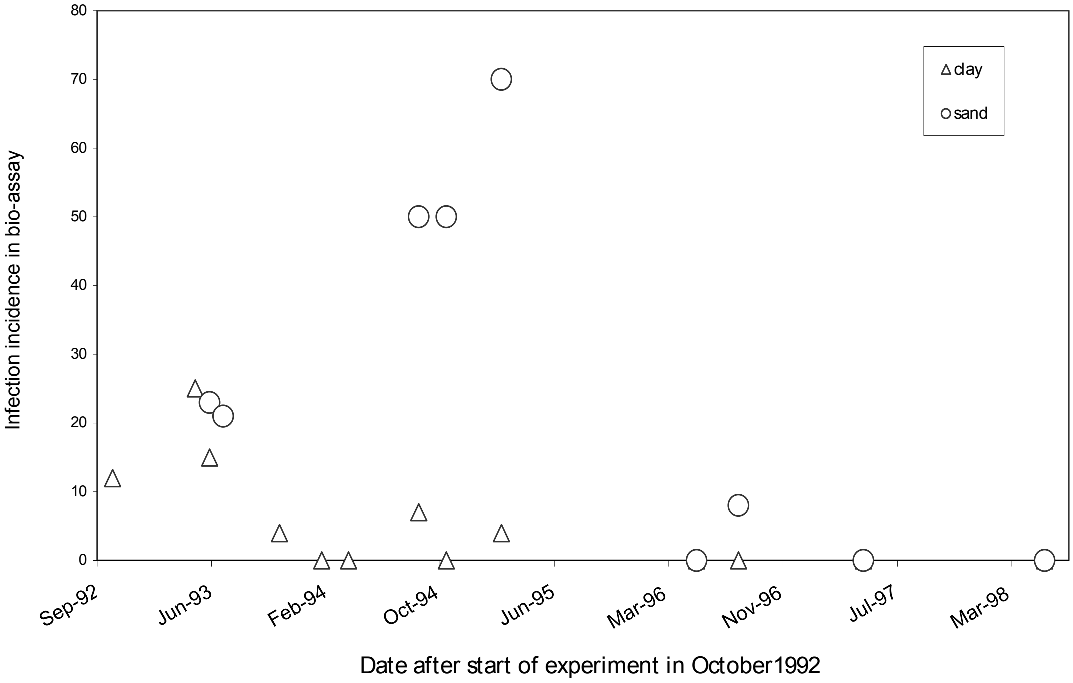

Figure 1. Germination response of oospores of Phytophthora infestans in a clay soil and a sandy soil under field conditions tested at regular intervals during a six year period. Each data point presents the outcome of a single spore-baiting assay.

Oospores seem to require extensive periods of free water for their germination and infection of leaves. High risks of oospore-initiated infections therefore seem to occur in waterlogged situations in poorly drained soils and when the foliage makes direct contact with the soil or is submerged. In a spore-baiting experiment, the first oospore-initiated infections of potato leaves were observed after 92 hours of waterlogged conditions.

While tuber borne inoculum forms a threat during the start of the growing season, oospores are able to germinate whenever the conditions are favorable. Therefore, they can initiate new infections from the emergence of the crop until harvest time. Such lesions develop on the lower leaves of the plant, and are therefore extremely difficult to detect. At present stem attack seems to be more common than in the past, and as such forms a long-lived source of secondary infections in the field. Such stem attack is especially associated with the presence of more aggressive strains, which have the tendency to develop under low, sub-optimal temperatures. The concealed occurrence of the oospore-initiated infections in combination with increased levels of aggressiveness of the pathogen will interfere with a proper late blight control strategy based on early warnings and the use of protective fungicides.

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Fourth Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
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Results of Validation Trials of Phytophthora DSS in Europa in 1999

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Abstract

In 1999 four DSS for the control of late Blight were tested in a European validation trial (SIMPHYT I/II, Plant Plus, NegFry and ProPhy). 9 trials were carried out in 6 countries. By employing DSS numbers of sprays could be reduced. SIMPHYT I/II and NegFry recommended less sprays than Plant Plus and ProPhy. Plant Plus advised more contact fungicides than the other DSS. Plant Plus and SIMPHYT I/II recommended systemic compounds. SIMPHYT I/II and NegFry tolerated higher Late Blight disease severities than Plant Plus and ProPhy. Due to some constraints and mistakes made during the conduction of the trials results need careful interpretation.

An infrastructure for further trials has been established. The validation efforts should be continued.

Key words: DSS, validation, late blight, trials

Introduction

During the third workshop of the European Network for Development of an Integrated Control Strategy of Potato Late blight at Uppsala, Sweden from 9th to 13th of September 1998 it was decided to lay out validation trials for the *Phytophthora* - DSS available to the participants of the DSS – Subgroup within the concerted action. Based on the results of the discussions on meteorological data (Hansen, 1998; Jörg & Kleinhenz, 1999a) the requirements for the availability and quality of meteorological data to be used as input for the DSS have been stated and made available to the participants in the validation trials during January 1999. A comprehensive proposal for the plan of the trials including a protocol has been given by Jörg & Kleinhenz (1999b). This proposal was discussed from January to March 1999 and finally agreed upon on a meeting of the participants and model builders in April 1999 at Lelystad. During April and May 1999 the DSS were installed at the participating institutions and last problems concerning the supply with meteorological data were solved. The trials were conducted from May til September 1999.

The activity had the following main aims:

- identification of the constraints to such an international validation trial and solution of the problems if possible,
- provision of an infrastructure for possible follow-up projects,
- comparison of the DSS results throughout Europe in different potato growing regions,
- learn about the DSS strategies to improve the existing DSS.

Validation Trials

In Europe several DSS for the control of Late Blight are available, which either predict the first occurrence of the fungus or recommend a fungicide strategy or do both. Among the participants in the validation trials it was decided to test complex models that are able to do both. Four „core models“ were decided upon to be included into the trials: Plant Plus, SIMPHYT I/II, NegFry and ProPhy. Participants should test these four DSS in their trials. It was permitted to include additional DSS into the trials. Table 1 gives an overview on the participants and the DSS under investigation.

For details of the trial plan see Jörg & Kleinhenz (1999b). Some major points under discussion should be addressed here. Availability of fungicides strongly varies between the European countries and not all a.i. or products recommended by the DSS could be used in the trials. So, some simplifications concerning the fungicide choice had to be made. For example, dithiocarbamates are not registered in all participants` countries; and so if contact fungicides were recommended by a DSS, it was mainly fluazinam that was employed, although a specific recommendation for a dithiocarbamate was given by a certain DSS. Another example is the use of translaminar products instead of systemic compounds. Concerning the fungicide strategy recommendations were taken as „strict orders“ rather than as a proposal when to apply a fungicide. In exceptional cases deviations on the day of treatment of one, at maximum two days were regarded as tolerable.

Table 1. Participants and DSS included in the validation trials 1999

Country	Institution	No. trials	DSS							
			SIMPHYT	NegFry	Plant Plus	ProPhy	Guntz-Divoux	MISP	Routine	Untreated
CH	FRIAA,Zürich	1	X	X	X	X		X	X	X
B	CRA,Gembloux	1	X	X			X		X	X
NL	PAV, Lelystad	3	X	X	X	X			X	X
IRL	Oak Park,Res. Cent.	1	X	X	X	X			X	X
A	BFL, Wien	1	X	X					X	X
D	TU München	1		X	X				X	X
D	LPP, Mainz	1	X	X	X	X				X

Sources of meteorological data could be standard weather stations and weather stations in the crop. This was possible because transformation of data is possible due to the availability of conversion programmes. If weather forecasts were implemented in the DSS and forecasted weather data were available they could be used for decision-making.

Results

First Appearance of Late Blight

Phytophthora infestans occurred in all the trials laid out. The dates of first appearance predicted by the different DSS varied considerably (see Fig. 1). In the average the time span between predicted and observed date of first appearance ranged from 15 to 30 days (SIMPHYT I and Plant Plus). NegFry and ProPhy forecasts were in between with 21 and 27 days. SIMPHYT I predictions were closest to the observed occurrence of Late blight. In two cases the model was too late (2 resp. 4 days). Minimum time spans ranged from 2 (SIMPHYT I and NegFry) to 8 days (ProPhy). At the maximum SIMPHYT I was 47 days earlier than the first appearance. The respective results for the other DSS were: 68 days for Plant Plus, 51 days for NegFry and 50 days for ProPhy.

Number of fungicide applications

In five of the nine trials the performance of Plant Plus, SIMPHYT I/II, NegFry and ProPhy could be directly compared. Plant Plus and ProPhy in the average recommended more than 9 fungicide applications (Fig. 2). The SIMPHYT I/II strategy required between 7 and 8 applications and NegFry recommended one treatment less (6.8 in the average).

In six trials the comparison of Plant Plus, SIMPHYT I/II and ProPhy was possible. ProPhy required most treatments (9.3) followed by Plant Plus (9.0) whereas SIMPHYT I/II recommended 7.3 fungicide applications. Also in six of the trials Plant Plus could be checked versus the NegFry strategy. Plant Plus recommended two treatments more than NegFry (9.0 and 7.0 resp.). A comparison of SIMPHYT I/II to NegFry (6 trials) showed that the latter DSS recommended the least intensive fungicide strategy (6.8 treatments instead of 7.8 in the SIMPHYT I/II strategy).

Fungicides

An overview on the groups of fungicides (a.i. groups) is given in Fig. 3. Systemic fungicides were recommended only by Plant Plus and SIMPHYT I/II. The share of systemic fungicide applications was about 10% in the SIMPHYT I/II strategy, whereas 2-3% of the applications recommended by Plant Plus were done with systemic fungicides. The relatively high share of systemic fungicides recommended by SIMPHYT I/II is due to the „emergency treatments“ in the case of *P. infestans* being present in the field (trial plot) under investigation. ProPhy did not recommend systemic compounds. In the NegFry strategy the use of systemic fungicides a priori was not taken into consideration.

The share of contact fungicides recommended by the DSS did not differ much between SIMPHYT I/II, ProPhy and NegFry. About 60% of the fungicides applied in these DSS-strategies were mainly fluazinam and to a lesser extent fentinacetat or dithiocarbamates. Plant Plus recommended a higher share of contact fungicide as can be seen in the comparison of all four DSS (more than 70%), or compared with SIMPHYT I/II and ProPhy (the same) or in the direct comparison with NegFry (65% versus 55%).

The share of translaminar products ranged from 25 to 45%.

To summarize: Plant Plus strategy consisted of more contact fungicides than the other DSS. Due to „emergency treatments“ SIMPHYT I/II recommended the highest share of systemic compounds. SIMPHYT I/II, ProPhy and NegFry had a share of one third to 40% of translaminar products in their recommendations.

Disease Severities

Neither by the DSS nor by the „routine treatments“ the crops could be kept free of Late Blight disease. Least disease severities mostly were recorded in the „routine treatments“, which consisted of much more treatments than the DSS- strategies.

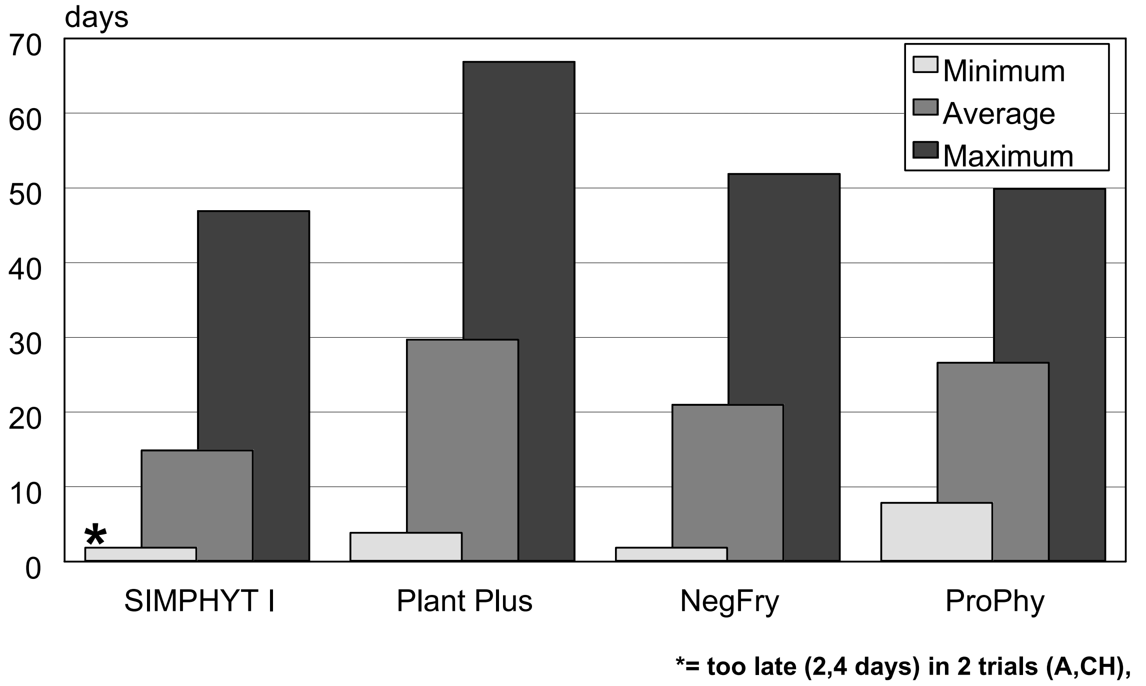

Figure 1. First appearance of Late Blight-difference between predicted and observed dates.

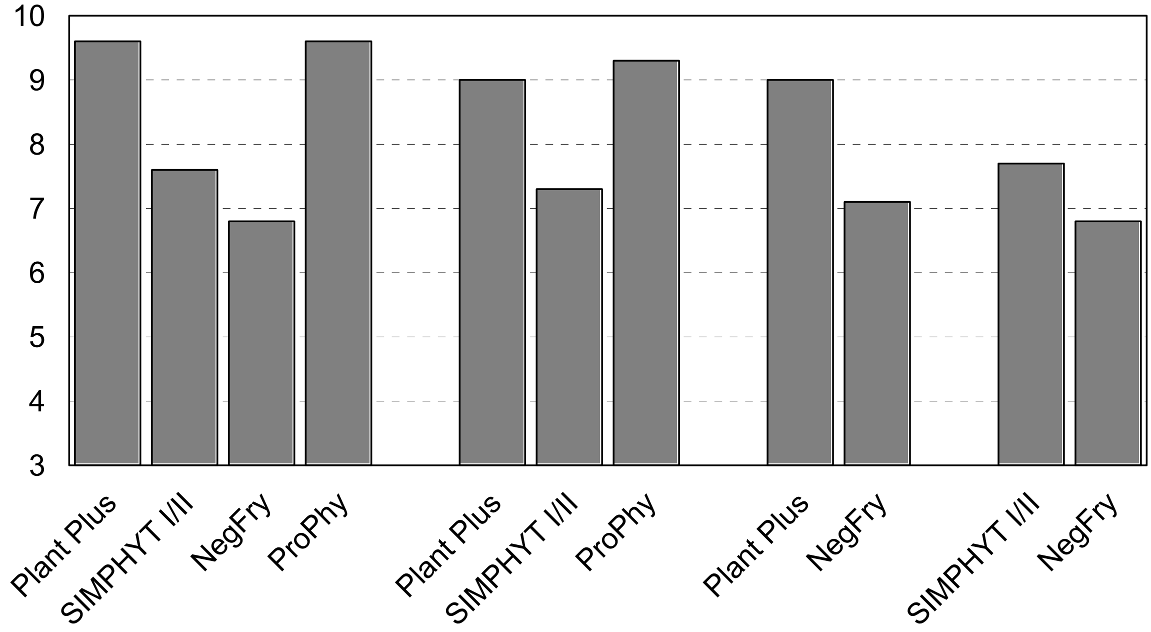

Figure 2. DSS-Validation 1999 – Number of treatments.

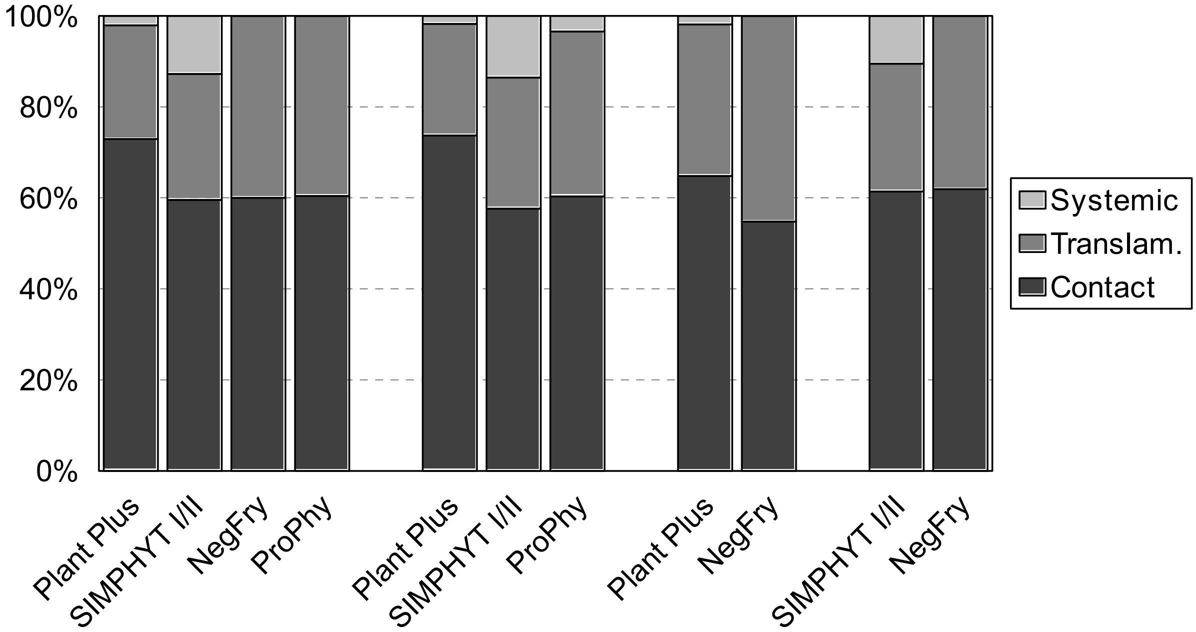

Figure 3. DSS-Validation 1999 –Share of recommended fungicide groups.

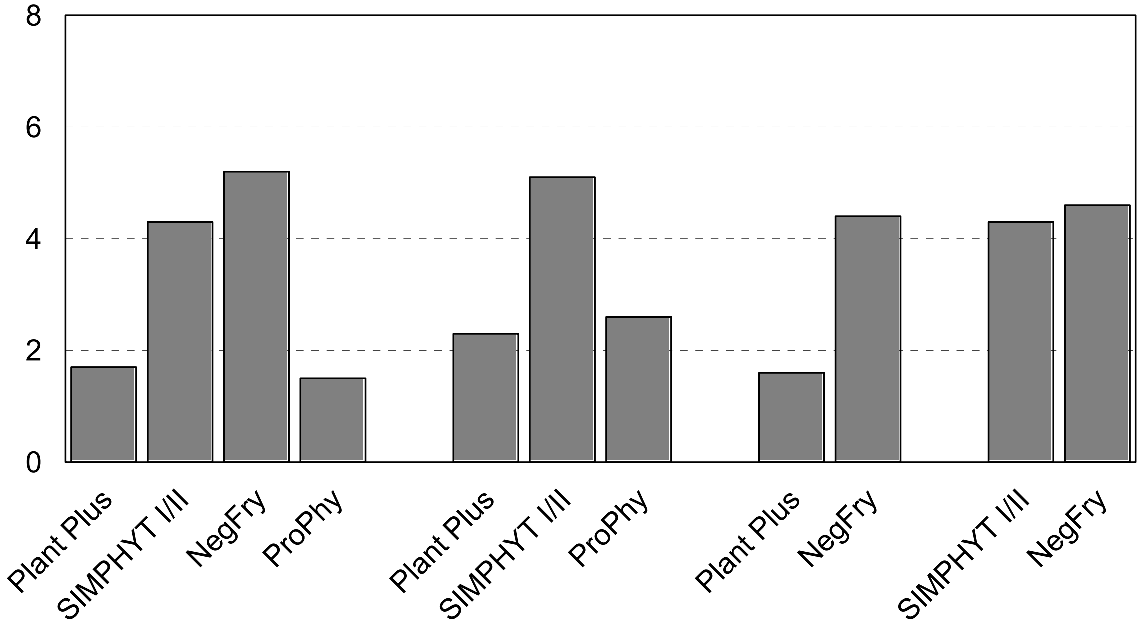

Figure 4. DSS-Validation 1999 – Disease severities of Late Blight in the late season.

No DSS could be identified which always gave best *Phytophthora*- control in all of the trials.

A comparison of the average disease severities observed in the trials in the late growth stages of the potato crops (>75) is given in Fig. 4. Plant Plus and ProPhy gave better control than SIMPHYT I/II and NegFry. The disease severities in the plots treated according to the first two DSS in the average were below 2 – 3 % whereas with the latter DSS 4 – 5 % Late Blight were recorded.

One may state that the disease severity varies according to the number of treatments applied to the potato crop.

Discussion

Some of the aims mentioned in the introduction have been met during the first year of the validation trials. The concept for the trials proved to be suitable for the purpose intended. Implementations of the DSS at the participating institutions was not without any problems but was done successfully with one exception where the installation was too late. Despite the strong diversity of hard- and software equipment the DSS were run without striking problems. The supply with meteorological data was mostly sufficient. Only in very rare cases data gaps occurred. More problematic is the quality of the weather forecast. If the forecast is not correct wrong decisions may be taken or superfluous treatments are done.

As a final conclusion concerning the organisation one may state that the infrastructure for follow-up projects on DSS validation has been installed.

In the various regions in which the **DSS** were tested in 1999 *Phytophthora infestans* – epidemics ranged from „poor“ to „severe“. So the DSS were validated under varying infection pressure. In general the DSS use resulted in a reduction of fungicide treatments with sufficient control of the fungus. These results have been reported for the single models: for Plant Plus (Hadders, 1997, 1998, 1999; Hinds, 1998), SIMPHYT I/II (Gutsche 1998; Zellner, 1998; Kleinhenz & Jörg, 1998,1999; Hausladen *et al*., 1999), NegFry (Leonard *et al*., 1998, 1999) and ProPhy (Nugteren, 1997).

The DSS differed in the numbers of treatments (SIMPHYT I/II and NegFry recommended less treatments), the choice of products (Plant Plus relying more on contact fungicides and SIMPHYT I/II recommending several systemic treatments) and the degree of Late Blight control (ProPhy and Plant Plus applications resulted in less disease severities).

However, the results are preliminary and must be regarded at with carefulness as they are obtained under certain constraints. So the interpretation has to be done within certain limits only. During the conduction of the trials some mistakes were made that cannot be assigned to DSS use. Products not advised by the DSS were applied. The delay of an application exceeded the tolerable limit of 2 days. Disease assessments started too late and so the DSS only received incomplete information on the fungus. In addition other information, like crop growth data, were not fed in the DSS.

Also some DSS could not show their full capability. This was due to registration of pesticides in the different countries. Some products were not available and had to be replaced by other products. Label restriction limited the application of fungicides to certain periods or a fixed maximum number of applications and prescribed minimum intervals between two applications prevented a fungicide schedule strictly in congruence with the DSS` decision-making.

No DSS proved to be the most appropriate for all the conditions tested. In general the DSS performed well in those regions (under those circumstances) in which they were developed. This calls for regional adaptations or inclusion of more/other parameters for decision-making. The approaches of the DSS differ considerably for no striking similarities in decision-finding could be observed (de Visser, 1999, pers. comm. on the workshop).

The latter fact offers good prospect for the improvement of the DSS. On the other hand

some DSS are marketed by private companies and so not all the informations on the models are commonly available and can be used by all model builders.
The DSS should be compared to a „routine treatment" to demonstrate the capability of the models. As a „routine treatment" weekly sprays with fluazinam were chosen. Compared to that all DSS considerably reduced the number of applications. But weekly sprays with contact fungicide throughout the season in many cases are not the „standard strategy" that is applied in a given region, and so the capability of the DSS must not be overestimated. A concept for a „maximal achievable control" must be developed to have a more appropriate yardstick for the comparison.

Despite all the constraints that have to be taken into consideration in interpreting the results of the 1999-validation trials the experience made was very positive. The participants decided to continue the validation efforts during the next year(s). It is also intended to establish a follow-up project to the concerted action focussing on the improvement of existing DSS (an aim that has not been reached in the first year), developing new submodels in neglected fields of work and also on implementation of the DSS results into agricultural practice.

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Fourth Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
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Integrated control of late blight in conventional and organic potato production using warnings and cultivars resistance: results in 1998 – 1999

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Introduction

The late blight warnings enable farmers to spare 1 to 5 pulverisation compared to their weekly routine protection program. Despite this progress, potatoes still require a much higher number of pulverisation than the other crops like wheat or sugarbeet. This year again 9 to 13 pulverisation were advised by the late blight warning services.

This intensive protection is necessary in Belgium because most of the cultivated varieties are very sensitive to the late blight. Among these ones, Bintje is cultivated in 64 % of the potato areas.

Consumers are getting harder to please as regards food. They are looking for products with a good presentation and a good taste. They demand products with a sanitary quality beyond reproach, namely as regards the presence of pesticides residues. They are also looking for food products made with respect for environment, without using too many fertilizers and pesticides. They adopted the lasting agriculture concept, which all the farmers will have to adopt. Important efforts are being made in the neighbouring countries to meet these requirements. In Belgium some big distribution companies are marketing integrated production products. In Wallonia the Ministery of Agriculture has launched a marketing campaign for the integreted potato production. Besides the conventional production, organic farming is also growing rapidly.

Since 1998, extension trials have been made within the framework of the 2078 European programme to give the necessary technical elements to reach a significant reduction of the number of pulverisation thanks to the late blight warning system and to the choice of more resistant varieties.

Seven protection program against late blight were studied : we compare pulverisations programs according to the warnings advises and programs based upon warnings but for which some pulverisation were not applied (table 1).

These programs were tested on the Bintje and Charlotte varieties in conventional agriculture and Bintje, Charlotte, Pompadour and Naturella in organic agriculture (table 2).

The different treatments (protection programs and varieties) were settled according to a Split-Plot design with the "pulverisation" on large plots and the "varieties" on small ones.

In 1998 the small plots were composed of 2 rows with 25 plants and in 1999 they were made of 3 rows with 20 plants. Late blight was introduced in a natural way on the whole testing field thanks to a dense network of untreated cv Bintje plants. These spreader plants were not destroyed in 1998 while in 1999 they were mowed 15 days after the first symptoms had appeared. Trials were conducted at Libramont in a region with weak late blight pressure conditions.

Table 1. Pulverisations programs.

Id.	Programs	1998	1999	1999 (orga.)
R	Routine weekly treatment	+ (Mz)	+ (Flua)	+
W	Treatment according warnings (Guntz-Divoux)	+	+	+
Ws	Treatment according warnings in severe and very severe risk of infection periods	+ (Mz)	+	+
W3	Treatment according warnings starting at the third treatment advise	+ (Mz)	+	
Wlb	Treatment according warnings starting at the first Late blight appearance in the trail field	+ (Mz)	+ (Emcy)	+ (Emcy)

(orga.) : organic agriculture using cupper based fungicides only.

\+ (Mz): only mancozebe was used for these treatments in 1998.

\+ (Emcy.): eradication strategy was tested in 1999: since the first symptoms appeared in the test field, 3 pulverizations were made at the interval of 3 days. In conventional agriculture we used a mixture of Shirlan 200 ml/ha + Acrobat 1,5 kg/ha ; in organic agriculture we used Hydoxyde cupper (Kocide)

Table 2. Ratings of sensitivity to late blight according to French (1998) or Dutch (1997) catalogues of varieties

	Foliage	Tuber
Bintje	3	4.5
Pompadour	4	4
Charlotte	6	6
Naturella	7	-

Table 3. Fungicides applied.

	Commercial name (and active ingredients)	Dosage
Contact	Dithane M45 (Mancozeb)	2 – 3 kg/ha
Contact with tuber protection	Shirlan (Fluazinam) Or Fentin hydroxyde (Brestan)	0.3 – 0.4 l/ha 0.6 - 0.8 l/ha
Penetrant	Acrobat extra (Dimetomorph + Mancozeb)	2 kg/ha
Systemic	Ridomil special (Metalaxyl + mancozeb) Or Ripost pepite (Oxadixyl + cymoxanil + mancozeb)	2 kg/ha 2.5 kg/ha
Contact in organic agriculture	Cupravit frote (Cupper oxychlor) Or cupper hydroxyde (Kocide)	4 – 5 kg/ha 4 kg/ha

Course of the test

In 1998 the season was favourable to late blight. However, the first symptoms were only observed on 22nd July although serious damage had been noticed in Hainaut since mid June. Nevertheless the climatic situation influencing the infection were much similar. The main reason why late blight appeared late is probably due to the fact there was no inoculum near the plot.

In 1999 the first late blight symptoms were observed on 14th July, i.e. one week earlier, in spite of a less humid climate. A serious source developed on one part of the testing field and could not be controlled.

Notations were made every week from the observation of the first symptoms according to the CIP scale. Date were analysed using analysis of variance procedures (General linear models module of SAS software) and differences between treatments were evaluated using Least Square Means type III MS.

The pulverisation were made with a duster carried on a tractor with a 12-meter ramp and 110° nozzles with spray pressure equivalent to 3-bar and volume equivalent to 300 l/ha.

Table 4. details of culture and first appearance of late blight.

	1998	1999	1999 – organic
Planting date	5/5/98	26/4/99	3/5/99
Emergence	25/5/98	20/5/99	25/5/99
First appearance of late blight in the trial field	22/7	14/7	14/7

Table 5. details of pulverisations.

	1998		1999		1999 – organic	
	Number of pulve.	Date 1st pulve.	Number of pulve.	Date 1st pulve.	Number of pulve.	Date 1st pulve.
DSS	5	12/6/98	8	10/6/99	7	10/6/99
R	7	10/6/98	10	11/6/99	10	11/6/99
W	5	11/6/98	7	11/6/99	7	11/6/99
Ws	3	17/6/98	3	1/7/99	3	1/7/99
W3	3	7/7/98	4	1/7/99		
Wlb	1	3/8/98	5	15/7/99		16/6/99

Assessment of sensitivity of varieties

The trial was conducted in Libramont and in Gembloux (region with average pressure of late blight) . The panel of varieties cover all the range of sensitivities.

In Gembloux we put plots with 2 rows of 10 plants with 1 spreader plant of cv. Bintje on each side of every row. In Libramont plots with 2 rows of 25 plants were put without any infecting spreader plant; the trial field lay near an untreated plot of cv. Bintje. The plant were not protected and became naturally infected. Disease scoring were made every week from the observation of the first symptoms according to the CIP scale.

Results and discussions

Reduction of the number of pulverisation - 1998

In spite of the important inoculum pressure from the unprotected plots and the infecting rows the disease was perfectly controlled thanks to the warnings with a protection level which is equal to the 7-days systematic treatment.

As regards the Bintje variety the Guntz and Divoux model has to be applied strictly:

- the impasse up to the first symptoms cannot avoid the epidemic development of the disease,
- the protection limited to the serious and very serious risks as well the impasse on the first two treatments would not be sufficient to contain the disease in stronger disease pressure conditions.

Thanks to its slightest sensitivity, the Charlotte variety could behave in a quite satisfactory way in these two last protection programs. But as for the Bintje variety, the outcome of the impasse until the first symptoms was that plots were destroyed quickly.

Reduction of the number of pulverisation – Conventional agriculture - 1999

The 1998 results were not confirmed in 1999:

- the Charlotte variety proved to be more sensitive to the late blight than the Bintje one as regards the leaves contrary to its ranking in the variety catalogues and the observations on the previous years.
- none of the protection programs allowed us to control the disease sufficiently. It progressed very quickly since the first symptoms appeared. An important source developed from the plots which were protected less intensively; several plots which were in this area were quickly destroyed in spite of the later pulverisation.
- the emergency strategy could not confine the epidemic

- the most intensive pulverisation programs with a treatment every 7 days or according to the warnings did not give satisfactory results even though the protection level was far higher than the other.

Due to significant interaction between the treatments by the replications, no clear statistical conclusions can be drawn. Thus managing tests in small plots remains very uncertain because the heterogeneousness of the sources interferes with the treatments.

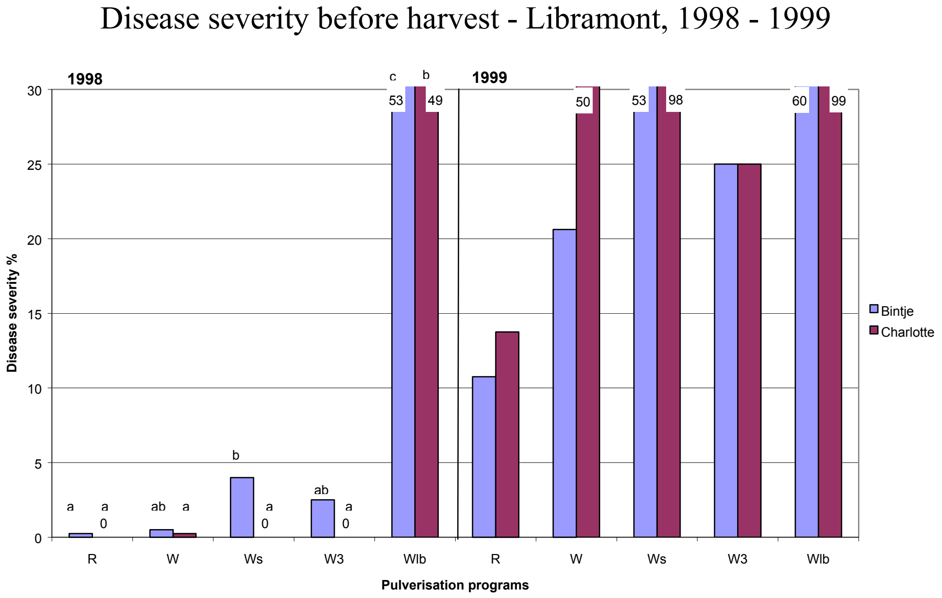

Figure 1.- Disease severity before harvesting – Conventional agriculture – Libramont, 1998 – 1999.

- Results with the same letter are not significantly different (LSM – Type III MS)
- 1999: interaction between the treatments by the replications

Reduction of the number of pulverisation in organic agriculture - 1999

The same observations can be made about this test for Bintje and Charlotte. The leaf destruction at the end of the cultivation reached very high levels and it can absolutely not be accepted.

Moreover, you can observe this:

- the Pompadour variety, however less affected than the Charlotte and Bintje ones, did not resist enough. In high disease pressure conditions, the copper-based fungicides do not seem to be sufficient to protect sensitive varieties.

- Naturella was very little affected by late blight, and this for any treatment. After the end of the pulverisation (on 19/9) the leaves were quickly destroyed on the unprotected plots. The protection program with pulverisation only in case of serious or very serious risks enabled a perfectly satisfactory protection or the Naturella variety with 6 pulverisation less compared to the 7-day systematic treatments and 4 pulverisations less compared to the treatments according to the classical warnings.

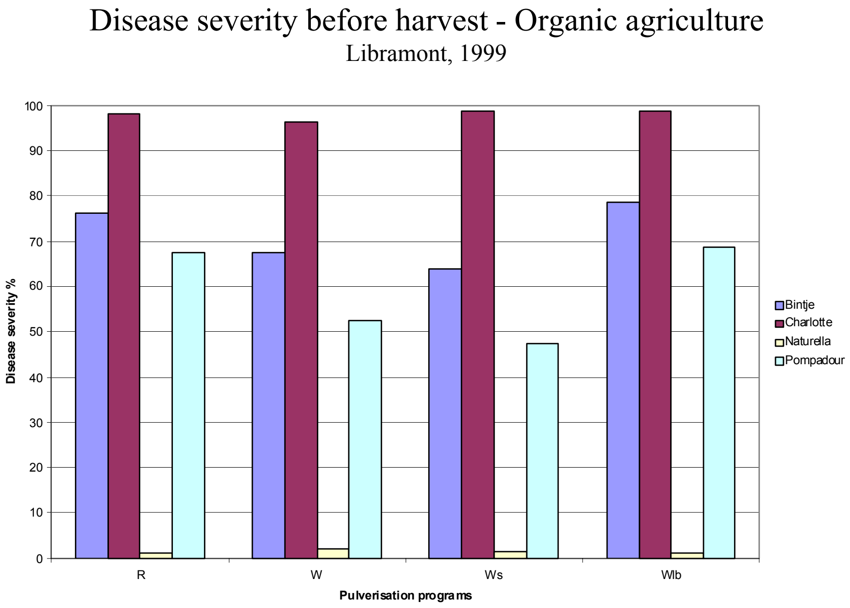

Figure 2.- Disease severity before harvesting – Organic farming – 1999.

- Results with the same letter are not significantly different (LSM – Type III MS)

Evaluation of the varietal sensitivities - 1999

As we could see in the tests where the number of pulverisations are reduced in the conventional agriculture and the biological one, the notes about the resistance of the varieties to the foliage late blight given by the variety catalogues can no longer be applied to the Charlotte variety. Now this one appears to be more sensitive than the cv. Bintje. In the two trial sites, the collapse of the resistance of cv. Charlotte was totally confirmed.

At first, we classified the varieties according to the degree of destruction of the leaves in Gembloux on 19/7 and in Libramont on 12/8. This ranking was compared to the sensitivity notes in the Dutch (1997) or French (1998) catalogues. We can say this:

- we observed a very marked rise in sensitivity in the 2 plots with Monalisa, Asterix and Victoria varieties (sensitivity similar to the Bintje one) as well as the Ditta, Sava and Exquisa ones.
- There was a sharp rise in sensitivity of the Nicola variety in Libramont and Agria in Gembloux.
- a behaviour true to the classification in the Dutch and French catalogues was observed for the other varieties.

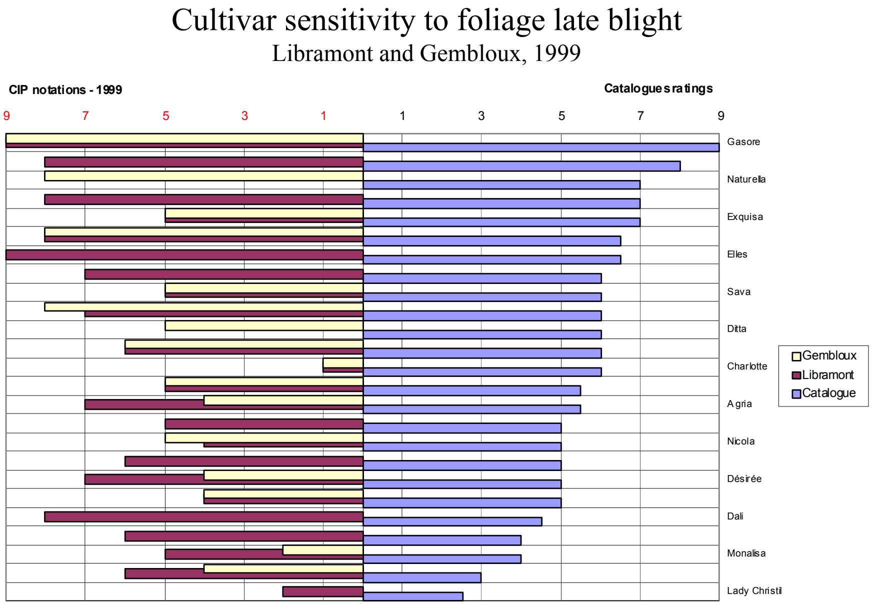

Figure 3.- Foliage sensitivity to late blight of varieties

We also notice that these catalogues sometimes give very different sensitivity notes for some varieties. So Exquisa is quoted 7 in the Dutch catalogue but 4 in the French one while Monalisa is quoted respectively 4 and 6.

Among the tested varieties which could be marketed in Belgium, here are the ones which can well resist the late blight attacking leaves:

- As regards the consumption potatoes of the salade type: Juliette
- As regards the consumption potatoes: Naturella, Gasore
- As regards the chip industry: Symfonia, Remarka
- As regards the starch industry: Kuras, Kardal, Elles.

Conclusions

The varieties which are now cultivated in Belgium are generally sensitive to the foliage late blight. A lot of varieties which were still considered rather tolerant have got a sensitivity level now which can be compared to the Bintje variety and they need a very intensive fungicide protection.

There is a limited choice among the new weak sensitive varieties. However, we saw that that type of varieties would allow a substantial reduction of the number of pulverisation.

Beyond the lower number of treatments allowed by warnings, a new significant reduction of these treatments will make it necessary to market new resistant varieties which meet the various demands of consumers and industry.

In organic agriculture, only varieties with sufficient rate of late blight resistance may be cropped successfully in heavy disease pressure conditions. Copper-based fungicides are not able to protect foliage of sensitive cultivars in these conditions.

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Estimation of probable yield losses by *Phytophthora infestans* depending on nitrogen supply of organic maincrop potatoes

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Introduction, Materials and Methods

It is usually assumed that *Phytophthora infestans* is the most important cause of the low yields recorded in organic potato production in Central Europe. The literature offers no consideration of the impact of other growing factors like the supply of nutrients (mainly nitrogen) on yield in organic potato production.

An intensive survey was carried out between 1995 and 1998 on organically managed potato fields within 100 km of Freising (near Munich). Soil samples were taken from late April/early May to the mid-June at ten-day intervals. In mid-June, the beginning of July, mid-July and at harvest-time, plant samples and sequential harvests were taken to determine potato tuber growth, nitrogen content of foliage and uptake of nitrogen. To describe the phytopathological situation, late blight necrosis and unspecific necrosis (percentage necrosis, percentage infected plants) were assessed weekly. Depending of the position in the crop rotation and application of additional organic manure, the fields are divided into three different groups, with ”high”, ”middle” and ”low” nitrogen supply, respectively.

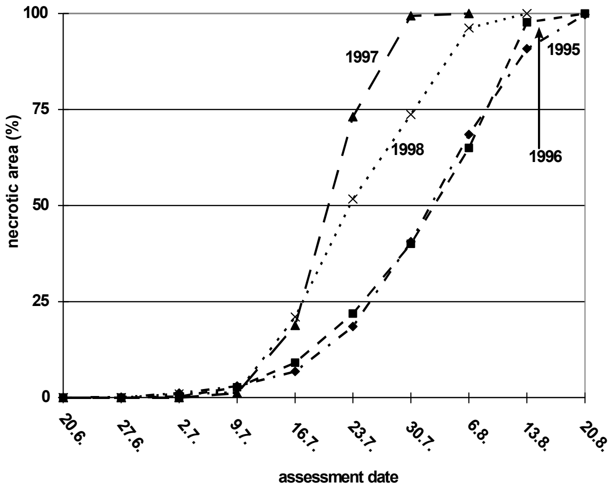

Figure 1. Development of necrosis on potato haulm depending on sampling year, mean of all sampled organic maincrop potato fields.

Results

Necrosis on potato haulm:

In 1995, the growing conditions for potatoes were unfavourable due to a long dry period; in 1996, 1997 and 1998 growing conditions were very favourable. In 1995 and 1996, *Phytophthora*-disease destroyed potato foliage relatively late (third week of August). In 1997, foliage of potatoes was destroyed in late July; in 1998 at the beginning of August, in both years severe disease developed (Figure 1).

Tuber growth and yields:

Figure 2 shows tuber bulking depending on sampling year. The results shows a great impact of the unfavourable growing conditions in 1995, but only little correlation between yields and *Phytophthora*-disease-impact in the following three years.

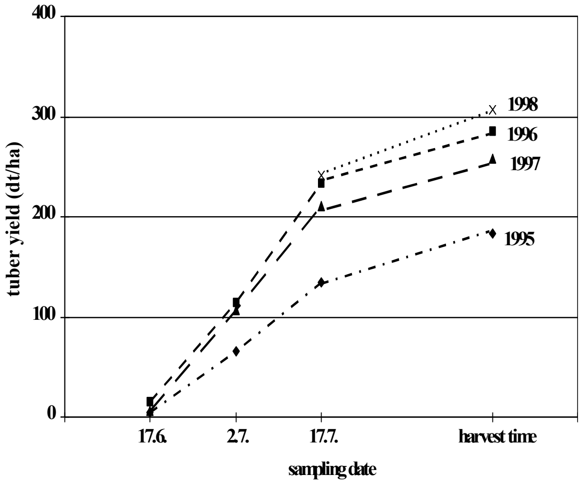

Figure 2. Tuber bulking of organic maincrop potatoes in Southern Bavaria depending on sampling year, mean of all sampled fields.

Figure 3 shows the tuber bulking behaviour depending on nitrogen supply level: fields with a „low“ N-level ceased tuber bulking nearly at the middle of July, while tubers specially on fields with a high nitrogen supply level continued to growth until harvest time. The yield differences between the different groups on middle of July and at harvest time were significant.

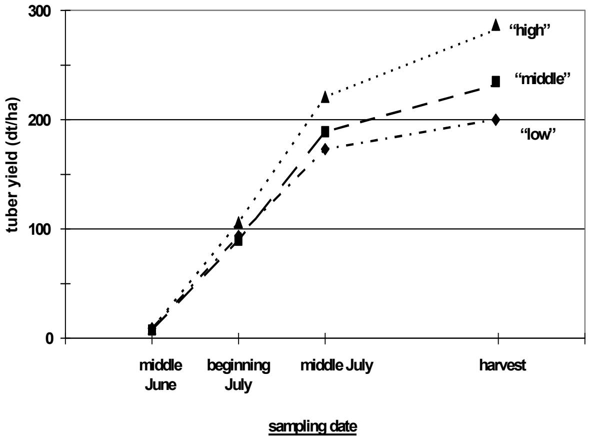

Figure 3. Influence of „N supply level“ on tuber bulking of maincrop organic potatoes in Southern Bavaria/Germany, mean of all sampling years.

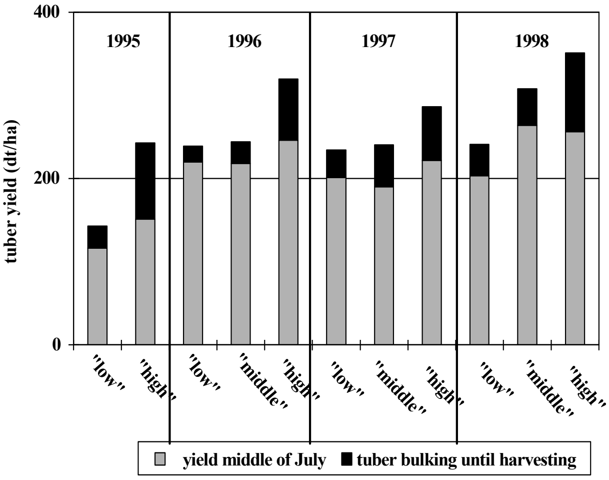

Figure 4. Influence of „nitrogen supply level" on tuber yield at middle of July and at harvest time depending on sampling year.

Figure 4 shows the yield (dt/ha) of maincrop potatoes in each year in the different nitrogen supply groups. The grew bars represents the yields on middle of July, black bars the additional tuber growth until harvesting time, both bars together the yields at harvesting time. Fields with „low N supply level" (for example, fields with a cereal as the preceding crop, no or only little additional organic manure) with a mean N uptake on middle of July of 75-80 kg N/ha stopped tuber growth almost completely on the in the middle of July each year (7-8 weeks after plant emergence), independently of *Phytophthora*-disease impact on these fields in each year.

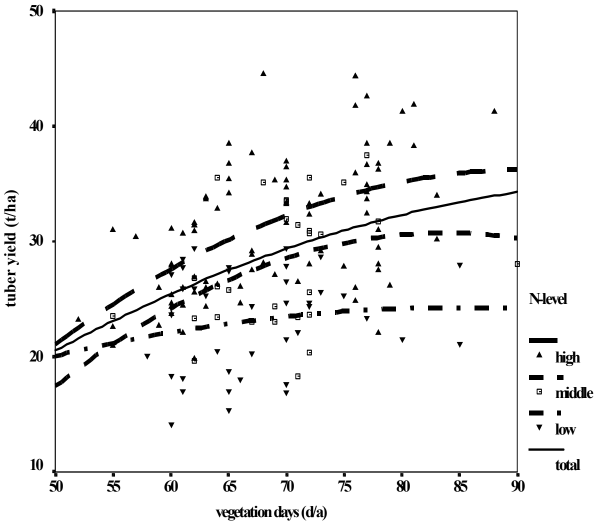

Figure 5. Regression of the relation between lenght of growing period and tuber yield depending on N-supply level (Bavaria, 1996-98).

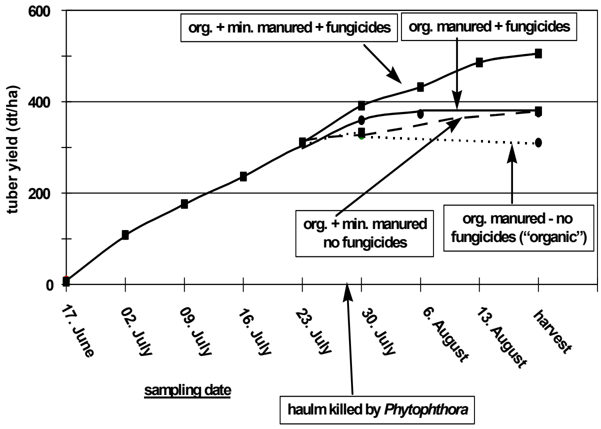

Figure 6. Tuber bulking depending on nitrogen supply and Phytophthora-disease - field trial on Klostergut Scheyern research station 1996 - 1998 - cv. Agria. No yield differences until end of July.

On fields with high nitrogen supply (fields with a clover-gras-mixture as a preceding crop, for example, or fields with cereal as preceding crop with a high application of organic manures and a mean N uptake on middle of July about 110-120 kg N/ha) potatoes continued growth after middle of July. At the end of the growing season, yields in fields with a high nitrogen level were statistically higher than in fields with low nitrogen supply (an average of nearly 9.3 t/ha for the four years). The comparison of yields und tuber growth after middle of July for the fields of high N supply level shows, that in 1997 with the strongest late blight impact, yields and tuber growth after middle of July were afected only by nearly 40 dt/ha in comparison to 1996 and 1998, the three years with comparable weather conditions and water supply. In 1998 late blight epidemics was a little slowlier than 1997, the haulm of potato crops was destroyed one week later than 1997, but two weeks earlier than 1996 (Figure 1). In 1998 no differences in yields in comparison to 1996 were obtained.

In Figure 5 the results of the relation between tuber yield and lenght of growing period (sum of vegetation days between potato emergence until haulm killing by Phytophtora) is presented: the meassured growing period have only very little impact on yields of fields with low N-supply level, in fields with middle or high N-supply level yields were afected much more by the lenght of growing period.

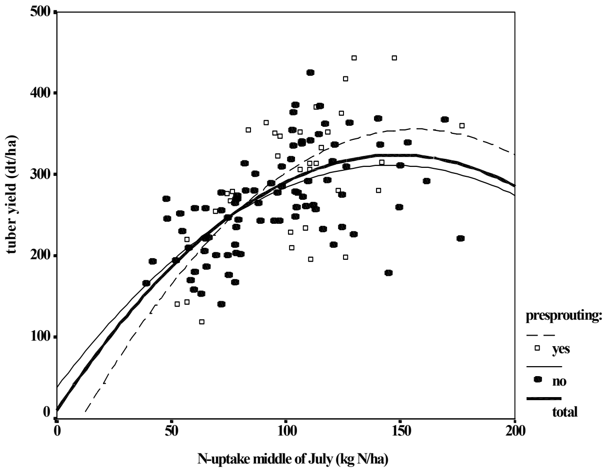

Figure 7. Regression of the relation between nitrogen-uptake by potatoes middle of July and tuber yield depending by seed tuber presprouting.

The results on organic fields were confirmed by additional field trials on the research station Klostergut Scheyern (data shown in Figure 6). The fungicide-treated organic manured variants with a N-uptake of about 120 kg N/ha (like the organic fields with a high N supply level) ceased in tuber growth after the first week of August, while the fungicide-treated an additionally fertilized variant (N uptake about 170-180 kg N/ha, like in conventional potato crops) proceeded with tuber growth for at least two weeks.

Seed tuber presprouting is commonly known as one important agronomical strategy to reduce yield losses by *Phytophthora.* The results in Figure 7 does show, that seed tuber presprouting enhanced tuber yields only if potatoes are able to get more than 100-110 kg of nitrogen per hectare.

In the four years only slight problems with tuber blight were recorded (data not shown).

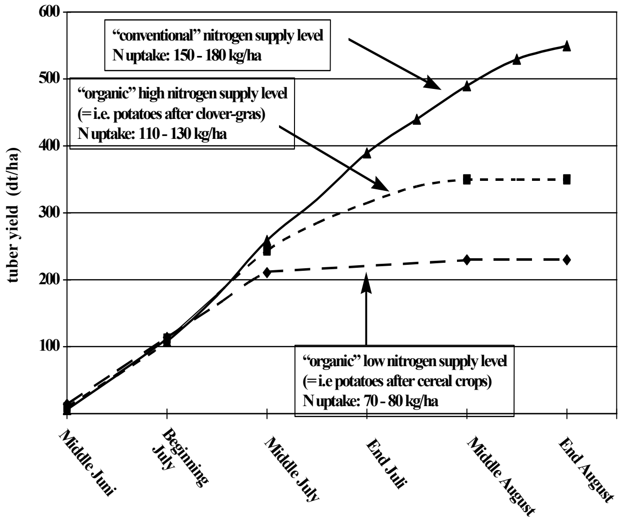

Figure 8. Model of tuber bulking behaviour of potatoes depending on different levels of nitrogen supply in organic maincrop potatoes.

Models of tuber growth depending on N-supply and probable yield losses by *Phytophthora*:

To assess the impact and interaction of the two factors *Phytophthora*-disease and nitrogen supply on tuber yields of maincrop potatoes is necessary to simulate and understand the tuber bulking behaviour of potatoes depending on different growing factors.

Tuber growth model:

Following tuber initiation, tuber growth of potatoes is generally linear (with a nearly constant growing or bulking rate) provided adequate water is available (HARRIS, 1992; VOS, 1999; BEUKEMA and van der ZAAG, 1990; HONEYCUTT et al., 1996). Tuber yields is determinated by tuber growth rate during the linear phase of tuber bulking and the duration of this period of linear growing of tubers (KLEINKOPF et al., 1981, cited by HONEYCUTT et al. 1996). Nitrogen affects both yield determinants (i.e. HONEYCUTT et al. 1996). When one factor becomes limiting tuber bulking ceased within few days. Figure 8 shows a tuber growing model for different levels of nitrogen supply. The data until the middle of July are the data of the three last years of the sampled organic crops.

For the fields of „low“ N-supply it is assumed, that growth is limited mostly by nitrogen-availability and the phase of linear growing finished more or less on middle of July. This assumption is supported by the little tuber growth after middle of July in each year, independly of late blight impact.

More difficult is to make a growing model for the fields of „organic high N-supply level". The little differences in yields of these fields in the last three sampling years in spite of the great differences in *Phytophthora* disease indicated, that tuber bulking on these fields ceased on the most fields at the end of July/beginning of August. This data was confirmed by the growing curve of the „organic" manured and treated variant of the additional field trial, as shown in Figure 6: the linear phase of tuber bulking ceased on these *Phytophthora*-treated variant at beginning of August. The model of growing curve of the fields of „organic high N-supply level" based on data of treated but only organically manured variant of trial shown in Figure 6, growing curve of „conventional" crops based on treated and additional fertilizer-manured plots of trial shown in Figure 6.

It is important to take in consideration in this models, that the beginning of tuber bulking was one factor which influenced the date of the end of tuber growth: in years with a cold and wet spring season development of potatoes is delayed for some days. Furthermore there are differences in bulking behaviour of the different comercial cultivars: cultivars like Nicola and Désirée beginns seven to ten days earlier with tuber bulking than cultivars like Agria and Aula. The beginn of tuber bulking was influenced also by seed tuber presprouting.

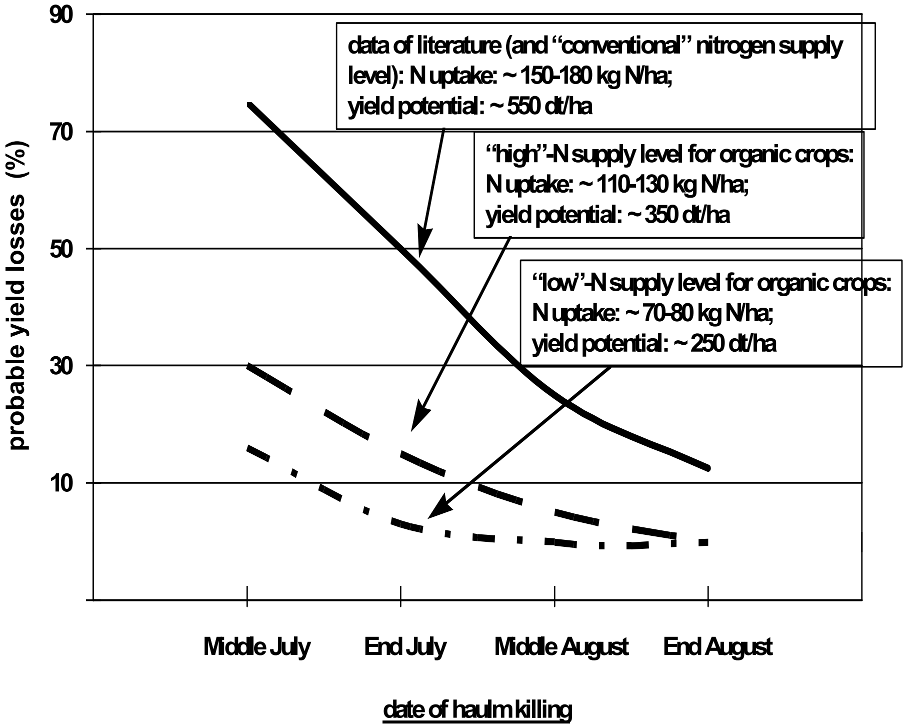

Figure 9. Estimation of mean probable loss of organic maincrop potatoes depending on „nitrogen supply level" and date of haulm death in comparison with data of literature.

Model of probable losses by *Phytophthora:*

From the tuber bulking model in Figure 8 is possible to make an estimation of the mean problable yield losses by late blight depending on nitrogen supply and haulm killing date. The model is presented in Figure 9 with a comparison with data available in literature about impact of *Phytopthora* (i.e. LARGE, 1952). The real losses depends additionaly on bulking behaviour of the crop, losses in early bulking crops are smaller than showed in Figure 9 (difference of nearly one week - earlier) , losses of late bulking cultivars higher (also nearly one week - later) than showed in Figure 9.

Discussion

The impact of *Phytophthora* disease on tuber yields of potatoes depends in organic crops on the nitrogen supply level. Results shows that the impact of late blight was generally overestimated by growers, advisers and scientists. On organic potato crops in southern Bavaria, Phytophthora disease often has only a low impact on yield. The most important limiting factor for tuber growth is on nearly 40 % of fields a low nitrogen supply level. Generally *Phytophthora* disease are able to cause yield losses mainly on fields with a relative high nitrogen supply. This assumption was confirmed by the data shown on Figure 7: seed tuber presprouting - one important agronomical meassure to avoid yield losses by *Phytophthora*, have only an effect on tuber yields if potatoes had a N-uptake higher than 100 kg N per ha.

Probably the use of copper-fungicides or other substances to avoid an infections generally are able to increase yields only if a sufficient level of nitrogen is available for the growing potatoes (exception: very early Phytophthora infections, followed by wet weather). In some countries of EU the use of copper in potatoes is restricted to 3 or 4 kg Cu/year, in this case to concentrate the applications in the time inbetween just before the appearence of *Phytophthora* and two weeks before the expected end of tuber bulking is may be the most effective strategy to improve yields and avoid losses by tuber blight due a short period of possible tuber infections by zoospores.

Furthermore a remark of further differences in laws concerning organic agriculture in Europe: in some countries growers are allowed to use a restricted amount of slurry of conventional managed farms (like in Netherlands and Denmark), other countries don′t allowed the use of such „effective“ nitrogen-manures (like Germany and Austria). This have a great impact on the common N-supply level.

May be the slight problems with tuber blight were influenced by the very fast destruction of foliage by *Phytophthora*-disease under favourable weather conditions for fungal development, these perhaps reduced infections due a very short time in which tuber infections could take place, and therefore limited losses by tuber blight (see review by BAIN and MÖLLER, 1999)

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A cultivation method that reduces soil loss and its effects on the disease susceptibility of potato plants

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Summary

A potato cultivation method that reduces soil loss is presented and first observations of its side effects on crop development and disease susceptibility are described and discussed.

Key words: cropping system, late blight, early blight, disease susceptibility

Introduction

The research station Klostergut Scheyern is situated in the ternary hilly region of southern Germany (40 km north of Munich). The prevalent cultivation of slopes in this area causes a high risk for soil washoff. To meet the demand for sustainable methods of cultivation, we are currently examinig a potato growing system that uses pre-drawn summer ridges which are covered by a mulch crop. The comparison with the conventional cropping system generally revealed a slight delay of physiological development. However, the most outstanding observation of the last two years was an alteration in the spread of *Phytophthora infestans* and *Alternaria solani* in the foliage of the trial plots.

Material and Methods

Experimental design

Trial fields were situated at two locations in a distance of 10 km. On each field, five different variants were tested in a randomized block design with 3 replicates in 1998, and 4 replicates in 1999. The plots had got a size of 6 x 50 m. In 1998, cultivar Agria was used, in 1999 Solara. Variants were cultivated as follows:

variant 1 (traditional cropping system) - After the harvest of the previous crop in August, the soil was treated with a cultivator. Subsequently, a catch-crop (mustard, *Sinapis alba*) was broadcasted. In December, the plots were ploughed (25 cm). The potatoes were planted at the end of April; the seedbed preparation was done with a cultirotor.

variant 2 (traditional cropping system, ploughless) - Soil treatment and planting followed the above pattern, except for ploughing in winter.

variants 3 to 5 (direct planting in summer ridges) - After the harvest of the previous crop in August, ground soil preparation, shaping of the summer ridges and sowing of a catch-crop was done by using a cultivator which was developed at Klostergut Scheyern (Kainz *et al*., 1999). The device consists of 9 tines, followed by a unit of 8 disc ridgers and a precision distributor, all fixed on a single frame. It enables to carry out the above cultivation steps by only passing the field once. Three different cover crops were used:

- mustard (*Sinapis alba*), not overwintering - variant 3
- bird rape (*Brassica rapa var. sylvestris*), overwintering - variant 4
- vetch (*Vicia villosa*), overwintering - variant 5

The overwintering catch-crops were allowed to grow until planting time (end of April), the mustard crop got killed by the first frosts in November. Potato planting into the pre-drawn ridges was carried out by using a modified planting machine with plain discs preceding the planting shares. All variants received the same protection against *Phytophthora infestans*. Akrobat, Ridomil MZ Gold, Shirlan and Ciluan were used until the end of July and Shirlan, Maneb and Brestan later on. 15 m at the end of each plot remained unsprayed.

Measurments and observations:

The soil temperature was measured in 30 min intervals using Th2-f sensors (UMS) combined with a delta-T logging unit. Three sensors per measuring site were placed in mother tuber depth and the means were calculated. Soil water content was determined gravimetrically. Samples were drawn of the ridge centre and 10cm below the ridge basis, respectively. Leaf colour was determined by a SPAD-meter (Norsk Hydro), examining the terminal leaflet of the first full expanded leaf. The detached leaflet assay was carried out in a climate chamber with T=13°C and a dark/light period of 12h/12h using petri dishes and water agar. The inoculum was a mixture of 3 *Phytophthora infestans* isolates originating from the Scheyern area. The concentration was adjusted to 1x10^4 sporangia/ml. Plant material was sampled from the unsprayed parts of each variant 1 and variant 4 plot of location Scheyern. Leafs of position one (1st fully expanded leaf), two and three were chosen. Field dynamics of *Phytophthora infestans* and *Alternaria solani* were evaluated by estimating the percentage of the necrotic leaf area, compared with the observed maximun foliage of each plot. Tuber bulking was observed by harvesting 2 m of two neighboured ridges at each sampling date and calculating the yields per ha. Final yields were measured by harvesting two ridges to the full length of each plot, calculating the yields per ha out of plot length and tuber yield.

Results

General development and yields

In 1998 as well as in 1999, a delay in canopy development of all systems, compared to variant 1, could be observed. The date of emergence and flowering was 1 – 3 days behind. Crop cover was achieved even later (3 – 7 days). This was not only because of a delay in speed of growth, but also due to lower levels in total leaf biomass (data not shown).

In 1998, the yield of Variant 5 distinguished clearly from all the others (Table 1). However, neither of the two experimental sites showed a significant difference of yields between variants. In 1999, a lower level of yield could be detected in variant 4. In one site (Ellenbach) significant differences in were found.

Table 1. Yields in 1998 and 1999. Letters in brackets indicate statistical differences (Bonferroni, p < 0,05).

		Ellenbach(dt/ha)		**Scheyern(dt/ha)**	
Variant Number and description		**1998**	**1999**	**1998**	**1999**
1	traditional	476	368 (ab)	479	429
2	traditional, ploughless	518	385 (ab)	428	442
3	direct planting, mustard	499	419 (a)	427	421
4	direct planting, bird rape	479	346 (b)	431	350
5	direct planting, vetch	584	423 (a)	525	467

Soil temperature

Measurements revealed a considerably higher soil temperature amplitude in the traditional system. At temperature maximum, a difference of about 2°C to the next lower (traditional, ploughless), and differences of 3-4°C to the most cool-tempered variants (direct drillig, vetch/bird rape) could be observed quite frequently (Figure 1). The sequence of temperature maxima was most likely due to the soil water content (Figure 2) and differences in soil coverage (data not shown). Regarding the temperature minima, the variants followed the inverse order, the traditional system being the variant with the lowest temperature minima. The calculation of temperature sums from planting to emergence (30.04. – 01.06.1999) resulted in 564 °Cd for variant 1, whereas variants 3 and 4 turned out to show 541 °Cd and 526 °Cd, respectively.

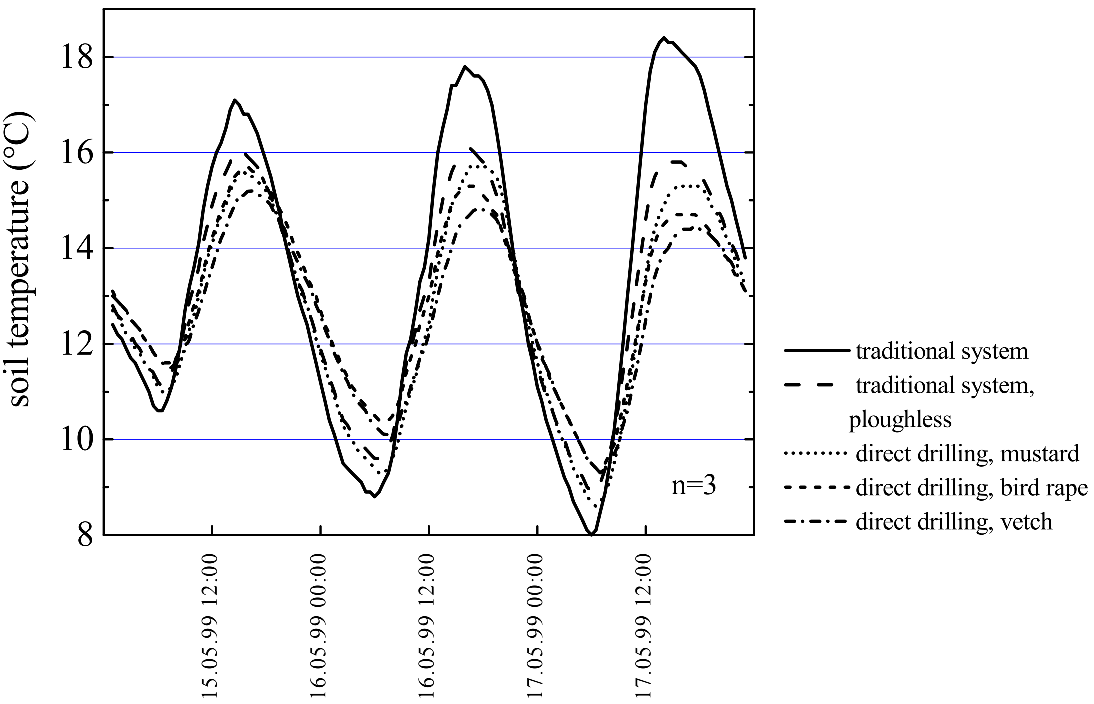

Figure 1. Typical temperature courses in mother tuber depth.

Soil water content

Soil moisture in mother tuber depth was significantly lower in the traditional system than in all the other variants, which did not differ from each other (Figure 2). However, 10 cm below the ridge basis the situation differed: Variant 1 showed the highest water content, followed by Variants 2 and 3. As a result of the transpiration activity of the bird rape and vetch canopy, the subsoil showed the lowest water contents in the variants 4 and 5.

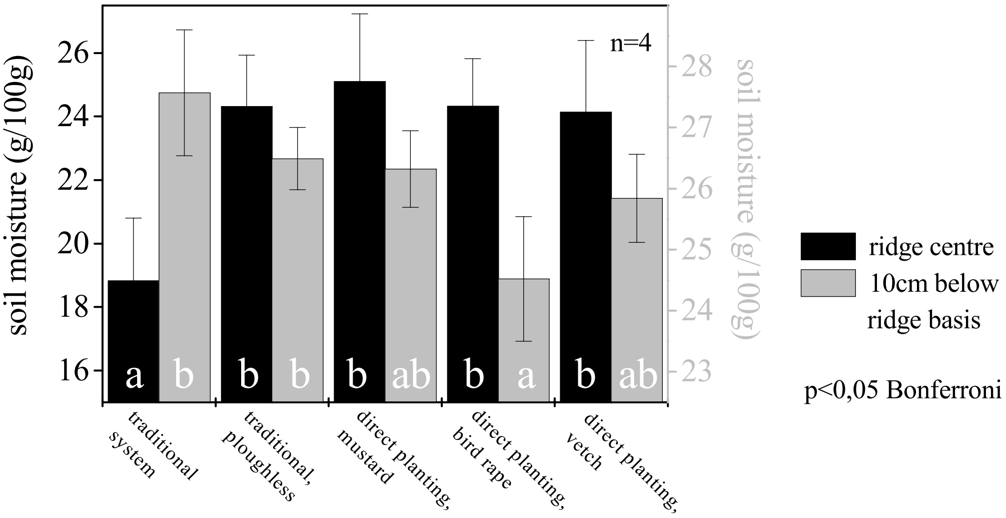

Figure 2. Soil water contents in mother tuber depth (ridge centre) and 10 cm below ridge basis. Error bars indicate standard deviation.

Chlorophyll contents

The chlorophyll contents of each variant behaved during the course of maturation and senescence in a characteristic manner which was influenced neither by the year nor by the conditions of location. As an example, figure 3 presents the 1999 Chlorophyll contents of location Ellenbach. It indicates that at every date of measurement, variant 1 had the lowest Chlorophyll contents except variant 4. The calculation of the areas under the chlorophyll curve shows for the variants 2, 3 and 5 chlorophyll contents which are 10-15% higher comparing to variant 1 in the total time interval of measurement.

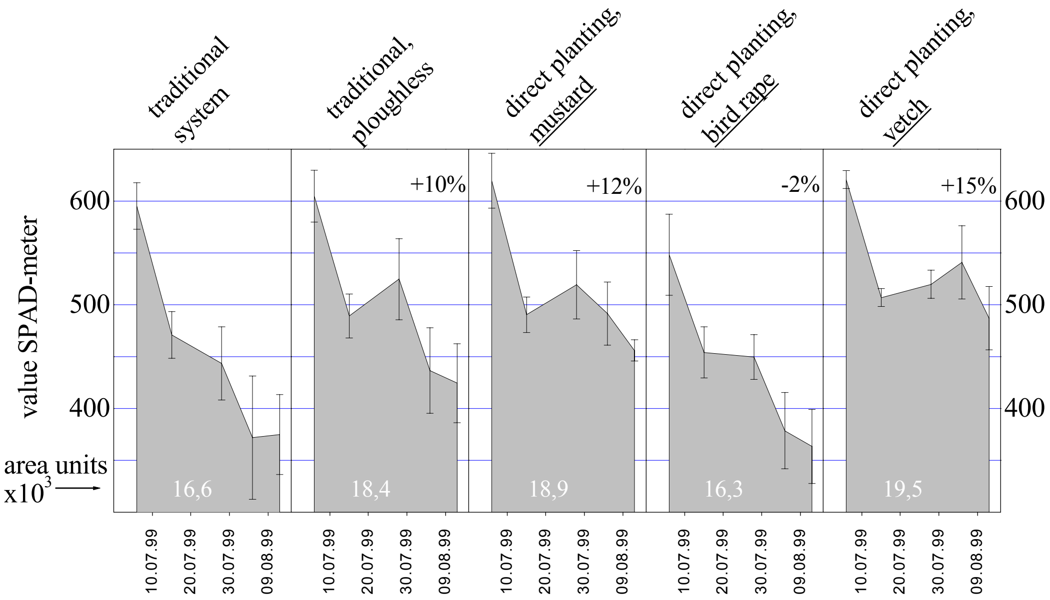

Figure 3. SPAD-meter values. (Error bars: standard deviation; white numbers: area units x 10^3; black numbers: area units compared to the traditional system)

Leaf resistance against Phytophthora infestans and Alternaria solani

In 1998 (cultivar: Agria), the variants at location Ellenbach exhibited drastic differences in the dynamic of Phytophthora infestans. By the beginnig of August, the unsprayed part of variant 1 was killed to almost 100% in contrast to the other variants, which were merely affected to an extent of 35 – 65%. Since the percentage of killed haulm changed exactly at the plot borders, any influence of changing soil texture or site-specific climate can be excluded.

In 1999 (cultivar: Solara) no clear distinction in late blight development could be observed, but the appearance of Alternaria solani in the late blight sprayed parts differed significantly, again the conventional system being the variant with the highest extent of disease, followed by variant 2 (Figure 4). In order to check the contribution of physiological properties to the phenomenons observed in the field, a detached leaflet assay was carried out (Figure 5). Variants 1 and 4 were tested. The results not only reflected an enhanced resistance of variant 4 (t-test, $p<0,05$), but also pointed out a clear effect of leaf age within the same variant.

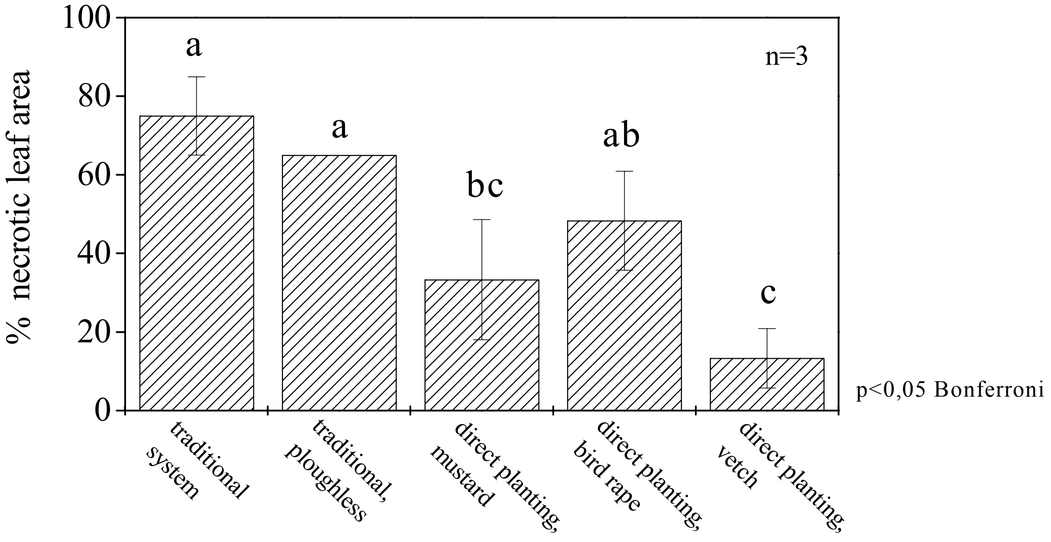

Figure 4. Necrotic leaf area caused by Alternaria solani. Error bars indicate standard deviation.

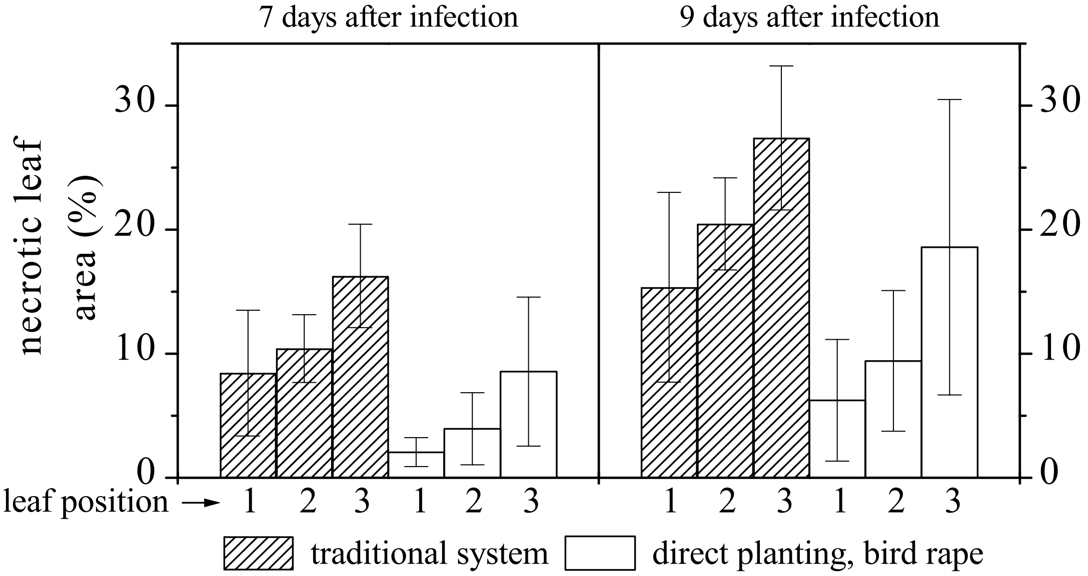

Figure 5. Detached leaflet assay, percentage of necrotic leaf area caused by Phytophthora infestans. Error bars indicate standard deviation.

Discussion

Looking at the development of foliage as well as tuber bulking rates, it is quite obvious that potatoes in the traditional growing system have got a faster start-off than in all the other variants. This observation can be explained by a higher soil temperature in variant1. The relatively high level of thermal energy in the conventional system is mostly due to (1) the increased input of solar radiation, unhindered by any soil coverage, and (2) a lower ridge heat capacity because of lower soil water contents and a higher pore volume. However, being the most vigorous growers during the first half of the summer, potatoes in the traditional cropping system also are the first to undergo senescence: Leaf colour as an indicator for vitality and chlorophyll degradation in the course of maturation shows this clearly. Furthermore, the actual courses of the SPAD-meter values (Figure 3) reveal an enhanced ability of all variants to stabilize degradation or even to regenerate chlolorphyll in favourable weather conditions, compared to the traditional cropping system. As an exception, the poor leaf colour of variant 4 can be explained by a somewhat suboptimal nitrogen supply due to the decomposition of the carbon-rich bird rape biomass and a generally low N content after the extremely wet 1998/99 winter.

After all, when discussing plant physiology in different cropping systems, N dynamic undoubtedly is a central point to look at. As there is very little data about N mineralisation in the examined cropping systems yet, we have to rely on more or less theoretical considerations at present. Being the variant with the highest soil temperature and air content in spring, the traditional cropping system is the one with the highest mineralisation rate immediately after planting. However, this is overlayed partly by the start N fertilizer, of which the same amount is applied to all variants. Shortly after emergence, soil in all variants is deprived of NO3-N to an extent of 80 – 90 % and therefore N supply is mainly dependent on mineralisation. As variant 1 has the best growing conditions before and a short time after emergence, it develops the highest amount of leaf biomass, using up all available NO3-N. Thus it (1) has got a relatively low reserve of easy-to-mineralize organic matter for the rest of the vegetation period, and (2) has got to support the highest amount of foliage. Unlike the traditional system, soil in the variants 3-5 produces less NO3-N in the early stage of plant growth (cooler temperature, less oxygen) and has therefore a prolongued period of mineralisation. Variant 2 takes its place somewhere in between. Additionally, the rotting of the mulch crop has to be taken into account. According to the C/N ratio of each of the cover crops, mustard (C/N ≈ 18) contributes only to a very small extent to the N supply, whereas bird rape (C/N ≈ 20-30) diminishes, and vetch (C/N ≈ 10) even increases N mineralisation. However, as the disease progress in field shows a similar tendency for variants 3-5, it can be concluded that the alteration of the N dynamic by different mulch crops is not responsible for differences in disease susceptibility.

The 1999 *Alternaria* obsevations and the detached-leaflet assay speak for the suggestion, that the examined growing systems not only exhibit visible alterations of physiological development, but also provoke differences in plant health status. However, the obvious differences in late blight development of 1998 could not be observed in 1999. This might be due to the change from cultivar Agria to Solara and/or differences in weather conditions, and it shows that possible distincitons in disease susceptibility can be dominated under field conditions easily. Taking into account, that general conditions of location like soil texture/colour/organic matter, exposition or previous crops are also capable to alter the growth factors discussed in the beginning, our findings give rise to the suggestion, that plant health status can be influenced thereby to a certain extent. But still it is unclear, what mechanisms stand behind these observations, and if slight changes in resistance could have any considerable effects on the spread of early or late blight. Therefore, future research will have to (1) assess the reproducibiliby and power of the observed effect, and (2) elucidate its origins.

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Fourth Workshop of an European Network for development of an
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Validation of the MISP model for the control of potato late blight in Switzerland from 1996 to 1999

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Abstract

Based on detailed epidemiological field observations in 1995 to 1996, the MISP (main infection and sporulation period)-model was developed in Switzerland. Defining weather conditions crucial for the development of potato late blight epidemics, the MISP-model could be used as a key-module in the late blight decision support model PhytoPRE+2000 (Cao et. al, 1996). To test this hypothesis, we used the MISP-model as trigger for the timing of late blight fungicide applications. In this simple MISP-DSS, the first fungicide application is indicated, when a first late blight attack is announced in the region. The second and the following fungicide applications must be realised short before or after a MISP.

From 1996 to 1999, this MISP-DSS was tested in field trials at Zürich-Kloten and compared with PhytoPRE (Forrer, 1993), the Danish NegFry DSS (Hansen, 1993) and a routine treatment.

In all situations the late blight control with the MISP-DSS was as good or better as with the other treatments. In 1996, a year with rather low disease pressure, considerable saving in fungicide applications were realised. Over all, the MISP-model proved to be a most promising tool in a weather-event based DSS.

Introduction

In Switzerland *Phytophthora infestans* (Mont.) de Bary, the late blight causing agent, is still one of the most important pathogens in agriculture. Since 1994, the advisory system PhytoPRE offers Swiss potato growers a plot-specific support to control late blight. The model relies mainly on the information of local epidemic pressure and field specific rain data, measured by the potato producer. Beside this, the susceptibility of the potato variety, the growth stage, the time since the last application and the type of fungicide, are taken in consideration for a spraying recommendation.

Since 1994 more than 4'900 potato fields were linked to PhytoPRE. The decision support system (DSS) proved to generate reliable recommendations. Nevertheless, for the 2^{nd} and the following late blight treatments PhytoPRE has a tendency of fungicide overuse, because weather conditions conducive for late blight are not recognised.

To make use of possible fungicide reductions we looked for a new model for the 2^{nd} and the following treatments. In an epidemiological field study from 1996 to 1997 meteorological conditions and periods crucial for the development of late blight were determined. These periods allowing infection and sporulation of *Phytophthora infestans* (Cao et al.,1997) we call **m**ain **i**nfection and **s**porulation **p**eriods (MISP). MISP's are defined as periods of 24 hours with at least 6 hours of precipitation, 6 consecutive hours with a relative humidity of ≥ 90% and an average temperature of ≥ 10°C. These conditions were installed in an event-based DSS and validated whether they may be used in a DSS-model. Field trials were carried out, in which the MISP-DSS was compared with the DSS's PhytoPRE, NegFry and a routine treatment.

Material and Methods

To validate different DSS's for the control of late blight, field trials were carried out during the years 1996-1999 at the trial site at Zürich-Kloten (Switzerland).

A randomised block design was chosen to compare the models with an unsprayed check treatment, with 5 replicates per treatment. Potato plots (3m x 5m) were separated by rows planted with the low susceptible varieties Panda and Matilda. In all years, the high susceptible variety Bintje was used to test the performance of the DSS's. Beside the fungicide treatments, the trial was managed with common conventional agronomic practice.

Weather data

Meteorological data were recorded hourly with an automatic weather stations (HP100, Lufft, Germany) installed at the trial site. In addition, hourly forecast data of 48 hours, based on calculations of a national forecast grid with a mesh size of 14 km, were used.

The forecast data were kindly provided by the national Swiss Meteorological Institute (SMA).

DSS-models

The three DSS, NegFry (Hansen, 1993), PhytoPRE (Forrer et al., 1993), MISP (Cao et al., 1997) and two check - treatments were compared.

NegFry:

Due to the early onset of the epidemics in Switzerland (Tab. 1), the first treatment in 1996 and 1997 was applied before the recommended NegFry date. The second and the following treatments were conducted strictly according to the recommendations of NegFry. In 1999 the first and the following sprayings were applied according to the NegFry rules. In 1998 NegFry was not tested at Zürich-Kloten (Tab.2).

PhytoPRE:

All fungicide treatments in the PhytoPRE procedure were applied according to the recommendations of the advisory system. In Switzerland PhytoPRE is used to support potato-growers in controlling late blight disease since 1993.

Table 1. Date of detection of the first late blight attack (LBA) in Switzerland, in the region and near the late blight field trials of Zürich-Kloten from 1996 to 1999.

	Date of first LBA in Switzerland; (distance ≤ 200 km)	Date of first LBA within a diameter of 20 km	Date of first LBA within a diameter of 10 km	Date of first LBA within a diameter of 1 km
1996	23.5.96	5.6.96	14.6.96	12.7.96
1997	16.5.97	2.6.97	4.6.97	27.6.97
1998	6.5.98	14.5.98	10.7.98	10.7.98
1999	8.5.99	8.5.99	25.5.99	22.6.99

MISP-DSS:

The DSS is based on the MISP (= Main Infection and Sporulation Period)-model. This model recognises epidemiological crucial days with weather conditions allowing infection and sporulation of Phytophthora infestans. MISP's are defined as periods of 24 hours with at least 6 hours of precipitation, 6 consecutive hours with a relative humidity of ≥ 90 % and an average temperature of ≥ 10 °C (Cao et al., 1997; Ruckstuhl et al., 1998).

In the trials, the MISP-model was used as trigger for the first and the following fungicide treatments: A first fungicide application must be realised as soon as the first late blight attack in the region (≤ 20 km) is announced. For the second and the following recommendations, again MISP-conditions are used as fungicide application trigger. During 6 days after a fungicide treatment MISP's are not considered to be relevant and no fungicides are applied in this period.

All applications were realised short after a relevant MISP, or near by a forecasted MISP. To examine the effect of pre- and post-MISP application, two models were used:

'MISP a': Execution of fungicide applications within 24-48 hours **after** a MISP period has occurred

'MISP b': Execution of fungicide application up to 36 hours **before** MISP period is predicted

Check-treatments:

Two check-procedures were used:

a) an untreated check with no fungicide treatments, or eventually an emergency treatment

b) a routine treatment with fungicide applications in intervals of 7-10 days to prevent any late blight attack

Until mid of July, in all procedures emergency treatments (1 x translaminar and after 3-4 days contact fungicide) were applied, if disease was detected in the plots.

In table 2 the validated DSS-models for each year are listed.

Blight severity was rated every three or seven days visually as the percentage of diseased leaf area in the two central rows of each plot. At the end of the season the proportion of chlorotic and necrotic foliage in the whole plot was estimated. Using the percentage data of diseased leaf area, the area under the disease progress curve (AUDPC) based on Julian days was calculated and subjected to standard statistical procedures.

Table 2. DSS validated in field trials in Zürich-Kloten, 1996-1999.

1996	1997	1998	1999
NegFry	NegFry	--	NegFry
PhytoPRE	PhytoPRE	PhytoPRE	PhytoPRE*
MISP a	MISP a + b	MISP a	MISP b
Routine	--	--	Routine

In 1996 and 1997 in all procedures the first application was given according to the recommendation of PhytoPRE (first late blight attack registered in Switzerland).

MISP a: fungicide treatment after MISP-conditions are fulfilled

MISP b: fungicide treatment before MISP (based on 48hrs weather forecast)

MISP a & b: minimal interval between two fungicide applications is 6 days

*: PhytoPRE 1999 plots just beside the main trial

Tuber blight and Yield

The two central rows of each plot were harvested. The diseased and healthy tubers were separated and counted. After 6-8 weeks of storage at a temperature of 4° C, a second check of the harvested tubers was done. Again, the diseased tubers of each treatment were recorded and the weight of the healthy tubers determined.

Fungicides

To avoid fungicide resistance biased results, only protectant and translaminar and no systemic fungicides of the phenylamid-group were used in the field trials.

Fungicides used in the NegFry model were 2.25 kg/ha Fentin Supra (maneb 62.5%, fentin acetat 9%), 0.5 l/ha Mapro (fluazinam 38%), 2.5 kg/ha Daconil Combi DF® (chlorothalonil 60%, cymoxanil 6%), 2 kg/ha Zetanil Combi (cymoxanil 6%, mancozeb 70%) and 4 l/ha Tattoo (propamocarb 248.2 g/l, mancozeb 301.6 g/l, copper 24.8 g/l). In the PhytoPRE model following products were used: 0.5 l/ha Mapro, 3 l/ha Daconil 500® (chlorothalonil 41%), 3 kg/ha Mancozeb 80 (mancozeb 80%) and 2.5 kg/ha Daconil Combi DF®. Fentin Supra, Daconil 500®, Mapro, Daconil Combi DF® and Zetanil Combi were used in the MISP model in the same concentrations as mentioned above. And for the routine treatment the four fungicides Mapro, Daconil 500®, Daconil Combi ®and

Zetanil Combi were used.

Results

In 1996, first late blight attack was detected on May 23 in Switzerland. One week later a first fungicide was applied in all procedures. This application was given in accordance to the PhytoPRE-rule for the timing of the first treatment.

Until middle of June, the epidemic pressure was low at the trial site, but increased when weather conditions became favourable at the end of June and beginning of July (Fig.1,1996). In the untreated check plots 85% of the leaf area was attacked until the end of July, although plots were treated once to stop the ongoing disease. All DSS-treatments reduced late blight significantly compared with the untreated check. The percentage of diseased leaf area was about 60% in the NegFry plots, 40% in the PhytoPRE plots and 27 % in the 'MISP a' plots (Fig.2). The three fungicide applications recommended by NegFry appeared to be insufficient to control late blight. Also the DSS PhytoPRE and 'MISP a' could not keep late blight out of the plots. However, the disease level was not higher then in the routine treatment and significantly lower than in NegFry. No differences were observed between PhytoPRE and 'MISP a', but PhytoPRE plots were treated with three treatments more than the 'MISP a' plots (Tab. 3).

1997 a year with a very high late blight infection pressure, the epidemic started already on the 16th of May. A first fungicide treatment was applied a week later on all plots, except the untreated check plots. Due to the rainy weather in June and most of July, it came to a rapid disease development in the untreated check plots, with total necrosis of the leaf mass by the 15th of July (Ruckstuhl et. al,1998). NegFry recommended only two fungicide treatments. The protection level was insufficient and no differences between the NegFry treated and the untreated check plots were found. As in 1996, the fungicide treatments suggested by PhytoPRE and the two MISP models couldn't keep the plots free of *Phytophthora infestans*, but they resulted in a better protection of the crops. Infection levels in these models, expressed as AUDPC values, were lower than 50% (Ruckstuhl et al., 1998)

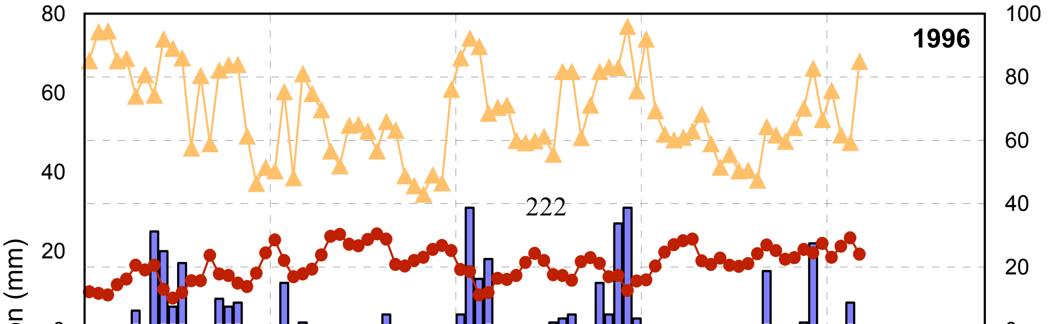

Figure 1. Weather conditions during the potato growing season at the trial site Zürich-Kloten (weather data of 1997, see Ruckstuhl et al., 1998).

In 1998, only PhytoPRE and the 'MISP a' model were tested at the trial site at Zürich-Kloten. A first late blight attack was announced very early on the 6th of May in the western part of Switzerland and on the 14th of May in the region of the trial site. At the trial site late blight occurred on the 10th of July (Tab.1). Though the weather conditions were favourable for the disease (Fig.1, 1998). only untreated plots had a very high level of disease at the end of August (Fig.3). The control of the disease by PhytoPRE and 'MISP a' was not significantly different, but one treatment could be saved with 'MISP a' model (Tab. 3).

In 1999, the situation of late blight was similar to 1997. The first late blight attack was already detected at the beginning of May (Tab.1). Ten days later the first fungicide treatment was applied in the PhytoPRE and 'MISP b'-procedure. Since NegFry was used in its original version, the first treatment was recommended later on the 7th of June. The weather conditions for the growing of *Phytophthora infestans* were favourable during the whole potato season with warm, rainy days and high relative humidity. A short, dry period of 12 days in July couldn't stop the development of the disease successfully (Fig.1, 1999). In the middle of July, untreated plots were totally diseased. NegFry, PhytoPRE and 'MISP b' reduced late blight infection significantly compared to the untreated check plots (Tab.3). PhytoPRE and 'MISP b' resulted in a better crop protection than NegFry, but fungicide input in PhytoPRE and 'MISP b' was higher than in NegFry (Fig. 4, Tab. 3)

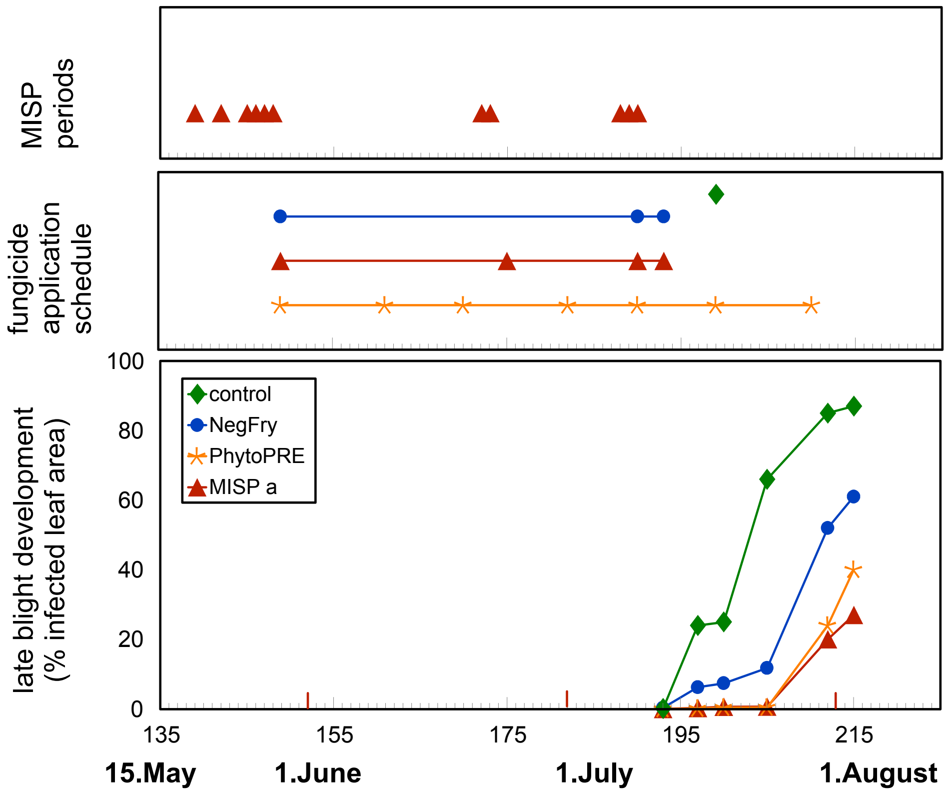

Figure 2. Comparison of different late blight DSS in 1996 (trial site Zürich-Kloten, potato variety Bintje).

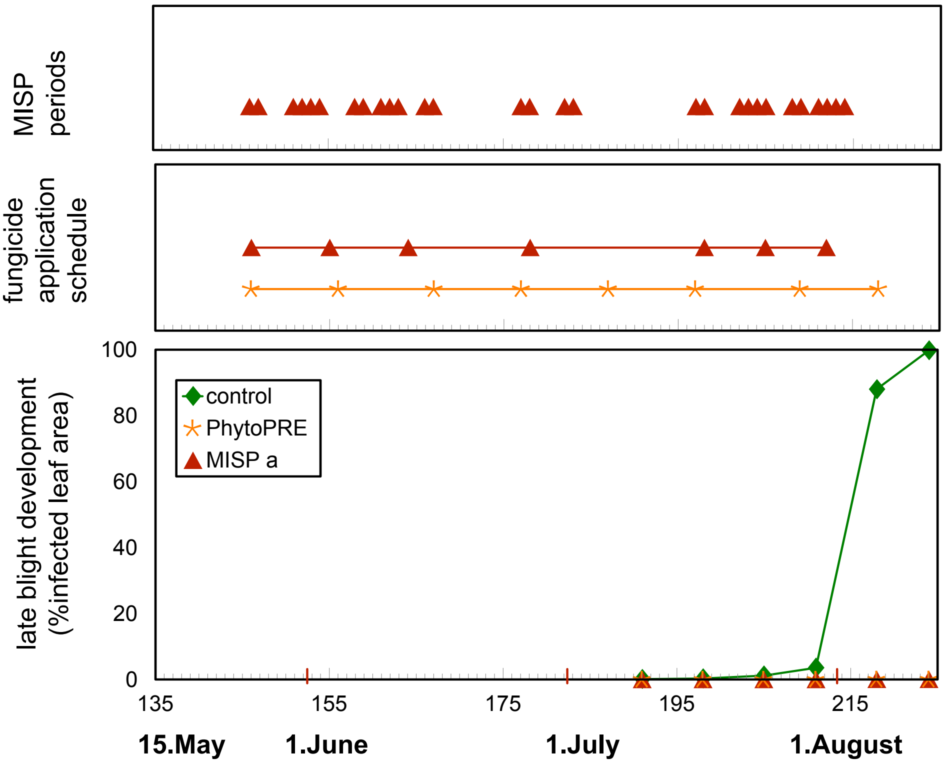

Figure 3. Comparison of different late blight DSS in 1998 (trial site Zürich-Kloten, potato variety Bintje).

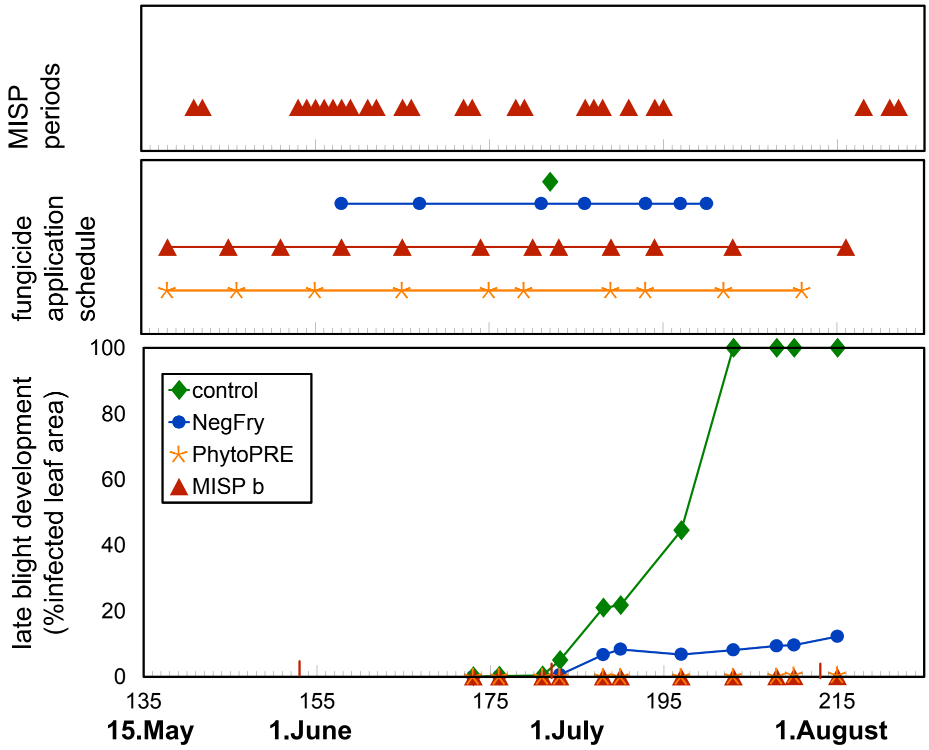

Figure 4. Comparison of differetnt late blight DSS in 1999 (trial site Zürich-Kloten, potato variety Bintje)

Table 3. Comparison of DSS in controlling late blight disease, tuber blight and tuber yield at the trial site Zürich-Kloten over the years 1996-1999.

1996	AUDPC % rel. to untreated check		no. of fungicide applications	Tuber yield % rel. to untreated check		Tuber blight No./ 100m^2	
Untreated check	100	c*	1	100	ns	48	a
PhytoPRE	16.3	a	7	110	ns	91	ab
NegFry	41.8	b	3	105	ns	165	abc
MISP a	13.0	a	4	103	ns	251	c
Misp b	--	--	--	--		--	
Routine	13.2	a	6	109	ns	227	bc

1997	AUDPC % rel. to untreated check		no. of fungicide applications	Tuber yield % rel. to untreated check		Tuber blight No./ 100m^2	
Untreated check	100	b	0	100	a	832	a
PhytoPRE	45.2	a	7	159	b	1237	ab
NegFry	97.4	b	2	94	a	755	a
MISP a	41.5	a	7	165	b	1299	ab
Misp b	38.8	a	8	167	b	1539	b
Routine	--	--	--	--		--	

1998	AUDPC % rel. to untreated check		no. of fungicide applications	Tuber yield % rel. to untreated check	Tuber blight No./ 100m^2
Untreated check	100	b	0	--	--
PhytoPRE	0.0	a	8	--	--
NegFry	--	--	--	--	--
MISP a	0.0	a	7	--	--
MISP b	--	--	--	--	--
Routine	--	--	--	--	--

1999	AUDPC % rel. to untreated check		no. of fungicide applications	Tuber yield % rel. to untreated check		Tuber blight No./ 100m^2	
Untreated check	100	c	1	100	a	143	ns
NegFry	12.4	b	7	157	b	104	ns
MISP a	--	--	--	--	--	--	--
MISP b	0.1	a	12	207	c	72	ns
Routine	0.1	a	13	200	c	65	ns
PhytoPRE**	0.2	--	10	207	--	87	--

figures within a column followed by the same letter are not significantly different at $P< 0.01$ (Fisher's unprotected LSD) ** PhytoPRE plots were just beside the main field trial

Tuber blight and Yield

Between late blight on leaves and tuber blight no dependencies were registered. In 1996 untreated plots with a high level of late blight even showed the smallest number of tuber infection. A similar effect was seen in 1997 with untreated and NegFry treated plots (Ruckstuhl et al., 1998). In contrary, in 1999, untreated and NegFry treated plots had the highest number of tuber blight.

In the year 1998 tuber blight and the yield were not determined, because preliminary checks revealed no infected tubers at all in all treatments.

1996 no differences were registered between the yields independent of the procedure. In 1997,

yields of DSS-treated plots, except NegFry plots, were higher than in the untreated check.

In 1999, all plots with DSS-procedures had a higher yield than the untreated check. But the 'MISP b' and the routine treatment had a yield 50% higher than NegFry (Tab.3).

Discussion

Since the field trial design was not every year performed exactly the same way, a comparison of the treatments over the four year period must be done carefully. Nevertheless clear trends and statements are possible.

None of the treatments completely controlled the late blight in the field trials in all years. This fact is mainly due to the extremely high infection pressure exerted by the unsprayed plots and good weather conditions for *P. infestans* in 1997, 1998 and 1999. Such conditions will be rarely found in practical agriculture. Therefore, it is worth to point out, that if the epidemic pressure of late blight can be held low under these extraordinary conditions, the chance of success in praxis may be even higher.

During this field trial-period and in practical use by farmers, the DSS-model PhytoPRE showed to be a save and reliable model. In 1996, 78% of the potato producers connected to PhytoPRE claimed that they would recommend the PhytoPRE system to their neighbours (Ruckstuhl et al., 1998, not published). In contrary to the MISP-DSS, only little fungicide reduction was possible with the PhytoPRE, even in a year with low infection risk as 1996. In such cases the MISP-model shows an advantage. This model takes unsuitable weather conditions into account and therefore allows to reduce the number of fungicide treatments. However, in 1999, PhytoPRE recommended less fungicide applications than the routine with a fixed 7 day treatment schedule.

In 1997, the differences of crop protection between 'MISP a'- and 'MISP b'-treatment were very small. This finding copes with the point, that ‘MISP b’ contains ‘MISP a’. With ‘MISP a’ one fungicide treatment could be saved. This shows, that weather forecast data in Switzerland are quite reliable – but nevertheless mistakes are always possible.

Results from Italy confirm also, that the MISP-model, together with the starting module “I.P.I.-monitoring” can be used to control the late blight disease successfully (Bugiani et al., 1999). So the rather simple MISP-rules seem to be a quite useful module for an DSS-model.

NegFry model was developed on a maritime characterised climate. This may be the reason why NegFry failed in controlling late blight disease in Switzerland, where a rather continental climate is found. To reach the same quality of reducing the disease as in Denmark, NegFry should be adjusted to Swiss weather conditions.

Conclusions

The results of the field trials have shown, that the MISP-rules are a useful tool for an event-based DSS-model. The late blight protection was better than with NegFry and always as good as those of the PhytoPRE and/or the routine-treatment. The MISP model proved to give a reliable late blight control under good conditions for late blight development as in 1997 and 1999. On the other hand, under dry weather conditions as in 1996, considerable savings in fungicides can be realised. To make best use of the MISP model, beside weather conditions and information about first attacks, also the susceptibility of the potato cultivar, the characteristics of fungicides, the level of fungicide protection and data on the occurrence of the fungus have to be linked with the model to get a reliable and comprehensive MISP-DSS.

Acknowledgements

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Perfecting a biological test assessing the resistance of anti late blight fungicide to the rainfastness

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Introduction

The control of the potato late blight, *Phytophthora infestans* requires repeated applications of several fungicides during the potato crop.

The fungicides behaviour are dependent on the weather conditions and growing methods. Among these ones, the rain and the irrigation are the most important factors in the reduction of the efficacy of the products.

Some studies with the view to assess this efficacy lost due to the rainfastness have already been undertaken.

However, it's only about either laboratory data or field data. Besides, the distinctive feature of the biological test perfected by the phytosanitary pole of Loos-en-Gohelle is to combine both laboratory and field data.

In fact, the experimental part in the field allows to be as near as possible with the real conditions encountered by the growers whereas the laboratory investigations assess the resistance of the tested fungicides to the rainfastness.

Materials and methods

Experimental part in the field

It's necessary to set up the experimental design in the field from May, so as to prevent the natural contamination of potato late blight.

This also provides a uniform protection of the foliage when the plants have the stage BBCH 38.

Experimental design in the field

Three plots with six modes each and measuring 18 m by 8 m are set up in the field.

The six modes are as follow : the control, the two references DITHANE DG and SAGITERRE, the product X, the product Y and the product Z.

The 3 plots correspond to the three tested conditions on the rainfastness: 0, 20 and 40 mm.

Before the treatment, 15 plants are chosen, in the central rows of each mode of each condition. Each plant is considered as a replication.

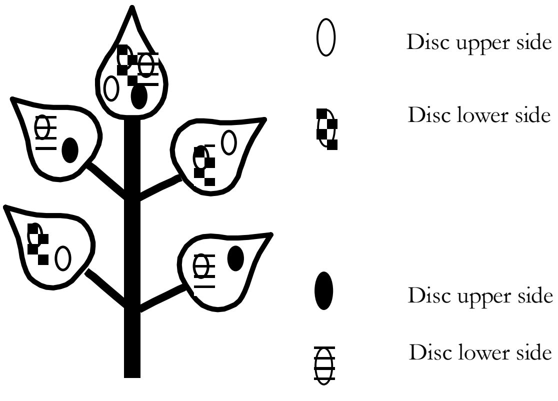
From each plant, 3 leaves well developed are marked at a same level corresponding each of them to a date of sampling. The plants are treated with an experimental sprayer ATH at a volume of 300 l per hectare.

Between 12 and 24 hours after the treatment, the plants are subjected to a simulated rain by means of sprinklers. Two dosages of rainfastness are tested: 20 and 40 mm, this amount is assessed by means of rain gauge. The intensity of the rain is the same under both conditions, about 9 mm per hour. It should be pointed out that no rainfall was recorded on the trial.

The leaves that were marked before the treatment are sampled at T+2 days, T+5 days and T+7 days; T being the date of the treatment.

Laboratory investigations

The two sides of the leaves are exploited. Discs are cut up from each leaf with a cork borer (figure 1).



The 6 discs (3 in lower side, 3 in upper side) placed in a Pétri dish containing an agar medium are inoculated with a late blight inoculum suspension. The inoculum concentration is contained in 10^4 to 10^5 spores/ml. Each disc receives 3 droplets of 10 µl of inoculum.

The 6 discs placed in the same way in a Petri dish are inoculated with water.
They are used as a healthy control so as to make sure that the sampled leaf is free from late blight.

Figure 1. Method of exploitation of sampled leaves.

The dishes are incubated at 16°C (photoperiod 16 h/18 h) for 7 days. After 7 days of incubation, on distinguishing the lower side to the upper side, each Petri dish is subjected to an assessment. The percentage of the sporulating surface area is assessed for each disc. If during the assessment, the control discs display some contamination, so the whole leaf will not be taken into account for the results exploitation. The results are analysed statically.

Results and comments

According to the results, the upper side is the most suitable side to assess the rainfastness effect on the tested fungicides. The results relating to the lower side make it possible to classify the fungicides according to their action and not their resistance to the rainfastness (figure 2). On the whole samplings, the product Y provides a good protection to the leaf lower side.

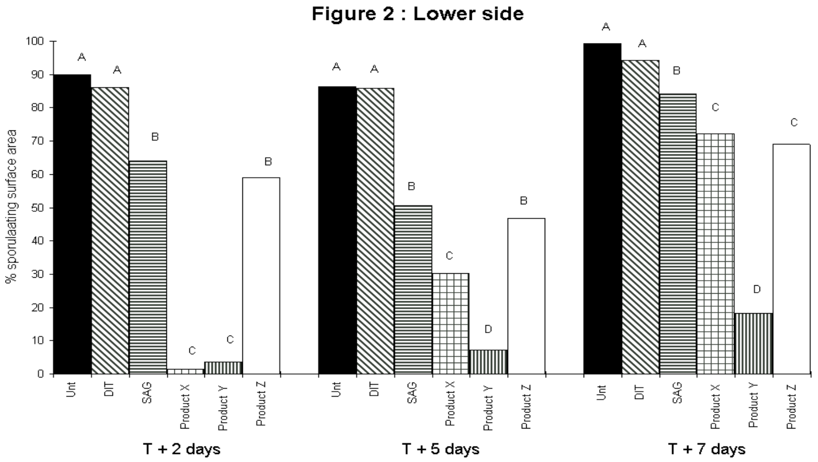


Figure 2. Lower side.

Effect of the rain dosage

The results obtained under the condition "non washed off" give some indications on the overall product efficacy in the absence of rainfastness (figure 3)

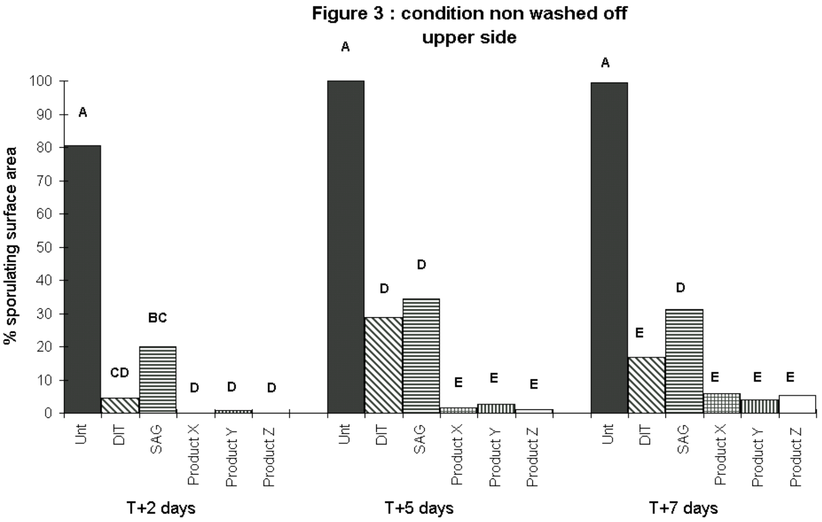


Figure 3. Condition non washed off upper side.

Thanks to these data, an assessment of the fungicide persistence can be done during the samplings.

Whatever the date of sampling, the 3 tested fungicides (X, Y and Z) have a very good activity.

Under the condition washed off at 20 mm, the reference DITHANE DG entirely loses its efficacy from the first sampling (T+2 days). However, as regard the reference

SAGITERRE non significant difference is put to light between the condition 20 mm and the condition non washed off, whatever the date of sampling. Under this condition, X has the same activity than under the condition non washed off only at T+2 days, then its action decreases (figure 4).

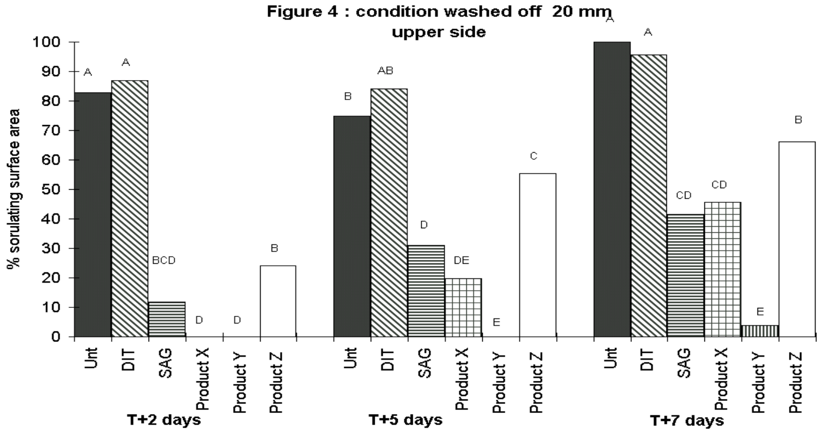


Figure 4. Condition washed off 20 mm upper side.

Throughout the samplings, the action of the fungicide Y is the same as that one noticed under the condition non washed off.

Under the condition washed off at 40 mm, the reference DITHANE DG loses its efficacy from T+2 days as well. Up to T+5 days, the reference SAGITERRE has an equivalent efficacy to those noticed under the condition non washed off and 20 mm. From T+7 days, its action goes down (figure 5).

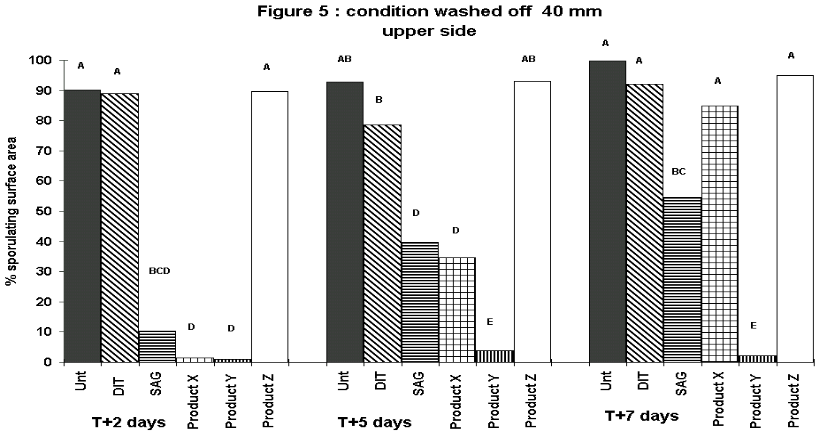


Figure 5. Condition washed off 40 mm upper side.

Under this condition, the activity of the fungicide X doesn't differ from the two previous conditions only at T+2 days. The fungicide Z entirely loses its efficacy under this condition, its efficacy is so equivalent to that one for reference DITHANE DG.

Whatever the date of sampling, the fungicide Y keeps a very good efficacy.

A rain of 40 mm doesn't change the action of this fungicide, this product can have a limit of resistance to the rainfastness higher than 40 mm.

Conclusion

This biological test enable us :

- to confirm the limit of resistance to rainfastness of the two references DITHANE DG and SAGITERRE, that is to say 20 and 40 mm.
- to assess the actions of the various dosage of rainfastness on the tested fungicides.
- to bring to light noticeable differences between the products though the test was not only conducted in laboratory.

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Status of late blight in Norway: Populations and control strategies

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Summary

Phytophthora infestans was isolated from potato leaves and tubers collected from different parts of Norway in 1993-98. Isolates were assessed for mating type, DNA fingerprints, resistance to metalaxyl and virulence phenotype. Differences in the A1/A2 ratio were evident among regions and A2 was not found in northern areas. In the southern part of the country the A2 frequency was relatively stable and 26 % of the isolates (*n*=1144) was mating type A2. Metalaxyl resistance was found in 31-59 % of the isolates in the period 1996-98 (*n*=988). All known virulence genes were found among isolates tested in 1996 (*n*=105), and race 1.3.4.7.10.11 was most common (resistance gene R9 was not included in the differential set). Oospores were observed in potato leaves from three locations in the southern part of Norway. RG57 fingerprints were determined for 102 isolates from 1996. A large number of genotypes and high genetic distances between the genotypes were found, which indicates that sexual reproduction is contributing significantly to the genetic variation of *P. infestans* in Norway. Validation of the warning system TELEVIS was carried out at one location in 1996-99. Treatments according to TELEVIS resulted in fewer sprays than conventional strategy without significant differences in haulm and tuber infections.

Key words: DNA fingerprints, mating types, metalaxyl resistance, oospores, *Phytophthora infestans*, virulence phenotype, validation trials, warning

Introduction

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 (Spielman *et al*., 1991, Fry *et al*., 1993). Indications of sexual reproduction of the pathogen have been reported from the Netherlands (Drenth *et al*., 1994), Poland (Sujkowski *et al*., 1994) and Sweden (Andersson *et al*., 1998).

Recently, data concerning the Norwegian and Finnish *P. infestans* populations from 1993-96 have been published (Brurberg *et al*. 1999, Hermansen *et al*. 2000). In this paper a summary of the Norwegian data is presented, including more recent results from 1997-98.

The epidemiological parameters for the ‘new’ population are so far poorly studied. If these parameters differ from the ‘old’ population, we would expects that warning systems based on studies of the ‘old’ population would not function well. Some data from validation trials with the warning system in Norway, TELEVIS, are discussed.

Materials & Methods

A. Populations

Collection of samples and isolation

Potato leaves and tubers naturally infected by *P. infestans* were collected from Norway during 1993-98. The majority of the samples originated from farm fields and untreated experimental plots. *P. infestans* was isolated on rye B agar plates (Caten & Jinks, 1968) amended with 400 mg L^{-1} pimaricin and 200 mg L^{-1} ampicillin, and incubated at 18 °C in darkness. Pure isolates were normally obtained after 1 or 2 transfers of hyphal tips on media containing antibiotics. Isolates were maintained on rye B agar without antibiotics at 18 °C and were transferred every 4-6 weeks until further characterisation or storage. Furthermore, sampling and isolations were as described in detail by Hermansen *et al.* 2000.

Mating type determination

P. infestans isolate CBS 430.90 (A1) and CBS 429.90 (A2) from Centraalbureau voor Schimmelcultures, Baarn, the Netherlands were used to determine the mating type. Mycelial plugs (5 mm diameter) with growing hyphal tips of the isolates were paired with the tester isolates (60-65 mm apart) on separate 90 mm plates with rye B agar. After 10-18 days of incubation at 18-20 °C in darkness, or at about 22°C in the laboratory in daylight, the plates were examined for oospores at the hyphal interfaces between the isolates. If a plate yielded oospores the test isolate was rated as the opposite mating type of the known isolate. Test isolates producing oospores with both A1 and A2 were scored as A1A2. These could be self-fertile isolates or a mixture of mating types, but this was not determined.

Response to metalaxyl

Metalaxyl sensitivity was determined on rye B agar plates (diameter 90 mm) with or without 10 mg L^{-1} of technical-grade metalaxyl. The fungicide was dissolved in 0.1 % DMSO. Control medium contained 0.1 % DMSO without metalaxyl. Mycelial plugs (5 mm diameter) were cut from the margin of actively growing colonies of *P. infestans* and placed with the mycelium in contact with the test medium in the middle of the plates. The plates were incubated for up to 21 days at 18 °C in darkness. Colony diameters (2 diameters at 90° angles) were measured on all plates when the control had a diameter of at least 30 mm. The measurements were averaged and corrected for the size of the agar plug. There were two replicate plates for each isolate tested. Sensitive, intermediate and resistant isolates were defined as exhibiting < 10 %, 10-60 % and > 60 % growth respectively on metalaxyl-amended agar relative to growth on the control (Shattock, 1988).

Virulence tests

The number of virulence genes of an isolate was determined from the number of compatible interactions on a set of single R-gene differential potato clones according to Tooley *et al.* (1986). A subset of isolates representing all the important potato growing areas was used. The virulence testing was described in detail by Hermansen *et al.* 2000. Race diversity was calculated using the normalised Shannon diversity index (Goodwin *et al.,* 1992). The virulence complexity (average number of virulence genes per isolate) was also calculated.

Oospore formation in vivo

During the collection of *P. infestans*-infected plant material during 1996, leaflets with two lesions were sampled from some locations and examined for the presence of oospores

(Hermansen *et al*. 2000).

DNA fingerprint analysis

A representative set of 102 isolates where chosen that covered 43 fields in all of the important potato growing areas in Norway in 1996. DNA was extracted and fingerprint analysis was carried out as described by Brurberg *et al.* 1999. A multilocus genotype was constructed for each isolate by combining data for mating type and 28 DNA fingerprint loci. Genotypic diversity was calculated by a normalized Shannon`s diversity index. Genetic distances between multilocus genotypes were measured by counting the number of different alleles between two genotypes and a distance matrix was generated (Brurberg *et al*. 1999).

B. Control strategies

Validation trials

The experimental plots were located in commercial fields of the cultivar Beate at Sandefjord, Sout-eastern Norway in 1996-99. The field experiments were organized as randomised complete block designs with four replicates. Each subplot was approx. 150 m^2.

The experimental treatments were as follow:

1. Not treated
2. Conventional sprays according to the farmers normal procedure (7-14 days interval more or less routinely sprays)
3. Spraying according to TELEVIS warnings based on revised Førsund-rules (see below)

Revised Førsund-rules (criteria on a daily basis):

1) Maximum temperature > 16 °C
2) Minimum temperature ≥ 8°C
3) Relative humidity ≥ 75 % at 12.00 a.m
4) Rainfall > 0.1 mm in the period

Fungicides used in the different years and treatments are listed in Table 1. The applications were carried out by the farmer (Hardi, air assistant sprayer, 120-150 l/haa).

Table 1. Fungicides (number of treatments in brackets) used in the validation trials in South-eastern Norway in 1996-99.

Treatment	1996	1997	1998	1999
2.Conventional	Dithane (3) Ridomil MZ (1) Tattoo (1)	Dithane (1) Shirlan (5)	Dithane (3) Shirlan (5) Tattoo (1)	Penncozeb (1) Shirlan (7)
3. TELEVIS	Dithane (1) Ridomil MZ (1) Tattoo (1)	Dithane (1) Shirlan (4)	Dithane (2) Shirlan (3)	Shirlan (4)

Registrations of late blight infections on the haulm were carried out several times during the growing season, but only data from the last registrations are presented. The B.M.S. key for late blight infection was used (Anonymous 1947). Tuber infections (percentage of tubers infected) were scored within 2 months after harvest. At least 2-3 weeks of this period the tubers were stored at about 15 °C. Disease data were subjected to analysis of variance.

Results

A. Populations

Mating types

There was a considerable variation in the proportion of A1 and A2 mating types among regions. In the northern and middle part of Norway only the A1 was found. In southern Norway the frequency of A2 ranged from 19 to 33 % the different years (Figure 1). In 35-40 % of the fields where more than one isolate was collected, both mating types were present.

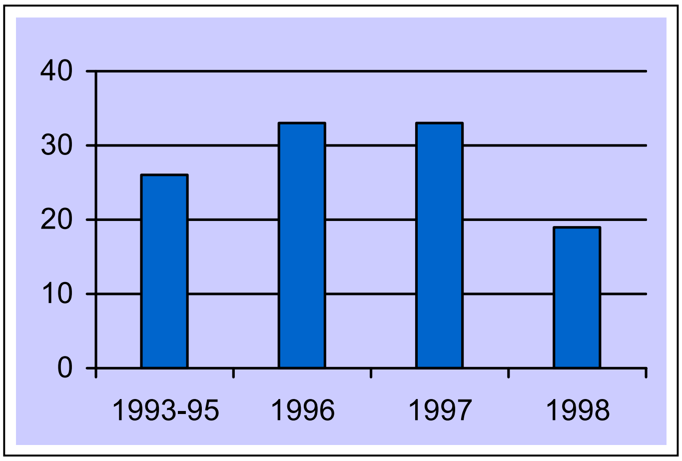

Figure 1. Occurrence of A2 mating type (percentage) in southern part of Norway 1993-98

Metalaxyl resistance

The proportion of metalaxyl-resistant isolates from different regions in Norway ranged from 0-100 %. Norwegian tuber isolates were more often resistant than isolates from leaves. Metalaxyl resistance was most frequent among A1 isolates (Hermansen *et al.* 2000).

Fifty-nine percent of the isolates were metalaxyl-resistant in 1996 (Hermansen *et al.* 2000). The data from 1997 and 1998 showed 31 % and 43 % resistant isolates, respectively (Table 2).

Table 2. Metalaxyl sensitivity$^{1)}$ among isolates of *Phytophthora infestans* in Norway in 1996-98.

Year	MS (%)	MI (%)	MR(%)	Isolates tested *(n)*
1996	14	27	59	491
1997	21	48	31	115
1998	24	33	43	382

$^{1)}$ MS: metalaxyl sensitive, MI: intermediate metalaxyl sensitive, MR: metalaxyl resistant

Virulence tests

With the exception of virulence to resistance gene R9, which was not tested, all known virulence genes were found in isolates from Norway. Most of the isolates (89 %) were able to overcome four or more R-genes. The virulence complexity (average number of R-genes overcome) was 5.78. The most common race was 1.3.4.7.10.11. Thirty-eight different races were detected among the 105 isolates tested, and normalised Shannon diversity index was 0.44 (Hermansen *et al*. 2000).

Oospore formation in vivo

Oospores according to the descriptions of oospores of *P. infestans* (CMI description No 838) were observed from three fields with cultivars showing intermediate resistance to *P. infestans,* located in the southern part of Norway.

DNA fingerprint analysis

A total of 51 different multilocus genotypes were identified among the 102 isolates. Thirty- five of the genotypes were found only once in the collection. Among all the pairwise genotype comparisions, only 7 % of the pairs of multilocus genotypes differed at less than three loci. On average, pairs of genotypes differed from each other at 6.3 of the polymorphic loci (Brurberg *et al*. 1999).

B. Control strategies

Validation trials

In all years fewer treatments were carried out according to TELEVIS warnings than according to the farmers normal procedure. In mean of the four years of experiments TELEVIS warnings triggered 4.25 sprays related to 7 in the conventional spraying regime. Some more diseased haulm at harvest was observed in the TELEVIS treatment than in the conventional treatment, but the differences were not significantly different (Table 3). Tuber infections were not detected or were at low levels (< 3 %). No significant difference was found between the different treatments regarding percentage of tuber infection.

Table 3. Number of sprays (mean spray interval in brackets) and diseased haulm at harvest in the validation trials in South-eastern Norway in 1996-99.

Treatment	1996	1997	1998	1999
2. Conventional	5 (10.5)	6 (11)	9 (7.5)	8 (8)
% diseased haulm	0.1	0.0	0.0	0.15
3. TELEVIS	3 (12.5)	5 (14)	5 (15)	4 (14)
% diseased haulm	0.3	0.03	0.1	0.8

Discussion

In Norway the A2 mating type was found during 1993, the first year of the survey (Hermansen *et al*. 2000). Mating type A2 was not detected in the middle and northern parts of the country. Throughout the period 1993-1998 the frequency of A2 was stable and averaged 26 % in southern Norway. In contrast, the A2 frequencies have declined in other European countries such as England and Wales (Day & Shattock, 1997), the Netherlands (Drenth *et al.,*1993) and Poland (Sujkowski *et al*., 1994). Why only A1 mating type was detected in some areas in Norway is not clear. One reason could be that the A1 genotypes are more fit in these regions because of differences in response to climatic parameters. Mizubuti & Fry (1998) reported that clonal lineages of *P. infestans* differed in response to temperature.

Most of the isolates were sampled late in the season and some samples came from fields where metalaxyl had been used curatively. Both of these factors favour the occurrence of resistant isolates (Gisi & Cohen, 1996). Only pre-packed mixtures of metalaxyl and mancozeb have been used. They are recommended for use only twice each season, and are not to be used in seed potato production. The proportion of metalaxyl-resistant isolates in Norway is however in the same range as in other European countries (Gisi & Cohen, 1996). In Norway the metalaxyl sensitivity test was carried out *in vitro* using metalaxyl-amended agar. This test might overestimate resistance in a field situation. However, there is good correlation between the *in vitro* and *in vivo* tests on leaf discs (Goodwin *et al*., 1996).

The most common race, 1.3.4.7.10.11 was also prevalent in Finland (Hermansen *et al*. 2000), France (Andrivon, 1994, Lebreton *et al*.,1998) and Switzerland (Gisi *et al.,* 1995). This race was also found among isolates collected during 1980 and 1981 in Denmark (Gürtler, 1984). Race diversity (number of races among isolates tested) in Norway is in the same range as in other European populations (Lebreton *et al.,*1998, Schöber & Turkensteen, 1992, Sujkowski *et al.,* 1996). Race diversity calculated by the normalised Shannon diversity index showed lower values in Norway (0.44) than from analyses of the 'new' population in the Netherlands (Drenth *et al*., 1994.) and Poland (Sujkowski *et al.,* 1996), but were about in the same range as in France (Lebreton *et al*., 1998). Most Norwegian potato cvs do not contain major *P. infestans* resistance genes (T Bjor, Agricultural University of Norway, personal communication). This indicates that R-gene selection has not been of importance in generating the observed pattern of race variation in the Norwegian *P. infestans* populations.

High diversity of genotypes such as found in our study have been described for *P. infestans* populations in central Mexico (Goodwin et al. 1992), Poland (Sujkowski et al. 1994) and in the Netherlands (Drenth et al., 1994).

Oospores were found in leaves from three locations in two regions in Norway. The cultivars in which oospores were formed had a medium level of race-nonspecific leaf resistance to *P. infestans.* This is common among cultivars used in Norway (T Bjor, Agricultural University of Norway, personal communication). There are reports indicating that more oospores are produced in cultivars showing intermediate levels of resistance to late blight than in more susceptible cultivars (Drenth *et al*., 1995, Hanson & Shattock, 1998).

The validation results regarding TELEVIS are in accordance to data from small plot experiments carried out in the period 1994-96 in Norway (Hermansen & Amundsen 1997). The experiments demonstrate that late blight treatments according to simple rules are possible in Norway. Other experiments have shown that in some locations the warnings from TELEVIS are not reliable every year, and the weakness of Førsund rules are discussed earlier (Hermansen & Amundsen 1997).

Conclusions

The high and relatively stable frequency of isolates of A2 mating type, the high number of fields with both mating types, high levels of genetic diversity in the populations and the findings of oospores suggests that sexual reproduction is involved in the development of *P. infestans* populations in Norway. Our data also indicate that metalaxyl should be used with care in the future, and further studies are needed to find the best strategy for optimum efficiency of this fungicide in Norway. Our virulence data show that breeding programmes in Norway need complex races in their late blight resistance tests for race-non-specific resistance.

The revised Førsund-rules for late blight warning seems to "fit" the behaviour of the "new" *P. infestans* populations in Norway. Optimal timing of the first treatment is a problem with the current warning system. More work is needed to elucidate the importance of different primary inoculum sources (oospores and infected seed tubers) in the epidemiology of *P. infestans.*

Acknowledgements

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Influence of meteorological factors and fungicide programme on the incidence of potato tuber blight *(Phytophthora infestans)*

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Abstract

Field experiments were conducted over several years and the incidence of tuber blight at harvest examined in relation to the severity of foliar blight and the timing of Smith Periods and rainfall. The incidence of tuber blight was not directly related to the number of Smith Periods during the season. Tuber blight was extensive if a Smith Period occurred when foliar blight was optimal for sporangia production and there was rainfall greater than 5 mm per day within several days. These meteorological conditions are called HRPTIs (high risk periods for tuber infection). In most years the incidence of tuber blight could be explained in terms of the HRPTIs and the coinciding severities of foliar blight. However, there is evidence that other factors, for example air temperature, can modify the relationship. Within years, the incidence of tuber blight for the fungicide programmes was generally related to the severity of foliar blight when the HRPTIs occurred. Programmes commencing with three phenylamide-based fungicides frequently gave the best control of tuber blight.

Key words: late blight, fungicides, Smith Period

Introduction

Decision support systems that improve the control of potato blight by optimising fungicide timing in relation to periods of high risk are being developed (Schepers & Bouma, 1998). However, these decision support systems at present consider the control of foliar blight only, they do not directly address the problem of tuber blight. Tuber infection by *P. infestans* occurs either during the growing season or during harvest if a crop with blighted foliage is lifted too soon after haulm destruction. Only infection during the growing season is considered in this paper. Many factors influence the risk of tuber infection but the main factors are likely to be the amount of inoculum produced on the blighted haulm (determined by the severity of foliar blight and whether meteorological conditions are suitable for sporulation) and the quantity of rain or irrigation water available to wash the inoculum down into the soil, allowing infection of tubers. This paper presents results of a preliminary investigation of the relationship between tuber blight and these main factors. The effect of different fungicide programmes was also examined.

Materials and methods

The field experiments, non-irrigated fungicide evaluation trials, were made over 10 years. The very susceptible cultivar King Edward was used throughout and the experiments were conducted in South Ayrshire on the west coast of Scotland. The experimental design was a randomised complete block with four replicate plots. Each plot consisted of four drills containing a total of 100 plants. Fungicide treatments were applied at UK label rates in 300 l of water per hectare. Flat fan spray tips and a spray pressure of 2.8 bars gave a medium/fine spray quality. The fungicides (Table 1) were applied at 10 to 14 day intervals, according to risk, except that the last two applications were at 7 to 10 day intervals. The plots were artificially inoculated with a mixture of several *P. infestans* isolates (including phenylamide-insensitive isolates) obtained from UK potato crops. Inoculation took place shortly after the first or second fungicide application. The percentage of foliage destroyed by blight was assessed using a modified version of a widely used key (Anon, 1947). Foliar blight was assessed regularly from its first occurrence until the trials were desiccated with diquat (Reglone) at 800 g ai/ha. Tuber blight was assessed by external inspection of a random sample of 60 washed tubers per plot. The sample was taken at harvest.

Table 1. Fungicide programmes.

Programme	Typical no. of sprays	Active ingredient(s)	Rate of a.i. ha^{-1}

1995-1997			
Dithane 945		mancozeb	1360
or Dithane DF	6	mancozeb	1275
then Brestan	2	fentin acetate + maneb	270 + 80
Fubol 75	3	metalaxyl + mancozeb	150 + 1350
then Dithane	3		
then Brestan	2		
Trustan	3	oxadixyl + cymoxanil + mancozeb	200 + 80 + 1400
then Curzate M	3	cymoxanil + mancozeb	90 + 1360
then Brestan	2		
Shirlan	8	fluazinam	150
1998-1999			
Shirlan	6		
then Brestan	2		
Fubol 75 (‘98)			
or Fubol Gold (‘99)	3	mancozeb + metalaxyl-M	1216 + 76
then Shirlan	3		
then Brestan	2		
Trustan	3		
then Curzate M	3		
then Brestan	2		
Merlin	3	mancozeb + propamocarb	1013 + 1013 (‘98) 938 + 938 (‘99)
then Shirlan	3		
then Brestan	2		

Results

In this paper high risk periods for tuber infection (HRPTI) are when a Smith Period is followed by at least 5 mm of rain on at least one day, within 7 days of the Smith Period.

The effect of fungicide programme on the incidence of tuber blight

In 1995 there was only one HRPTI. For the five treatments the incidence of tuber blight was related to the severity of foliar blight during the Smith Period (Table 2). The Fubol 75, Trustan and Shirlan programmes resulted in significantly less tuber blight than the untreated or Dithane which were similar. In 1996 also there was only one HRPTI. There were no visible foliar symptoms at the time of the Smith Period. Tuber blight was significantly less for the Fubol 75 and Trustan programmes compared with the untreated.

In 1997 there were two HRPTIs. The Dithane programme resulted in a significantly higher incidence of tuber infection than the untreated. The incidence of tuber blight was significantly less with the Trustan programme compared with Dithane. Fungicides were less effective in 1997 than 1995. At both HRPTIs the severity of foliar blight was greater than in 1995 and ideal for sporangia production, i.e. between 2% and 58%, except for the untreated in early September. At this severity of foliar blight sporulation would be limited. In 1997 tuber blight was lowest in the untreated.

In 1998 there were no significant differences in tuber blight between treatments but the phenylamide-based programmes resulted in better control, which reflected their superior control of foliar blight. The incidence of tuber blight was lower than expected given the four risk periods for tuber infection and favourable severities of foliar blight at three of them.

In 1999 the Trustan and Fubol Gold programmes gave significantly less tuber blight than the Merlin and Shirlan programmes. This reflected their better control of foliar blight.

Table 2. The incidence of tuber blight at harvest in relation to fungicide programme and the severity of foliar blight when a Smith Period was followed by one or more rainfall event(s).

Fungicide programme (see Table 1)	Estimated severity (%) of foliar blight during Smith Period	Incidence (%) of tuber blight at harvest
1995		
Untreated	36.0	26.6
Dithane.....	1.3	20.3
Fubol 75....	0.5	5.7
Trustan.....	0.5	7.8
Shirlan	1.0	8.3
Date of Smith	28-29 August	
Period	3, 4, 6[a]	
LSD (*P*=0.05)		9.36
1996		
Untreated	No symptoms	0.8
Dithane.....	"	0.3
Fubol 75....	"	0.0
Trustan.....	"	0.0
Shirlan	"	0.3
Date of Smith Period	19-20 August	
	0, 3, 6[a]	
LSD (*P*=0.05)		0.68

Table 2. continued.

Fungicide programme (see Table 1)	Estimated severity (%) of foliar blight during Smith Period		Incidence (%) of tuber blight at harvest
1997			
Untreated	56.0	98.6	14.0
Dithane.....	17.0	58.1	34.1
Fubol 75....	2.0	23.3	21.6
Trustan.....	3.0	18.5	18.8
Shirlan	10.0	27.5	20.4
Date of Smith Periods	19-20 August 0[a]	7-8 Sept. 3, 5, 6, 7[a]	
LSD (*P*=0.05)			14.72

Table 2. continued

Fungicide programme (see Table 1)	Estimated severity (%) of foliar blight during Smith Period				Incidence % of tuber blight at harvest
1998					
Untreated	0.4	45.5	98.5	100.0	2.6
Shirlan.....	0.2	1.2	20.8	60.0	3.0
Fubol 75.....	0.0	0.4	4.9	14.5	0.5
Trustan.....	0.0	0.4	6.9	33.7	1.0
Merlin.....	0.1	1.0	18.4	48.7	4.3
Date of Smith Periods	26-27 July 1, 7[a]	3-4 August 1, 3[a]	19-20 August 0, 3[a]	2-3 Sept. 4, 5, 6[a]	
LSD (*P*=0.05)					4.33

Table 2. continued.

Fungicide programme (see Table 1)	Estimated severity (%) of foliar blight during Smith Period			Incidence (%) of tuber blight at harvest
1999				
Untreated	< 3.8	86.0	96.3	2.7
Shirlan.....	0	4.2	4.8	11.8
Fubol Gold....	< 0.1	0.5	0.6	0.8
Trustan.....	< 0.6	0.8	0.8	0.6
Merlin.....	0	3.1	4.2	11.9
Date of Smith Period	15-16 July	13-14 August	25-26 August	
	0, 2, 3 [a]	1[a]	3[a]	
LSD (*P*=0.05)				9.2

[a] Timing of rainfall events: values represent days after the Smith Period on which rainfall was at least 5 mm (day 0=second day of Smith Period, day 1=one day after Smith Period, etc.)

Assessing the risk of tuber infection in different years

The risk of tuber infection was not directly related to the number of Smith Periods in one season (data not presented). Preliminary analysis of data for the years 1989 to 1999 relating the incidence of tuber blight in untreated plots of K. Edward to meteorological factors has demonstrated that for eight of the 10 years the incidence of tuber blight was related to the number of HRPTIs and the coinciding severities of foliar blight (Table 3). However, a high risk of tuber blight was indicated in 1990 and also 1998 but the recorded incidences of tuber blight were low. In both of these years the minimum air temperature when other factors favoured infection was relatively high. This may have prevented the extensive production of zoospores from sporangia. In the remaining six years a very low or low occurrence of tuber blight corresponded to the number of HRPTIs and the foliar blight severity data.

Table 3. The incidence of tuber blight at harvest in untreated King Edward in relation to the number of high risk periods for tuber infection (HRPTI), the severity of foliar blight during the HRPTI and minimum air temperature.

Year	% tuber blight at harvest in untreated	No. of high risk periods for tuber infection	Estimated foliar blight severity during each Smith Period	Minimum air temperature (^{o} C) at time of rainfall event(s)
1989	1.4	0		-
1990	1.3	3	10.2, 34.3, 80.9	11.7, 14.5, 13.3
1991[a]	ND	ND	ND	ND
1992	1.0	0		-
1993	4.3	1	0.6	7.2
1994	2.9	1	<0.2	12.8
1995	26.6	1	36.0	8.2
1996	0.8	1	0	8.2
1997	14.0	2	56.0, 98.6	19.0, 7.5
1998	2.6	4	0.4, 45.5, 98.5, 100.0	9.5, 12.5, 10.7, 13.8
1999	2.7	3	<3.8, 86.0, 96.3	10.3, 11.7, 11.0

[a] No data in 1991 for King Edward

Discussion

In most years, tuber blight incidence was related to the HRPTIs and the severities of foliar blight. However, there was evidence that air temperature may also be required to estimate the risk of tuber infection because of its effect on the extent of secondary germination of sporangia. Other factors may also need to be considered, e.g. cultivar resistance, soil moisture content prior to HRPTI and soil type. The need to include these additional factors will depend on results obtained at sites with more diverse meteorological and edaphic conditions. The data examined in this paper were obtained using one cultivar at sites within a few square miles of each other. Further investigation and evaluation is required at a large number of diverse sites over several seasons. In future investigations the incidence of tuber blight should be monitored throughout the growing season. The experiments in this paper were fungicide evaluation trials and therefore this was not included in the protocol.

Ultimately, a system for forecasting tuber infection should be incorporated into decision support systems for blight control that at present forecast the risk of the foliar phase of the disease only (Schepers & Bouma, 1998). The accurate prediction of high risk periods for tuber infection would help growers to 1) maximise the effectiveness of fungicides for the control of tuber blight by improving fungicide choice and timing, 2) time irrigation correctly to minimise tuber infection and 3) identify when to desiccate or destroy the haulm of blighted crops. The latter two may be particularly important to growers of organic potato crops.

Programmes with three phenylamide-based fungicides at the start generally gave the best control of tuber blight. This reflected foliar blight control. However, the spray intervals used were better suited to systemic fungicides given the susceptibility of the cultivar and the high blight risk at the trial sites.

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Characteristics of Finnish *Phytophthora infestans* population

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Summary

Population studies on *Phytophthora infestans* have been carried out since 1990 in Finland. Fungal samples collected from single lesions on potato leaves, stems and tubers have been characterised for their metalaxyl resistance, mating type, and virulence based on major R-genes. Metalaxyl resistant isolates were dominant in 1990-94 but their proportion has decreased towards the end of 1990's. A2- mating type was detected in 1992 and its proportion has been around 20 % in 1993-1999. The diversity of virulence races in Finnish blight population is very high indicating sexual reproduction of the pathogen. 16 different *P. infestans* isolates could be detected by PCR.

Key words: Potato, Potato late blight, *Phytophthora infestans*, metalaxyl, mating type

Introduction

Population studies on potato late blight were started in 1990 in Finland. The original aim was to monitor metalaxyl resistance. As a consequence of the migration of mating-type A2 to Europe it has become important to investigate different changes in population structure (Fry et al. 1992, Hannukkala 1999).

The role of oospores and possible soil infection in blight epidemiology is still unclear. Much of the work has been carried out in Nordic collaboration (Brurberg *et al.* 1999, Andersson *et al.* 1998, Bødker *et al.* 1998).

New tools to characterise and detect blight fungus in plant tissue are needed. Some quantitative PCR methods have already been developed for this purpose (Niepold and Schöber-Butin 1995, Tooley *et al.* 1996, Niepold and Schöber-Butin 1997, Tooley *et al.* 1997, Griffith and Shaw 1998, Ristaino *et al.* 1998). Also the use of qualitative PCR methods are under investigation.

Materials and methods

Yearly 50-500 blight samples have been collected from potato fields in 1990-99. Spore suspension prepared from single lesions in leaves have been used as an 'isolate' in most studies. 10 % of blight samples have been isolated on rye agar.

Metalaxyl resistance was studied with floating leaf disk method in metalaxyl concentrations 0, 0.1, 1, 10 and 100 ppm (Sozzi et al. 1992, Hannukkala 1999). Virulence based on ability to infect differential set of R-gene clones (R0-R11, R9 not included) of potato was investigated on floating leaf disks. Mating-type was confirmed by pairings on rye agar and on floating leaf disks (Hannukkala 1999).

P. infestans was detected by PCR using primers from the 428 bp repetitive sequence designed by Niepold and Schöber-Butin (1995). DNA was extracted from pure cultures by using DNeasy Plant Mini Kit by Qiagen or a little part of infested plant material was transferred with small brush into 100 µl sterile water and 4 µl was used in PCR reaction.

Results

A2- mating type was detected first time in Finland in 1992. The proportion of A1/A2 has since then been in the range of 80/20. Both mating types have been present in the majority of fields where several isolates has been tested. Both mating types have been found in a single plant. In 1998 and 1999 many samples were mixtures of both mating types.

Metalaxyl resistance was on very high level in the beginning of 1990's. As a result of decreasing use of metalaxyl products the proportion of resistant samples has decreased.
In Northern regions there are fields with high level of resistance, though metalaxyl fungicides have never been used.

All known virulence genes have been found in blight population. Virulence to genes R1, R3, R4, R7 and R11 is present in most samples. Virulence to R2, R5, R6, and R8 is very

rare.
The most common race is (R1,3,4,7,10,11) and it constitutes 36 % of the population.

To test the reliability of the primers 16 different *P. infestans* isolates were selected among Finnish genotypes for templates. All 16 races could be detected by PCR. As yhe altertnative for the commercial kit to prepare DNA for PCR an easy and rapid method was developed. Preliminary tests of this method to obtain amplifiable DNA from infected potato leaves, stems and tubers appeared to work. Sensitivity and reliability of this method should be further tested.

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Fourth Workshop of an European Network for development of an
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Field Evaluation of the combined use of IPI and different forecasting criteria for potato late blight control

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Abstract

IPI model is used in Italy to determine when to apply the first spray to control late blight either on potato and tomato. However, the model does not provide information about the subsequent sprays. Field evaluation of combined use of IPI model and different DSS for timing subsequent sprays over 3 years (1997-1999) was therefore carried out. DSS considered were MISP, Fry, value 4 of accumulated IPI index calculated from the time of last spray, and a calendar strategy with 7 days interval. Disease occurred in 1999 only. Results showed that, in 1997 and 1998 with no infection, all the DSSs were able to save useless sprays (from 50 to 83% compared with the calendar strategy). In 1999 with severe infection, still all DSSs gave satisfactory results in timing effectively subsequent fungicide sprays (more than 80% effectiveness). However, MISP, IPI and Fry systems permitted to save 28, 28 and 14% of sprays compared with the calendar strategy.

Keywords: Late blight, Potato, DSS

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 1990 (Cavanni P. *et al.*, 1990; 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 the achievement of certain risk threshold considered useful to apply the first spray. The model was then validated for potato crop and used for both crops by the regional Warning Service (Bugiani R. *et al.*, 1997,1998). IPI model proved to be the most suitable for our environment 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 so as to time correctly the subsequent sprays once accumulated IPI Index reaches the threshold for the first spray.

Materials and methods

Field trials were carried out in a typical potato growing area located in Mezzolara - Bologna over 3 years (1997-1999). All the experiments were carried out on cultivar Primura following a randomised complete block design with 4 replicates. Each plots measured about 25 m^2 (6 rows x 5 m). The first treatment was applied once IPI model reached the risk threshold value 15. Further sprays were applied following different criteria: Fry (Fry W.E. *et al.,* 1983), MISP (Cao K.Q. *et al.,* 1997; Rucksthul M. & Forrer H.R., 1998; Bugiani R. et al., 1999), value 4 of accumulated IPI index calculated from the time of last spray. Untreated plots were used as checks along with a commonly used calendar strategy based on 7 days fixed schedule. Ramedit Combi (cymoxanil 4.2% + copper ox. 40%) was used at the dosage of 2 kg/ha.

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 either the phenological stage, the occurrence of first symptoms and disease progress. Each plot was scored as whole for percentage of disease severity following the scale: 0 = no infection; 0.1 = only a few plants affected or up to 1 or 2 spots in a 10 meter radius; 1 = up to 10 spots per plant or general light spotting; 5 = about 50 spots per plant or 1 leaflet in 10 attacked; 10 = up to 4 leaflet in 10 affected. Plants still retaining normal form; 25 = nearly every leaflet with lesions but plants still retaining normal form and plots may look green; 50 = every plants affected and about half of leaf area destroyed by blight. Plots look green, flecked with brown; 75 = about 3/4 of the leaf area destroyed by blight. Plots look predominantly brown; 95 = only a few leaflets green, but stems still green; 100 = all leaves dead, stems dead or dying.

Volumetric Hirst-type sporetraps were placed within the unsprayed plot to measure the pathogen's inoculum (daily n° of airborne sporangia/mc) during the season.

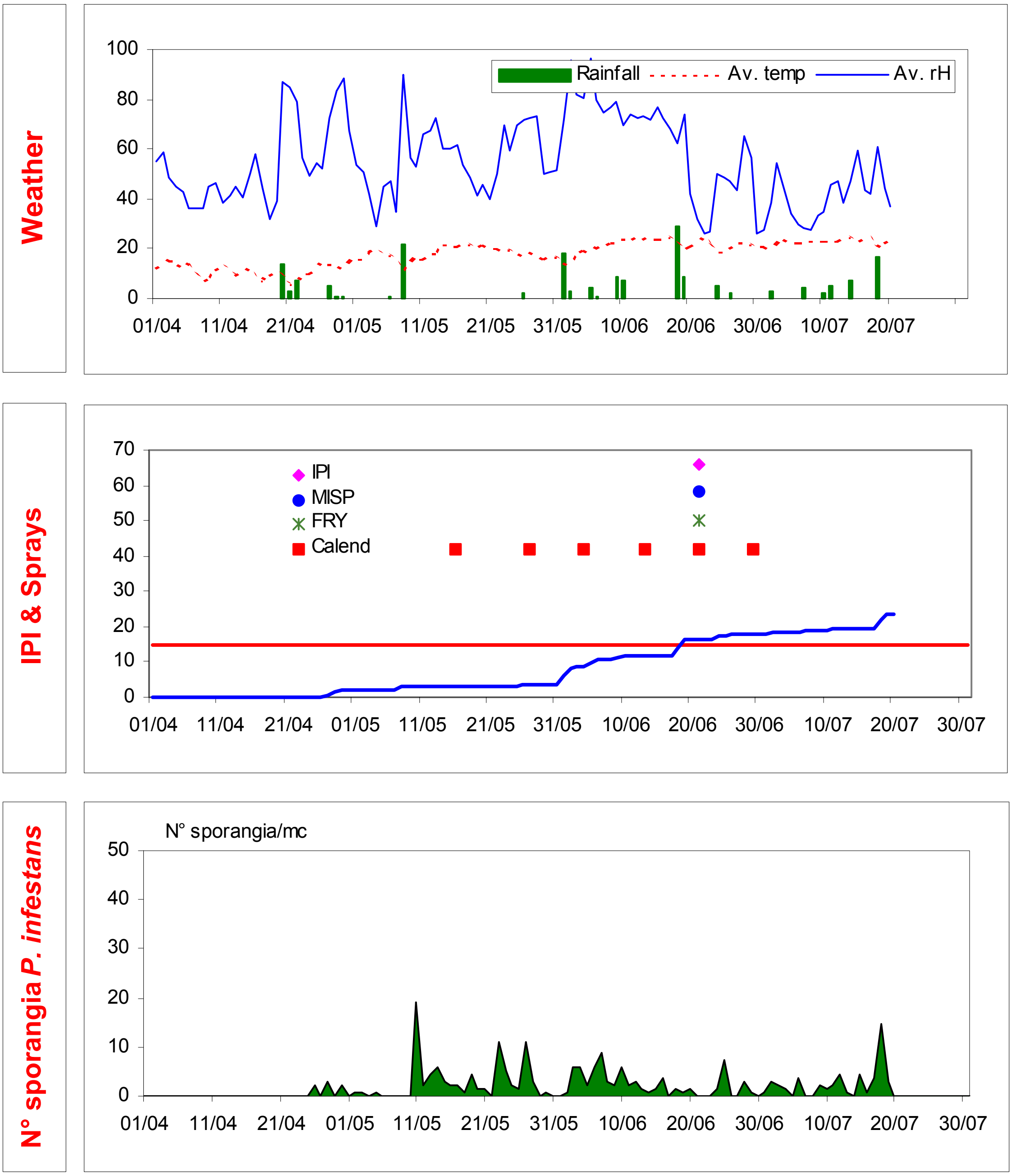
In 1999 because of the disease occurrence quantitative and qualitative recording was carried out.

Results

For all the years considered, planting date was in the first days of march and crop emergence (green rows indicating the 75-80% of plant emerged) in the first days of April. Harvest occurred between 16 and 23 July.

1997. Year 1997 was at low blight risk. No disease occurrence has been detected neither in the experimental field nor in all the regional potato growing area. IPI model reached the risk threshold on 19 June. Therefore, the first treatment was applied on 21 June. Subsequently, none of all DSS considered indicate the need for further treatments. Exception would be Fry cumulative fungicide units (threshold 15) that would indicate a further spray on 10 July. However it was not applied because too close to harvest (20 July). For calendar strategy the first spray was applied on 16 may. Further chemical applications were carried out at 7 days interval until 29 June due to safety period (20 days). Therefore only one spray was applied throughout the season for all the DSS compared with 6 sprays in the calendar strategy plot.

Spore concentration was moderately low throughout the season. Highest concentration (19 sporangia / mc) was recorded on 11 may. Weather conditions, IPI output, sprays and aerobiological monitoring are represented in fig.1.



Figur. 1. Climate, accumulated IPI risk index and time of treatments with the different DSS and spore concentration in 1997.

1998. Year 1998 also was characterised by lack of blight occurrence on potato crops, even though climate in April and may seemed to be favourable for the disease. IPI model reached risk threshold on 23 may and the first treatment was applied on 26 may. Subsequently, Fry DSS indicated the need for further treatments on 3 and 16 June, 2 and 20 July. The latter was not applied because too close to harvest (23 July). IPI and MISP models both indicated a further spray on 1 June and another on 9 and 16 July respectively. Even in this case the latter sprays were not carried out due to the safety period. For calendar strategy the first spray was applied on 9 may. Further chemical applications were carried out at 7 days interval until 2 July due to safety period. On the whole, Fry, IPI and MISP models indicated 4, 2 and 2 sprays respectively, compared with 8 sprays in the calendar strategy plot.

Spore concentration was very low throughout the season. Highest concentration (10 sporangia / mc) was recorded on 9 may. Weather conditions, IPI output, sprays and aerobiological monitoring are represented in fig.2.

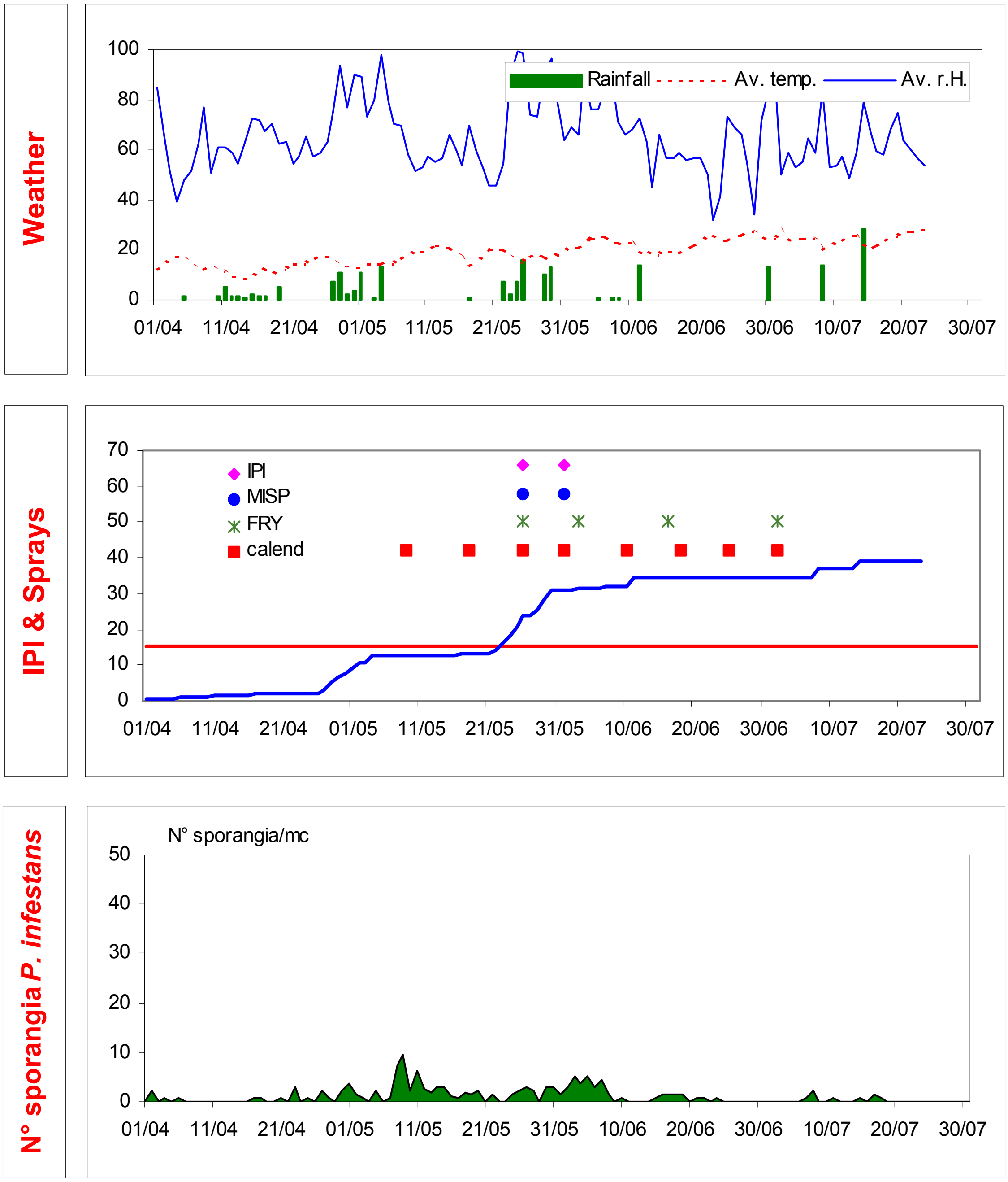


Figure 2. Climate, accumulated IPI risk index and time of treatments with the different DSS and spore concentration in 1998.

1999. Year 1999 was characterised by climatic conditions extremely favourable for late blight. Several rainy days with high relative humidity and prolonged periods with leaf wetness occurred from the end of April until the first decade of may. At that time, plants were already susceptible to the disease (canopy covered almost completely the ground). IPI model reached the risk threshold on 10 may and in the same day first symptoms on the experimental plots were observed. Therefore IPI model warning for the first spray was in this case too late and the first chemical application was carried out with a very light infection on the plots on 13 may. Subsequently, IPI and MISP models both indicated furthers sprays on 19 and 25 may, 16 and 22 June. Fry DSS indicated further treatments on 19 and 25 may, 7, 16 and 24 June. Calendar strategy's first spray was also applied on 13 may. Further chemical applications were carried out with 7 days interval (except in the period between 25/5 and 7/6 because of lack of rain and low relative humidity) until 29 June. During the season, IPI, MISP and Fry models scored 5, 5 and 6 sprays respectively, compared with 7 sprays in the calendar strategy plot.

Spore concentration began to rise at the end of April. Two peaks (18 and 27 sporangia/mc) were recorded before disease occurrence on 30 April and 6 may respectively. Highest concentration (85 sporangia/mc) was recorded on 26 may in coincidence with the maximum disease progress in the check plots (fig.4). Weather conditions, IPI output, sprays and aerobiological monitoring are showed in fig.3.

At harvest, the 16 July, the 2 central rows of every plots for 2 m. length were separately harvested for quantitative and qualitative recording. Total and marketable yield (40 < Ø < 75 mm) was then calculated (Tab.1). No infected tubers were observed at harvest.

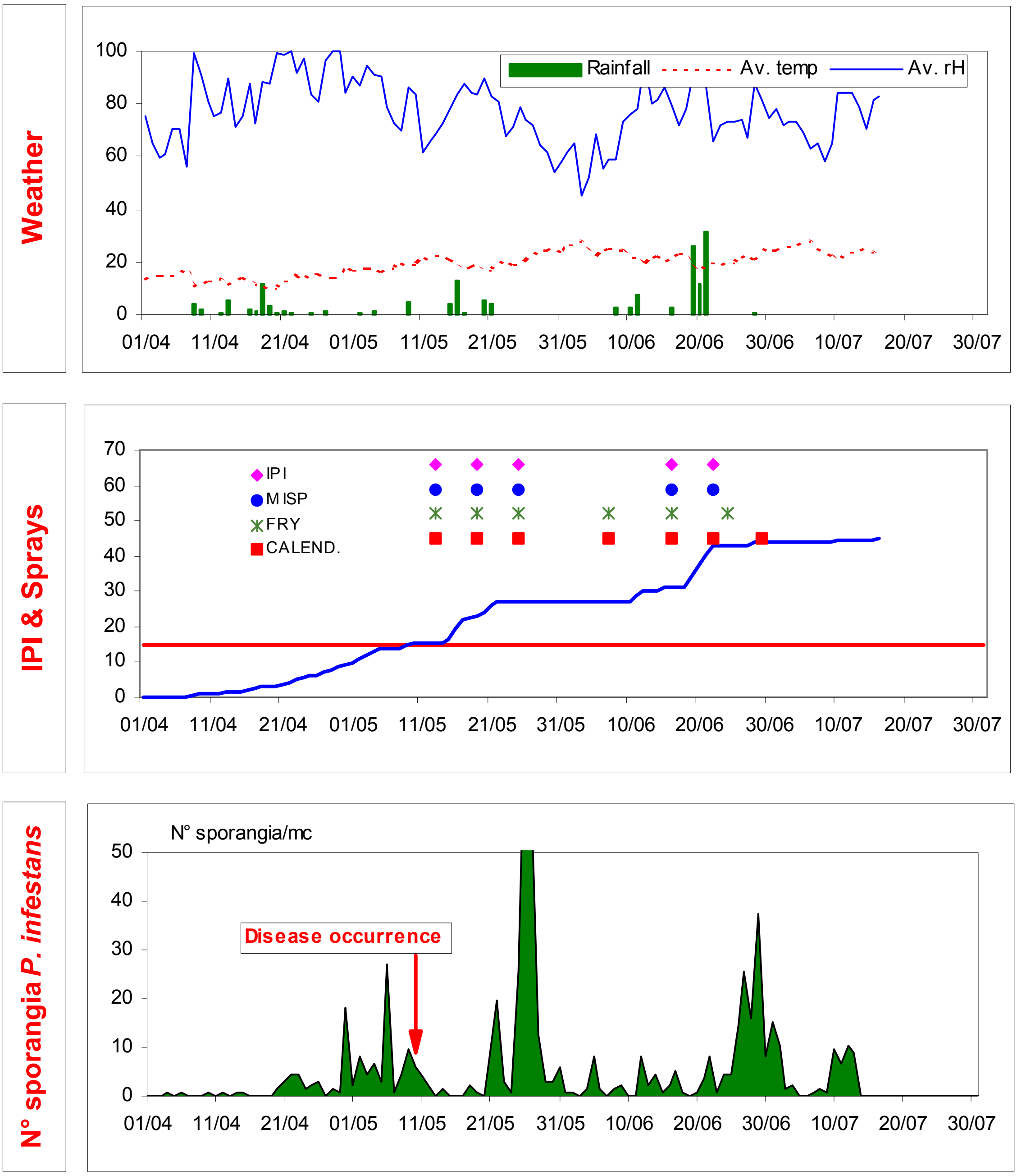


Figure 3. Climate, accumulated IPI risk index and time of treatments with the different DSS and spore concentration in 1999.

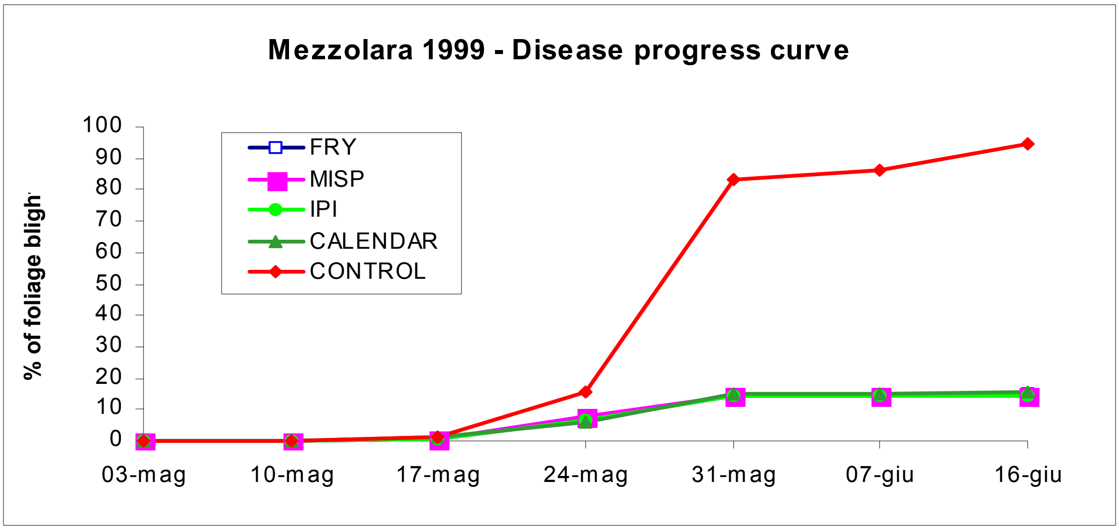


Figure 4. Mezzolara 1999: Disease progress curve in treated and untreated plots.

Tabel 1. Mezzolara 1999. Effect of different disease control strategies on percentage of foliage blight and tuber production.

Criteria	**N° treatments**	**AUDPC (% over control)**	**Production plots (Kg)**				**Marketable production t/ha**
			marketable	**Ø>75mm**	**Ø<40mm**	**total**	
FRY	6	18.6 a	13.4	0.9	0.9	15.2 a	4.48
MISP	5	18.9 a	13.3	0.6	0.9	14.8 a	4.43
IPI - 4	5	18.5 a	13.7	1.2	0.8	15.8 a	4.58
CALENDAR	7	19.4 a	13.2	1.0	0.8	15.0 a	4.40
CONTROL	-	100.0 b	6.2	0.0	1.1	7.3 b	2.08

Discussion

The combined use of IPI models with different DSSs for timing subsequent sprays to control the disease seems to give promising results. Results showed that, years unfavourable to late blight like 1997 and 1998 when no infections were observed either in the experimental plots nor in the whole potato growing area of Emilia-Romagna region, the use of DSSs once the IPI risk threshold was reached, permits to save useless sprays. In 1997 trial all the DSSs considered were able to save from 83% of chemical applications compared with the calendar strategy. In 1998 MISP, IPI-4 and Fry systems permitted to save 75, 75 and 50% of chemicals applied. In 1999 with severe infection, still all DSSs gave satisfactory results in timing effectively subsequent fungicide sprays (more than 80% effectiveness on foliage blight and no tuber blight at harvest were observed) during the season. However, MISP, IPI and Fry systems permitted to save 28, 28 and 14% of sprays compared with the calendar strategy.

Aerobiological monitoring carried out during 3 years seems to confirm the potential risk of blight onset in the experimental plots. In fact, in 1997 and 1998 with low blight risk, spore concentration remained at relatively low level throughout the season even though in 1997 a single peak of 20 spore/day (which may be considered an alert) was observed. However climatic conditions were not blight conducive. In 1999, on the contrary, 2 peaks of spore concentration above 18-20 were observed prior the disease onset in the field. At the same time climatic conditions were very favourable for the infection.

IPI model confirms to be a quite reliable "negative prognosis" model for the environmental condition of Emilia-Romagna region. In most of the cases it is able to warn correctly for the first occurrence of potato late blight. However, like in 1999, when late blight occurs very early in the season, it may reach the risk threshold almost in coincidence with the disease occurrence therefore not allowing farmers to apply the fungicide in time to control the disease. Further studies are needed to understand if these few cases are due to unreliable met-data or rather to a model's underestimation of some climatological parameters.

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Fourth Workshop of an European Network for development of an
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Investigation on the varietal resistance

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The SRPV-FREDEC set up an experiment programme on the potato late blight aiming at using the varietal resistance to supervise the fungicide control. This experiment programme is set up within the scope of the INTERREG projects Hainaut and West Flanders.

In 1999, 3 trials were set up to study the resistance to late blight.

– 2 variety showcases of 200 plants gathering ware potato varieties.
– 1 variety showcase of 24 plants combining ware varieties, starch varieties and varieties called « R ». The latest is chosen because it possesses only 1 gene of resistance (R1, R2).

Objectives

- To identify the gene of resistance « R » and the races of late blight present in the trial environment.
- To assess and compare the susceptibility to late blight of the various varieties with the view to limiting phytosanitary applications.
- To integrate the parameter of varietal resistance into the criteria of treatment triggering from the model MILSOL.

Experimental design

2 trials in large plots are set up for each variety. 100 tubers are planted, 2 replications so as to limit the environment influence and homogenise the results. No artificial contamination on the 3 trials.

Experimental design of the 2 trials and planted varieties. A trial on the resistance and the characterisation of the late blight races is set up. For each variety, 2 replications of 12 plants are planted.

Contaminating rows of a susceptible variety (Nicola) are planted in order to homogenise the natural contamination.

Results on the variety trial

The trials in large plots provide information about the earliness of attacks and the variety resistance under high pressure of disease.

Earliness of attacks

The varieties can be classified into 3 groups :

Varieties affected early **:** Bintje, Nicola, Monalisa, Ditta, Aïda

Intermediate varieties **:** Charlotte, Jenny, Juliette

Varieties affected lately**:** Santé, Raja, Naturella, Gasore, 89891, Bondeville

Resistance to late blight under high pressure

A classification of the varieties into 3 groups is carried out:

Susceptible varieties	Intermediate varieties	Resistant varieties
Bintje a *Charlotte b* Nicola b Monalisa ab	Ditta bc	Jenny de 89891 e Bondeville e Naturella e Raja e Gasoré e

Results on the investigation about the characterisation of the late blight races

- On 2 July, a few symptoms on some varieties
- On 9 July, some other varieties are affected by late blight.

➢On 16 July, there is a high development of the disease :

- over 50% of destruction on varieties
- from 10 to 25% of destruction on varieties
- less than 10% of destruction on varieties
- no symptoms on varieties

A susceptibility classification can be done.

Earliness of attacks

- **Susceptible varieties**: Charlotte, Innova, Maritiema, Agata, Russet, Bintje, Kaptha, Ostara, R3, Calgary, Ditta, Donald, Mondial, Punto, Nicola
- **Intermediate varieties**: Elkana, Monalisa, R1, R4, R7, Samba, Saturna, Victoria,
- **Resistant varieties**: Jenny, Juliette, Felsina, Santé, Bondeville, R11, Turbo, Fregate, Producent, R2, Raja, R5, R6, Naturella, R10, Gasoré
- R8

Resistance to late blight under high pressure

- **Varieties affected early :** Kaptha, Ostara, R7, Saturna, Calgary, Samba, Victoria, R4, Monalisa, Russet, R1, Agata, Ditta,
- **Intermediate varieties :** Felsina, R3, R11, Santé, Maritiema, Innova, Nicola, Turbo, Juliette, Frégate, Mondial, Elkana, Jenny, Punto, Bintje, Charlotte, Bondeville
- **Varieties affected lately :** Producent, R5, R2, Naturella, Gasoré, R10, R6, R8, Raja

Conclusion

The trial results show the interest of using the varietal resistance in the potato late blight control. The fungicide programme can be adapted to the variety. The susceptible varieties have to be treated even if the pressure of disease is low, whereas the resistant varieties require a treatment only in case of high pressure of disease. The monitoring on the late blight development on the genes R shows that the genes R1 and R11 are bypassed lately. The genes R8, R6, R9 and R10 do not display any attack of late blight. They are not therefore bypassed by late blight.

Status of *Phytophthora infestans* in Northern France since 1997: Mating type, resistance to Metalaxyl

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Introduction

The potato late blight (*Phytophthora infestans*) is the most prejudicial disease to potato crops. With the view to identifying the population present in Northern France, a monitoring has been set up by classifying the isolates according to their resistance to metalaxyl and determining their sexual type (Emery et al.).

Materials and methods

Materials

The isolates of *Phytophthora infestans* were collected from the fields, private gardens and piles of waste and volunteers. These isolates were originating for most of them from the northern part of France (areas of Nord Pas de Calais, Picardy and Champagne Ardenne)
The resistance to metalaxyl is tested on each isolate together with an identification of the mating type.

Methods

Test of resistance to metalaxyl

The method to assess the resistance to metalaxyl is that one described by the FRAC (Fungicide Resistance Action Committee) using the floating leaf disc method (Sozzi and al, 1992).

Leaf discs obtained from potatoes grown in greenhouses are cut with a cork borer. Five discs are placed in Petri dishes (55 mm diameter) containing 12 ml of water or metalaxyl (RIDOMIL 25 WP). A range of 6 doses is tested: 0.001; 0.01; 0.1; 1; 10; 100 ppm. Two replications are performed for each concentration.

Each disc is inoculated with a droplet of 10 µl of the tested isolate inoculum. The inoculum is prepared in distilled sterile water and its concentration is between 10^4 to 10^5 spores /ml. The inoculated discs are incubated at 16 °C for 7 days with a photoperiod 16h/8h. After this incubation of 7 days, each disc marked from 0 to 5 according to the percentage of the sporulating surface. The Ec_{50} is afterwards determined graphically for each tested isolate:

$EC_{50} \leq 0.01$ ppm	sensitive isolate
$0.01 < Ec_{50} \leq 10$ ppm	intermediate isolate
$Ec_{50} > 10$ ppm	resistant isolate

The sexual type determination

The isolate sexual type is determined by 2 different methods :

- *Confrontation test on V8 agar medium*

Mycelium plugs from the strain to be tested are confronted with reference strains A1 and A2 on V8 agar medium. After 10 to 12 days of incubation at 16 °C in darkness, the dishes are observed under microscope at the level of the confrontation line so as to detect the possible presence of oospores.

The oospores formation requires the two opposite mating types.

- *Confrontation test on leaf discs*

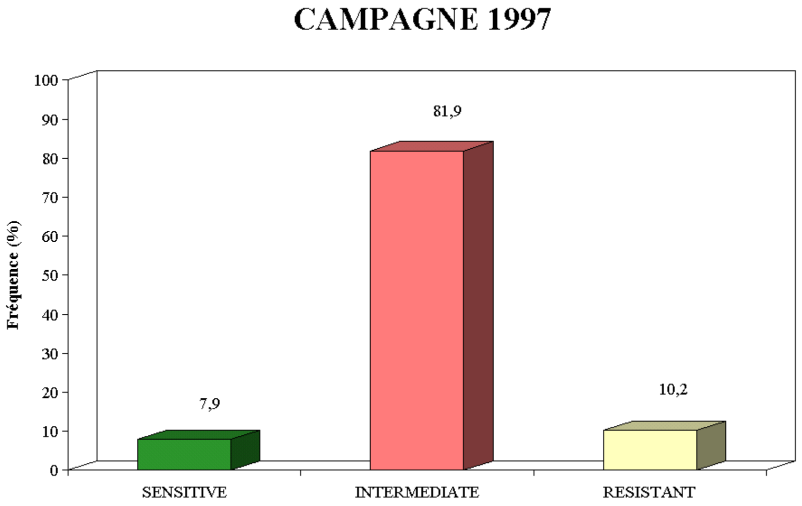
The two leaf discs are placed on water in a Petri dish. A droplet of the spore suspension (20 µl) of the isolate to be tested is laid down on each disc. Another droplet from a known isolate (A1 or A2) is laid down between 2 and 5 mm apart from the first one.

After 14 days of incubation at 16 °C with a photoperiod of 16h/8h, the leaf discs are boiled in ethanol 80%. Then, these discs are crushed under the cover glass with a mixture of glycerol 50% and examined under microscope.

If the leaf discs contain oospores, the tested isolate is rated as the opposite mating type of the known isolate.

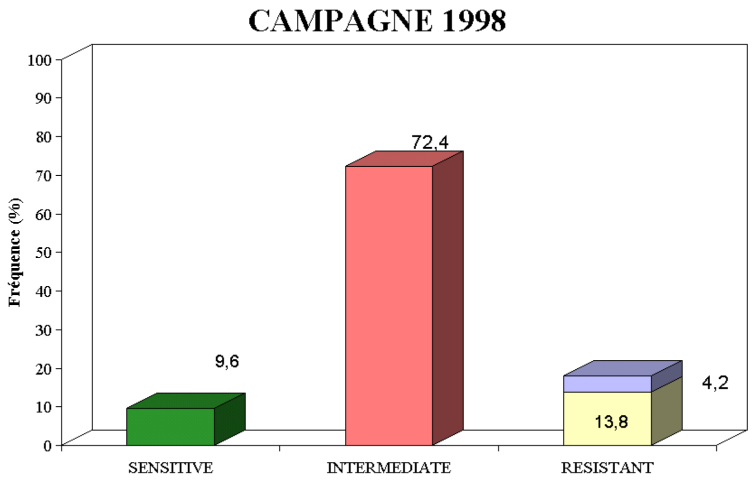
From 1997 to 1999,498 isolates have been tested for their resistance to metalaxyl and for the determination of their mating type.

Results



		Sensitive	Intermediate	Resistant	Total
Field		4	90	8	102
Garden	Potato	4	23	0	27
	Tomato	7	31	3	41
Waste piles		0	15	5	20
Volunteers		0	5	4	9

Figure 1. Results resistance metalaxyl in 1997.

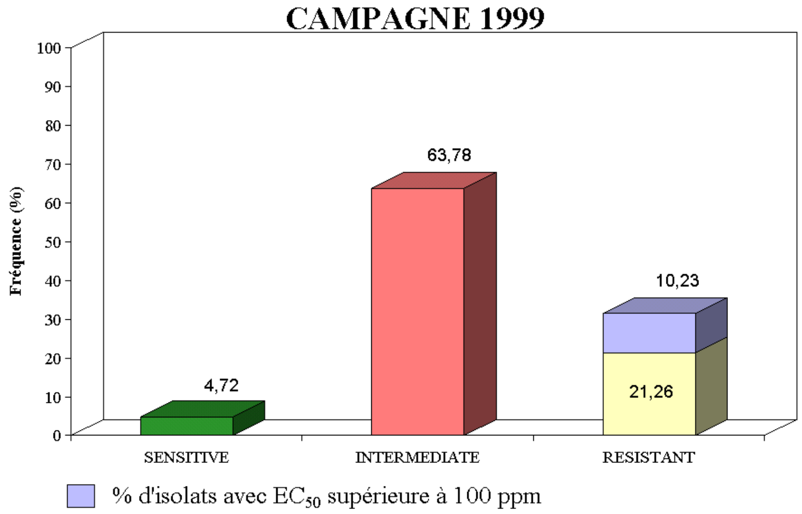


		Sensitive	Intermediate	Resistant	Total
Field		11	75	19[1]	105
Garden	Potato	3	27	2	32
	Tomato	0	5	0	5
Waste piles		1	10	6	17
Volunteers		0	3	3[2]	6

[1] 5,7 % with $Ec_{50} \geq 100$ ppm

[2] 33,3 % with $Ec_{50} \geq 100$ ppm

Figure 2. Results resistance metalaxyl in 1998.



		Sensitive	*Intermediate*	**Resistant**	**Total**
Field		3	39	23[1]	65
Garden	Potato	0	4	4[4]	8
	Tomato	0	0	0	0
Waste piles		0	8	3[2]	11
Volunteers		1	6	2[3]	9

[1] 9.2% with Ec_{50} ≥100 ppm

[2] 9.1% with Ec_{50} ≥100 ppm

[3] 11.1% with Ec_{50} ≥100 ppm

[4] 12.5% with Ec_{50} ≥100 ppm

Figure 3. Results resistance metalaxyl in 1999

Determination of the mating type

Date of sampling	Nature and origin of the sample	Direct study on leaf discs	Study by purification on the mating type isolate
		Results	Results
9/6/97	potato/field	A2	A1
6/7/97	tomato/garden		A2
7/7/97	potato/garden		A2
7/7/97	potato/garden		A2
6/7/97	tomato/garden		A2
10/7/97	potato/field		A2
15/7/97	tomato /garden		A2
16/7/97	potato/field		A2
16/7/97	potato volunteers		A2
21/7/97	tomato/garden		A2
24/7/97	tomato/garden		A2

In 1997, 11 isolates A2 were detected in Northern France. In 1998, only one isolate A2 was found on tomato in a garden.

Comments

Most of the isolates are originating from commercial fields of potatoes. Over these 3 last years, the proportion of resistant isolates increased (10.2% in 1997, 18% in 1998 and 32.3% in 1999).

Since 1998, we have been noticing a significant proportion of isolates (4.8% in 1998 and 10.23% in 1999) for which the Ec_{50} value is higher than 100 ppm. A change in the level of resistance does exist for these two last years. That fluctuation in the proportion of resistant isolates is difficult to account for with the use of metalaxyl fungicides.

Most of the resistant isolates come from production areas (gardens, volunteers…) where metalaxyl is not used in an excessive way.

However, the intermediate class remains predominant among the tested isolates. In 1997, 11 isolates A2 (4.4% of the population) were found. Most of them were originating from tomato or potato crops in gardens. Gardens did play an important role in the expression of this kind of strain (juxtaposition of different varieties stemming from several origins, short rotation and waste).

In addition, the number of isolates tested in 1997 was very high, it is so difficult to assert if the expression of these strains A2 is a new phenomenon or if the high number of samples favoured the expression of this type of strains.

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Comparison of Smith Periods recorded in the field with those from the synoptic stations for the forecasting of potato late blight caused by *Phytophthora infestans*

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Summary

Meteorological data were obtained from in-field weather stations via cellphone analogue networks at eight sites: Downderry, Lostwithiel and Polpever in Cornwall, Trawsgoed in Wales, Harpenden in Hertfordshire, Arthur Rickwood in Cambridgeshire, Cawood and High Mowthorpe in North Yorkshire, between 1996 and 1998. The sites were chosen to provide a range of disease pressures and crop development relative to infection date. The occurrence of Smith Periods as recorded by in-field monitors were compared with those at the nearest synoptic meteorological stations and at stations at least a further 15 and 45 km radius from each site. Overall, the differences in forecasting the first occurrence of blight between the stations for a single site were not significant and it is concluded that there is no advantage in using in-field weather stations for recording Smith Periods. The results suggest that forecasting schemes should only serve as an aid to decision making in relation to fungicide application and to be effective they require intelligent interpretation together with knowledge of both crop and disease development in a locality.

Key words: Smith Period, forecasts, potato blight, weather

Introduction

The national potato late blight forecasting scheme used in the UK is the Smith Period (Smith, 1956). Interest in forecasting for potato blight in the UK began in the 1930s when

Beaumont (1947) evaluated the Dutch Rules (van Everdingen, 1926) in the south-west of England. These parameters proved to be unsatisfactory as there was an unacceptable period between the predicted outbreak of blight and its actual occurrence. Beaumont (1947) recognised the importance of high humidity and its duration. The 'Dutch Rules' relied upon dew. Beaumont considered humidity to be more important as, during a period of high humidity, there was no wind and the nightly drop in temperature was most likely to result in dew formation and leaf wetness. The Beaumont Period was evaluated by Large (1953; 1956) over a period of five years (1950-1955). He concluded that 'an "operations-chart" method of interpreting the occurrence of Beaumont periods in screens at standard weather stations (about 40 synoptic weather stations were used) enables broad regional forecasts of the date of blight outbreaks to be made successfully in England and Wales, provided that the indications from the whole network of stations were taken into account and due regard paid to the seasonal and regional differences in the forwardness of crops'. It was important, therefore, that a number of synoptic sites reporting Beaumont Periods were interpreted rather than relying on a single station for decision making for an individual locality.

Large (1956) used the term 'flushes' of periods from a number of stations. Only when a number of stations in a region are recording blight conditions should action be considered. Smith (1956) reworked the 1950-1955 operations charts of Beaumont to test the validity of using a shorter period of higher humidity of 90% for 11 h in each of two days instead of the 75% for 48 h. It was not until 1975 that the Smith period came into full operation and formed the basis of blight forecasting by the agricultural extension services in the UK. The recent development of reliable, inexpensive, in-field weather stations has created an interest in using them to provide forecasts. The absence of bespoke models for 'in-crop' monitors has meant that Smith Periods have been used as the forecasting scheme in many instances. This paper compared the meteorological output of weather stations in relation to the Smith Period at a range of spatial scales in order to determine whether in-field weather stations improve on the accuracy of blight forecasts.

Methods

Meteorological data were obtained from in-field weather stations via cellphone analogue networks at eight sites: Downderry, Lostwithiel and Polpever in Cornwall, Trawsgoed in Wales, Harpenden in Hertfordshire, Arthur Rickwood in Cambridgeshire, Cawood and High Mowthorpe in North Yorkshire between 1996 and 1998 by the methods of Hims *et al*. (1995). The sites were chosen to provide a range of blight infection pressures and crop development relative to infection date (Fig. 1). The cultivar used was King Edward which is highly susceptible to foliar blight (Anonymous, 1999). Smith Periods were calculated from the data collected by the in-field weather stations. Dates on which Smith Periods occurred for the synoptic stations were supplied by the Meteorological Office. The occurrence of Smith Periods as recorded by the in-field monitors were compared with those at the nearest synoptic stations and at stations at least a further 15 and 45 km radius from each site. Crops were monitored regularly for the first outbreak of blight. The occurrence of blight and the first Smith Period recorded in-field and at the synoptic weather stations were compared using single factor analysis of variance on the means for the in-field monitors and each of the synoptic station groupings.

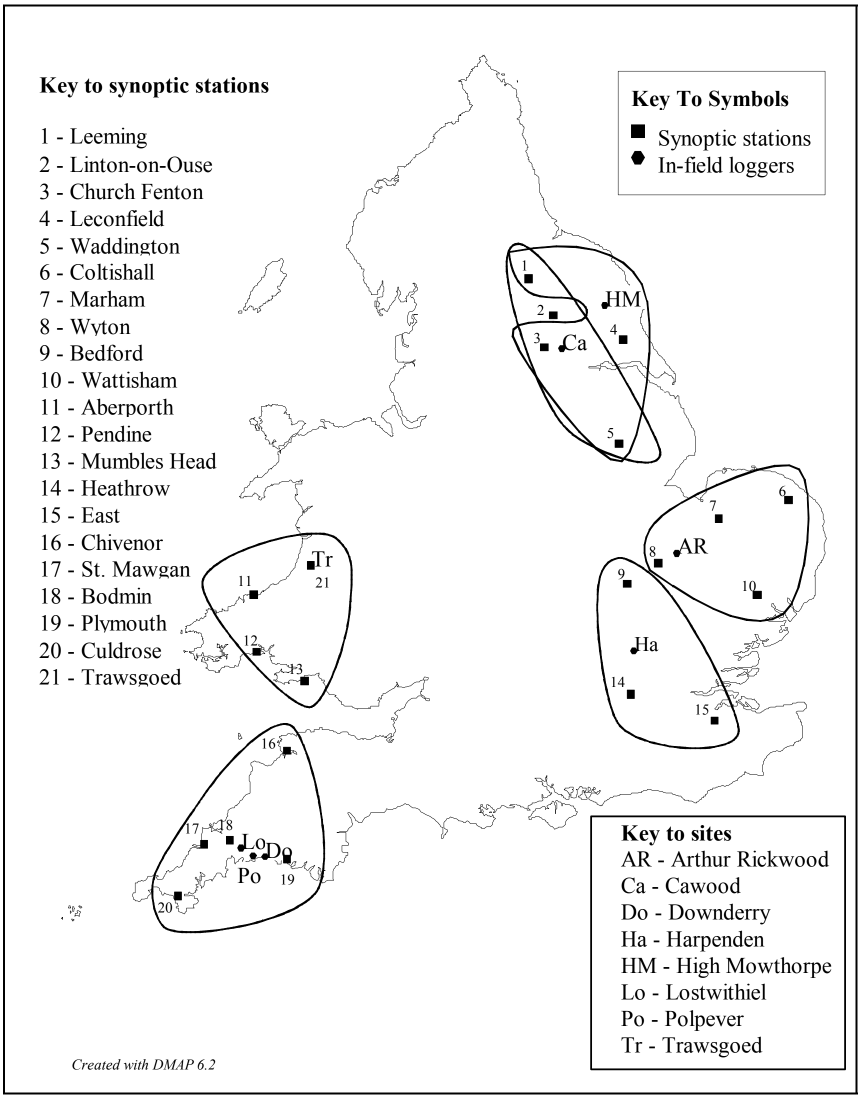

Figure 1. Map of sites and location of stations

Results

The time from the first Smith Period to the first outbreak of blight varied both within and between sites (Table 1). Blight was not recorded at the Arthur Rickwood or Harpenden sites in 1996. At one site in each of the three years blight occurred in the trial before a Smith Period was recorded. This occurred in 1996 at High Mowthorpe where blight was recorded 26 days prior to a Smith Period being recorded at the station at Church Fenton 55 km away. The stations at Leconfield (28 km away) and Waddington (104 km away) recorded a Smith Period only three days prior to blight being found. The in-field station, however recorded a Smith period 34 days in advance. At the Trawsgoed site in 1997, blight was recorded six days before the nearest synoptic station at Trawsgoed recorded a Smith Period. However, both the in-field and stations at Aberporth and Mumbles Head (48 and 86 km away, respectively) were consistent in being 27, 26 and 26 days in advance respectively. In 1998, the in-field weather station at Trawsgoed recorded a Smith Period 34 days after blight appeared in the trial (a sensor was thought to be reading incorrectly). The synoptic stations at Trawsgoed, Aberporth and Pendine (75 km away) were in accord, forecasting blight 11 days ahead of the outbreak.

There were differences in response at the sites. The Cornish sites showed least variability between the in-field and synoptic stations in each of the three years. In 1996, all forecasts were over-cautious, indicating a blight risk from between 34 and 52 days before it occurred. Smith Period output in relation to the High Mowthorpe site was also very variable in 1996 but in 1997 there was good agreement between the in-field and nearest synoptic station and between the two more distant stations. In 1998, the two more distant synoptic stations were in close agreement with the in-field station, warning eight days earlier than the nearest station at Leconfield. There was little agreement between the in-field monitor at the Cawood site and synoptic stations in 1997 but in 1998 all the synoptic stations gave identical forecasts which were seven days behind the in-field monitor.

Over all, the differences between the stations for a single site were not significant (P =< 0.05) (Table 1).

Table 1. Number of days between the first Smith Period and the first record of blight at each of the trial sites in 1996, 1997 &1998 (a negative figure indicates blight was found in the crop before a Smith Period was recorded).

Site	Location & type of weather station			
	in-field	synoptic		
		nearest	at least 15 km from site	at least 45 km from site
1996				
Arthur Rickwood	NB*	NB	NB	NB
Harpenden	NB	NB	NB	NB
High Mowthorpe	34	3	-26	3
Downderry	52	53	47	34
Trawsgoed	34	34	35	32
1997				
Arthur Rickwood	17	4	4	4
Cawood	27	11	11	20
High Mowthorpe	24	22	13	13
Lostwithiel	19	18	12	19
Trawsgoed	27	-6	26	26
1998				
Arthur Rickwood	8	5	9	15
Cawood	21	14	14	14
High Mowthorpe	22	31	23	23
Polpever	16	17	17	17
Trawsgoed	-34	11	11	11
Mean	21	17	15	18

NB - No Blight

Discussion

These data suggested that there was no advantage in using in-field weather stations for recording Smith Periods used to predict the occurrence of potato late blight. The UK synoptic network provided an accurate and reliable forecast when using a robust scheme such as Smith and Beaumont Periods which rely on simple meteorological parameters, i.e. temperature and humidity. In the operation of the Beaumont Period, Large (1959) stated that periods reported from single sites were sometimes incorrect and the accuracy in regional forecasting was increased when the periods were added to an ‘operations chart’ and flushes of periods from a region taken as the indicator of risk. This reduces the risk of errors from one station and also from particular weather events that were not representative of the location of the crop. It was expected that by using in-field weather stations the accuracy of blight risk prediction could be improved. However, if the optimum forecasting period was 14 days in advance of blight appearing in the crop (Large, 1959) failures occurred at all but two sites, Arthur Rickwood in 1997 and Popover in 1998. No site, was consistent over the whole range of spatial scales. Therefore, forecasts that rely on one station, regardless of distance from the crop, cannot be considered safe for a number of reasons, not least the accuracy of the instrumentation (Hardwick, 1998; Taylor *et al.*, 1998). It is important that the data, from what ever source it originates, is evaluated as part of a network.

The variation in the topography of sites in relation to synoptic stations was not explored. However, most of the stations in the synoptic network are located at airfields and are predominantly in more open, often flatter, locations. Arthur Rickwood, being located on the Cambridgeshire Fens is probably most accurately represented by its local synoptic stations, whereas High Mowthorpe in the Yorkshire Wolds is represented by sites in the Vale of York which are in a more open area of the country. Despite this, there is no evidence of improved forecasting from the synoptic network at Arthur Rickwood compared with High Mowthorpe. Blight forecasts are potentially an important tool in optimising pesticide use and achieving improved gross margins in potato production. However, farmers' expectations of such schemes, and their accuracy, is generally unrealistic but they will undoubtedly loose confidence when disease forecasting schemes fail. It remains the case that forecasting schemes for potato blight should only serve as a guide. To be successful they require intelligent interpretation based on experience of the crop and disease development in a particular locality.

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Two Decades of Phenylamide Resistance Monitoring

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Resistance to metalaxyl was confirmed in isolates of *Phytophthora infestans* (Mont.) de Bary from a field crop in 1980. (Dowley & O'Sullivan, 1981). This was the first record of phenylamide resistance in commercially grown potatoes. In 1981 phenylamide based products were withdrawn from use in Ireland. In the same year a monitoring programme was initiated to determine the distribution of phenylamide resistance in the main potato growing areas of the country.

Crops in the main potato growing areas of the country were sampled at random. Four samples of 100 infected leaves were taken from each hectare sampled and tested for phenylamide resistance. A sample was considered to contain phenylamide resistance when leaf discs developed complete necrosis accompanied by sporulation at all levels of metalaxyl

The % of crops with resistance present was highest in 1981 but fell rapidly in the absence of phenylamide use between 1981 and 1984 (Dowley & O`Sullivan, 1985). Penylamides were reintroduced to the Irish market in 1985 following an early and severe outbreak of late blight. Despite the existence of an anti-resistance strategy the use of the phenylamides was largely curative between 1985 and 1989 (Dowley & O`Sullivan, 1991). This resulted in a rapid increase in the number of farms with phenylamide resistance present. From 1990 onwards there was close adherence to the anti-resistance strategy and as a result the distribution of phenylamide resistance again declined.

In the 1990's phenylamide resistance was confined to about 50% of crops tested. This figure increased slightly when late blight appeared early in the season and coincided with the application phenylamide based sprays. A drop in the distribution of phenylamide resistance was recorded when late blight appeared late in the season. Seasonal distribution of resistance also confirmed that resistance distribution increased as the season progressed.

Field trials confirmed that where phenylamide/mancozeb mixtures were used according to the anti-resistance strategy there was excellent control of both foliage and tuber blight even in the presence of phenylamide resistant strains (Dowley, 1994).

Conclusions

- Phenylamide resistance increased following curative application of phenylamides
- Phenylamide resistance decreased where the anti-resistance strategy was followed
- The distribution of phenylamide resistance increased consistently from the beginning to the end of each season
- Phenylamide/mancozeb mixtures gave good control of foliage and tuber blight when used according to the anti-resistance strategy.

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