PAV-Special Report no.5

January 1999

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

Uppsala, Sweden, 9-13 September 1998

Huub Schepers & Erno Bouma (eds.)

Funded by European Commission in the FAIR programme
Proj. Nr. FAIR1-CT95-0206

COMMISSION
OF THE EUROPEAN
COMMUNITIES

Applied Research for Arable Farming and
Field Production of Vegetables

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

Uppsala, Sweden, 9-13 September 1998

Funded by European Commission in the FAIR programme
Proj. Nr. FAIR1-CT95-0206

Huub Schepers & Erno Bouma (eds.)
Applied Research for Arable Farming and
Field Production of Vegetables
P.O.-Box 430
NL-8200 AK Lelystad
Tel: +31 320 291111
Fax:+31 320 230479

ISSN: 1386-3126

PAV-Report no. 5 January 1999
Publisher:
Applied Research for Arable Farming and
Field Production of Vegetables
P.O. Box 430
NL-8200 AK Lelystad

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

H.T.A.M. Schepers

Third Workshop, Uppsala, 1998

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 Uppsala, Sweden, 9-13 September 1998. The Workshop was the third of four Workshops 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 were formed on epidemiology, fungicides and Decision Support Systems. In these sub-groups first steps were made towards on indication gaps and co-ordinating ongoing research.

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

Secretariat
Research Station for Arable Farming
And Field production of Vegetables
P.O.-Box 430
NL-8200 AK Lelystad
ATT: H.T.A.M. Schepers
Telephone +31 320 291111
Telefax +31 320 2340479
E-mail: H.T.A.M.SCHEPERS@PAV.AGRO.NL
http://www.agro.nl/pav/pavintp2.htm

Contents

Third Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

The development and control of *Phythophthora infestans* in Europe in 1998

H.T.A.M. SCHEPERS
Applied Research for Arable Farming and Field Production of Vegetables
P. O. Box 430, 8200 AK Lelystad, The Netherlands

Abstract

In most European countries the first recorded outbreak was again earlier than in 1997. This early appearance of the fungus is certainly influenced by the favourable weather conditions in 1997 and 1998, but an influence of a new type of population of *Phytophthora infestans* cannot be excluded. For 1997 and 1998 the (very) **early** outbreaks of the disease do not correspond with the english name for the disease namely **late blight**. In the north of Europe where rainfall was abundant and temperatures moderate, the epidemic developed progressively and caused severe damage. In the south of Europe weather was dry and warm and *P. infestans* could be effectively controlled.

Introduction

From 9-13 September 1998 a Workshop was held in the framework of a Concerted Action on control of *Phytophthora infestans*. Representatives from 17 European countries presented the development and control of late blight in their country in 1998. In this paper these presentations are summarised. The weather conditions of 1998, the disease progress and the input of fungicides are presented.

Weather conditions

In the district of Emilia Romagna (**Italy**) hardly any rain was recorded during the 1998 growing season whereas the temperatures were often higher than 30 °C. Due to these unfavourable conditions for late blight no disease symptoms were observed in potato crops. In tomatoes the first observations of blight outbreaks were recorded in June. In the Basque Country (**Spain)** the growing season was characterised by very high temperatures resulting in a very low blight pressure. The disease was only observed in 1% of the potato fields in this district. In **Switzerland** the first blight attack was registered already on 6 May in a polythene covered crop in the western part of the country. From the beginning of May until the end of July, 12 high risk periods, characterised by "Main Infection and Sporulation Periods" (MISP's), were observed in 1998. This is a considerably lower number than in 1997 when 21 MISP's were recorded in the same period. The lower number of critical periods together with exceptionally dry and warm weather between the MISP's reflects a situation that was not favourable for blight. In **Austria** the onset of the epidemic was early but the relatively dry and warm weather conditions only allowed a weak epidemic of blight. *Alternaria solani* was causing more problems than *P. infestans*. In **Romania** the weather conditions in spring were favourable for blight, primary infections appeared at least two weeks earlier when compared to 1995-1997. After abundant rainfall in May, June and the second half of July, a dry and hot (>30 °C) period stopped the further development of the disease. In **Northern Germany** the continuous rainfall in June and July caused an early outbreak of blight and very severe epidemics, especially in organic crops. In **Southern Germany** higher temperatures and less rain was recorded, resulting in a later occurrence of blight and a less severe epidemic. In the North of **France** the first blight was observed on a waste pile in the beginning of June. A lot of rain in the beginning of June promoted infections and sporulation of *P. infestans*. At the end of June the disease spread because of continuous rainfall. In some fields 30-50% of the foliage was destroyed. Many rain showers maintained the disease pressure in July, in August the disease pressure decreased because of dry and hot weather. At the end of August and beginning of September rain showers created favourable conditions for the fungus once again. In **Belgium** high risk weather conditions are used by the Guntz-Divoux model to recommend sprays. In the wet months June and July this resulted in 4 and 5 spray-recommendations, respectively. The first blight was observed in a polythene covered crop on 28 April, two weeks earlier than in 1997. In **The Netherlands** the first report of blight was in the beginning of May in a polythene covered crop in the south-west. Like in all other north-west european countries the continuous rainfall favoured the development of blight and the number of infected fields increased rapidly in June and July. The warm and dry weather in August prevented a further development of the disease. In **England** and **Wales** the first confirmed blight outbreaks came at the end of May from polythene covered crops. Due to almost continuous rainfall and moderate temperatures in June and July the disease spread very quickly to many potato growing areas. In August and September the weather changed to drier and warmer and blight became less of an issue. In south-west **Scotland** the disease pressure was the highest recorded in the past 12 years. In the south-east, the majority of the crops had some blight. In the north-east, 1-5% of the crops were affected at low levels. In **Northern Ireland** the first initial outbreak was on 28 May in a dump and 8 June in a field. In some areas the blight pressure remained very high all summer. Up to 31 August, 8 Smith periods were recorded, comprising a total of 31 days conducive to blight spread. In **Ireland**, June was wetter than in 1997, but the total rainfall during the growing season was lower than in 1997. Also the accumulated risk value was in 1998 lower than in 1997. Although blight appeared earlier than in 1997 the epidemic was less severe, mainly because of the dry July and August.

In **Poland** the disease was first observed in the beginning of June, two weeks earlier than in 1997. The disease spread rapidly over the country in June and July but the warm and dry weather in August stopped the epidemic. Due to regular rainfall during June, July and August, the weather conditions in **Latvia** were very favourable for the development of late blight. In 1998, as in 1997, blight appeared almost one month earlier than in 1996 and 1995. In **Finland** blight appeared in general 1-2 weeks earlier than in 1997. The favourable blight weather, infected seed potatoes and volunteer plants led to the development of blight in most fields, in 10% of the fields the epidemic was severe.

In **Sweden**, like in many other countries the planting of the potatoes was late due to bad weather conditions. Blight was first observed in the south-west of Sweden around 15 May in a polythene covered crop. The first attacks in this area have been found earlier and earlier during the 90's and there is a suspision of soil-borne inoculum (oospores) in this area. In June, July and August it rained very much and blight could spread in the whole of Sweden as far north as Boden (65° 50' N, 21° 45'E). Only once or twice in 10 years blight can be found in the whole of Sweden. In **Norway**, June and July were exceptionally wet resulting in an early observation of blight on 20 June in the south. In the main potato growing areas blight appeared also 2-4 weeks earlier than normal, also more stem blight was observed. In **Denmark** the first blight was observed on 16 June, two weeks earlier than in 1997. The favourable weather conditions resulted in the earliest blight warning in 20 years. One week later numerous blighted fields were reported. As in the other Scandinavian countries the epidemic in Denmark was very severe.

Fungicide input

The combination of very early blight observations together with prolonged periods of rain resulted in an early start of fungicide sprays. Many farmers started spraying too late and could not spray when blight appeared because of waterlogged fields and rain. During the growing season it was sometimes impossible to achieve adequate spray intervals, because of waterlogged fields, vigorous haulm growth and collapsed canopies. Application by aeroplane was in some cases the solution to this problem. In The Netherlands farmers wanted to apply eradicant/curative fungicides on their affected fields by aeroplane, but because of environmental side effects of these fungicides, no permission was given. Due to frequent use the availability of some fungicides during the season was low. The choice of fungicides was in many cases not only influenced by its biological properties but also by its availability on the market. Metalaxyl was often used curatively or as an eradicant. The selection pressure for fungicide resistance is increased by this use, in some cases poor efficacy of metalaxyl was explained by resistance. In the UK the use of adjuvants that increase rainfastness was reported. In Poland about 40% of the 1310000 ha of potatoes is treated with an average of 1.7 sprays per season.

Tuber blight

Only a few reports were available on the occurrence of tuber blight, mainly due to the late season. Harvesting conditions are in some cases extremely difficult with a lot of soil adhering to the tubers. These conditions might favour the development of tuber blight. In Romania it is estimated that 10-15% yield loss is caused by tuber blight. In England and Wales tuber blight was only reported in poorly sprayed crops.

Organic crops

In north Germany and The Netherlands severe epidemics with high yield losses occurred. Because of these extremely favourable conditions for late blight, a special registration was issued for use of copper in organic crops in Germany and The Netherlands. In Scotland, Belgium and Austria copper is registered for use in organic crops for a number of years already, in 1998 it was used on almost all organic potato crops.

In Scandinavia copper is not registered in organic crops. In Norway the yield of organic crops is estimated to be much lower than normal. In Sweden most organic fields were heavily infected and a lot of tuber infection was observed. Fields in some areas were ploughed under because of early attacks of late blight. About half the normal harvest is expected. In Finland some late emerging crops that were infected very early by blight were completely destroyed before tubers were formed. In Denmark early and heavy attacks were observed in organic crops.

Table 1. Weather conditions favourable for the development of late blight and dates of first recorded outbreaks of blight in potato in 1998 in relation to other years.

	May	June	July	August		First outbreak			
						1998	1997	1996	1995
Austria	*	**	**	*		25 June	17 July		
Belgium	**	***	**	*		28 April[1]	15 May[1]	September	30 May[1]
Denmark	***	***	***	**		16 June	end June	begin July	20 June
Finland	**	***	***	**		20 June	1 July	17 July	26 July
France	**	***	**	*		20 April[2]	23 May[2]	13 June[2]	1 April[2]
Germany	**	***	***	**		5 June	30 May	12 June	19 June
Italy	*	*	*	*		no blight	no blight	19 May	30 May
Ireland	*	***	*	*		1 July	25 July	28 July	15 August
Latvia	**	**	***	**		20 June	25 June	25 July	1 August
Netherlands	**	***	**	*		beginning May	2 June		
Norway	*	***	***	***		20 June[1]	6 August	29 July	
Poland	**	***	***	*		beginning June	end June		
Romania	***	***	**	*		3 July	25 July	23 August	20 July
Spain	*	*	*	*		15 June	1-7 June		
Sweden	***	***	***	**		15 May[1]	24 May[1]		
Switzerland	*	*	*	**		15 May[1]	16 May	23 May	29 April
United Kingdom									
*Northern Ireland	**	***	***	***		28 May[2]	30 May	27 June	20 June
*England/Wales	**	***	***	**		31 May[1]	29 May		
*Scotland	**	***	***	**		25 June	3 July		

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

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

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

	Average number sprays/season		
	1996	1997	1998
Austria	4-6	5-6	?
Belgium	8-12	14-15	12-14
Denmark	6	7-10	4-12
Finland	3-4	4-5	3-8
France	9-11	11-14	?
Germany	5-6	7-9	3-10
Italy	6-8	6-8	4-5
Ireland	?	?	?
Latvia	1	2	7
Netherlands	5-12	7-15	7-15
Norway	2.9	4	5
Poland	1.6	1.7	1.7
Romania	2-4	4-7	3-4
Spain	3	5-6	3
Sweden	4-7	4-7	4-12
Switzerland	6-7	7-9	5-7
United Kingdom	2-10	4-18	?
*Northern Ireland	2-10	3-15	4-16
*England/Wales	?	?	?
*Scotland	?	?	(1997)+2

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

Report of the meeting of the Subgroup Epidemiology

DIDIER ANDRIVON

INRA, Station de Pathologie Végétale, BP 29, F-35653 Le Rheu Cedex, France

Participants: N. Adler, B. Andersson, G. Ampe, D. Andrivon (chair), R. Bain, C. Chatot, L. Cooke, A. Hermansen, E. O'Sullivan, M. Ruckstuhl, M. Sandström, B. Schöber-Butin, D. Spikerboer, A. Strömberg.

The third meeting of the subgroup on Epidemiology of *Phytophthora infestans* took place in Uppsala, Sweden on September 12th, 1998. Discussions focused on four major topics.

Cultivar resistance and its use in integrated control strategies

All participants in the subgroup agreed that cultivar resistance is a major factor to be implemented in integrated control strategies of late blight. However, the general impression is also that resistant cultivars are not as widely used as they might be. Two main questions therefore arose: 1) how to manage the resistance that is currently available? and 2) how to convince growers to switch to more resistant cultivars. The discussion on these two questions highlighted that the pressure of 'end-users' (industrial groups, marketers, etc...) is determinant in the choice of cultivars by the growers. Most participants thought that the technical information (e.g., relative performance of resistant vs susceptible cultivars, amount of fungicide that can be saved by growing resistant cultivars, etc...) required to convince the 'true' decision-makers is available, but is usually not distributed to the correct persons. The subgroup therefore recommends that industrials and policy-makers (e.g., representatives of supermarkets...) be invited to the next workshop of the Concerted Action.

Population biology and epidemiology

Three topics for study emerge from the presentations at the workshop and discussions between participants: the biology and epidemiological significance of oospores; the relationships between stem and leaf blight; and the factors influencing tuber blight. The discussions within the subgroup outlined the fact that while the trend towards earlier outbreaks observed in 1998 may be circumstantial, there is an urging need to globally reappraise the part and incidence of the various sources of initial inoculum (especially oospores and tuber infections) in early outbreaks, and to determine the conditions leading to their prevalence. This can be best done by 'dissecting' early infections, either in growers fields (scouting the first outbreaks and identifying their cause) or in experimental field plots. Several groups involved in the Concerted Action are active in the field of oospore biology (particularly in Nordic countries), and in investigations of stems and tuber blight (Scotland, Germany, France). These investigations will be carried on, and more data on these topics should be presented at the next workshop.

Exploitation and dissemination of the information gathered in the questionnaires

All participants in the subgroup thought that the information about population structures and aggressiveness of *P. infestans* populations in Europe should be disseminated and updated to remain useful. Most of the discussion centered around the way to to so most efficiently. It was agreed that D. Andrivon will prepare a report along the lines of the presentation made at the workshop for inclusion in the proceedings. Most participants also thought it useful to design a Web page to disseminate the information collected to groups not particpating in the Concerted Action, and who might not get the Proceedings. The question of reaching groups (both within and outside the Concerted Action) who currently do not have an easy access to the Internet was discussed. It was decided that the contents of the Web pages (probably more detailed than the report in the Proceedings) would be mailed to unconnected members of the Concerted Action. As far as updating is concerned, it did not seem useful to send the questionnaire again to the groups who received it in 1998, since there would most likely not be much to be updated; however, the questionnaire will be sent to the groups from eastern Europe who joined the meeting in Uppsala, since information from these countries will most usefully complement that already available from western European countries.

Projects

One of the goals of Concerted Actions is to have proposals for research projects emerge and mature. In the field covered by the subgroup, preliminary discussions have been engaged at the workshop to set up a research proposal on the epidemiology of 'new' populations of *Phytophthora infestans* in Europe. The possibility of having a project related to the performance and mechanisms of action of cultivars associations is also investigated. As far as the concerted Action itself and the possibilities it offers for short-term exchange of scientists are concerned, it was felt by most participants that short-term visits are difficult to organise in a productive way in the areas covered by the group, simply because of the average length of experiments. Therefore, no plans for such exchanges were envisioned for the coming year.

I would like to thank all participants in the discussion for very lively and useful exchanges, and I look forward to many interesting presentations at the workshop in Belgium in 1999.

Report of the sub-group discussions on the practical characteristics of potato late blight fungicides

Participants: Nick Bradshaw (Chairman, UK), Jan Bouwman (The Netherlands), Constantin Draica (Romania), Serge Duvauchelle (France), Johann Habermeyer (Germany), Asko Hannukkala (Finland), Howard Hinds (UK), Josefa Kapsa (Poland), George Little (UK), Raquel Marquinez (Spain), David Michelante (Belgium), Huub Schepers (The Netherlands), Elizabeth Schiessendoppler (Austria)

Objective:

The main objective of the sub-group was to discuss the summarised responses to the questionnaire relating to fungicide efficacy which had been circulated previously to sub-group participants during 1998. The responses had been collated by Schepers (NL) and included information from research institutes/ extension organisations and agrochemical companies/ approval holders in the various participating countries (PAV-Special Report No.3, January 1998, pp15-22).

There was general agreement for many attributes relating to the effectiveness and mode of action of some late blight fungicides. However, in many instances, different ratings were given by respondents which reflected the wide range of formulations/co-formulations marketed in the participant's countries and also the varying application rates used. It was therefore impossible to reach a concensus solely on the questionnaire responses. The sub-group discussed and agreed ratings for the activity of the eleven most important active ingredients used within Europe based on a specified spray interval. These ratings were intended as a guide for the development of new Decision Support Systems or the improvement of existing ones.

Although the ratings given were subjective, as no experimental data was available comparing all the active ingredients for all attributes, they were made taking into account questionnaire responses and the participants' own experiences. The ratings were given using the following key :- 0 = no effect ; + = reasonable effect ; ++ = good effect ; +++ = very good effect. Ratings in the table assume a phenylamide-sensitive population.

However, strains of blight resistant to phenylamide fungicides occur widely within Europe and phenylamides are available only in formulations which also contain protectant fungicides. 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 a substantial proportion, curative activity, protection of new foliage and the effect on tuber blight will be reduced.

It was apparent from the discussions that definitions were needed to clarify some of the attributes given to late blight fungicides. Definitions of protectant, curative & eradicant activity were proposed by Schepers - NL and agreed by the sub-group as follows:

Protectant activity - Spores killed before 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

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.

The sub-group were keen to ensure that accurate information on the effectiveness & mode of action of fungicide active ingredients was made available by the agrochemical companies. The sub-group chairman (Bradshaw -UK) would therefore welcome comments from other researchers and agrochemical companies which could further improve the accuracy of the ratings.

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.*

Table 1. 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 Uppsala workshop, 1998.

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	++(+)	++	++	+++	++(+)	++(+)	++(+)	+++	systemic
oxadixyl*	10	++(+)	++	++	++	++(+)	++(+)	++(+)	+++	systemic
copper	7	+	0	+	+	+(+)	0	0	+	contact
chlorothalonil	7	++	0	(+)	0	++	0	0	++(+)	contact

*** = See text**

Third Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

Report of the discussions of the Subgroup DSS

JENS GRØNBECH HANSEN

Danish Institute of Agricultural Sciences
Department of Agricultural Systems,
Research Group for Informatics and Agrometeorology
Research Centre Foulum, DK-8830, Denmark

Participants

Pieter Vanhaverbeke, Andre Verlane, Riccardo Bugiani, Nigel Hardwick, Benno Kleinhenz, Ludovic Dubois, Roland Sigvald, Robert Leonard, Markus Ruckstuhl, Erno Bouma, Gheorge Olteanu, Inara Turka, Laura Cobelli, Hans-Rudolf Forrer, Wim Nugteren. Poul Lassen and Jens G. Hansen (Chairman of subgroup DSS)

Subject areas:

1. Description of DSS's
2. Validation of DSS's with historical data. Including components and consequences of new Phytophthora population for DSS's
3. Protocol for field trial validation of DSS's
4. Availability and use of meteorological data for late blight DSS's
5. Internet monitoring system for late blight.

Description of Decision Support Systems (DSS) for the control of potato late blight

A report with a description of several DSS's was presented including: ProPhy, *The Netherlands,* NegFry, *Denmark,* Simphyt, *Germany,* Plant-Plus, *The Netherlands,* Televis,

Norway, Guntz-Divoux, *France,* Guntz-Divoux, *Belgium*, I.P.I.*, Italy,* PhytoPRE+2000*, Switzerland.*
The report should be finalised by Erno Bouma. All participants of the DSS subgroup will receive a full report, and an extract of major results will be published in the workshop proceedings.

Validation of DSS's with historical data. Including components and consequences of new Phytophthora population for DSS
Results from validation on historical weather data was presented for Plant-Plus, NegFry and Prophy. It was decided to compare the different DSS's forecast of first spray for datasets: Ask97 (Denmark), Ch97reck (Switzerland), Mezool97 and 98 (Italy), DK97_27 (Belgium) and HH_tra97 (UK). Secondly to compare the recommendation of subsequent sprays based on fixed dates of first application for each dataset. Risk periods or daily values for disease development should be calculated during the season and compared in one graphics including Plant-Plus, Prophy, NegFry, SIMPHYT, I.P.I., MISP, Smith periods and Guntz-Divoux. If possible results should be published in the workshop proceedings.

Protocol for field trial validation of DSS's
A proposal for a protocol for DSS field trial validation by Benno Kleinhenz and others was discussed. A revised proposal should be published in the workshop proceedings. Responsible: Nigel Hardwick and Benno Kleinhenz.

Partners from four countries expressed their interest in performing a field trial validation of more DSS's in 1999: Holland, UK, Ireland and Germany. Benno Kleinhenz where appointed responsible to co-ordinate the plans and to make time schedules for this action. Four DSS's was suggested for validation at two or more sites in Europe: Plant Plus, Prophy, NegFry and Simphyt.

Model builders agreed to meet at two locations in May to ensure a proper DSS installation and to have a training course in the practical use of each DSS.

Availability and use of meteorological data for late blight DSS's

Results of a questionnaire on availability and use of meteorological data for DSS's was presented by Erno Bouma. The need for update and corrections of the results was identified. More than 50 % of the users of weather information had answered that quality control of the weather data was not a routine procedure. Many late blight forecasting models and methods are based on weather data and bad weather data can lead to wrong decisions. Therefor the quality of weather data should have much attention in the future, and it was decided to add more questions about quality control of weather data before the finalisation of the questionnaire report.

Internet monitoring system for late blight

An Internet monitoring system for early attacks of late blight was presented by Jens Grønbech Hansen. This system was developed for the 1998 season as a component of an Internet based Nordic warning system for potato late blight. Data recorded in the monitoring system are used for i) warning services by the extension service ii) validation and improvement of existing forecasting systems and iii) analysis of the importance of local climate, crop rotation, crop resistance etc. for very early establishments of primary attacks. Samples of plant material and soil from primary attacks will be investigated for late blight mating type and presence of oospores. In the future this system will be extended to include more countries and in operational use the system will be used to evaluate the risk of a secondary spread of disease from one region or country to another. A similar system has been developed by DACOM (Plant-Plus) in Holland.

Activities until next workshop

Descriptions of DSS's and the questionnaire report on quality and use of weather data should be finalised and published in the workshop proceedings. A validation of more DSS's with historical data should be published in the workshop proceedings or as a report. Methods like MISP, I.P.I and Smith Periods should be included in this analysis. A protocol for field trial validation of DSS's should be finalised and more DSS's should be validated in field trials during the 1999 growing season.

Third Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

Availability and quality of Meteorological data used in late blight DSS

E. JÖRG AND B. KLEINHENZ

State Institute for Agronomy and Plant Protection of Rheinland-Pfalz
Essenheimer Str. 144, D-55128 Mainz, Germany

All DSS available for the control of Late Blight epidemics depend on meteorological data. Parameter needed for predition of decision making are air temperature, relative humidity and rainfall. From these parameters critical periods, dates of epidemic outbreak, epidemic pressure and disease progress curves for *P.infestans* are derived.

Hansen (1998) analysed the strong influence of meteological data quality on decisions taken by the NegFry-DSS. His results generally apply to all other DSS as well. Hardwick (pers. Comm) proposed tolerance levels of levels of accuracy for the measurement of weather parameters. For precipitation deviations of ± 0,2 mm, for relative humidity ± 0,2% and for temperature ± 0,2 °C could be tolerated. Data should be available at least on an hourly base.

At Uppsala the DSS-Subgroup briefly discussed meteorological data availability and quality. We were asked to shortly present some informations on the operation of networks of meteorological staions, gaps in meteorological data supply and the maintenance of the quality of meteorological data. In the following we report on the experience and the comprehensive databank system AGMEDA/MOVO99.

AGMEDA/MOVO99 stores meteorological data and makes them available to all DSS and other purposes. Secondly AGMEDA/MOVO99 ensures the high quality of our meteorological data.

Meteorological stations

The government crop protection service of Rheinland-Pfalz (south western part of Germany) operates a network of 33 automatic agrometeorological stations. These meteorological stations record numerous meteorological parameters hourly and are

located within the agriculturally important regions, so that the recorded data are representative for the growing regions. Temperature and relative humidity only show little variation within a region wheras precipitation strongly varies between localities. Therefore the creation of "virtual meteorological stations" by using more local precipitation measurements in combination with regional temperature and humidity measurements is planned.
The meteorological stations are maintained twice a year and the sensors are regularly calibrated or replaced. In causes of failure within two days the meteorological stations are repaired. A complete meteorological station and several sensors are kept in reserve. The manpower needed to warrant an operation without greater disturbances is 1 man per year (including the maintenance of data quality).
Data are automatically imported into the computers from the meteorological stations once per day (via modems). This ensures that the DSS can be run actually. Furthermore data gaps immediately can be detected.

Gaps

Data gaps can be closed for the following parameters: temperature (air, soil), relative humidity, global radiation and wind speed. Gaps are divided into small gaps (less than four hours without measurement) and large gaps, when data are missing up to 14 days. Normally data gaps do not exceed two days, because stations are repaired and sensors replaced within this timespan.

Small gaps are closed by linear interpolation of the two measurements before resp. following the gap.
Large gaps are closed with data from neighbouring stations within the network. The appropriate station is identified by calculating the correlations between the data 48 hours before and 48 hours after the gap of neighbouring stations. Data from the station with the maximum correlation are used to replace the missing values. The data sequence needed is copied into the gap. If necessary vertical shifting is done so that dat sequence fits well between the neighbouring data points of the gap. The complete data series is tested for plausibility.

Plausibility of Data

All imported data from the meteorological stations are automatically checked on plausibility. The results of the plausibility check is stored in the AGMEDA/MOVO99 databank together with the values.
At first the measured values are compared with absolute limits that by no means must be overridden or fallen below. Severe problems, e.g. the failure of a sensor, can be expected if a violation of such limits occurs. This is a rather rare event, whereas a slow drift of measurements by certain sensors more often is recorded. Such a problem can be detected by another part of the plausibility check, the comparison of values with the previous and subsequent measurement. The differences between these values are compared with maximum differences that are tolerable. The maximum tolerable diferences are depending on the season (month), day-night rhythm and the parameter to be measured.
In any case a person with a thorough meteorological knowledge must decide whether values, that are identified as “not plausible” by the automated procedure, should be replaced or if they may be accepted.

By employing the system described above we warrant a frictionless operation of our Late Blight DSS throughout the vegetation period. This not only holds for Rheinland-Pfalz but for the whole of Germany, 13 governmental crop protection services work with this or a similair system to that. In total meteorological data from more than 350 meteorological stations (110 owned by the German Weather Servic, 250 owned by the crop protection services) are processed.

References

Hansen, J.G. 1998. Availability and use of meteorological data for disease forecasting in Denmark. PAV-Special Report 3. Proceeding of the Workshop on the European network for development of an integrated control strategy of Potato late blight. Eds. Schepers, H. and Bouma, E., Lelystad: 104-110.

Third Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

Proposal for the validation of late blight DSS in field trials

E. JÖRG AND B. KLEINHENZ

State Institute for Agronomy and Plant Protection of Rheinland-Pfalz,
Essenheimer Str. 144, D-55128 Mainz, Germany

To facilitate the acceptance of DSS in agricultural practice their suitability for a wide range of climate-site combinations must be proven. DSS should be tested under humid, maritime climate as well as under dry, continental weather conditions.

Based on our experience with the PASO-Project in Germany, where numerous DSS have been validated, and on the OEPP/EPPO "Guidelines for the Efficacy Evaluation of Plant Protection Products" Vol. 2 Fungicides and Bacteries, Paris 1997, PP 1/2(3) we elaborated a proposal for a comparative evaluation of DSS for the control of Late Blight of potato crops. The proposal also includes the results of a fruitful discussion within a working group of the DSS-Subgroup at Uppsala.

The aim was to create standards and minimum requirements for the layout of the trials and the data to be recorded during validation of DSS. For the latter case a comprehensive report form has been attached to the field trial guideline. A further aim was to allow the inclusion of the DSS validation in existing normal trials (e.g. for registration).

As agreed by the members of the DSS-Subgroup the analyses of the results are done by our institution, and so the complete record forms should be sent to:

Benno Kleinhenz
Landesanstalt für Pflanzenbau und Pflanzenschutz
Essenheimer Str. 144
D-55128 Mainz
Tel. +49 6131/9930-40 or –0; Fax: -80
Email: bkleinhenx.lpp-mainz@agrarinfo.rpl.de

In addition to the guidelines the following points have been discussed and should be kept in mind.

Date of first *Phytophthora infestans* Appearance versus Fungicide Strategy

- The trials are primarily laid out to compare the efficacy of the spraying strategies of the different DSS. So the starting date should be the same for all DSS. The field should be free of disease (visual assessment). To warrant this it was proposed that the whole trial area should be treated with a systemic fungicide before the strategies are started. Note that such a treatment will favour strategies that accept higher risks (recommend less sprayings or prefer contact fungicides), whereas such a treatment disadvantages rather conservative strategies. Therefore an overall treatment prior to the starting date of the strategies should be done.
  The validation of predictions of the starting dates of *P.infestans* epidemics can easily be done by recording first symptoms in untreated plots, preferably close to a meteorological station, and comparing the predicted date with the observed date.
- Validation of the predictions and the fungicide strategies should not be coupled.

Choice of fungicides

- A problem arises from the registration of Late Blight fungicides in the different European countries. Not all the fungicides recommended by the DSS are available in all the countries participating in the validation project. It was agreed that the fungicides are grouped into four categories: contact, contact with sporicidal action, translaminar and fully systemic. From these groups the products must be chosen.

Before the start of the project the participants have to agree more specific on the products used in the trials.

Dates of Fungicide Application

- The treaments must be done on the date that is recommended by the DSS. However, if it should not be possible to spray in time a delay of one, at maximum two days should be tolerated.

Untreated Control Plots

- The control plots stay untreated till harvest or desiccation shortly before harvest. Due to the intervention of some of the working group it is possible (though not recommended!) to treat the control plots after first symptoms of *P.infestans* have appeared. Note again that this creates disadvantages for conservative DSS whereas progressive ones are favoured. The same applies to untreated strips around the trials plots.

Weather data

- The meteorological station that provides the DSS with data should be as close as possible to the trial site.

Field trial guideline for the validation of *Phytophthora infestans* DSS

The following guideline is based on the OEPP/EPPO "Guidelines for the Efficacy Evaluation of Plant Protection Products" Vol.2 Fungicides and Bactericides, Paris 1997, PP 1/2(3) English.

1 Trial conditions

Cultural conditions (e.g. soil type, fertilisation, tillage, row spacing) should be uniform for all plots of the trial and should conform with local agricultural practice.
It is important to plant uniform equal-sized tubers on the whole trial field. The origin of the tubers with the fungicide regime to which the mother crop was subjected should preferably be known. The seedbed must be ridged. A popular cultivar irrespective of its susceptibility should be grown.

2 Design and lay-out of the trial

- Trial sites should be laid out in typical potato growing regions.
- Trial sites should not be on an altitude above 400 m sea level.
- Trial sites under plastic cover or with irrigation are not permitted.
- Pesticides other than fungicides may be used if necessary.
- Plot size (net): at least 25 m^2, and 4 rows wide (preferably larger plots).
- Replicates: at least 4.

Because of the risk of cross infection, it may be necessary to treat the control plots with a quick-acting desiccant if damage increases to an unacceptable level.

Plots should be rectangular and of the same size in one trial. Long thin rectangular plots are suitable for mechanical harvesting.

Lay-out of plots

The number of treatments depends on the DSS tested in the trial and may be adapted.

1.	1	3	2	5
2.	3	5	4	2
3.	5	2	1	4
4.	2	4	3	1
5.	4	1	5	3
	A	B	C	D

Treatment 1:	Untreated control plots
Treatment 2:	Routine treatment as usual in the region
Treatment 3:	Model 1
Treatment 4:	Model 2
Treament 5:	Model 3
Etc.	

3 Application of treatments

3.1 Mode of application

Applications should comply with good experimental pratice (GEP).

The type of application (e.g. a spray) should be as specified for the intended use. Application(s) should be made with equipment which provides an even distribution of product on the whole plot or accurate directional application where appropriate. Factors which may affect efficacy (such as operating pressure, nozzle type) should be chosen in relation to the intended use.

3.2 Doses and volumes

The product should normally be applied to the dosage specified for the intended use. The dosage applied should normally be expressed in kg (or litre) of formulated product per ha. It may also be useful to record the dose in g of active ingredient per ha. For sprays, data on concentration (%) and volume (litre ha^{-1}) should also be given. Deviations from the intended dosage should be noted.

4 Type, time and frequence of assessment

4.1 Type

The growth stage of the crop at each date of application should be recorded. Plots are assessed for the extent of blight spots on the leaves. Each plot is scored as a whole for % disease severity, for example by rating the plot in relation to the appropriate % disease category described below in terms of average number of spots per plant, number of leaflets attacked, the form of the plants and the general appearance of the plot, or else by reference to a pictorial key (Appendix I).

Percent disease:

- ♦ 0 = no infection
- ♦ 1 = up to 10 spots per plant or up to 1 leaflet in 10 attacked
- ♦ 5 = around 50 spots per plant or up to 1 leaflet in 10 attacked
- ♦ 10 = up to 4 leaflets in 10 affected; plants still retaining normal form
- ♦ 25 = nearly each leaflet with lesions but plants still retaining normal form; plot may look green though every plant is affected
- ♦ 50 = every plant affected and about half of leaf area destroyed by blight; plot looks green, flecked with brown.

In practice, if % infection levels above 25 occur in a plot, further assessment serves no useful purpose and such plots may be treated with a quick-acting desiccant.

4.2 Time and frequency

First assessment: when the first disease symptoms appear on the leaves in the trial. Successive assessments are made just before each further application and when necessary. Last assessment: just before harvest (or desiccation).

4.3 Effects on non-target pests

Any observed effects, positive or negative, on the incidence of other pests and diseases should be recorded.

5 Quantitative and qualitative recording of yield

Plots should normally be treated with a desiccant before harvesting to avoid tuber infection during lifting.

The following should be recorded for each plot:

- potato yield in ton ha^{-1}. At least two rows should be harvested from the centre of each plot;
- weight of each size class after grading (specified national or international standard);
- percentage of tubers affected by the disease after at least two weeks and up to 8 weeks of storage under normal conditions (voluntary);
- starch content (voluntary).

Questions and reports may be send to:

Benno Kleinhenz

Landesanstalt für Pflanzenbau und Pflanzenschutz

Essenheimer Str. 144

D-55128 Mainz

Tel. +49 6131/9930-40 or-0; Fax: -80

Email: bkleinhenz.lpp-mainz@agrarinfo.rpl.de

Field trial on Phytophthora DSS

Report Form

1. Participant

Name of researcher	
Name of the institution	
Country	
Address	
Telephone	
Fax	
E-mail	

2. Trial site identification

Name of trial site	
Name of the next village or town	
Name of weather station	
Distance: trial site – weather station (km)	
Cultivar	
Planting date	
Emergence date	
Row spacing	
Spacing in row	
Soil type	
Previous crop	
Pre previous crop	

3. First appearence of *Phytophthora infestans* on the trial site

Date		

BBCH		
Phytophthora on leaves?	0 yes	0 no
Phytophthora on stems?	0 yes	0 no
Date predicted by models Model 1 Model 2 Model 3		
Soil covered by water for more than 8 days after planting	0 yes	0 no
Trial site close to a river or lake	0 yes	0 no
Last year potatoes emerging on the field	0 yes	0 no

4. First appearence of *Phytophthora infestans* in the region (represented by the weather station)

Date		
BBCH		
Phytophthora on leaves?	0 yes	0 no
Phytophthora on stems?	0 yes	0 no
Date predicted by models Model 1 Model 2 Model 3		

Characteristics of the field where the first appearence of P. infestans was recorded:

Soil covered by water for more than 8 days after planting	0 yes	0 no
field close to a river or lake?	0 yes	0 no
Last year potatoes emerging on the field	0 yes	0 no
Potatoes under plastic cover nearby?	0 yes	0 no
Potatoes with irrigation?	0 yes	0 no
Potatoes in housegarden?	0 yes	0 no

5. Fertilization

Date	BBCH	Product	Dose

6. Crop protection

6.1 Herbicides

Date	BBCH	Product	Dose

6.2 Insecticides

Date	BBCH	Product	Dose

6.3 Fungicides

Treatment (DSS, Standard, Untreated

Control :______________________

Applications

	Model recommendation			Treatment		
	Date	Product	Dose	Date	Product	Dose
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Disease assessements

	Disease severity (in 6 classes)		Replicates				
	Date	BBCH	A	B	C	D	Average
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

7. Harvest and tuber infection

7.1 Yield ton ha^{-1} (obligatory)

Treatment	Replicates				
	A	B	C	D	Average
Untreated					

7.2 Starch content (%) (voluntarily)

Treatment	Replicates				
	A	B	C	D	Average
Untreated					

7.3 Tuber infection (%) (voluntarily)

Treatment	Replicates				
	A	B	C	D	Average
Untreated					

Third Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

Population biology and aggressiveness of *Phytophthora infestans* : a compilation of European studies

DIDIER ANDRIVON

INRA, Station de Pathologie Végétale, BP 29, F-35653 Le Rheu Cedex, France
with input from

B. Andersson and M. Sandström (Sweden), L. Bodker (Denmark), R. Collier (Jersey, UK), L. Cooke (N. Ireland), G. Cristinzio and A. Testa (Italy), J. Day and N. Pipe (UK), S. Duvauchelle, (France), W. Flier and D. Spijkerboer (The Netherlands), A. Hannukkala (Finland), A. Hermansen (Norway), R. Marquiñez (Spain), D. Michelante (Belgium), M. Ruckstuhl (Switzerland) and B. Schöber-Butin (Germany).

Some background information

This paper reports on the results gathered in a European survey, intended to compile the information available on populations of *P. infestans* in Europe. Undertaking this survey was decided in September 1997 in Carlow (Ireland), during the second meeting of the subgroup Epidemiology of the EU. NET. ICP Concerted Action, with the triple aim of **distributing this information to everyone interested, identifying emerging projects,** but also **identifying knowledge gaps**. It was made possible only thanks to the activity of the persons listed ahead, whom I most warmly thank for their input.

The survey was made through a set of two distinct questionnaires (one focusing on population structures, the other on aggressiveness). To make them faster to fill and easier to exploit, both questionnaires were built as questions with multiple answers covering all the areas (methodology, results, interpretation) of the topics surveyed. The questionnaires were sent by regular mail to all participants in the EU.NET.ICP concerted action. Fourteen of the 30 questionnaires sent were returned, and four groups sent letters indicating either lack of data or providing partial information. Furthermore, several recipients who did not work themselves in the areas covered by the questionnaires forwarded them to other scientists.

Population studies

Analyses of the answers to the questionnaire revealed that surveys are now operating in most countries of northern and western Europe. Many programmes have started or have been strengthened since the mid 1990s (Table 1).

Most (if not all) studies are based on yearly collections of relatively small samples (< 20 isolates) at a number of sites, usually sampled once in the season. The markers most commonly used are mating type and metalaxyl resistance, while virulence and allozymes are not frequently used (table 1). Among molecular markers, RG57 fingerprints are popular, as are mtDNA polymorphisms. However; there is a trend towards using AFLPs instead of (or together with) RG57.

In terms of population characteristics, the A2 mating type is found (almost) everywhere: only exceptions so far are Spain and Jersey. A2 is usually more frequent on tomato than on potato, and in northern climates than in western or southern situations (Table 2). However, oospores have been recorded in the field only in Scandinavia and in the Netherlands. Populations present in all parts of Europe (except possibly Jersey?) are ‘new’, as determined from the presence of the A2 mating type and sometimes of oospores, but also from allozymes and molecular markers (RG57, mtDNA), or from increased diversity. Metalaxyl resistance is highly variable, both between regions and between years; conversely, race patterns seem fairly similar all over Europe, and relatively stable over a time span of several years.

Aggressiveness

Comparatively little has been done on this aspect: only seven groups (in Italy, Norway, Ireland, Germany, UK, the Netherlands, and France) responded they had data.

Most workers used detached potato leaves, and few compared them with whole plants. Only two groups (in Germany and Italy) mentioned testing on stems and/or tubers. Tomato was tested only in a limited number of cases (Italy, France, Ireland), and other plants (*S. nigrum; S. dulcamara*) were occasionally tested only in Germany.

Some criteria for assessing aggressiveness were shared by all studies (infection efficiency, sporulation); most, but not all, also measured latent period, lesion growth rate, and spore germination. Only one group, in Norway, examined the relationships between aggressiveness and temperature. No other climatic factor was investigated so far.

Where to next?

This paper is a very synthetic compilation of the information contained in the answers to the questionnaires. To be fully exploitable, this information needs now to be disseminated into more detail than is possible within the frame of these Proceedings. Plans for dissemination include the setup of a Web page, where the detailed analysis and data will be displayed. This should be done before the next workshop (see also the report of the subgroup Epidemiology).

The questionnaire also aimed at identifying new projects. Emerging projects in the field of population studies are mainly focused on the development and use of molecular markers. New tools (such as AFLPs or microsatellites) are rapidly spreading, which allow a very fine description of local and regional populations. These types of markers will also be most useful in the projects developing on oospore biology. As far as investigations on aggressiveness are concerned, studies on the impact of climatic factors (temperature, relative humidity) on the development of current isolates of *P. infestans* are being undertaken, and will continue in the future.
The analysis of the answers to the questionnaires also point out some future research directions that should be investigated, although these were not explicitly mentioned by respondents. Three areas should be considered most particularly : 1) the impact of cultivar resistance in late blight management, in terms of both the potential for oospore production in cultivars with different levels of partial resistance and of the buffering effect on pathogen evolution of gene deployment strategies (exclusive use of race non-specific resistance, impact of R genes and their use, possibilities of using cultivar associations instead of pure stands, etc...); 2) investigations on aggressiveness components to tubers, which has been very rarely measured directly up to now; and 3) the relationships between *P. infestans* populations on potato and those on other host plants, particularly tomato.

Table 1. Survey characteristics of populations of *Phytophthora infestans* in Europe: markers used and time span covered.

Country	**Type of marker used**								
	Mating type	Fungicide resistance[a]	Virulence	Allozymes	RG57	mtDNA	RAPD	AFLP	others
Belgium[b]	1994	1994	1994	1994		1994			
Denmark	1997								
Finland	1994	M: 1990		*1998*[c]	*1998*				
		P: 1995							
France	1988	M: 1981	1991	1991/93	1995	1994			
Germany	1985	M: 1980	1954	*1998*		*1998*			
Italy	1984	M: 1984	1984		*1998*			*1998*	
Netherlands	1987	M: 1981	1960	1980 *[d]	1992	1992		1997	
Norway	1993	M: 1996	1993		1996				
Portugal[b]	1992		1992	1992					
Spain	1995 *	M: 1995	1992-95[b]	1992-95[b]		1995[b]			
Sweden	1997				*1998*			*1998*	
UK									
England	1985	M: 1993			1995	1993			
Wales (local)	1995-97				1995-97	1995-97		1997	microsat.
N. Ireland	1987	M: 1981			*1998*	*1998*	*1998*		
Jersey		M: 1984							

[a] M: metalaxyl; P: propamocarb-HCl

[b] Only few isolates tested

[c] Dates in italics signal research planned, but not necessarily engaged yet

[d] Data available for a limited number of isolates collected earlier

Table 2. Frequency of the A2 mating type (in percent of isolates tested) on potato and on tomato in Europe. Data are compiled from the answers received to the questionnaire on population structures ; they usually relate to the period 1990-1997.

Country	On potato				On tomato			
	0	1-5%	5-15%	>15%	0	1-5%	5-15%	>15%
Norway				X				
Sweden				X				
Finland					X			
The Netherlands			X	X			X	
Germany		X	X	X				
United Kingdom		X					X	
Northern Ireland	X	X						
Jersey	X							
France/Belgium		X				X		
Switzerland		X				X		
Spain	X							
Italy			X					X
Portugal	X							

Third Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

Overview of Standard Descriptions of Phytophthora Decision Support Systems

E. BOUMA[1] AND J. G. HANSEN[2]

[1]DLV-Meteo, P.O.-Box 7001, NL-6700 CA Wageningen
[2]Danish Inst. Of Agric. Sci., Dep. Of Agric. Systems, P.O.-Box 23 DK-8830 Tjele

Abstract

We have made a shortened overview of Phytopthora Decision Support Systems with contributions of: ProPhy, The Netherlands, NegFry, Denmark, Simphyt, Germany, Plant-Plus, The Netherlands,Televis, Norway, Guntz-Divoux, France,Guntz-Divoux, Belgium, I.P.I., Italy, PhytoPRE+2000. The original, detailed information will be send on request by the PAV in Lelystad (NL) or by the authors of this document.

Tabel 1. General overview of different systems.

	ProPhy	Negfry	Symphyt	Plant-Plus	Televis	Guntz – Divoux (France)	Guntz – Divoux (Belgium)	I.P.I.	PhytoPRE+2000
General inf:									
Contact person (technical)	W. Nugteren Opticrop BV P.O.-Box 34 NL-2140 AA Vijfhuizen	J.G. Hansen DIAS, Dept. of Agricultural Sci. Res. Centre Foulum Dk-8830 Tjele	V. Gutsche BBA-Inst für Folgenabschätsung Stahnsd. Damm 81 D-14532 Kleinmachnow	Dacom Automatisering BV P.O.-Box 2243 NL-7801 CE Emmen	A. Hermansen Plant Prot. Centre Dep. Of Plant Path. Fellesbygget N-1432 As	L. Dubois S.R.P.V. – F.R.E.D.E.C. 81 rue B. Palissy BP87 F-62750 Loos-en-Gohelle	P. Vanhaverbeke PCA Karreweg 6 B-9770 Kruishoutem	R. Bugiani Servizio Fitosanitario Regione Emilia-Romagna Via Corticella 133 I-40129 Bologna	H.R. Forrer Swiss Fed.Res. Stat. for Agroecol. and Agriculture Reckenholzstr. 201 CH-8046 Zürich
Main target users	Farmers, advisors Extension officers	Farmers, advisors	Plant Protection Service, extension officers	Farmers, advisors,suppliers, processors	Farmers, advisors	Advisors, extension service	Advisors, extension service	Advisors, farmars	Advisors, farmers, plant prot. Service
General status	Commercial exploitation	Commercial exploitation	No commercial exploitation	Commercial exploitation	No commercial exploitation	No commercial exploitation	No commercial exploitation	No commercial exploitation	No commercial exploitation
Development info:									
Original developer	Opticrop BV	Hansen, Friss, Lassen, Andersen	V. Gutsche, E. Kluge	Dacom Automatisering BV	E. Førsund	S.R.P.V.	PCA	Servizio Fitosanitario Emilia-Romagna	H.R. Forrer, M. Ruckstuhl, P.M. Fried
Original year of development	1988 – 1991	1992 – 1996	1982 – 1998	1990 – 1998	1957/1965/1995	1963 – 1998	1996	1990	1995 – 1998
Updates	Annual	Annual	Annual	Annual	--	--	Annual	--	Annual

Tabel 2. General overview of different systems.

	ProPhy	Negfry	Plant-Plus	Televis	Symphyt	Guntz- Divoux (France)	Guntz- Divoux (Belgium)	I.P.I.	PhytoPRE+2000
Technical info:									
Submodels	-Import weather-data -import weather forecast -Presentation weather data -Field data registration Infection/sporu-lation -First sprayiong -Disease pressure index -Dosage advice -Protection status -Chemical selection	-CDI.DLL (Climate Data Interface) -AMIS.DLL -NegFryModel.DLL -submodel 1 -submodel 2	-Micro-climate -Weather forecast -Sporulation -Ejection and dying of spores -Dispersion of spores -Penetration time -Unprotected part of the crop -Latend period		-Import Weather data -Field data registration -Forecast of first appearance (Simphyt I) -Monitoring of Phytophthora epidemics, including decision making (Simphyt II)	-Calculation based on RH (under development) -import weather forecast -field data registration -protection status	Validation of Weather data -Calculation based on RH -Calculation based on Leaf Wetness -Calculation based on combination of LW and RH (under development) -import weather forecast -field data registration -protection status	-Calculation based on relative humidity --Calculation based on temperature -Calculation based on rainfall	-Import weather data -Import weather forecast data -Presentation of weather data -Registration of customer data -Registration of field data -Registration of disease observation data -Estimation of local risk -Estimation of regional infection risk -Estimation of protection status -Treatment advice
Imput	-Weather data (hourly) -Field data -Other data	-Weather data (hourly) -Field data	-Micro climate -Crop info -Product info	-Weather data (hourly) -Daily weather data	-Weather data (hourly) -Field data	-Weather data (hourly and daily)	-Weather data (hourly and daily)	Daily data of: -air temperature -relative humidity -precipitation	-Weather data (hourly) -Field data -Other data

Tabel 3. General overview of different systems

	ProPhy	Negfry	Symphyt	Plant-Plus	Televis	Guntz- Divoux (France)	Guntz- Divoux (Belgium)	I.P.I.	PhytoPRE+2000
Output	-Weather overvieuws -Field data -Advice Daily data	-Reccommendation for first spray -Subsequent fungicide applications	-Field data -Advice -Daily data	-Map with sources of investation -Graph with Sporulation, changes of infection period and protection of the crop since last spraying	Infection changes -Incubation rate -Appearence of lesions of new sporulation -Daily overvieuw(infec-tion, incubation	-The output is disseminated by a voice board system	-The output is disseminated by a voice board system	-Daily infection changes -Determination of blight-free periods -Time of first spray	-Regional information -Field-specific information
Manual/ Help facility	-Extensive on-line help facility -manual	-User manual -hotline	On-line hotline	-on line help -manual		----	----	----	----
Price information	Dfl. 1550 (+/- 740 ECU) Updatecontract Dfl 350/year (+/-166 ECU)	600 Dkr	No commercial exploitation	Not given	No commercial exploitation	No commercial exploitation	No commercial exploitation	No commercial exploitation	No commercial exploitation
Number of users	250 farms 50 advisors 15 commercial companies 800 Fax/videotex 20 others	200 farms 25 advisors	100 advisors 10 others	500 farmers and advisors	800 farmers	2000 farmers	800 farmers	70 advisers	600 farmers

Third Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

Compilation of questionnaires on availability of meteorological data for late blight warning in operational use

E. BOUMA[1] AND R. SIGVALD[2]

[1] DLV-Meteo, P.O.-Box 7001, NL-6700 CA Wageningen

[2] Swedish Univ. of Agric. Sci., P.O.-Box 7044, S-75007 Uppsala

Abstract

Computer based decision support systems for late blight need high quality meteorological data. From recent investigations and discussions within the DSS-subgroup it was known that there were differences in passing on the met-data. Therefore it was decided within the subgroup to work out a questionnaire on the availability of met-data for late blight. In most of the countries the met-info is provided in a regular way. There is not always a quality control and the information is not always easy to handle for the end-users. It is difficult to make a good comparison of the costs of the weather information. The met-data is delivered most of the time in a very fast, electronic way to the end-users.

Keywords: DSS, weather-information, decision support system, late blight

Introduction

As written in the report of the DSS-subgroup discussions of last year, there are difficulties in the availability and use of meteorological data, especially when DSS systems are used in operation by farmers and advisors. Two of the main problems are the high costs of the primary data and the data are not always available on an operational base and many times not in a format that can be used by DSS's directly.

Therefore a questionnaire was developed to try to identify major problems on availability and use of met-data for late blight warning. When there are problems with the availability we can use the results of the questionnaire to help in a process to increase the pressure on national met offices to build weather information systems for agriculture. Otherwise it has no meaning to build high sensitive late blight DSS systems for farmers.

Results

We received questionnaires from 14 countries, they used 14 DSS or advanced advisory systems in another form. Most of the country representative filled in the questionnaire for his “own” system.

Number of users and systems:

Table 1. What DSS are operational in your country and how many users are there (in 1998).

Country DSS	D	S	FIN	UK	SCO	IRL	CH	F	E	NL	N	DK	I	B
SIMPHYT	40-50													
Plant@info												300		
Negfry		20	20/ 50*			1						400		
I.P.I.													70	
Smith periods				1**	Trial									
Guntz-Divoux								1968						
Milsol								1990						
Plant-plus				10					trial	400				
ProPhy										335				
PCA														70 0
CARAH														50 0
CRA														30 0
PhytoPRE							800							
Televis											800			

*20 for the internet version and 50 for the Metpole version

** operated as a bureau service

Interesting is the number of users per system on average it is 240 users per system. Those 3300 users need very regularly good weather information during approximately 4 months a year.

How is the weatherinfo provided:

How the weather-info is provided differs per country, how the information is provided depends mainly on the system that is used. When the system requires data that can be measured by the official met-office in most cases it is also provided by the official met-office. Otherwise it is provided by local on-farm met stations or by the supplier of the system that is used. (See table 2)

Table 2. How is the required weather-info provided.

Country	**D**	**S**	**FIN**	**UK**	**SCO**	**IRL**	**CH**	**F**	**E**	**NL**	**N**	**DK**	**I**	**B**
By the met office	X		X*	X	X		X		X		X	X**	X	
Not by the met office		X	X			X	X	X		X	X	X		X
It is provided by:	1	2	2				3	4		5	6	2		7

1. The information is also provided by crop protection services
2. The system requires met-data from an on-farm weather station
3. The regional crop protection services
4. The network of Service Regionale de la Protection des Vegetaux
5. The system requires met-data from an on-farm weather station, one station is normally used by a group of DSS-users
6. The Norwegian Crop Research Institute
7. The network of Centre de Rechérches Agronomique (payed by the Ministry of Agriculture)

*Only for the Internetsystem
**Only for the Plant@info system

In most of the countries the weather-info is provided in a regular way, see table 3. The farmer can receive the “raw”-met data that can be used in his own system, an other possibility is that he receives met-data that is manufactured in the DDSs and only the results are delivered to the end-users.

In a lot of cases there is no end control of met-data for errors (is 57% of the filled in questionnaires). In all that cases there is a possibility that the end-user receives a wrong advice, a study in the UK learned that a small deflection of a sensor had a large effect on the total number of applications.

Furthermore the information should be easy to handle for the end-users. Only in 50% of the countries it is the case. There is a lot that can be improved.

Table 3. The required weather-info is provided .

Country	D	S	FIN	UK	SCO	IRL	CH	F	E	NL	N	DK	I	B
In a regular way		X	X	X	X	X	X	X	X	X	X	X	X	X
Free of errors	X			X		X	X	X			X			
For direct use by farmers	X	X		X	X					X	X	X		

The costs of the weather information:

It is not easy to get a good overview, because is very difficult to compare the cost between the different countries. In most of the countries the weather-info is not free of charge.

Question 4. Is the weather-info free or not free.

Country	D	S	FIN	UK	SCO	IRL	CH	F	E	NL	N	DK	I	B
Free	X				X		X		X					
Not Free		X	X	X		X		X			X	X	X	

There are a lot of differences in the height of the costs and how it is calculated. The costs depend in most of the cases on : the number of consultations, the kind of the advises, how the information is provided, if an on-farm weatherstation is necessary and if only an advice is delivered to the farmer. So a general overview is difficult to make. And therefore it is not possible to compare the costs of the information between the countries with the results of this questionnaire.

Is it possible to use the weather-data every day?

In almost every country the information is available seven days a week, only in Italy and Belgium this is not the case. But in those countries the information is calculated at a central place and the advices are sent by telephone/internet or normal post to the end-users. See table 5.

Table 5. Is the required information available seven days a week ?

Country	D	S	FIN	UK	SCO	IRL	CH	F	E	NL	N	DK	I	B
Yes	X	X	X	X	X	X	X	X	X	X	X	X		
Only *6* Days														
Only *5* Days													*X*	*X**

* : with the advice of spraying

Is it necessary to have weatherforecasts?

With the help of weatherforecasts it is possible in some system to calculate the dangerous periods in the next days. In other words, the DSS recommends whether the farmer needs to spray and if it is possible to spray.

In most of the countries it is possible to use weatherforecasts it in the late blight DSS, see table 6

Table 6. Is it also required to have weatherforecasts.

Country	**D**	**S**	**FIN**	**UK**	**SCO**	**IRL**	**CH**	**F**	**E**	**NL**	**N**	**DK**	**I**	**B**
Yes							X	X	X	X	X		X	
No	X	X	X	X		X						X		X

How is the information delivered to the farmer?

Most of the systems are using high quality data to give high quality advices. But when it takes too long to get that met-information in the system, the data are used inefficiently. So in table 7 an overview is given how different countries pass the weather information to the end-users. In most of the cases very fast, modern electronically ways are used to get the information by the end-users. Only in some special cases the information in send by (relative) slow "normal" post.

Table 7. The required information is provided to the users (on a regular base) by.

Country	**D**	**S**	**FIN**	**UK**	**SCO**	**IRL**	**CH**	**F**	**E**	**NL**	**N**	**DK**	**I**	**B**
Data link by :														
Telephone	X			X					X	X		X*	X	
Fax	X			X				X						X
Videotext	X			X										
Automatic telephone	X			X							X			X
Internet	X		X	X	X		X					X**	X	X
Connection with station		X*		X		X								
Mail					X			X						X

*Hardi

**Met. Office

What kind of meteorological data need the systems?

Almost all the systems are using hourly based data, only the Finnish NegFry-system needs three hourly data and the Italian I.P.I-system needs daily-based weather data. Except the Dutch Prophy system (which needs crop based information of temperature and relative humidity) all the systems are satisfied with data measured at 150/200 cm (the official WMO-measuring height). Almost all systems need precipitation data and some systems need additional data of windspeed, winddirection and global radiation, see table 7- table10.

Table 7. What meteorological data (measured on official height) require the systems.

System	Relative Humidity	Temperature	Precipitation
Televis (N)	X	X	X
Guntz-Divoux (B,F)	X	X	X
Milsol (F)	X	X	X
Smith Periods (UK, SCO)	X	X	X
Plant@info (DK)	X	X	
Negfry (DK, S, IRL)	X	X	
SYMPHYT (D)	X	X	X

Table 8. What meteorological data requires system.

Meteorological data	PlantPlus (E, NL)	SYSTEM ProPhy (NL)	PhytoPRE (CH)
Relative Humidity (2.00 meters)	X		X
Relative Humidity (in crop)		X	
Temperature (2.00 meters)	X		X
Temperature (in crop)		X	
Precipitation	X	X	X
Windspeed	X	X	X
Winddirection	X		X
Global Radiation	X		X

Table 9. What meteorological data requires SYSTEM : NegFry (Finland).

	Hourly base	3-hourly base	Daily base
Relative Humidity (2.00 meters)		X	
Temperature (2.00 meters)		X	
Precipitation		X	

Table 10. What meteorological data requires SYSTEM : I.P.I. (Italy).

	Hourly base	3-hourly base	Daily base
Relative Humidity (2.00 meters)			X
Temperature (2.00 meters)			X
Precipitation			X

Conclusions

In the outcomes it was clear that 3300 users of Late blight decision support systems need at least four months a year high quality weather information. How the weather information is provided differs per country, most of the time it depends on the system that is used. In most of the countries the weather-info is provided in a regular way, but there is not always a quality control of the data. In only half of the cases the information is easy to handle for the end-users.

It is very difficult to make an overview of the costs of the met-information, a good comparison is not possible. It is a pity that a good comparison is not possible, because it has no sense to build good quality DSS systems when the met-information is not available or the price is too high. In almost every country which took part in this questionnaire, the met-data was available seven days a week. In a lot of countries it is also possible to use the weather forecast in the late blight decision support systems. The met-info is delivered in a very fast, modern electronic way to the end-users. Only in some special occasions it is provided by “normal” post. In most of the systems the Relative Humidity, Temperature and precipitation measured on official height are needed for a good calculation of the dangerous periods of late blight.

References:

J. G. Hansen & R. Sigvald (eds.) 1994 Proceedings of the Workshop on Weather Informa-tion and Plant Protection. Danish Institute of Plant and Soil Sci. SP-Report no. 10. 1995. 116 pp.

B. J. M. Secher , V. Rossi & P. Battilani (eds.) 1993. Proceedings of the Workshop on Computer-based DSS on Crop Protection. Parma, Italy 23-26 November 1993. Danish Institute of Plant and Soil Sci. SP-Report no. 7. November 1993. 233 pp.

B. J. M. Secher , J. Frahm (eds.) 1996. Proceedings of the Workshop on Decision Systems in Crop Protection. Münster, Germany 4-8 November 1996. Danish Institute of Plant and Soil Sci. SP-Report no. 15. October 1996. 112 pp.

B. J. M. Secher & E. Bouma (eds.) 1996. Survey on European Crop Protection Decision Support Systems. Danish Institute of Plant and Soil Sci. SP-Report no. 16. December 1996. 95 pp.

H.T.A.M. Schepers and E. Bouma (editors).1998. Proceedings of the Workshop on the European network for development of an integrated control strategy of potato late blight. PAV-Special Report no.3, January 1998, 240 pp.

J. Wieringa. 1996. Is Agrometeorology used well in European Farm Operations. Enquiry review by EC-Cost Action 711. Operational applications of meteorology to agriculture and horticulture. Wageningen, September 1996 24 pp.

Third Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

Compilation of questionaires on practical characteristics of fungicides used to control potato late blight

H.T.A.M. SCHEPERS
Applied Research for Arable Farming and Field Production of Vegetables
P. O. Box 430, 8200 AK Lelystad, The Netherlands

Introduction

Information and efficacy of fungicides is an important part of Decision Support Systems designed to improve the control of late blight in potatoes. In discussions however it became clear that the practical characteristics of fungicides are not always rated in the same way. In order to collate and evaluate existing information on fungicide characteristics from all possible sources, a fungicide questionnaire was developed in the sub-group fungicides of the Concerted Action "European network for development of an integrated control strategy of potato late blight" (Schepers, 1998). The questionnaire was sent to representatives of agrochemical companies and research institutes/extension services in all European countries participating in the Concerted Action.

Results

Filled-in questionnaires were returned from 10 countries. In total 48 replies were received from agrochemical companies and 58 replies from research institutes/extension services. The replies from the agrochemical companies did not show much variation and relatively few questions were answered with question marks. Some of the company replies were supported with references. The replies from the institutes showed more variation and a considerable number of questions were answered with question marks. References were not included, probably most ratings were based on personal experience/judgement.
Information was given on a range of late blight fungicides with in total 16 different active ingredients (Table 1). Information was provided on fungicide composition and dose rates, as well as on effectiveness and action modes of the active ingredients. All information is summarised on data sheets for each key active ingredient. Data sheets are made for the

following active ingredients: benalaxyl, chlorothalonil, copper, cymoxanil, dimethomorph, dodine, fentinacetate, fentinhydroxide, fluazinam, fosethyl-Al, mancozeb, maneb, metalaxyl, oxadixyl, propamocarb-HCl, tolylfluanid. Table 2 shows the data sheet of cymoxanil. The other data sheets are freely available and can be obtained by contacting the author of this paper.

General information: For most active ingredients a number of formulations are registered throughout Europe. This range of different formulations together with the different dose rates makes it difficult to compare the questionnaire responses.

For example cymoxanil + mancozeb is registered in France as a product that contains 40 g/kg cymoxanil + 465 g/kg mancozeb with a dose rate of 2.5 kg/ha. This results in 100 g/ha cymoxanil + 1162 g/ha mancozeb. However, in The Netherlands the composition and dose rate registered result in 112 g/ha cymoxanil + 1700 g/ha mancozeb.

Fluazinam is registered throughout Europe in the same formulation (500 g/l), but the dose rate varies from 0.3 to 0.4 l/ha. In Switzerland a dose rate was mentioned of 0.5 l/ha. Why different dose rates are registered is not clear. Probably differences in disease pressure and market situation play a role.

Effectiveness: The overall effectiveness and control of leaf blight were mostly rated as good (++) or very good (+++). The question asking for the efficacy in the new growing point appeared to be a confusing one. The question was asked to find out whether the active ingredient was rated as also being active on plant parts that had not been in direct contact with the fungicide. An active ingredient can only protect an unsprayed growing point when it is systemically transported in the plant in sufficient amounts to be biologically effective.

The agrochemical companies were very positive in rating their products on efficacy against stem and tuber blight. However, the institutes/extension services rated the efficacy considerably lower or even filled in question marks.

Action modes: From the answers it became clear that it was necessary to harmonise the definitions of the different action modes. In the sub-group meeting these definitions were proposed and discussed (Bradshaw, 1999). Most respondents agreed on the ratings for the protectant action mode of fungicides. Fentinacetate and dodine were in some cases rated as curative. With fentinacetate this rating was based on the efficacy after germination of the spore but before penetration in the leaf. However, when curative activity is defined as activity during the immediate post infection period, fentinacetate can not be considered as a curative active ingredient. The ratings of the curative efficacy of cymoxanil, dimethomorph and propamocarb varied considerably. Also the anti-sporulant efficacy of fungicides was rated with a lot of variation and question marks. This indicates that there is no European consensus on ratings for curative and anti-sporulant efficacy of late blight fungicides.

Discussion and conclusions

An overview on practical characteristics of potato late blight fungicides was obtained from most European countries. In most cases the composition and dose rates are not harmonised within Europe. This situation makes it difficult to compare practical characteristics between countries.

Although some respondents included references of publications on biological efficacy of fungicides, it is clear that most ratings were based on the basis of a combination of the following factors: trial results, personal experience, personal judgement. The development of a database with trial results on biological efficacy of late blight fungicides would solve this problem.

This compilation of questionnaires does not provide all the answers on practical characteristics of late blight fungicides. For a number of characteristics consensus is present but for some important characteristics such as curative and eradicant efficacy and control of stem and tuber blight a variation in ratings remains. Since use of late blight fungicides is becoming more and more triggered by factors such as weather conditions, infection pressure and epidemiology of the fungus, questions on these characteristics are nowadays asked more often than several years ago. The development and use of Decision Support Systems certainly increased the need for more detailed information on fungicides.

This compilation has resulted in a number of ratings that can be included in DSS, but is has also shown that for a number of important characteristics more detailed research is necessary.

References

Bradshaw, N. Report of the sub-group discussions on the practical characteristics of potato late blight fungicides. Proceedings of the Workshop on the European network for development of an integrated control strategy of potato late blight. PAV-Special Report no. 5, February 1999.

Schepers, H.T.A.M. Report of discussions of the subgroup potato late blight fungicides. Proceedings of the Workshop on the European network for development of an integrated control strategy of potato late blight. PAV-Special Report no. 3, January 1998: p. 15-22.

Table 1. Information on a range of late blight fungicides from 10 EU-countries.

	B	CH	E	F	FIN	I	IRL	N	NL	UK
protectant fungicides										
chlorothalonil (+mancozeb)		*								
copper-compounds		*			*	*				
dodine						*				
fentinacetate + maneb				*			*		*	*
fentinhydroxide							*			*
fluazinam	*	*		*	*				*	*
mancozeb		*	*	*	*		*			*
maneb				*						
tolylfluanid					*					
translaminar fungicides										
cymoxanil + chlorothalonil		*								
cymoxanil + copper						*				
cymoxanil + mancozeb	*	*	*	*					*	*
dimethomorph + copper						*				
dimethomorph + mancozeb		*	*	*	*				*	*
systemic fungicides										
benalaxyl + copper						*				
benalaxyl + mancozeb		*								
fosethyl-Al + copper						*				
fosethyl-Al + cymoxanil + folpet			*							
metalaxyl + mancozeb			*		*					*
metalaxyl + copper						*				
metalaxyl-M + fluazinam		*								
metalaxyl-M + mancozeb		*								
metalaxyl + maneb + fentinacetate									*	
oxadixyl + copper						*				
oxadixyl + mancozeb + cymoxanil		*								*
propamocarb + chlorothalonil				*		*			*	*
propamocarb + mancozeb (+copper)		*			*		*	*		*

Table 2. Data sheet of cymoxanil with ratings of characteristics from 7 EU-countries.

No information from AU, D, DK, S								
cymoxanil	**B**	**CH-1**	**CH-2**	**E**	**F**	**I**	**NL**	**UK**
General								
active ingredients	cym+mcb	cym+mcb	cym+chloro	cym+mcb	cym+mcb	cym+cop	cym+mcb	cym+mcb
composition	45+650	40+465	60+600	40+400	40+465	42+397	45+680	45+680
dose rate/ha	2.0-2.5	3.0	2.0	2.5-3.0	2.5	2.0-3.0	2.5	2.0
cymoxanil/ha	90-112	120	120	100-120	100	84-126	112	90
mancozeb/ha	1300-1625	1395	1200	1000-1200	1162	794-1191	1700	1360
Company								
Effectiveness								
Overall	very good	very good	very good	*	*	good	very good	very good
leaf blight	+++	++	+++	*	*	+++	+++	+++
spray interval	8	8-okt	7-10	*	*	7	8	10
new growing point	limited	0	only diffusion	*	*	?	++	++
stem blight	?	+++	+++	*	*	+++	?	+++
tuber blight	+	+++	?	*	*	+++	++	++
Action mode								
protectant	+++	++	+++	*	*	+++	+++	+++
curative	+++	++	+++	*	*	+++	+++	+++
anti-sporulant	++	++	?	*	*	+	++	+++
Institute								
Effectiveness								
Overall	*	very good	very good	reasonable	(very) good	good	very good	(very) good
leaf blight	*	+++	+++	++	++	++	++(+)	++
spray interval	*	8-10	8-10	7	7	6-10	5-10	10
new growing point	*	0	only diffusion	0	0	?/+(+)	?	0
stem blight	*	++	++	++	(+)	?/+(+)	?	?
tuber blight	*	0	0	+	+	?/+(+)	+(+)	?
Action mode								
protectant	*	+++	+++	++	++	++	++(+)	+++
curative	*	+	+	+++	+++	++	++	++
anti-sporulant	*	++	++	++	0	0/+	++	++

Third Workshop of an European Network for Development of
an Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

Information and decision support for the control op potato late blight based on integrated PC and internet applications

JENS GRØNBECH HANSEN, POUL LASSEN, ALLAN LECK JENSEN
and
IVER THYSEN

Danish Institute of Agricultural Sciences
Department of Agricultural Systems,
Research Group for Informatics and Agrometeorology
Research Centre Foulum, DK-8830, Denmark

Summary
In Denmark decision support for potato late blight is available via PC-NegFry, a DSS for the chemical control of potato late blight and Pl@nteInfo®, an Internet based information and decision support system for agriculture. This paper describes the components in both systems and how they are integrated. Finally, some ideas of a future integrated PC- and Internet based late blight DSS are discussed.

Key words: Potato late blight, NegFry, Pl@nteInfo®, decision support system, Internet.

Introduction

In Denmark the agricultural sector has reduced the use of pesticides with about 50 % since the mid eighties (Danish EPA, 1997). Only within the potato growing area the use of pesticides has increased during this period. In 1997 the PC-NegFry decision support system for control of late blight was released for use by farmers (Hansen, Andersson & Hermansen, 1995; Hansen, 1997; Hansen, 1998). Also in 1997 decision support and information related to late blight control was implemented in Pl@nteInfo®, a Danish Internet based information system for agriculture (Hansen, 1997; Jensen et al, 1996; Jensen et al., 1997; Jensen et al, 1999).

This article describes the components in NegFry and Pl@nteInfo® and how they are integrated. Finally, some ideas of a future decision support system for the control of late blight based on integrated PC and Internet applications are discussed.

Decision support for potato late blight in Denmark

NegFry

NegFry is a Windows® based decision support system programmed in the object oriented C++ programming language. Components in the system, inputs and outputs are given in Table 1. The NegFry main program controls the data exchange between databases and model components and it contains all the user interfaces for inputs and outputs in the program.

A Climate Data Interface component (CDI) controls the import, transformation, quality control and interpolation of weather data. The CDI component also controls the merging of weather data from up to three different sources. It is developed as a DLL component, and it can be used by any PC-program that requires import and control of weather data (Lassen & Hansen, 1999).

A special component was developed for the access via the Internet to 10*10 km grid interpolated weather data from the Danish Meteorological Institute (DMI). These data may be used as an alternative to data from onfarm weather stations or they may supply local weather data if data are missing for periods of more than 5 hours. The late blight submodels are all implemented in one NEGFRYMODEL component (Table 1).

Pl@nteInfo®

Pl@nteInfo® (*www.planteinfo.dk*) is an Internet based decision support system for crop management including just-in-time information and decision support the control of crop diseases and pests, needs for irrigation etc. A subscription system enables the system to personalise the information (Jensen et al, 1999).

The architectural design of the Pl@nteInfo® system involves a main WWW server at the Danish Institute of Agricultural Sciences (DIAS) and a collaborating server at the Danish Agricultural Advisory Service (DAAC). The data, models and information of Pl@nteInfo® are divided between these two WWW servers. The main web server at DIAS contains the entire logical framework to extract and compile information from the collaborating organisations. Most of the application logic is performed on the server side and only static or assembled HTML documents with graphics and JavaScript codes are sent to the clients.

The dynamic HTML documents are assembled in real time from static or real time produced components using SAS programs and Perl CGI scripts at the DIAS server. The algorithmic code of the decision support models and the procedures for graphical presentation of the model output were written as SAS programs and stored on a SAS application server. The web server communicates to the SAS application server using the SAS/IntrNet™ component (SAS Institute Inc., 1998).

Much of the dynamic information is based on weather data, so databases with original and derived weather data are essential. For efficient model execution the weather databases are stored on the Pl@nteInfo® server together with the model programs. Hence, the database with original weather data including weather forecasts is updated every morning by an ftp-transfer from the Danish Meteorological Institute (DMI). Weather radar images are transferred every 10 minutes for animations to predict local precipitation.

The dynamic information in Pl@nteInfo® is created either from database look up (e.g. field recordings of diseases and pests) or from the activation of decision support models. Naturally, Pl@nteInfo® also contains static (but up-to-date) HTML documents. The different facilities are located on the WWW servers of the two collaborating organisations, but in general the origin of the information is not visible to the user. Components in the system, input and outputs related to late blight are given in Table 1.

The Pl@nteInfo® main program controls the generation and facilities of each web page and available information and facilities are personalised based on user ID. The late blight web page with disease forecast and disease monitoring may include comments and interpretation from local advisor (news service). The system will know the growers geographical position and the weather forecast will be local as well as the weather radar film may be zoomed to local level based on the geographical information in the user information database. Local grid interpolated historical and forecast weather data will be used if the user enters the irrigation management system.

The late blight forecast in Pl@nteInfo® is based on the first part of the NegFry system and results are given either as accumulated or daily risk values for about twenty weather stations in Denmark using a mean date for crop emergence. The user may interactively change the date of crop emergence and a click on a local station leads to graphics of accumulated or daily risk values from crop emergence to current date for the selected station.

The monitoring system is organised by The Danish Agricultural Advisory Service (DAAC). Via a monitoring network, plant samples of early attacks of late blight are sent via postal mail to DAAC. The same day the sample is received at DAAC, symptoms are verified by experts, and the result including background information is entered into the system via a web page Interface. A few minutes later the map with late blight recordings in Pl@nteInfo® will be updated.

Integration and coordination of PC-NegFry and Pl@nteInfo®

The forecast of the risk of primary attack in Pl@nteInfo® is identical to the first part of the PC-NegFry DSS. Most users of NegFry use data from Hardi metpoles and all weather based components in Pl@nteInfo® are driven by data from ordinary meteorological stations. Growers that use Hardi metpoles may compare the local risk values from PC-NegFry with risk values from nearby meteorological stations in Pl@nteInfo®. Assuming that risk indices based on ordinary meteorological data are the "truth" this may be used as an overall quality control of Hardi metpole measurements. The risk indices shown on maps in Pl@nteInfo® also indicate in which regions and when early attacks are expected. Early attacks in one region of the country may result in a risk of secondary spread of disease with wind over longer distances. Users of local weather data in Pl@nteInfo® pay 400 Dkr per year. This payment also allow the user to access interpolated weather data from DMI for use in PC-NegFry.

Table 1. Components, needed input and output from NegFry and Pl@nteInfo®.

NegFry (PC)	**Pl@nteInfo® (Internet)**
Components:	*Components and methods for generation of web pages relevant for late blight control:*
• **NegFry main program**. Data control, table and graphics outputs, activity report etc. • **Climate Data Interface.** Import and control of weatherdata • **Access via Internet to grid Interpolated weather data** from the Danish Meteorological Institute (DMI) • **NegFryModel** with submodels for recommendation of first and subsequent sprays • **Databases and tables** (paradox) and help files	• Pl@nteInfo® **main program** controls the generation and facilities of each web page • **Import** via FTP and control of **weather data** from DMI • **Databases** containing weather data, disease data, field trial data, PC-NegFry outputs etc. • **Graphics programs** for generation of maps and figures • **Monitoring system** for input of disease data • **Dynamic and custom tailored news services** with input from DIAS, DAAC and local advisors • Generation of **Local weather forecasts** including weather radar pictures updated every 10 minutes • **HTML text and images**
Needed inputs	*Needed inputs for late blight components*
• **Hourly weather data** for temperature, Rh and precipitation • **Crop data** for variety susceptibility, crop emergence date and irrigation	• **Hourly weather data** for temperature and Relative humidity • **Crop emergence date** to start accumulation of NegFry risk values • **Disease recordings** for the monitoring network • **Dynamic news service uploads**
Outputs	*Outputs*
• Tables and graphics of daily and accumulated **risk values and blight units** • **Quality control** of weather data • **Graphics of used weather data** including a possibility of comparison of data from different data sources • **Activity report** of spraying regime and irrigations	• **Late blight prognosis** based on NegFry. Maps and graphics • **Late blight monitoring.** Map and table. Link to Nordic Map. • **Day to day interpretation and advice** from research and extension service organisations • **NegFry homepage** - Program update - Download user manual - Download articles - FAQ about NegFry • **Links** to late blight biology, description of forecasting method, pictures etc. • **Local weather forecast** • **Results from field trials** under DAAC

The forecast of primary attacks in NegFry and Pl@nteInfo® assumes that the primary inoculum source is infected tubers. In 1997 the forecast was about one week too late in the southern part of Denmark. Investigations of the distribution of mating types in the same year showed an approximately 1:1 distribution of A1 and A2 mating types and field observations indicated that early infections was caused by oospores in the soil (Bødker et al., 1998). Infections from oospores and/or a change in late blight aggressiveness may be the reason for the earlier attacks than was expected from the forecast.

The indications of a shift in epidemiological behaviour of the disease was a major reason to initiate the monitoring network for early attacks of late blight as a supplement to the forecast. Users of PC-NegFry now use the monitoring system as a precautionary measure, to avoid being too late with the first preventive fungicide application. If early attacks are found in a region before the first spray has been recommended by NegFry, growers should start their spraying program and continue with the second part of NegFry for subsequent fungicide applications (not available in Pl@nteInfo®).

After slight modifications of thresholds in the forecast model, the forecast in Pl@nteInfo® in 1998 was in right time compared to recordings in the monitoring network. Anyway, growers were very satisfied with the monitoring system and it will continue in 1999. In addition to the use in the warning service the data obtained in this monitoring system will be used in an ongoing late blight epidemiological research project.

A homepage for NegFry is available in Pl@nteInfo® . Via the homepage users of NegFry can download program updates, user manual and articles and read a FAQ about NegFry. Links to late blight biology, description of forecasting method, pictures, results from field trials etc. is also available. In the coming years the potato part in Pl@nteInfo® will be extended and improved via a project titled "Development of an Internet based Information and decision support system for the potato production chain". General discussions in DIAS and DAAC are ongoing how to integrate and utilise advantages and constraints in PC- and Internet solutions.

Advantages and constraints in use of PC and Internet solutions

The NegFry DSS transforms, quality controls, merges weather data and calculates risk indices based on hourly weather data. On a modern PC, this is done very fast. If the NegFry system is implemented on a web server, local weather data must be transferred to the server, which including data processing may be quite slow (Table 1).

A local PC-program is easily linked to local databases on the same PC, e.g. a farm management program containing all farm and field data or weather data from an onfarm weather station. Today Internet based DSS's can not automatically access local PC-databases, obviously because of safety precautions. To integrate the large Danish PC-based farm management system called "Bedriftsløsningen" with Pl@nteInfo®, a solution in the future will be to extract the necessary farm or field data from Bedriftsløsningen and transfer these data via FTP to the web server in a process that is controlled by the user himself. In this way basic farm and field data only have to be entered in a (local) database once and the use of data are controlled solely by the farmer himself.

PC-programmes are normally independent of communication lines. On the other hand the use of Pl@nteInfo® must have a fast and reliable Internet connection and the speed and power of these connections still sets the limit of the performance of Internet based systems. For example the transmittance via Internet of weather radar pictures from Pl@nteInfo® to a local PC at present may take some time.

Table 2. Advantages and constraints in the use of PC and Internet based informations and DSS's.

PC programs		**Internet systems**	
Advantages	**Constraints**	**Advantages**	**Constraints**
• Model calculations fast • Easy access to local databases • Independent of communication lines • Personal data not available for others • Many facilities for building user interfaces	• Slow and expensive to update • Currently interaction with experts restricted • Dependent on operating system	• Custom tailored information • Collaborative information systems (CIS) • Independent of operating system • Fast and cheap to update • Local and regional information available • Possible to include regional data in local calculations • Currently advice and interpretation from experts	• Server model calculations may be slow • Difficult access to local databases • Dependent on fast and reliable communication lines • Personal data need high degree of protection • Restricted facilities for building user interfaces

Pl@nteInfo® is a collaborative information system (CIS) as the system integrates and co-ordinates information and data from many different sources (Jensen et al., 1997). Compared to PC-solutions the system is fast and cheap to update. The content of information and decision support components in the system increase very rapidly, but the user information database makes it possible to personalise the system in a way that only relevant information for a specific user are available.

It has been agreed with the Danish Meteorological Institute that all weather information for agriculture are disseminated through Pl@nteInfo® and the daily transfer and use of weather data from the Danish network of ordinary weather stations makes the system unique. The regional calculations of risk indices for pest and diseases, crop growth, water balance, need of fertilisation etc. supplement or substitute PC-based calculations on local level, often with the use of weather data from onfarm weather stations. The online access to weather data from ordinary meteorological stations is an advantage for the Internet solution, but a lack of precision in interpolated weather data may be a serious drawback.

In Denmark the station network is quite dense, and the land surface is flat all over the country.

Information and comments to outputs in Pl@nteInfo® are given by experts at DIAS and DAAC. Farmers often rely very much on advice and interpretations from his local advisor. Therefor Pl@nteInfo® contains the facility to include informations and interpretations by local advisors directly into the system via a news service. A local advisor can establish a news service and via the system decide what users, that should be able to read his comments. In that way Pl@nteInfo® is not intended to be a substitution for the advisory service, but as information and decision support that interacts and integrate with the local advisory services. This is totally unique compared to the use of PC-based DSS systems.

Future DSS for the control of late blight based on integrated PC and Internet applications

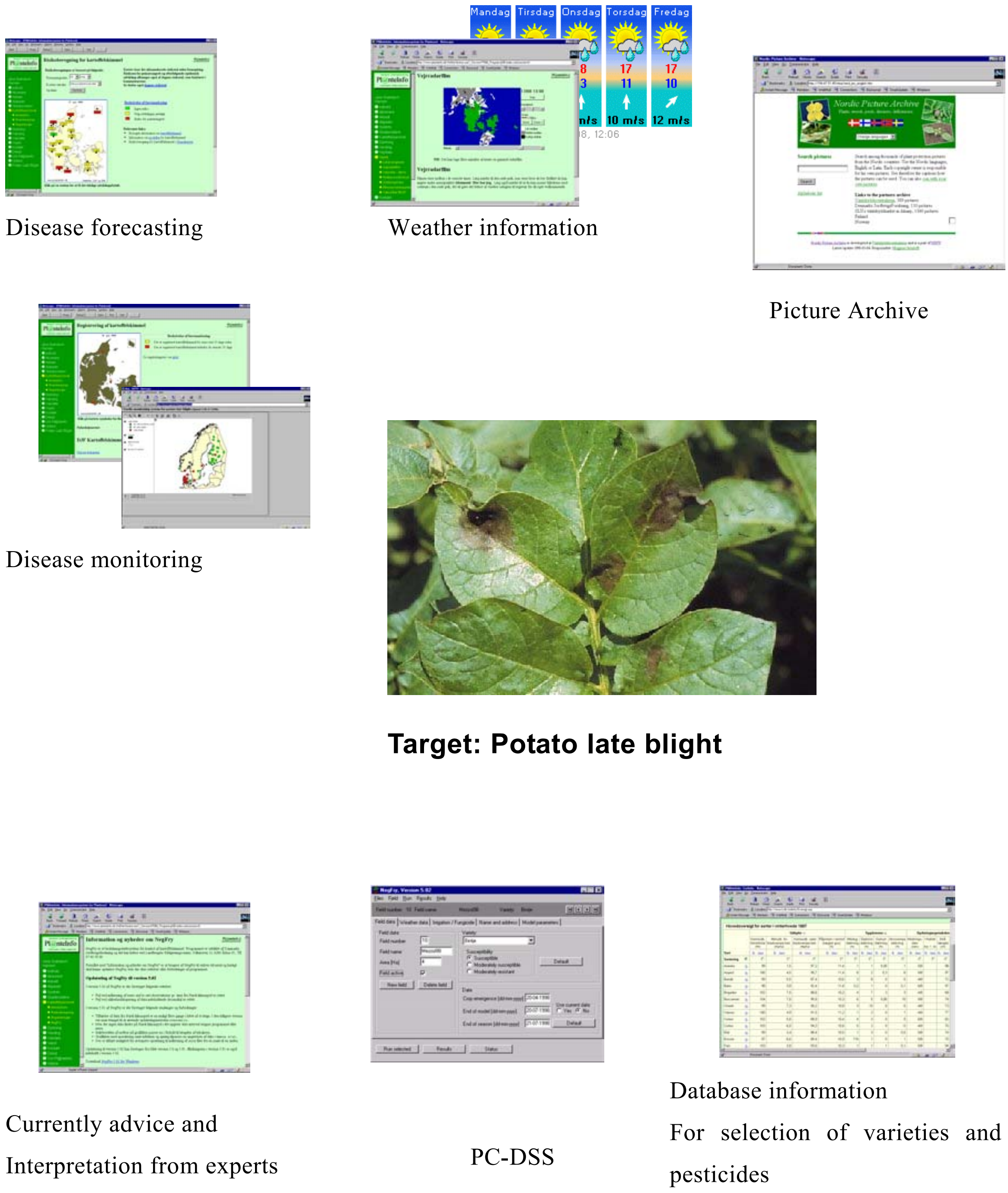
The number of farmers having a PC increase every day. An Internet connection will be standard in most homes and the reliability and speed of these connection will increase. Today the user interfaces in PC-programs and Internet-applications are quite different regarding design and facilities. In the future however probably the PC and the Web interfaces will merge into a common standard.

Future decision support systems should obviously take advantage of integrating PC and Internet based programs. Ideas of components in an integrated PC and Internet based DSS for the control of potato late blight is given in figure 1.

A local PC-DSS including a field management database and modules for comprehensive model calculations probably is the basic tool of the system. The PC-program controls the information and data exchange between the PC-program and integrated Internet applications. Model calculations using local weather data are supplemented by regional calculations of the risk for disease development based on national networks of weather stations. A web or GIS-based national monitoring network for early attacks of late blight supplements and verifies the local disease forecasts and it calculates a secondary inoculum pressure index for the region. This index should interact with and have influence on the PC DSS calculations of the need for crop protection with fungicide. Weather forecasting data are used in local and regional model calculations and weather radar data are used for the right timing of fungicide applications according to the risk of rainfall during the forthcoming period. Web based database information including searchable databases for, fungicides, variety selection, imagies, literature etc. integrates with the PC-DSS. Comments and interpretations from scientists and local advisors are available based on personalised Internet based news services.

In year 2000 all Internet based components in figure 1 will be an integrated part of Pl@nteInfo® . In the future more components will be developed in cross-country collaboration. For example the searchable picture database is developed in Sweden as a part of a Nordic collaboration project and therefor all texts are available in five different Nordic languages and English (Grøntoft, 1998). The Internet based monitoring system was developed in Denmark, but used in 1998 by all Nordic countries. The GIS applications presenting the recorded disease data was developed by the MTT group, Agricultural Research Centre of Finland (Hansen et al., 1999). The potential use of the Internet platform for development of DSS components points in the direction of extended collaboration between expert groups in different organisations and countries.

Figure 1. Components in a future Information and decision support system for the control of potato late blight. For explanation, see text.



Conclusion

For potato late blight, as well as for other agricultural crop diseases and pests, computer based systems for information dissemination and decision support are highly relevant. Different types of information from different sources have to be collected and combined to give precise informations and recommendations. Computer based information and decision support systems may be installed locally on the user's PC, or on an Internet server. This paper have pointed out and discussed some of the advantages and constraints in both types of systems using PC-NegFry and Pl@nteInfo® as examples.

In Denmark research is ongoing to develop integrated PC and Internet DSS's that utilise the advantages of both types of systems, and the results are applied and tested using potato late blight as an example.

References

Bødker, L. Kidmose, R., Hansen, J.G. and Holm, S. (1998). Potato late blight - before and now. 15th Danish Plant Protection Conference, Pest and Diseases. DJF report No 3., 81-88. Danish Institute of Plant and Soil Sciences, Research Centre Foulum, 8830 Tjele, DK .

Danish EPA, 1997. Danish Environmental protection Agency: www.mst.dk/activi/06050000.htm.

Grøntoft M. (1998). Nordic Picture Archive, including crops, weeds, pests and diseases and deficiencies (http://194.47.51.45/nba/nord_pic_english.htm).

Hansen, J.G., Andersson, B. & Hermansen, A. (1995) NEGFRY - A system for scheduling chemical control of late blight in potatoes. In: (Eds. Dowley, L.J., Bannon, E., Cooke, L.R., Keane, T. & O'Sullivan, E.) Proceedings "PHYTOPHTHORA 150 Sesquicentennial Scientific Conference, Dublin, Ireland, 201-208. Boole Press Ltd.

Hansen, J. G. (1997) Field specific and regional warning for development of potato late blight. Proceedings from Workshop: European Network for Development of an Integrated Control Strategy of Potato Late Blight 28. Sept.- 4. Oct, 1996., 127-134.

Hansen, J. G. (1998) Availability and use of meteorological data for disease forecasting in Denmark. In: Proceedings from Workshop: European Network for Development of an Integrated Control Strategy of Potato Late Blight, PAV-special report no 3, January 1998, 125-136.

Hansen, J.G., Jensen A.L., Andersson, B., Sandström, B., Lindholm M., Hannukkala, A., Hermansen, A. (1999). Forecasting and monitoring of potato late blight in the Nordic countries in 1998. Report of a Nordic Internet Project on Plant Protection, NIPPP. EFITA papers (www.Efita.org).

Jensen, A.L., I. Thysen, J.G. Hansen, T. Jensen, B.J.M. Secher & O. Juhl (1996). An information system for crop production on World Wide Web, In: C. Lokhorst, A.J. Udink ten Cate & A.A. Dijkhuizen (Eds.) Information and Communication Technology applications in Agriculture: State of the art and future perspectives, Agro-informaticareeks nr. 10, Wageningen, Holland, 604-609.

Jensen, A.L., I. Thysen & B.J.M. Secher (1997). Decision Support in Crop Production via the Internet, Petria (1997) 7 (Suppl. 1), 147-154.

Jensen, A.L., P.S. Boll, I. Thysen & B.K. Pathak (1999). Pl@nteInfo® – A web-based system for personalised decision support in crop management. Computers and Electronics in Agriculture. Accepted for publication.

Lassen, P. and Hansen, J.G. (1999) CDI: A flexible tool for import and control of weather data in DSS's (this proceedings).

SAS Institute Inc. 1998. SAS/IntrNet™ Software: Delivering Web Solutions, Cary, NC: SAS Institute Inc., 1998. 40 pp.

Third Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

Further experience with decision support systems for the control of late blight under Irish conditions

R. LEONARD[1], L. DOWLEY[1], B. RICE[2] & S. WARD[3]

[1] Crop Protection & Breeding Department, Oak Park Research Centre, Carlow, Ireland
[2] Crop Production & Engineering Department, Oak Park Research Centre, Carlow, Ireland
[3] Department of Agriculture & Food Engineering, University College Dublin.

Abstract

Routine fungicide application for the control of late blight was compared with the Negfry decision support system in field trials during 1996, 1997 and 1998. 1996 was a normal blight year while 1997 and 1998 were severe blight years. There was no significant difference in disease control or yield between routine fungicide application and the Negfry blight system in 1996, 1997 and 1998. The reduction in fungicide use was 56%, 22%, and 20% respectively. Within the Negfry system, fluazinam tended to give better disease control than mancozeb.

Air-assisted application of fungicides has not given any significant benefits in these trials, but further trials are planned to examine the effect of air-assistance on the incidence of stem blight.

Keywords: Decision support system, *Phytophthora infestans*, validation trials.

Introduction

The area of potatoes in the republic of Ireland dropped from 18,153 ha in 1996 to 15,502 ha in 1997 due to the low prices obtained for the crop in 1996 (National potato census 1997, 1997). It has been estimated that the area of potatoes has increased to 16,600 ha in 1998 due to an increase in the price of potatoes in 1997 (T. Maher, 1998, personal communication).

The value of the potato pesticide market is approximately £3.5 million of which 63% (£2.2 million) is spent on fungicides for the control of late blight caused by *Phytophthora infestans*. If there are to be reductions in the amount of pesticides used on Irish potatoes, the most obvious starting place is with the fungicides used to control late blight.

The use of decision support systems to determine when fungicide treatments should be applied for the control of *Phytophthora infestans* (Mont.) de Barry are becoming more acceptable across Europe. This has been helped by legislation which is aimed at reducing pesticide inputs. Ireland has no legislation in place and there is none envisaged in the immediate future. As a result, decision support systems used in Ireland must produce a direct benefit to the farmer.

The results achieved in Ireland with decision support systems in conjunction with air-assisted spray application technology in 1996, 1997 and 1998 are presented in this paper.

Materials and Methods

Trials were conducted at Oak Park Research Centre, Carlow, on the maincrop cultivar \`Rooster\` during 1996, 1997 and 1998. This cultivar is susceptible to late blight having ratings of 4 and 6 for foliage and tuber blight resistance respectively (Dowley, 1995). The design for each trial was a randomised complete block with four replications per treatment. Each replicate consisted of 6 drills 7.69 m long. The drill width was 81.28 cm and the distance between tuber centres was 31.75 cm. The total replicate size was 37.5 m^2 from which 25 m^2 were harvested across the centre 4 drills. Weed control consisted of paraquat (600 g a.i./ha) and simazine (600 g a.i./ha) applied pre-emergence. This trail procedure follows the EPPO (European and Mediterranean Plant Protection Organisation) guidelines for the biological evaluation of fungicides.

Routine fungicide application commenced in mid-June when the plants were beginning to meet along the drill and was repeated at prescribed intervals throughout the season. The spray volume was equivalent to 250 l/ha and the spray pressure was 3 bars.

Fungicide treatments and application

Details of the spray treatments used in 1996, 1997 and 1998 are given in tables 1, 2 and 3 respectively. Air-assisted application was included in the 1997 and 1998 trials.

Decision support systems

The decision support system evaluated was the Negfry in conjunction with the Hardi Metpole.

The Metpole is a portable in crop weather station for the recording of weather data in an individual crop. It collects such weather data as rainfall, air humidity, air temperature, windspeed, soil temperature, and soil humidity amongst others. The data collected by this pole was used by the Negfry model to predict the fungicide treatment timings. The Negfry model uses only air temperature, air humidity, and rainfall to predict the fungicide application times. The data from the Metpole could also be used for other disease forecasting systems or timing of irrigation or any other weather dependant procedure.

Negfry is a computer based program for scheduling chemical control of late blight. It was developed by the Danish Institute of Plant and Soil Science and is based upon a combination of two prediction models. The first is the 'Negative prognosis' (Ullrich & Schrödter, 1966) which forecasts the date of disease outbreak and the first fungicide application. The second is the FRY-method (Fry et al,1983) for calculation of weather and cultivar dependant spraying intervals.

The first part of the programme calculates the epidemic free period before spraying is required. This interval depends on the time of emergence of the crop and the subsequent weather patterns. Once the first spray has been triggered, the second part of the program is then initiated and this calculates subsequent spray intervals. The weather for disease development is expressed in blight units as set out by the FRY- method.

Crop assessment

During the growing season, disease levels were assessed at weekly intervals up to desiccation using the British Mycological Society foliage blight assessment key (Cox & Large, 1960). Disease outbreak was recorded as the date when the first blight lesions were observed in the centre 4 drills of each replicate. Delay in the onset of disease was the number of days by which the disease outbreak was delayed by each fungicide when compared with the unsprayed control. The crop was desiccated with diquat at the end of September and harvested in October/November using an elevator digger. The produce was stored at a temperature of over $10^{O}C$ for at least two weeks to allow tuber blight symptoms to develop and was then graded into the following grades:- < 45 mm, 45-65 mm, 65-85 mm, > 85 mm, blighted and other diseases. After grading the produce was weighed and the yields expressed in tonnes per hectare.

Data analysis

The results of each year were analysed separately using analysis of variance procedures and differences between treatments were evaluated using the Student's t-test.

Results

1996 results

Late blight was first observed on unsprayed plots on 31 July, which is about normal for the area. During 1996, the Negfry programme reduced the number of fungicide applications by 56% when compared with routine fungicide applications at 10-day intervals. Results for disease development and yield during 1996 are presented in Table 4. It can be seen that all sprayed treatments were significantly better than the untreated control in terms of area under the disease progress curve and marketable yield.

No significant differences were observed between the routine fungicide applications (Dithane DF and the routine Ridomil MZ programme) and the three reduced input programmes in terms of delay in disease onset, area under the disease progress curve and marketable yield. In terms of tuber blight control only the Negfry programme based on full rate Dithane DF was significantly worse than the unsprayed control, the Negfry programme based on half rate Dithane DF and the routine Ridomil MZ programme.

1997 results

Late blight was first observed on unsprayed plots on 25 June, which is about one month earlier than normal. Disease pressure continued to be high during the year. During 1997, the Negfry programme reduced the number of fungicide applications by 22% when compared with routine fungicide applications at 10-day intervals. The Negfry model failed to suggest the first spray early enough in this season, as by the 23 June the blight attack had already commenced.

Results for disease development and yield during 1997 are presented in Table 5. It can be seen that all sprayed treatments were significantly better than the untreated control in terms of area under the disease progress curve.

Within the sprayed treatments, the routine fungicide treatments tended to delay disease onset more than the fungicides applied as per the Negfry programme. The only significant difference was between the Negfry programme based on ¾ rate Dithane DF with air-assistance and the routine spray treatments. Disease progress as measured by the area under the disease progress curve shows that the routine fungicide applications gave significantly better disease control in 1997 compared with the Negfry programmes based on Dithane DF. However, the Negfry programmes based on Shirlan were not significantly different to the routine programmes.

In terms of yields there were no significant differences between any of the routine programmes and the Negfry programmes. The only significant difference present was between ¾ rate shirlan with air-assistance and ¾ Dithane DF, both on the Negfry routine. In terms of tuber blight there were no significant differences present.

1998 results

Late blight was first observed on unsprayed plots on 2 July, which is about one month earlier than normal. Disease pressure continued to be high during the year. During 1998, the Negfry programme reduced the number of fungicide applications by 20% when compared with routine fungicide applications at 10-day intervals.

Results for disease development and yield during 1998 are presented in Table 6. It can be seen that all sprayed treatments were significantly better than the untreated control in terms of delay in disease onset and area under the disease progress curve. It can also be seen that there are no significant differences between any of the spray programmes.

Spray savings

Each year the Negfry programme has achieved savings in the number of sprays applied over the conventional spray programme. The percentage of spray applied following the Negfry routine in comparison with the 10 day routine programme is shown in Table 7.

The savings have varied from 55.6% in 1996 to 20% in 1998. In terms of active ingredient applied the savings range from 8,440 g/ha (1996) to 3,376 g/ha (1998), for a Dithane DF spray programme.

Problems

A number of problems were encountered with the Negfry/Metpole combination in 1997, stemming mainly from the Metpole.

The Metpole battery housing became water logged on two occasions, and this resulted in the loss of 3 days of weather data. Inserting missing data is time consuming and difficult and may be insurmountable for many farmers. The Metpole receiver can be put out of action by an electrical storm. This is easily rectified by temporarily disconnecting the power from the receiver. However, data can be lost if the problem is not noticed immediately.

The Negfry model would not calculate blight units after the updating of missing data in the Metpole programme. This problem was only over come by installing the windows version of the Negfry programme. This resulted in the second spray in 1997 being applied 4 days late. There was no repetition of this problem in 1998.

Discussion

1996 was an average blight year and the Negfry model performed well, giving a greater delay in disease onset and better foliage blight control than the routine fungicide treatments. The Negfry did not control tuber blight as well as the routine sprays but levels of tuber blight were low and this resulted in a higher marketable yield than with routine spraying.

1997 was a very severe blight year and the results were different to 1996. The Negfry model did not perform as well as the routine application of fungicides. However, there was no significant difference in the level of disease between routine and Negfry spray programmes.

The Negfry probably did not perform as well in 1997 as in 1996 and 1998 due to two main reasons. These are that the initial warning was triggered about 3 days late and also that the second spray was applied 4 days late. The second spray was four days late due to problems that had been encountered with the system as explained earlier. The four days between when the spray warning was given and the spray was applied were four days of blight conducive weather.

1998 was a sever blight year, but good control was achieved with all spray programmes. The Negfry model gave as good a level of control as the routine programme and there is no indication that one routine was better than another.

References

Cox, A. E. and Large, E. C. 1960. Potato blight epidemics through out the world. Agricultural Research Service, United States Department of Agriculture, *Agricultural Handbook No. 174.* 230 pp.

Dowley, L.J. and O'Sullivan, E. 1995. Potato late blight control, Technical manual. Teagasc, Dublin. ISBN: 0-948321-91-1.

Fry, W.E., Apple, A.E. and Bruhn, J.A. 1983. Evaluation of potato late blight forecasts modified to incorporate host resistance and fungicide weathering. Phytopatlology 73, 1054-1059.

Maher, T., 1998. Personal communication. Teagasc, County Office, Chareville Rd, Sheena, Tullamore, Co. Offaly, Ireland.

An Bord Glas, 1997. National potato census 1997. An Bord Glas, Dublin.

Ullrich, J., & Schrödter, H., 1966. Das problem der vorhersage des auftretens der kartoffelkrautfäule (*Phytophthora infestans*) und die möglichkeit seiner lösung durch eine "Negativprognose". Nachrichtenblatt Deutsch. Pflanzenschutz-dienst (Braunschweig) 18, 33-40.

Table 1. Details of 1996 fungicide treatments.

Commercial Name	Iso Name	Rate of Product/ha	Grams a.i./ha	Number of applications	Dates of applications
Unsprayed	None	None	None	None	None
Dithane DF	Mancozeb	2.25 kg	1688	9	21/6, 1/7, 11/7, 22/7, 1/8, 12/8, 22/8, 2/9, 12/9
Ridomil MZ 72 fb Dithane DF	Metalaxyl + Mancozeb Mancozeb	2.50 kg 2.25 kg	200 + 1600 1688	3 6	21/7, 1/7, 11/7 22/7, 1/8, 12/8, 22/8, 2/9, 12/9
Dithane DF as per Negfry	Mancozeb	2.25 kg	1688	4	23/7, 6/8, 20/8, 2/9
Dithane DF as per Negfry	Mancozeb	1.68 kg	1266	4	23/7, 6/8, 20/8, 2/9
Dithane DF as per Negfry	Mancozeb	1.12 kg	844	4	23/7, 6/8, 20/8, 2/9

Table 2. Details of 1997 fungicide treatments.

Commercial Name	Iso Name	Rate of Product/ ha	Grams a.i./ha	Number of applications	Dates of applications
Unsprayed	None	None	None	None	None
Dithane DF	Mancozeb	2.25 kg	1688	9	17/6, 27/6, 7/7, 18/7, 28/7, 7/8, 18/8, 28/8, 8/9
Dithane DF (air-assisted)	Mancozeb	2.25 kg	1688	9	17/6, 27/6, 7/7, 18/7, 28/7, 7/8, 18/8, 28/8, 8/9
Ridomil Gold	Metalaxyl + Mancozeb	2.50 kg	200 + 1600	3	17/6, 27/6, 7/7,
fb Dithane DF	Mancozeb	2.25 kg	1688	6	18/7, 28/7, 7/8, 18/8, 28/8, 8/9
Dithane DF as per Negfry	Mancozeb	2.25 kg	1688	7	23/6, 18/7, 28/7, 8/8, 18/8, 26/8, 5/9
Dithane DF as per Negfry	Mancozeb	1.68 kg	1266	7	23/6, 18/7, 28/7, 8/8, 18/8, 26/8, 5/9
Dithane DF as per Negfry (air-assisted)	Mancozeb	1.68 kg	1266	7	23/6, 18/7, 28/7, 8/8, 18/8, 26/8, 5/9
Dithane DF as per Negfry (air-assisted)	Mancozeb	1.12 kg	844	7	23/6, 18/7, 28/7, 8/8, 18/8, 26/8, 5/9
Shirlan as per Negfry	Fluazinam	0.3 l	150	7	23/6, 18/7, 28/7, 8/8, 18/8, 26/8, 5/9
Shirlan as per Negfry (air-assisted)	Fluazinam	0.3 l	150	7	23/6, 18/7, 28/7, 8/8, 18/8, 26/8, 5/9
Shirlan as per Negfry (air-assisted)	Fluazinam	0.2 l	100	7	23/6, 18/7, 28/7, 8/8, 18/8, 26/8, 5/9

Table 3. Details of 1998 fungicide treatments.

Commercial Name	Iso Name	Rate of Product/ ha	Grams a.i./ha	Number of applications	*Dates of applications*
Unsprayed	None	None	None	None	None
Dithane DF	Mancozeb	2.25 kg	1688	10	16/6, 26/6, 6/7, 16/7, 27/6, 6/8, 17/8, 27/8, 8/8, 17/8.
Dithane DF (air-assisted)	Mancozeb	2.25 kg	1688	10	16/6, 26/6, 6/7, 16/7, 27/6, 6/8, 17/8, 27/8, 8/8, 17/8.
Shirlan	Fluazinam	0.4 l	200	10	16/6, 26/6, 6/7, 16/7, 27/6, 6/8, 17/8, 27/8, 8/8, 17/8.
Ridomil Gold fb Dithane DF	Metalaxyl + Mancozeb Mancozeb	2.50 kg 2.25 kg	200 + 1600 1688	3 7	16/6, 26/6, 6/7. 16/7, 27/6, 6/8, 17/8, 27/8, 8/8, 17/8.
Dithane DF as per Negfry	Mancozeb	2.25 kg	1688	8	22/6, 3/7, 16/7, 27/7, 4/8, 19/8, 1/9, 8/9.
Dithane DF as per Negfry	Mancozeb	1.68 kg	1266	8	22/6, 3/7, 16/7, 27/7, 4/8, 19/8, 1/9, 8/9.
Dithane DF as per Negfry (air-assisted)	Mancozeb	1.68 kg	1266	8	22/6, 3/7, 16/7, 27/7, 4/8, 19/8, 1/9, 8/9.
Dithane DF as per Negfry	Mancozeb	1.12 kg	844	8	22/6, 3/7, 16/7, 27/7, 4/8, 19/8, 1/9, 8/9.
Shirlan as per Negfry	Fluazinam	0.3 l	150	8	22/6, 3/7, 16/7, 27/7, 4/8, 19/8, 1/9, 8/9.
Shirlan as per Negfry (air-assisted)	Fluazinam	0.3 l	150	8	22/6, 3/7, 16/7, 27/7, 4/8, 19/8, 1/9, 8/9.
Shirlan as per Negfry (air assisted)	Fluazinam	0.2 l	100	8	22/6, 3/7, 16/7, 27/7, 4/8, 19/8, 1/9, 8/9.

Table 4. Effect of fungicide treatment on disease outbreak, AUDPC, marketable yield and tuber blight (Oak Park Research centre, 1996).

Treatment	Delay in disease onset(Days)	AUDPC	Marketable Tuber yield (tonne/ha)	Tuber blight (tonne/ha)
Unsprayed	0	1782.3	39.16	0.01
Dithane DF (2.25 kg/ha)	12.75	214.7	47.78	0.05
Ridomil MZ 72 fb Dithane DF	25	11.2	50.76	0.00
Dithane DF (2.25 kg/ha) as per Negfry	17	33	49.02	0.18
Dithane DF (1.68 kg/ha) as per Negfry	9	197.1	49.58	0.06
Dithane DF (1.12 kg/ha) as per Negfry	5.5	119.5	47.99	0.004
L.S.D. (0.05)	26.374	537.75	8.08	0.1435

Table 5. Effect of fungicide treatment on disease outbreak, AUDPC, marketable yield and tuber blight (Oak Park Research centre, 1997).

Treatment	Delay in disease onset (days)	AUDPC	Marketable Tuber yield (tonne/ha)	Tuber blight (tonne/ha)
Unsprayed	0	2980.78	29.7	0.19
Dithane DF (2.25 kg/ha)	24.5	363.65	47.91	0.29
Dithane DF (2.25 kg/ha) (air-assisted)	26.25	420.35	45.13	0.23
Ridomil MZ fb Dithane DF	29.75	299.25	41.66	0.23
Dithane DF (2.25 kg/ha) as per Negfry	15.75	777.53	41.94	0.36
Dithane DF (1.68 kg/ha) as per Negfry	19.25	702.1	36.21	0.25
Dithane DF (1.68 kg/ha) as per Negfry (air-assisted)	5.25	1093.75	39.09	0.28
Dithane DF (1.12 kg/ha) as per Negfry (air-assisted)	14	1101.63	42.55	0.24
Shirlan (0.3 l/ha) as per Negfry	17.5	412.3	46.58	0.42
Shirlan (0.3 l/ha) as per Negfry (air-assisted)	21	107.54	49.78	0.2
Shirlan (0.2 l/ha) as per Negfry (air-assisted)	15.75	193.38	45.89	0.29
L.S.D. (0.05)	17.42	443.78	12.60	0.42

Table 6. Effect of fungicide treatment on disease outbreak and AUDPC (Oak Park Research centre, 1998).

Treatment	Delay in disease onset (days)	AUDPC
Unsprayed	0	1522.15
Dithane DF (2.25 kg/ha)	63.25	0.00
Dithane DF (2.25 kg/ha) (air-assisted)	54.00	0.7875
Shirlan (0.4 l/ha)	47.75	0.6125
Ridomil Gold fb Dithane DF	55.25	0.6125
Dithane DF (2.25 kg/ha) as per Negfry	58.25	1.4875
Dithane DF (1.68 kg/ha) as per Negfry	53.00	0.6125
Dithane DF (1.68 kg/ha) as per Negfry (air-assisted)	55.75	0.35
Dithane DF (1.12 kg/ha) as per Negfry (air-assisted)	54.00	0.175
Shirlan (0.3 l/ha) as per Negfry	51.75	0.4375
Shirlan (0.3 l/ha) as per Negfry (air-assisted)	57.50	0.35
Shirlan (0.2 l/ha) as per Negfry (air assisted)	51.25	0.875
L.S.D. (0.05)	22.24	707.11

Table 7. Effect of Negfry on fungicide usage from 1996 – 1998.

	Year		
Rate	1996	1997	1998
Full rate	44.6%	77.7%	80.0%
¾ rate	33.3%	58.3%	60.0%
½ rate	22.2%	38.8	40.0%

Third Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

Experience of a DSS for the control of potato late blight in Bavaria

H. HAUSLADEN, J. HABERMEYER, V. ZINKERNAGEL

Lehrstuhl für Phytopathologie
TU München-Weihenstephan, D - 85350 Freising, Germany

Abstract

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

This paper describes the basis of the Phytophthora model Weihenstephan, a model for the integrated control of late blight caused by the fungus *Phytophthora infestans*. The experience and the results of the year 1998 in Bavaria are presented and discussed.

Key words: DSS, SIMPHYT, late blight, warning system

Introduction

In Bavaria, potatoes are grown on an area of 60.000 hectares. This area has been very stable since 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 optimise 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.

The first step was to compare different blight forecasting models. In the years 1994 to 1996 the Institute of Phytopathology in co-operation with the Bavarian State Institute of Agronomy and Crop Protection tested several DSS in experimental plots. Results of the validation over three years showed that SIMPHYT I/II developed by the Federal Biological Research Centre for Agriculture and Forestry was one of the best models tested.

Based on the results of this research we decided to work with SIMPHYT further on. Therefore in the year 1997 this model was tested in 30 field trials in the Bavarian region. In the same year a warning service of potato late blight was introduced, 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 in Bavaria this year.

Materials & Methods

The experiences of the recent years have shown that a working Phytophthora advice service needs a blight forecasting computer-model and that it is necessary to observe the recommendations on the start of spraying, the spraying interval and fungicide usage in field trials. This main idea is realised in the **Phytophthora model Weihenstephan.**

Thus, the Phytophthora model Weihenstephan is based on two components (Fig. 1):

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

Figure 1. Phytophthora model Weihenstephan.

In 1997 the weather-based prognosis was founded on the blight forecasting model SIMPHYT which consists of the sub-model SIMPHYT I and II. SIMPHYT I forecasts the time to start fungicide spraying. SIMPHYT II calculates the spraying interval and the type of fungicide. In 1998 the prognosis was based on SIMPHYT I and SIMPHYT III, a further developed and modified sub-model.
Hourly meteorological data on temperature, relative humidity and rainfall are provided automatically by weather stations belonging to the Bavarian State Institute of Agronomy and Crop Protection. Such weather stations had 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 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 belonged to farmers, also contained an untreated control plot of about 100qm. No fungicide applications were 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 were two or three monitoring-fields in the vicinity of each weather station.

Both types of information - disease observation and the output of the computer-based model (SIMPHYT) - were evaluated and interpreted and then an advice for fungicide applications is drawn. Twice a week we sent the recommendation to the official advisory service and published it in a weekly newspaper for agriculture called „Landwirtschaftliches Wochenblatt" which is subscribed by nearly all of the Bavarian farmers.
In 1998 this Phytophthora warning system was introduced via World Wide Web. In this system the information from the Phytophthora model Weihenstephan was available (http://www.weihenstephan.de/pp or http://www.lbp.bayern.de).

Results and Discussion

Dry climatic conditions with rare rainfalls in May were not conducive to the development of *Phytophthora* late blight. At the end of May few rainfalls were measured but the temperature increased so the unfavourable situation for blight remained. More precipitation was measured in mid-June.
In Bavaria 1998, late blight was first detected at the end of June. In most of the monitoring fields *Phytophthora* outbreak occurred at the beginning or middle of July in the untreated control plots.
The rainfall in July was normal, but the temperature in the mid-July was very high. Consequently, late blight in the untreated plot spread very slowly at most sites. At the end of July the temperature decreased to the normal level and therefore the *Phytophthora* disease developed more quickly. In August there was no precipitation for the first three weeks and the temperature was very high. As a result, potato late blight was halted. Most of the untreated haulm had been killed by this time by *Alternaria solani* .Also the fungicide treated foliage were infected by early blight.
The time for the first fungicide treatment was forecast by the sub-model SIMPHYT I. 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 1) and outbreak.

The results demonstrate that there was no outbreak of *Phytophthora* late blight before the time for the first fungicide treatment calculated by SIMPHYT I. At most of the weather stations, the outbreak was observed two to three weeks after the recommended treatment time. These results confirm the results obtained in 1997.

In figures 3 and 4 there are two examples of the epidemic pressure during the growing season. The epidemic pressure is calculated by SIMPHYT III. The time of applications is marked by an arrow.

Figure 3. Weather conditions and infection pressure 1998 at Binding, Lkr. Neuburg.

Figure 4. Weather conditions and infection pressure 1998 at Obersteinbach, Lkr. Roth.

The arrow in the weather chart marks the first observation of *Phytophthora infestans* in the untreated plot. No late blight was observed in the fungicide treated field at either of the two sites.

Conclusions

The results of a poll 1997 indicate that farmers are very interested in an applicable Phytophthora advice service. The warning system presented has been established since 1997. The good results of the sub-model SIMPHYT I obtained over the last two years

must be confirmed in the coming years. It seems that the sub-model SIMPHYT III worked better in periods of high and very high infection pressure compared with SIMPHYT II. The SIMPHYT III model needs to be further tested in years with lower disease pressure.
In addition, the Phytophthora model Weihenstephan must be tested at more sites over several years to verify the function of this model for the integrated control of potato late blight.

References

Gutsche, V. 1998. Usage of SIMPHYT in frame of the project PASO in Germany from 1994 to 1997. In: E. Bouma and H. Schepers (eds.), PAV-Special Report no3, January 1998, 104-110.

Gutsche, V. , Kluge, E. 1996. SIMPHYT I und II. In: 50. Deutsche Pflanzenschutztagung. Mitt. Biol. Bundesanst. Land-Forstwirtsch.. Berlin-Dahlem 321, 332.

Hausladen, H., Habermeyer, J., Zinkernagel, V. 1998. Phytophthora-Modell Weihenstephan: Prognose und Bekämpfung der Kraut- und Knollenfäule an Kartoffeln in Bayern. In: 51. Deutsche Pflanzenschutztagung. Mitt. Biol. Bundesanst. Land-Forstwirtsch.. Berlin-Dahlem 357, 103-104.

Kleinhenz, B., Jörg, E., Kluge, E., Rossberg, D. 1995. PASO - Rechnergestützte Entscheidungshilfen für den Pflanzenschutz. Gesunde Pflanzen 47 (6), 222-230.

Zellner, M. 1998. Untersuchungen über die Treffsicherheit von Prognosemodellen zur termingerechten Bekämpfung von *Phytophthora infestans* (Mont.) de Bary an Kartoffeln in Bayern, Ph.D.thesis, Freising-Weihenstephan.

Acknowledgement

We want to thank the Bavarian Ministry for Food, Agriculture and Forestry for financial support of this work.

Third Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

Potato late blight disease forecasting – Commercial use of Plant-plus in the UK in 1998

HOWARD HINDS & LESLEY MITCHELL

DMA Crop Consultants Ltd,
Unit 5, Beacon Court,
Ollerton, Notts. NG22 9QB.

Summary

A commercial service of potato late blight forecasting using the PLANT-*Plus* system was implemented by seven potato growers in the East Midlands. The service used real-time local weather data which was collected using Adcon Telemetry weather stations as well as crop information collected through weekly crop inspections, by DMA Crop Consultants (DMA) advisors. This data was integrated with a 5-day local weather forecast and used in the PLANT-*Plus* Decision Support System (DSS) to generate crop protection advice. The interpretation of the model output and the communication of subsequent advice were performed by DMA.

Each grower allocated 20ha of potatoes to the project. The remaining part of their crop was to be treated according to normal practice in order to provide a comparison of disease and fungicide costs. Comparisons were also available from growers who were not part of the PLANT-*Plus* user group.

Disease pressure during June was severe and numerous fields in the area became infected with blight. Growers following DMA advice derived from PLANT-*Plus,* sprayed at shorter intervals in this period than did nearby growers using normal practice programs. The result of this was that there were more outbreaks of blight infection in the normal practice crops. The crops of PLANT-*Plus* growers remained blight free, with the exception of one crop managed by a grower who delayed his implementation of advice.

The total number of fungicide treatments applied during the season was similar for both systems, with the difference being that the PLANT-*Plus* growers applied more fungicide treatments in June, but less in July and August.

The freedom from infection in crops treated in accordance with DMA advice generated from the use of PLANT-*Plus,* gave growers confidence in the system to such an extent that they implemented the forecast advice on a large proportion of their crops.

Key Words forecast, DSS, Internet, interpretation, advice, blight, confidence, telemetry, weather.

Introduction

Previous work carried out by DMA in the East Midlands during the 1997 growing season, compared the theoretical implementation of two different blight models; Ullrich Schrödter and PLANT-*Plus* (Hinds 1997). These models were assessed to determine their suitability for development as a commercial service to be offered to local potato growers.

In 1997, growers continued their normal practice treatments whilst observing and evaluating the theoretical spray programmes generated by the models. The conclusion from what turned out to be a summer of severe blight infection, was that PLANT-*Plus* would be a more suitable system as the basis of a disease forecasting service.

One of the main advantages of PLANT-*Plus* over Ullrich Schrödter, is the integration of a local five day weather forecast, which is used in the generation of a predictive disease forecast for significant infection periods. Timely warnings generated from this prediction, allows growers time to spray with protective treatments before the actual infection periods. PLANT-*Plus* also takes account of new growth, chemical wear off and nearby sources of infection, (Hadders 1996).

It was clear from the evaluation in 1997 that the PLANT-*Plus* model had the ability to generate treatment recommendations at short intervals in periods of high risk, whereas Ullrich Schrödter was not flexible enough to do this. Ullrich Schrödter and other models have been evaluated (Bradshaw 1997) but this is the first time PLANT-*Plus* has been used in a commercial context in the UK.

The following shows how PLANT-*Plus* was implemented by DMA in an integrated commercial service in 1998 and describes its performance in protecting potato crops from late blight infection during the season.

Method of Operation of the Service

Growers and Crops

Growers who had been involved in previous studies were approached and seven agreed to follow PLANT-*Plus* and DMA advice. The system was to be carried out on a crop area of 20ha with most growers choosing 2 individual fields to make up this area. This area was chosen to make it easier for growers to react to the advice provided and treat the crops within a day or two of the recommended timing of treatment. The remaining crop area for each grower would act as the commercial control and be treated in accordance with normal practice. This would allow cost benefit comparisons to be made at the conclusion of the work.

Most of the growers were growing processing potatoes for the crisping market, with the most common variety being Saturna which has moderate resistance to blight. The other varieties grown were, Maris Piper (moderate resistance) and Shepody (low resistance).

Local Weather Data

Local weather data was collected using a network of Adcon Telemetry weather stations. The site of data collection varied but was usually located within 2 - 3 km of the test fields. Data for rain, temperature, humidity, windspeed and wind direction are required by PLANT-*Plus* and suitable sensors were installed to provide this data. The network consisted of 6 linked solar radio stations transmitting real-time data by telemetry to a DMA central receiver and PC data server.

Local Forecast Weather

A five day weather forecast was generated from 2 synoptic stations, one in the south and one in the north of the network. Forecast weather data was automatically updated every 3 hours by the service provider.

Data Transfer

Before the season commenced an Internet connection was established between Dacom NL and DMA. Every 6 hours the recent actual site weather data was automatically compressed and sent using this Internet pathway to Dacom NL. The data server of Dacom NL was also provided with the local weather forecast which was allocated to the appropriate actual data and integrated with it for each site. The complete data file was then called at regular intervals from the Dacom NL data server by DMA advisers and locally processed through the PLANT-*Plus* software.

Dacom Systems UK Limited

The PLANT-*Plus* software, system support and administration used in this project was provided by Dacom Systems UK Limited.

Crop Recording

An essential component of this project was the gathering of crop information through weekly field inspections. During visits, the crops and nearby dumps were scouted for blight infection and recordings were made of crop growth and density. As well as this any incidence of blight in other crops in the district was also recorded. These measurements and records were converted into suitable scores and input into the system software.

Advice

The data was processed and the output monitored each day during the growing season, by DMA advisors. 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, initially by telephone, was established with the grower. During this communication the disease risk was discussed and a spray timing was advised.

Product selection was based not only on the required activity of the fungicide, but also on availability and cost. Once a product was agreed a spray recommendation was faxed to the grower. When the field had been treated it was the growers responsibility to communicate to the advisor, details of the application such as time, date and product rate.

Results of the Service

Local weather

After a dry period towards the end of May, the beginning of June was wet with heavy rainfall occurring on all sites. Throughout June there was no relief from the rain, with some sites receiving up to 150mm of rain during this month. The rainfall did relent in July and August but the general pattern throughout the summer was unsettled with no significant periods of dry weather.

PLANT-*Plus* Model Advice

The early wet weather combined with rapid new growth and nearby infection sources resulted in the model triggering treatment recommendations at very short intervals (4 to 7 days) during the whole of June. During July and August the spray interval advice was extended, but only to 8 to 12 days depending on the period. Figure 1 is an example of infection chances as calculated by the PLANT-*Plus* model during the season.

In the upper section of the graph, the line upwards indicates growth and the line downwards indicates the degradation of the product applied. The degradation rate depends on the product used, the applied dose, radiation and precipitation. The white area represents the total area of unprotected leaf. After a spraying with a full dose, the crop is assumed to be completely protected. The black areas within the triangles represent products which have curative and protective properties. In the bottom graph the black areas represent the duration and the severity of infection periods.

Figure 1. PLANT-*Plus* year summary for site A.

Spray Application Timing

Reaction by growers to DMA recommendations based on PLANT-*Plus* was in general very good. When a recommendation was given, application was usually made within 2 days and sometimes on the day itself. Throughout June most growers using the service were applying treatments at 5 to 7 day intervals. During this period growers using normal practice were typically spraying at 8 to 10 day intervals.

Table 1 shows the number of treatments applied per month for each grower site. This shows that around 50% by number of treatments to the end of August were applied in June, which was far higher than in normal practice crops. However, the average total number of sprays for the group for the season was 11.6 which was equal to the normal practice spray programmes used in the area.

Table 1. Sprays per month at PLANT-*Plus* sites 1998.

Grower	June	July	August	Total
A	5	3	3	11
B	5	4	3	12
C	6	3	3	12
D	6	3	2	11
E	7	3	3	13
F	5	3	3	11
G	4	5	2	11

Of the seven growers, only grower G was significantly late with the first spray. Thereafter grower G's treatment intervals were extended well beyond recommendations. The reason for this hesitant start was due to a shortage of sprayer capacity. The grower did manage to improve timing eventually but it was too late to prevent some blight infection.

As infection became established in the district it was noticed that growers using the service began to implement the service advice on the rest of their crop area. Therefore the only true normal practice programs available for comparison are those of neighbouring growers.

Crop Infection

Blight infection in potato dumps was also observed (and recorded in the model) near most sites in the project, even before emergence of the crops in May.

As a consequence of the wet June and local infection sources, all crops were under severe blight pressure for a long period. Reports of field infections were recorded after only the second week of June and by the end of June accounts of blight affected crops were numerous from growers using normal practice spray programs.

With the exception of grower G's sites which became infected with blight towards the end of June, all service sites remained blight-free throughout the whole season. Within grower G's 20ha block, blight was noticed first in the variety Shepody, developing into a few small areas of infected plants. About 10 days later (early July) a few infected stems and leaves were observed in Saturna in the other field of the block. In both cases the blight was subsequently kept under control but required intensive spraying.

The PLANT-*Plus* model graphics shown below in figure 2, compare the infected G site, with the D site, which remained blight free. Blight infection at G probably occurred between the 20th and 26th June. Up to this point only 3 fungicide treatments had been applied at G compared with 5 fungicide treatments at the D site.

Figure 2. Comparison of treatments and infection pressure for sites G and D in June. Site G

Site D

Interpretation and Implementation of Advice

In most cases the advisors in this project persuaded growers to implement advice for both fungicide timing and choice. Communication by telephone was the most effective and efficient way of passing on the advice. Interpretation of risk from the model, although not always day perfect was generally in accordance with the apparent risk to the crop, as reflected by the increase in the number of sprays in June. Communication back from the grower was often slow and spray records usually had to be chased up on the telephone by the advisor.

IT Performance

Considering this was the first year of running an Internet based service from an Adcon Telemetry weather station network, data transfer was remarkably trouble free. The support provided by Dacom Systems UK Ltd was an important factor in the smooth running of the project.

Discussion

The PLANT-*Plus* forecasting service certainly had a baptism of fire. Right from the start spray recommendations were being generated at an alarming frequency. At first some growers were unsure of the short spray intervals being advised in June. However once they became aware of infection in neighbouring crops in this period, they realised PLANT-*Plus* had identified the risk correctly. In their eyes this validated the system and crucially gave them the confidence to follow its advice.

Proof of this confidence was shown in the way the growers adjusted their whole spray programs, to tie in closer with the service advice.

The early part of the season was so bad that crops which had not been treated at least 4 times by 20th June were at risk from infection. As other growers were following label recommendations at 7 to 10 day intervals, they did not achieve the target number of sprays by this date. Consequently many experienced blight infection in crops. What became apparent at this time was the fact that under such severe conditions products were not effectively persisting, even for the minimum spray interval.

Therefore, PLANT-*Plus* had correctly identified the limited duration of fungicides in June. The frequency of advised treatments reduced in July and August, albeit only extending intervals from 6 to 10 days.

In July, ‘routinely’ sprayed crops were then intensively treated to hold back infection which was present. The result was that both normal practice programs and forecast programs used a similar number of sprays for the season. Despite not saving any chemical, a comment from one PLANT-*Plus* grower was that “he felt more in control“. PLANT-*Plus* growers also have blight free crops and the added comfort of storing uninfected tubers.

From an advisers point of view the service worked well because if anything the model does err on the side of caution. For example, in severe weather conditions with new growth, chemical wear off and local sources of infection nearby, the PLANT-*Plus* model can generate a spray recommendation after only 4 days. Traditional thinking indicates that this is too soon. However once the warning is communicated it usually takes the grower a day or so to take action, mainly because the weather is against application. Sometimes the interval could have been extended to 5, 6 or 7 days but is most likely still within the safety limits of a good product. What went wrong for routine spray programs in the 1998 season was that aiming to spray every 7 days was similarly pushed back to day 8, 9 or 10 days. Experience from this season confirms that at times this interval was too long.

Whatever the margin of safety built into PLANT-*Plus* there are practical considerations to take into account when running any agricultural service. Not only can inclement weather influence spray timing but sprayer availability, irrigation, and chemical shortage are all factors which can cause a delay in application timing.

This season having sufficient sprayer capacity was critical as one PLANT-*Plus* grower found to his cost, however the model will highlight weaknesses in this area, and can be used as a tool to plan for sprayer requirements for a farm.

Intense use of potato fungicides throughout Europe in 1998 caused certain products to run out mid season. Most model growers did have some stock in reserve and those that didn’t were made aware of the importance of buying key fungicides ahead of time.

Crops in the project were irrigated quite frequently once soil dried out in July and August. Although the irrigation application did not appear to significantly increase disease pressure with PLANT-*Plus*, the irrigation machinery could add to the complication of running the model. If an irrigation system was at work in a field when a spray recommendation was given, it would soon put that particular field out of sequence from a block of fields. This could then substantially add to the individual number of programs required for any one farm.

On top of all the factors affecting late blight forecasting, any service still relies on the relationship between grower and advisor. In this respect PLANT-*Plus* helps satisfy both the advisor and the grower requirements of a model. Where the advisor requires a good science based system, with a common sense approach, the grower does not want to spend time on interpretation, he just wants to know with as much warning as possible, “what to do and when to do it”. Therefore providing the advisor has a good understanding of blight and fungicides, and the grower has the flexibility to implement advice, the service can work to the advantage of both parties.

Conclusion

The PLANT-*Plus* commercial service implemented by DMA Crop Consultants in the UK in 1998 worked well for both advisers and the potato growers it serviced. Next season it is planned to extend the service both in number of growers and in individual crop area. During the winter of 1998/99, work with PLANT-*Plus* is planned with potato growers in Portugal and Spain.

References

Hadders J. (1996). Experience with a late blight DSS (PLANT-*Plus*) in starch area of the Netherlands in 1995 and 1996. PAV-Special Report 1997.

Hinds H. (1997). Experiences of running late blight models on Adcon network weather data in the UK. PAV-Special Report 1998

Bradshaw N, Taylor M.C., Hardwick N.V. (1997). Problems with forecasting potato blight in England and Wales, 1994-1997. PAV-Special Report 1998.

Third Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

Validation of SIMPHYT I/II – A decision support system for late blight control in Germany

B. KLEINHENZ AND E. JÖRG

State Institute for Agronomy and Plant Protection of Rheinland-Pfalz
Essenheimer Str. 144, D-55128 Mainz, Germany

Abstract

SIMPHYT, a decision support system for the control of late blight (*Phytophthora infestans*) consists of two sub-models: SIMPHYT I – a predictor for the date of first appearence of *P.infestans* and SIMPHYT II – a model to improve the fungicide use (choice of products, spraying intervals).

SIMPHYT I/II was validated from 1994 to 1998 in all relevant potato growing regions of Germany. Results were very promising. The share of timely forecasts for the start of Late Blight epidemics by SIMPHYT I is about 90% (with the exception of 1997). SIMPHYT II strategies needed less fungicide input than conventional strategies. In the average two applications could he saved and in addition more cheaper contact fungicide were recommended by SIMPHYT II. Control efficacy of both strategies did not differ.

SIMPHYT I/II is the most important tool in integrated crop protection of potatoes and has been introduced into practice in Germany on a large scale by governmental crop protection services. As demanded by the extension services SIMPHYT III, a model informing on dry periods and infection pressure of *P.infestans* has been elaborated. SIMPHYT III results are widely used in the warning services.

Keywords: *Phytophthora infestans*, decision support system, SIMPHYT, fungicide use, forecast, warning service

Introduction

During the eighties and early nineties numerous Decision Support System (DSS) for the control of pests and diseases in various arable or vegetable crops have been elaborated. But only a few DSS have been introduced into agricultural crop protection practice, mainly on a limited scale. At the end of 1993 the German Federal Ministry of Food, Agriculture and Forestry started a three years pilot project on the "Introduction of Computer-aided Decision Support Systems into Agricultural Pratice" (Kleinhenz et al., 1995). The main aim of this "Paso-Project" was the availability of the results of ten DSS, mainly for arable crops, for farmers. Governmental crop protection services of eleven German states ("Bundesländer") had to validate the performance of the DSS, modify them if necessary and provide the farmers with the DSS-results via warning services (different media, e.g. fax, answering machines etc.). Because of the great success the pilot-project was prolonged for another year until the end of 1997.

Among the DSS to be validated and introduced into practice on a large scale SIMPHYT I/II proved to be one of the most successful models.

SIMPHYT I/II

The SIMPHYT-DSS consists of two modules: SIMPHYT I predicts the date of first appearance of *Phytophthora infestans*. In crop protection this date determines the start of the fungicde schedule. SIMPHYT I needs as input temperature and relative humidity on a 3-hourly base and daily precipitation. In addition a regional factor (characterising the longterm climatic conditions) and an estimate (classification in four groups) of the seed potato infestation with *P.infestans* is needed. For more details see Gutsche and Kluge (1995, 1996) and Gutsche (1998).

SIMPHYT I predicts the date of first appearance for eight crop emergence-date classes and two risk levels for the production sites, i.e. predicted dates in total (see Figure 1). The emergence-date classes cover all relevant potato growing regions in Germany. Sites close to lakes or rivers or with waterlogged soils or where highly susceptible potato varieties are grown are grouped into "risk level 1", indicating a high risk for early epidemic outbreaks of *P.infestans*. "Risk level 2" characterises sites with a lower risk, e.g. medium susceptibility of the grown cultivar or rather dry conditions. SIMPHYT I is run at least twice a week by extension officers of the governmental crop protection services thus guaranteeing a forecast-timespan of eight days.

Figure 1. SIMPHYT I – prediction of the date of first appearance late blight.

SIMPHYT II monitors the onset of *Phytophthora*-epidemics and recommends a spraying strategy. Originally SIMPHYT II signalised dry periods in which the fungus dies back in the field and as a consequence one may renounce on fungicide applications. During the PASO-Project SIMPHYT II has been developed into a comprehensive DSS. A detailed description of the model structure is given by Gutsche & Klug (1995, 1996) and Gutsche (1998). SIMPHYT II recommends plotspecific fungicide applications (see Figure 2). The choice of active ingredients and the length of spraying intervals is varied according to an internally calculated infection pressure. SIMPHYT II includes several functions for fungicides efficacy of contact, translaminar and systemic fungicides (see Figure 3) over time. The model differentiates the products registered in Germany into five groups (Table 1).

Figure 2. SIMPHYT II – recommendation of plot specific fungicide stategy.

Figure 3. SIMPHYT II – relative loss of fungicide efficacy after application.

Table 1. SIMPHYT II – fungicides registered in Germany are grouped into 4/5 classes.

Contact fungicides	
F1:	Propineb, Mancozeb, Maneb, Metiram
F2:	Fluazinam
F5:	Fentinacetat/-hydroxid + maneb
Translaminar	
F3:	Dimethomorph, Cymoxanil, Propamocarb

	(all in combination with mancozeb)
Systemic F4:	Metalaxyl + Mancozeb

SIMPHYT II calculates disease progress curves and the daily increases of disease severities for untreated plots treated with fungicides (see Figures 4 and 5).

Figure 4. SIMPHYT II – untreated plot: disease progress curve and daily increase of disease severities.

Figure 5. SIMPHYT II – plot treated with fungicides; disease progress curve daily increase of disease severities.

Material and methods

Before introduction into crop protection practice the DSS was validated in all relevant potato growing regions of Germany. As SIMPHYT was elaborated in Eastern Germany the DSS performance was well known under the rather continental climatic conditions of that part of the country. No information was available on how SIMPHYT works under maritime weather conditions with higher infection pressure. The inherent regional factors needed to be validated and if necessary, modified.

SIMPHYT I was validated by comparing the predicted dates of first appearance with observed date in potato fields. During the project phase of PASO numerous observations of first Late Blight appearance were recorded (1994:47; 1995:58; 1996:78; 1997:73). Each field was identified by an emergence date class for the crop, a risk-level of the production site and the assignment of a weather station. SIMPHYT I gave a timely forecast when the predicted date of first appearance was earlier than the observed date.

For SIMPHYT II validation small trials were laid out consisting of three treatments: - untreated plot (on a volunteer base), - conventional fungicide strategy, - SIMPHYT II strategy. The “conventional plots” were treated either by farmers or by extension officers according to their optimal regional Late Blight strategy. “SIMPHYT II plot” were treated on the dates and with the fungicides recommended by the DSS. A treatment one or two days later than recommended by SIMPHYT II was tolerated. Several *P.infestans* disease severity assessments were made during the season and in some trials tuber yields and starch contents were measured (data are not reported in this paper).

Results

SIMPHYT I

More than 330 observations on the date of first appearance of *P.infestans* have been recorded to validate the performance of SIMPHYT I during the PASO-project from 1994 to 1998. With the exception of 1997 the results are very promising. The share of timely forecasts of the beginning of the late blight epidemics mostly exceeded 90% (Figure 6). After the first year of validation slight modifications of the inherent regional factors were necessary which resulted in a higher share (+ 4 to 10%) of correct predictions. Mostly the disease occurred one to fourteen days after the predicted date. In 1996 the timespan between predicted and observed date of first appearance often exceeded fourteen days and in many plots *P.infestans* did not occur at all.

SIMPHYT I results in 1997 were insufficient. In 40% of the cases the prediction of the date of first Late Blight appearance was too late (Figure 6). The delay ranged from one or two days in south-western Gemany to two or three weeks in the central and northern part of Germany. Satisfying results were obtained in the eastern and southern parts of Germany.

Figure 6. SIMPHYT I – share of timely forecasts (%).

SIMPHYT II

During the five years of validation it became obvious that there is a high potential for less intensive fungicide strategies by employing SIMPHYT II. In the first phase of SIMPHYT II validation, from 1994 to 1996, conventional spraying schedules required 6-7 fungicide applications for effective *P.infestans* control whereas the DSS recommended 4-5 treatments. In the average two applications could be saved by using SIMPHYT II (see Figure 7). In 1995, a rather moist year SIMPHYT II recommended about five treatments whereas in the more dry vegetation period of 1994 and 1996 only four treatments were necessary. Since 1997 SIMPHYT II is intoduced into pratice on a large scale. So conventional fungicide strategies to a high degree also reflect the DSS-strategy. However, by strictly observing SIMPHYT II-recommendations still 1-1,4 applications could be saved, even in a year like 1997 with rather severe Late Blight epidemics in Germany. 1998 data presented in Figure 7 are still incomplete.

Figure 7. SIMPHYT II – number of sprayings in conventional and SIMPHYT II plots.

A comparison of the fungicide choice revealed similarities as well as differences between conventional and SIMPHYT II strategies (Figure 8). In 1995 and 1996 the share of the different fungicide groups applied in both strategies was equal. In 1997 conventional spraying schedules heavily relied on translaminar and systemic ingredients, whereas SIMPHYT II recommended a higher share of contact fungicides, especially dithiocarbamates. Also in 1998 SIMPHYT II used more dithiocarbomates, but in both strategies equal shares of contact fungicides (about 60%) were employed.

In accordance with the results of Gutsche (1998) both strategies resulted in the same Late Blight disease severities at the end of the season.

One main reason for the reduced number of applications in SIMPHYT II strategies is the occurrence of dry periods. In several trials SIMPHYT II signalised one or two periods with detrimental effects on late Blight epidemics (Figure 9). The length of these periods varied from 10 days to more than five weeks. In the latter case 3-5 applications could be saved by the DSS strategy in some trials.

Figure 8. SIMPHYT II – comparison of fungicide choice in conventional and SIMPHYT II strategies.

Figure 9. SIMPHYT II – length of dry periods which allow a reduction in fungicde use.

Discussion

SIMPHYT I/II proved to be of high value for decision making in *Phytophthora*-control. By employing SIMPHYT I the start of the epidemic could be predicted correctly in most of the cases. But still there is a share of about 10% predictions that were too late. As our analyses showed SIMPHYT I may give false predictions on sites where potatoes grown under plastic cover neighbour unprotected potato crops, where volunteer potatoes from last year do not freeze off during winter and emerge in the following potato crop on the same field and where irrigation with high amounts of water is applied. The impact of these factors is not represented in SIMPHYT I and may be the cause for the delayed prediction. Prediction models for irrigated fields and potato crops under plastic cover are in development.

In 1997 SIMPHYT I gave poor results, only 60% of the forecasts were in time. The reasons for the early outbreak of Late Blight in 1997 have been discussed at Carlow (see Schepers and Bouma, 1998). Frequent heavy rainfalls and high soil moisture have provided optimal conditions for early infections. But as Schlenzig and Habermeyer (1998) stated the early phase of Late Blight epidemics is not yet fully understood and up to now there is no comprehensive approach available to include the factors mentioned above into DSS.

SIMPHYT II also gave very promising results. In the average the DSS strategy needed two treatments less than conventional strategies. Highest reductions in the numbers of applications were obtained under dry weather conditions. In moist weather conditions and with frequent rainfall no differences between conventional and SIMPHYT II strategies could be observed. In two trials where frequent and heavy rainfalls (>40 litre/m^2) occurred SIMPHYT II was not able to control the blight epidemic sufficiently. One reason for unsatisfactory results could be that the weather station was not representative for the trial site (rainfall!). On the other hand, if the date of first appearance of *P.infestans* as input for SIMPHYT II is predicted too late difficulties with the simulation of the Late Blight epidemic may occur. SIMPHYT II assumes as a starting point a potato field free of *P.infestans*. If the fungus is already present in the field the inoculum is underestimated and SIMPHYT II generates less severe epidemics than those occurring in reality. As the epidemic level is taken into consideration for decision making wrong decisions concerning the fungicide choice or the length of spraying intervals may result from underestimation.

In general more experience with the performance under rather humid maritime climatic conditions are needed.

Further development

Within the DSS SIMPHYT I/II decisions are taken on two levels, on a plotspecific level (SIMPHYT II) and on a regional level resp. for groups of plots (SIMPHYT I). SIMPHYT I/II is mainly used by the extension officers of German crop protection services, who advice numerous farmers in groups rather than single farmers. There is a strong demand for informations on the regional/local level. Lower priority is given to plotspecific strategies.

Therefore SIMPHYT III has been developped, a model that provides extension officers with informations on epidemic pressure and dry periods. SIMPHYT III can be considered as a “regionalisation” of SIMPHYT II. The model itself does not recommend a fungicide strategy, but from the SIMPHYT III general strategies can be derived.

In cases of low epidemic pressure and when only a few days with occupation rates occur (Figure 10) cheap dithiocarbamate fungicides may be recommended within a spraying schedule. During dry periods one may omit a treatment. On the other hand under higher epidemic pressure and longer periods with occupation rates (Figur 11) systemic or translaminar fungicides must used.

The results shown in Figures 10 an 11 for meteorological stations in south-western (Figure 10) and north-western (figure 11) Germany highly correlated with *P.infestans* epidemics reported from these regions in 1998.

The acceptance of SIMPHYT III by the crop protection services is high.

Figure 10. SIMPHYT III – Low epidemic pressure in the south-western part of Germany in 1998.

Figure 11. SIMPHYT III – High epidemic pressure in the north-western part of Germany in 1998.

References

Gutsche, V. & Kluge, E. 1995. Das neue Phytophthora-Prognoseverfahren SIMPHYT. Kartoffelbau 46.(5), 1995, 198-201.

Gutsche, V. & Kluge, E. 1996. The epidemic models for *Phytophthora infestans* and *Pseudocercosporella herpotrichoides* and their regional adaption in Germany. OEPP/EPPO Bulletin 26: 441-446.

Gutsche, V. 1998. Usage of model SIMPHYT in frame of project PASO in Germany from 1994 to 1997. PAV-Special Report 3. Proceedings of the Workshop on the European network for development of an integrated control strategy of Potato late blight. Eds. Schepers, H. & Bouma E., Lelystad.: 104-110.

Kleinhenz, B., Jörg, E., Kluge, E. & Rossberg, D. 1995 PASO – Rechnergestützte Entscheidungshilfen für den Pflanzenschutz. Gesunde Pflanzen, 47 (6): 222-230.

Schlenzig, A. & Habermeyer, J. 1998. Is information on latent infection and sporangial movement of *Phytophthora infestans* in potato crops useful in support of forecasting-systems. PAV-Special Report 3. Proceedings of the Workshop on the

European network for development of an integrated controlstrategy of Potato late blight. Eds. Schepers, H. & Bouma, E., Lelystad.: 40-48.

Third Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

Availability and use of meteorological data for potato and tomato late blight warning in Emilia-Romagna (Italy)

R.BUGIANI (*), P.GOVONI (*), L.COBELLI (*), R.ROSSI (**)

(*) Servizio Fitosanitario, Regione Emilia-Romagna
Via Corticella 133, I 40129 Bologna
(**) CRPV (Centro Ricerche Produzioni Vegetali)
Via Emilia Levante 18, I 40026 Imola

Abstract

Late blight potato and tomato is the most dangerous disease in Emilia-Romagna. A warning service for the occurrence of the disease using IPI model was set up in the past. Good quality meteorological data are essential for a good disease prediction. A co-operation between the Warning Service, the Regional Meteorological Service and CRPV (Research Centre for Plant Production) was established in order to provide the warning service with met-data and produce elaboration of IPI model. The present work aims to illustrate the met-data flow in Emilia Romagna and its improvement through the modification of SIPI (Integrated Production Information System) into GIAS (Global Information for Agricultural Service) using GIS technology. Example of IPI model elaboration using GIAS is given.

Key-words: Late Blight, weather data, DSS, IPI forecasting model

Introduction

In Emilia Romagna, potato is intensively grown in a well defined area in Bologna province while tomato are largely cultivated throughout the region. Potato crop has a long tradition and it is cultivated mainly for fresh market even though many varieties for industrial processing are also present. Emilia Romagna region has long been involved in I.P.M. programmes, at the beginning regarding fruit production, and since 1993 vegetable production, with tomato and potato crops included. Such activity, aiming to reduce the use of pesticide against late blight, while maintaining high yields and quality, led firstly to the elaboration of IPM crop-specific guidelines and secondly to the development and use of I.P.I. forecasting model for the first occurrence of the disease (Bugiani R. *et al.*, 1993). In 1992 the regional Plant Protection Service has set up a Warning Service for tomato late blight (and extended on potato crop in 1997) using such model to help IPM field technicians and farmers to make decision about need to spray to control the disease depending on the real risk of infection. Even though warnings are elaborated not only using forecasting models but also biological information provided by a network of sporetraps, meteorological data, their quality and efficient flow, represent undoubtedly the core of the system.

The model requires daily met-data of average, minimum and maximum temperature, average relative humidity and rainfall. This paper describes the availability of meteorological data and their use to elaborate the warnings for the first occurrence of late blight using IPI model as example. Moreover, it presents differences between the old Information System (SIPI) (Malavolta C., *et al.,* 1991) for data acquisition, and the new one (GIAS) based on GIS technology.

Network of meteorological stations of Regional Meteorological Service

The network of weather stations in Emilia Romagna comprises 4 synoptic meteorological stations, 5 meteorological stations fitted with same equipment of the formers, yet not synoptic, and 24 meteorological stations used for agricultural purposes. The synoptic meteorological stations are set up to be used in weather forecasting and therefore are placed near the coasts and airports. The other weather stations are placed within the most important agricultural areas of the region. All the weather stations mentioned are automatic and provide hourly met-data in real time.

Moreover almost 600 mechanic weather stations are present in the region, but data are up-dated only every week and therefore they are not of practical usage.

Since 1997, radar for quantitative monitoring of precipitation is operating over the regional territory and issues pictures in steps of 30 minutes available via Internet.

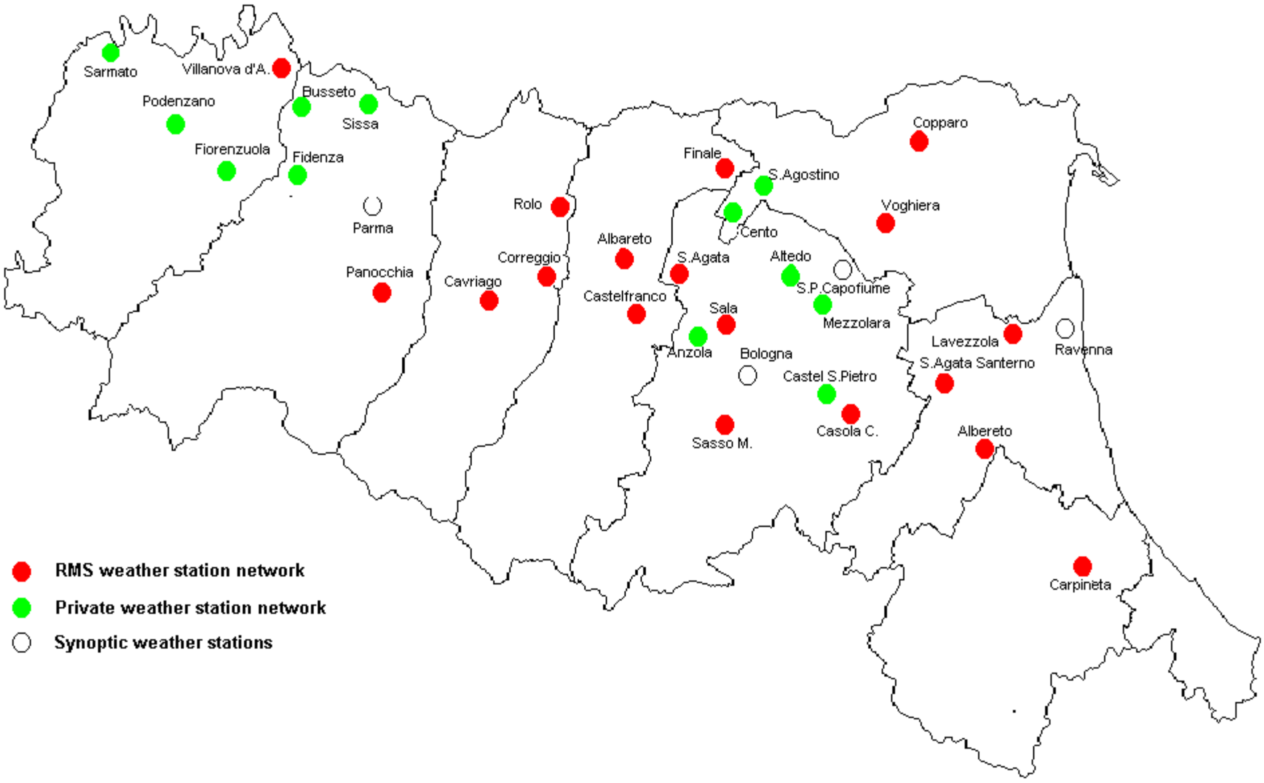
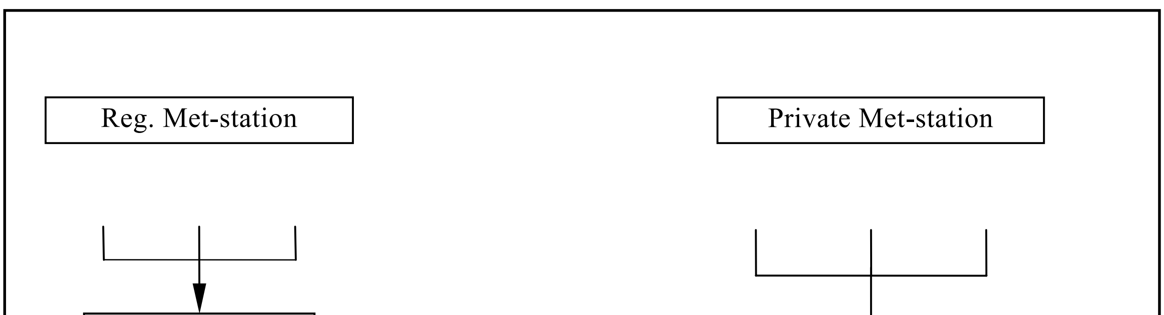


Figure 1. Network of weather station used for potato and tomato late blight warnings in Emilia Romagna.

Collaboration between Warning Service, CRPV and the Regional Meteorological Service

Met-data are delivered to warning service through the Integrated Production Information System (SIPI), developed since 1989 by the Agricultural Engineering Institute of the University of Bologna and the Advanced Service Centre of the Centrale Ortofrutticola in Cesena and now managed by the CRPV (Centro di Ricerca Produzioni Vegetali) (Fig. 2). One of the aim of the Information System and computer network was to supply meteorological data and their elaboration to the technicians on real time. To allow better processing of meteorological data, these are transformed in bi-hourly data and lacking ones are estimated and re-built before their diffusion. The reconstruction of missing data is made for temperature, humidity and wetness duration only.



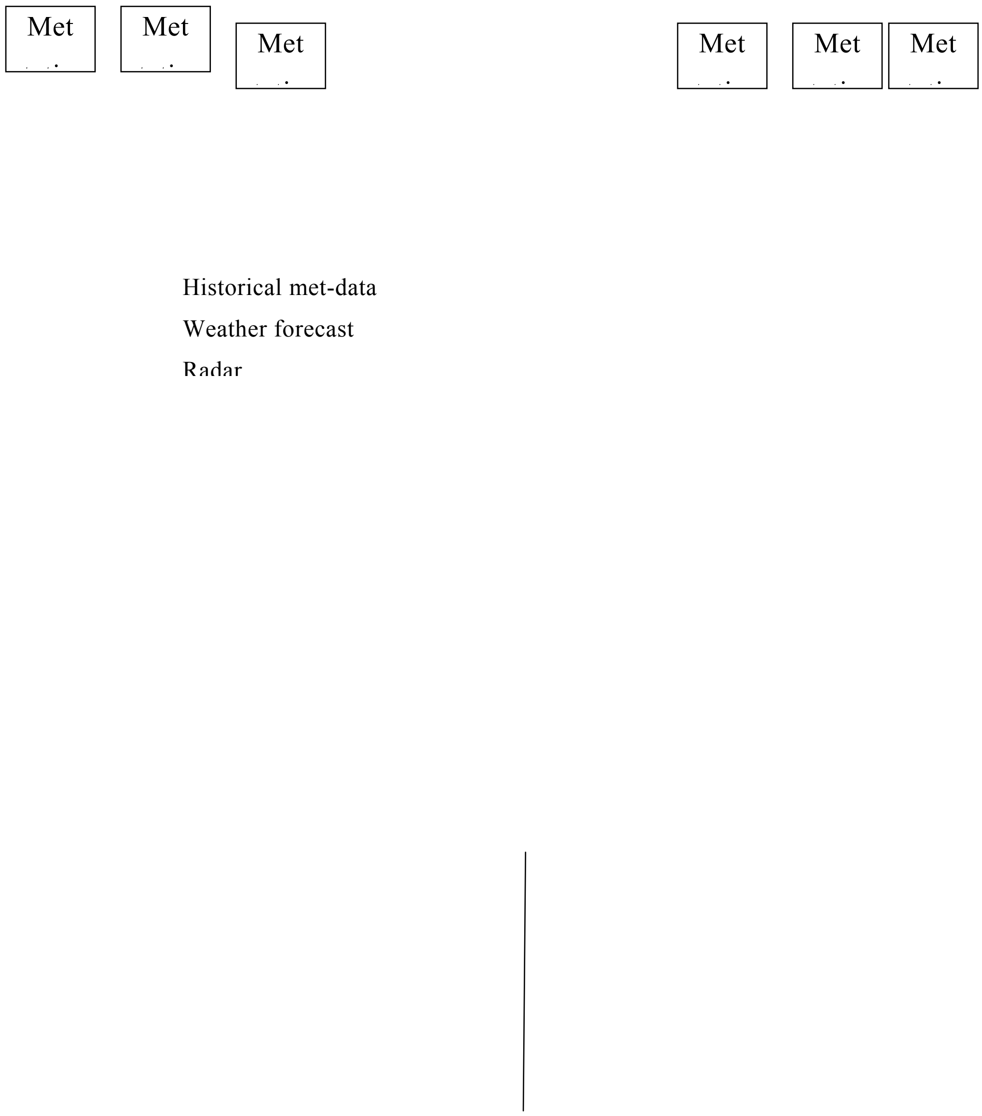


Figure 2. Flow of meteorological data and weather information used for the elaboration of I.P.I. model warnings about late blight risk on potato and tomato in Emilia-Romagna region. The Regional Meteorological Service provides Plant Protection Service with met-data daily. I.P.I. warnings are diffused to extension services and farmers.

Beside real time met-data, RMS and CRPV provide 5 days forecasting data of temperature, relative humidity and 3 days probability of rainfall (Table 1).
Beside meteorological data, the system is able to process biological data (phenology, sprays, sex-traps survey, disease severity, etc.) obtained from field surveys carried out by IPM technicians who digit them directly on a PC connected with the Information system at the CRPV. Information Service allows advisors to process data and make elaboration (degree-days sums and forecasting models for pests and diseases). CRPV retrieves met-data from DIGITAL ALPHA (with operative system OPEN VMS) using KERMIT as

communication protocol. Data elaboration from ASCI to RANDOM format are given to technicians by an "account" on PC on which the operative system SCO-UNIX is installed. Data are transferred via modem by ZMODEM protocol. Exchange of data on diskettes are also possible in cases of data provided by private met-stations network not directly connected with the warning service.

Regional Meteorological Service (RMS), CRPV and Warning Service made a formal agreement for a mutual exchange of met-data for the elaboration of warnings and the dissemination of meteorological information. Primary data are not allowed to be given to third parties if not paid.

However, since the beginning of 1998 historical data (last 10 days) of each weather station and forecasting weather data (3 days) of each province are available either numerically and as regional map via Internet from the RMS (Table 2). Forecasting weather data are elaborated by LAMBO model essentially based on the Limited Area Model of the National Centre for Environmental Prediction operating in Washington.

Unfortunately, problems with met-data occur frequently and the elaboration of warning for late blight sometimes is not totally reliable. Reconstruction of missing data regarding R.H., and wetness duration causes several problems particularly using IPI model which accumulate daily risk indexes up to a certain threshold. In this case, missing data or reconstruction errors might be accumulated throughout the season and lead to wrong blight warnings.

Table 1. Met-data provided by RMS and available via SIPI at the Warning Service.

Historical data of each weather station	Forecasted data (5 days) of each weather station
Air temperature every two hours Relative humidity every two hours Wind speed and main direction every two hours Precipitation every two hours Global radiation every two hours Wetness duration every two hours	Air temperature every two hours Relative humidity every two hours Probability of rainfall every 3 days (of each province)

Table 2. Met-data available provided by RMS via Internet.

Historical data (last 10 days) of each province	Forecasted data (3 days) of each province
Daily minimum temperature Daily maximum temperature Daily maximum wind speed	Air temperature every six hours Relative humidity every six hours Rainfall every six hours

Daily precipitation Daily average relative humidity	

Local weather data and collaboration with private network

Along with the regional network of automatic weather stations are some private networks of local weather stations belonging to farmer consortiums and provincial government; such weather stations are located inside the canopy.

Most of the met-stations are made by SILIMET and provide hourly data about temperature, relative humidity, rainfall and wetness duration. Formal agreement between Warning Service and the owners allows to process such data to obtain further elaboration. However elaboration of such data is not totally automated and therefore leads to an increase of time and labour.

The decision to use on-farm data was taken to give farmers more accurate information about the risk of blight infection. Using such data has the advantage to measure climatic conditions more closely related to the specific field where the weather station is located. On the other hand the information obtained is limited to small areas and cannot be extended, if not with a certain approximation, for a territorial technical assistance.

Future evolution: GIAS (Global Information for Agricultural Service)

New software technologies will allow a substantial improvement of the old Information System. Regional government in 1997 supported the update of the old information system using GIS technology. The new information system called GIAS (Global Information for Agricultural Service) was born to give to the most evoluted farmers, farmer associations and co-operatives willing to apply Integrated Production guidelines and EU Regulation 2078/92, a professional tool able to provide all the knowledge and elaboration useful to make decisions regarding farm management. The new system is based on two distinct yet integrated software: GIAS-PC working on personal computer and GIAS-NET working on the WEB. The former will be available to farmers and field advisers, the latter to anyone connected with Internet. The system works in WINDOWS 95 environment using VISUAL BASIC 5. Data from field surveys can be digited directly by farmers and consultants and data elaboration may be retrieved via personal computer or Internet. The system makes use of Oracle data-base located at the CRPV in Bologna. A connecting module allows to retrieve in real time from GIAS-NET all the information needed to make GIAS-PC work. Geographic Information System (GIS) ArcView Gis 3.0 by ESRI makes meteorological data interpolation on a grid of 5 x 5 km; data interpolation may lead to high quality met-data promptly available. The basis for the grid values are hourly data from synoptic and automatic stations, and radar (TAB. 3). Grid covers most of the region except mountain areas (FIG. 3).

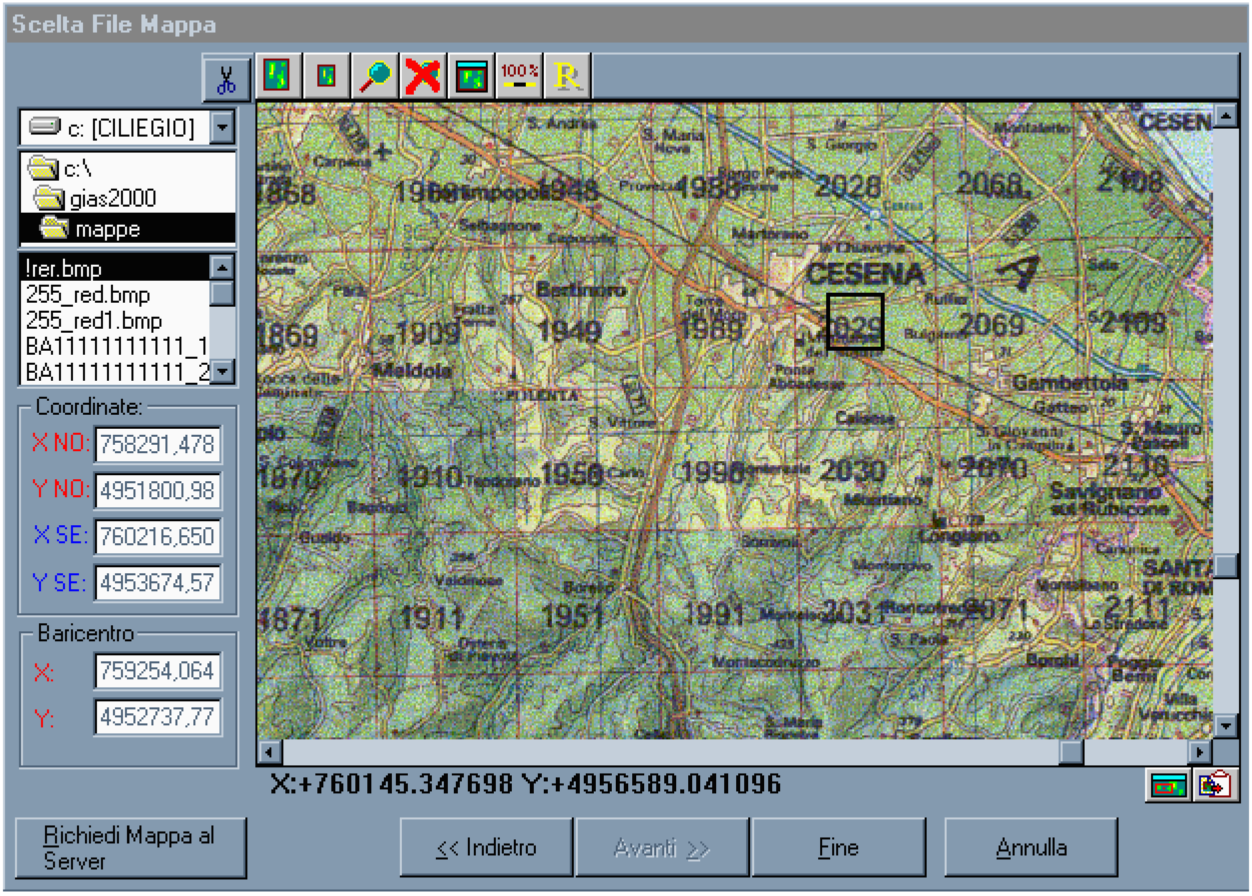


Figure 3. Example of the 5 x 5 km grid in GIAS.

Table 3. Met-data provided by RMS and available via GIAS at the Warning Service.

Grid historical data	Grid forecasted data (5 days)
Air temperature every hour	Air temperature every hour
Relative humidity every hour	Relative humidity every hour
Wind speed and main direction every hour	Rainfall every hour
Precipitation every hour	Wetness duration every hour (yes/no)
Global radiation every hour	

Wetness duration every hour	

GIAS is made up of different modules (irrigation, fertilisation, pest and disease control, weed control, etc.). Module regarding pest and disease control strategy includes the possibility to run (among others) I.P.I. forecasting model to obtain information about the risk of blight infection on potato and tomato crops (FIG. 4).

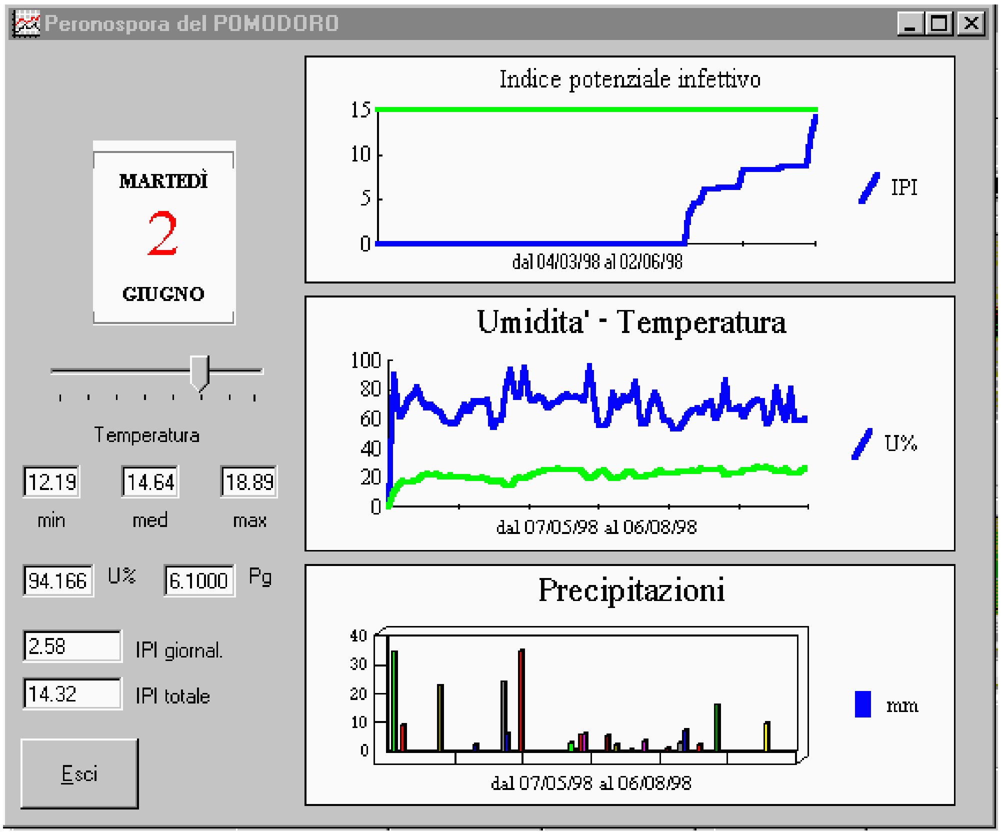


Figure 4. Output of IPI model elaborated by GIAS that farmers and technicians may obtain connecting with GIAS-Pc.

GIAS is undoubtedly a step forward in the build-up and use of DSS in Emilia Romagna. It brings a better availability of met-data whose interpolation allows the regional territory to be wider monitored for blight occurrence and the information derived by model elaboration ever more diffused. Moreover it permits to build-up territorial maps of blight risk that could be useful for an area based blight control strategy.

The main risk using GIAS is the excessive automation of the system that may lead any error (in particular met-data) difficult to be detected. Before the new information system be fully operating, a service able to constantly check it and perform a quality control of the data and information diffused would be needed.

References

Bugiani, R., Cavanni, P. & Ponti, I. 1993. An Advisory service for the occurrence of *Phytophthora infestans* on tomato in Emilia-Romagna region. Bulletin OEPP/EPPO Bulletin, 23, 607-613.

Malavolta, C., Donati, D., Rossi, R., Rotondi, A. 1991. An information system for integrated pest management and integrated production on orchard and vineyard in Emilia-Romagna (Italy). Danish J.Plant and Soil Sci,., 85 (S-2161), 134-144.

Third Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

How to Evaluate Model Performance

J. YUEN

Dept. Of Applied Plant Protection, Swedish University Agric. Research,
P.O. Box 7044, S-75007 Uppsala

The formulation of advisory systems requires estimation and modelling of pest growth, yield loss, and the cost of control. One should ascertain if the decision rules are based on subjective or objective interpretations.

- Pest growth – how is this modelled?
- Yield loss – how is this calculated?
- Control – what is the efficacy and cost?

For single decisions made during the growing seasons, the estimation of predictor performance is relatively straightforward. If a disease prediction algorithm can produce a range of values, and is never a perfect predictor, any decision threshold based on this algorithm (such as ‘spray if the point accumulation is above a given level’) yields one of four possible situations.

Table 1. Different Error Types in Predictors.

	Truly present	Truly absent
Predicted presence	A	B
Predicted absence	C	D
Total	A+C	B+D
	A/(A+C) true positive	B/(B+D) false positive

The cells A and D represent the number of correct decisions, whereas B and C represent the incorrect decisions. If a pest occurred in a total of A+C fields, and our algorithm predicted this would occur in A fields, then the true positive rate (TP) would be A/(A+C). Likewise, if (B+D) fields had the pest, and our algorithm predicted it would occur in B of these fields, then the false positive rate (FP) would be B/(B+D). The TP and FP rates can be affected by changing the decision threshold. For example, predicting the presence of a pest with a lower point accumulation would increase the TP rate, but may also increase the FP rate. An ideal algorithm would maximise the TP rate and minimise the FP rate.

Figure 1. A ROC curve from an uncalibrated predictor for fungicide use in Sclerotinia stem rot.

The relationship between TP and FP for the risk prediction algorithms can be examined graphically by plotting receiver operating characteristic (ROC curves (figure 1). These curves plot the TP as a function of the FP at all possible thresholds. In a ROC curve using our example, the origin of the graph represents the decision 'not-to-spray' for all fields. This decision yields no false positives (i.e. a recommendation to spray in the absence of the need to spray: the quantity B in Table 1 is 0) but captures no true positives (recommending a spray for those fields that truly require one: the quantity A in Table 1 is also 0). The upper right corner would recommend spraying all fields, thus detecting all fields that truly require a spray (C = 0, TP rate = 1) but also recommending a spray for all fields that do not require them (D = 0, FP = 1). An efficient algorithm would yield a curve 'pushed to the upper left corner'.

The use of ROC curves allows for comparing risk algorithms that do not the same scale. An added advantage is that it allows for flexibility on the part of the decision maker. Variable decision thresholds, with varying TP and FP rates, can reflect the risk attitudes (utility functions) of the decision maker. Thus, a risk averse decision maker may set his criteria level further to the right, and spray his fields with a lower 'point accumulation', when compared to a decision maker more willing to take risks. He could thereby increase his true positive rate, but at the cost of increasing his false positive rate. The advantage of the ROC curves is that the rate of both kinds of errors (applying an unneeded spray, and missing a needed spray, in our example) can be estimated. Given these error rates and the relative costs of both kinds of error, the decision maker can determine a critical value for his decision threshold, that reflects his attitudes toward risk.

The development of risk assessment algorithms needs to be guided by the required specificity of the final algorithms. If data from a wide variety of cropping situations (variations in cultivars, cultural practices, climate etc.) is used to develop these algorithms, the result may have wider applicability at a loss of specificity. Likewise, restricting the variation in the underlying data may not permit the discovery of important factors, merely because they are always present (or absent), though this may not necessarily affect the validity of the resulting algorithm in that particular setting.

There are additional complications with multiple decisions. There may not be a clear relationship between available data and risk and the individual decisions that are made during the growing season are correlated with each other. The actions at one point in time will affect what happens at other points in time. There are not simple methods of deriving risk algorithm or comparing methods.

Potato Late Blight can be used as a conceptual model. One can think of a process driven by weather and other environmental variables. When this process has proceeded far enough, it would then trigger the initial and repeated fungicide applications. The relationship between driving variables and the process 'speed' needs to be determined. This has traditionally been derived from purely biological information, such as the effect of moisture and temperature on spore germination and leaf wetness on infection or the effect of temperature on fungal growth. It is difficult to validate the overall process in controlled experiments.

How might a statistically derived prediction model appear? It would consist of a statistical analysis of historical data blight occurrence, with field specific information and weather data. One might try to estimate the optimum time of application of the first fungicide spray with a hazards model, which would allow for calibration of the internal relationships between the different predictor variables. As in the single decision example, there are different types of error, in that sprays can be begun too early or too late.

The calculation of the spray intervals could also be examined statistically, but this is a more complicated model due to the internal relationships between the different sprays.

Third Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

Attempt of perfecting an integrated control in the potato production

S. DUVAUCHELLE*, L. DUBOIS**

*S.R.P.V. Nord Pas-de-Calais, BP47 - 62750 Loos-en-Gohelle, France
**F.R.E.D.E.C. Nord Pas-de-Calais, BP74 - 62750 Loos-en-Gohelle, France

Abstract
In 1997 and 1998, trials on supervised control against the potato late blight combining epidemiological models and varietal resistance were set up. The objective was to use the models MILSOL and GUNTZ-DIVOUX in order to reduce even more the number of treatments beyond the present "supervised protection - warning". The matter is to define pertinent criteria of non-treatment. The strategies were tested on three varieties possessing a different susceptibility to the late blight.

In 1997, two trials conducted (Nord Pas-de-Calais, Picardy). The implanted varieties were Bintje (susceptible), Saturna (resistant) and Santé (very resistant).

In 1998, three trials were set up (Nord Pas-de-Calais, Picardy, Champagne Ardenne). The variety Santé was replaced by Samba (quite resistant). The varieties Bintje and Saturna were kept on.

An artificial contamination was carried out on some contaminating rows. The late blight development on these rows was controlled (uprooting of plants overinfested) so as to prevent a too high disease pressure. The difficulty lies in the fact that you have to have some late blight to be able to assess the efficacy of the tests, whereas the purpose of the advice is to prevent the disease occurrence !

Three fungicide strategies were tested :

- The supervised protection - warning (A),
- Treatments in high risk periods (B),
- Treatments in very high risk periods (C).

The treatments were decided according to both the risks provided by the models and the disease pressure in the environment.

Three products were used, dimetomorph (ACROBAT M), fluazinam (SAGITERRE or OHAYO), and mancozeb (DITHANE DG).

In 1997, the trials made it possible to bring to light the differences in susceptibility of varieties to the late blight under an equal pressure of disease (ex : trial in Nord Pas-de-Calais, cf. curves 1 to 4).

In late June, the control plot Bintje was completely destroyed, the variety Saturna was affected by 50%, whereas the variety Santé didn't display any symptom (curve 1).

At the programme level, the spray balance showed significant differences :
- In the condition (A), 14 sprays were performed,
- In the condition (B), 10 sprays were carried out,
- In the condition (C), with a more important risk-taking, 9 sprays were made.

Savings in treatments were possible in the early campaign and in August. The disease pressures were weaker on these two periods.
This reduction in the number of treatments had no consequences on resistant varieties. The three strategies had the same efficacy (curves 3 and 4).
On the susceptible variety, the suppression of the first treatments furthered the occurrence of the late blight (cf. curve 2). The relative destruction of the vegetation was higher (50%) in the conditions (C) and (B) than the condition (A) (30%).

In 1998, over the 3 trials, the difference in the varietal susceptibility was again demonstrated (cf. curves 5 and 6). Bintje remained the variety the most susceptible to the late blight. On the trial Nord Pas-de-Calais, the varieties Saturna and Samba were similar, whereas on those in Picardy and Champagne Ardenne, the variety Samba showed a level of resistance higher than the variety Saturna.

At the strategy protection level, some reductions in the number of treatments were obtained over the 3 trials (let's take the example of the trial set up in Picardy, cf. curves 7 to 9).
At the spray balance level (end of the trial in the early August), 9 treatments were performed under the condition warning (A), 7 under the condition (B) and 4 under the condition (C).
On Bintje, the condition (B) was similar to (A). On the other hand, the disease developed under the condition (C) (the first treatment was carried out too late).

On Samba, the 3 conditions were equal. Treatments could only be saved at the beginning of the season (weaker risk) under the conditions (C) and (B).
For the condition (A), the first treatment was made on 11 June. The first spray took place 11 days later for the condition (B) and 20 days later for the condition (C).
The results from the trials conducted in 1997 and 1998 proved that the differences in the resistance to the late blight among the varieties were real, however, except for Santé, the resistance remains moderate.

On Bintje (very susceptible variety) under high pressure of disease (1997 and 1998), there wasn't almost any flexibility to reduce the number of treatments.
On varieties less susceptible, it was possible to reduce the number of treatments, nevertheless, it was advisable to remain vigilant for most varieties in France are very susceptible, and some fields of less susceptible varieties are "swamped" by those with very susceptible varieties.
The decision criteria of treatment or delaying it still have to be specified.

Third Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

Validation of the MISP model for the control of potato late blight by means of sporangial movement and leaf disease assessment

M. RUCKSTUHL, K.Q. CAO, H.R. FORRER

Swiss Federal Research Station for Agroecology and Agriculture
Department of Farming Systems and Landscape Ecology
CH-8046 Zürich, Switzerland

Summary

Disease monitoring and spore trapping in the air stream were used to validate the MISP model, developed in Switzerland for the control of potato late blight caused by *Phytophthora infestans*. In the 1998 field trials, a relationship between days with MISP conditions and the onset of sporangia release was detected: Periods of major catches of sporangia in the air stream were regularly registered one to two days after a MISP day. We concluded that this delay in sporangia release after MISP situations may allow the use of contact fungicides until the first day after a MISP situation had occurred.

The trials in 1998 have further shown that only one out of fourteen MISP situations did not result in the predicted disease increase in untreated potato crops. Therefore, the trial has clearly reconfirmed that MISP conditions are a reliable tool to identify weather events crucial for the development of the late blight epidemics both within and between fields, respectively.

Additional Keywords: *Phytophthora infestans*; PhytoPRE; advisory system; DSS; plant protection.

Introduction

The advantage of short-term, local weather events over long-term observations for predicting the probability of infections on potato plants with *Phytophthora infestans* (Mont.) de Bary, and for forecasting the disease development in infected crops, has been emphasised by many authors using various decision support systems for the control of potato late blight (Gutsche, 1998; Goeminne *et al.*, 1998; Cooke and Little, 1998).

Based on epidemiological studies in 1995, we developed an event based model that defines crucial weather conditions for late blight epidemics. Since 1996, we applied the ”**M**ain **I**nfection and **S**porulation **P**eriod” (MISP) model to trigger fungicide applications for field trials. The MISP model suggested spraying regimes that controlled late blight almost perfectly, both under low (Ruckstuhl and Forrer, 1998) and high disease pressure (Cao *et al.*, 1997), respectively.

In 1997, we tested the MISP model based on leaf disease assessments in small-plot experiments. As a result, we noted an excellent fungicide protection status during the whole season in plots treated according to spraying schedules derived from the MISP model. However, we could not conclude on the efficiency of the applied fungicide regime, because we had no tools to identify periods of low disease pressure (Ruckstuhl and Forrer, 1998). Due to the rainy weather during most of the 1997 potato growing season, the asexual reproduction cycles overlapped frequently, and therefore fresh symptoms, observed in the unprotected check plots, could not unambiguously be traced back to a specific infection period.

In 1998, we compared single plant blight assessments with records of the aerial sporangia concentration as tools to validate the MISP model, both in terms of blight control and accurate estimate of the actual disease pressure, respectively.

Material and Methods

To validate the MISP model in 1998, four different potato varieties were planted in two strips of each 20 observation plots at the institute’s field trial site at Zurich-Reckenholz. Single plots were 5 m in length and consisted of 6 rows (4.5 m). No fungicide treatments were applied, but otherwise, agronomic practices followed conventional recommendations.

In 1998, late blight was not detected in the Zurich region during the month of May. To assure experimental results, the isolated trial site at Reckenholz was artificially inoculated at June 3. Four single plants were treated with a spore solution at late evening and covered with plastic bags for 48 hours. To reduce disease pressure, all but five blighted leaflets were removed from the field. The first secondary infections deriving from these remaining inoculum sources were detected in the observation plots at June 14. Subsequently, late blight development and sporangial concentration in the air stream were recorded from June 1 to August 6.

MONITORING DISEASE DEVELOPMENT. Blight development was registered daily, counting all leaflets with newly expressed symptoms of 12 potato plants from the unsprayed trial strip. To prevent multiple readings, diseased leaflets from these plants were cut off every day and cleared away from the field. A new set of 12 plants was selected for observation each time that more than approximately 10% of the leaflets were removed. Thus, from June 7 to August 6, disease was assessed first on 4 sets of Bintje plants (highly susceptible variety) and later on 2 sets of Agria plants (moderately susceptible variety), respectively. To determine the latent period, healthy Bintje plants were artificially infected with diseases leaflets every two to three days during the whole growing season.

MONITORING SPORANGIA RELEASE. Sporangia concentration in the air was recorded with a seven-day volumetric spore trap (Burkard Manufactoring Co. Ltd., Hertfordshire, UK), that was placed inside the unsprayed trial strip. Air volumes of 10 l/min were screened for the presence of *P. infestans* sporangia. The spore trap was installed with the inlet at 1.2 m above ground, positioned towards the major local inoculum source, which was the artificially inoculated plot at the western end of the experimental unit. This orientation was identical with the direction of the prevalent westerly winds. Particles were caught on a transparent, double-sided adhesive plastic tape which was renewed at least every second day to prevent sporangia from shrivelling. To facilitate fungal identification, tapes were stained with a mixture of lactophenol and cottonblue prior to counting *P. infestans* sporangia on an hourly scale under the microscope.

RECORDING WEATHER DATA. Meteorological data were recorded every 10 minutes with an automatic weather station HP-100 (G.Lufft Mess- und Regeltechnik GmbH, Fellbach, Germany), placed next to the spore trap in the experimental field. Registered data included relative humidity, temperature, and precipitation. They were entered into the PhytoPRE meteo database as hourly averages, and analysed for the presence of MISP conditions, which are defined as periods of 24 hours with at least six consecutive hours with a relative humidity of ≥90%, and at least six non-consecutive hours with precipitation at air temperatures ≥10°C (Cao *et al.*, 1997).

Results and Discussion

MONITORING DISEASE DEVELOPMENT. As shown in Table 1, from June 1 to August 7, a total of fourteen days with MISP conditions was detected (MISP 1-14), most of them clearly separated from each other. Taking the varying length of the latent period into account, the related fourteen days were predicted at which fresh blight symptoms ought to be detected (Exp 1-14). At nine of these days, a very distinct increase of newly diseased leaflets, compared to the previous day, was recorded such as for Exp 4-9 and Exp 11-13.

For the further development of the MISP model, the precise analysis of the remaining five EXP days is of particular interest. As for Exp 1-3, we suspect that the infection pressure at the related MISP days was still too weak to cause a measurable disease increase. In contrast, the remaining green-leaf area at Exp 14 was insufficient, so that a serious disease assessment could not be performed anymore.

Rather unexpected, however, was the lack of a significant disease outbreak at Exp 10 which was predicted for July 29. The analysis of meteorological data revealed a period of very hot weather between July 19-21 and at July 23. At all these days, at least six hours with air temperatures ≥28°C were recorded. We assume that these conditions are inhibiting sporangia formation and/or germination. While the MISP 9 day (July 21) coincided with the onset of the sporulation phase of the new symptoms from MISP 8 and therefore caused new infections that appeared at Exp 9 (July 26), the MISP 10 day (July 24) fall into a period where the overwhelming majority of symptoms ceased to produce viable sporangia due to the long lasting heat. To eliminate this kind of error, a kill-off temperature function has to be built into the MISP model.

MONITORING SPORANGIA RELEASE. In 1998, a volumetric Burkard spore trap was used to monitor the air-borne *P. infestans* sporangia movement in order to validate the MISP model. The spore trap results are presented in Figure 1 and Table 1, respectively. As compared to a study from Bavaria from 1994/95, we measured extremely low sporangia concentrations in the air (Schlenzig and Habermeyer, 1998). The small amount of aerial sporangia may be due to the permanent removal of infectious leaflets in parts of the observation plots right in front of the spore trap opening. After the abrupt increase in late blight severity in Bintje at July 8, the remaining green leaf area was probably the limiting factor for a more distinct sporangial harvest towards the end of the season. How far these low concentrations were a result of the sub-optimal position of the spore trap in our trial has to be further investigated.

However, the seasonal sporangia distribution was very similar to the Bavarian study with only a few days during the whole season with distinct peaks in the number of sporangia caught (Schlenzig and Habermeyer, 1998). Although the measured spore concentrations were low, five days were identified at which at least five times more sporangia were detected than on average during the two previous days (June 27, July 3, 4, 17, August 2). All these days followed right after periods with MISP conditions (MISP 6-8, 12-14). However, following the MISP days 9-11, major records of air borne sporangia were not detected at all, probably because most lesions ceased to sporulate under the high temperature regime from July 19 to July 31.

We assume that on typical MISP days with high humidity and at least six hours of precipitation, spores will be displaced by rain splashes within the canopy where they proliferate late blight through plant-to-plant, short-distance infection. However, they hardly reach the air stream above the canopy and are therefore not contributing to the long-distance blight dispersal.

The important period for spore release into the air stream takes place one to two days after MISP conditions were met. Furthermore, a considerable amount of sporangia was caught outside any MISP situations, but their survival rate might be very low since they are usually released under dry conditions. However, once they are out of the canopy in the air stream, they can be dislocated over long distances, where they might meet suitable infection conditions.

Conclusions

Epidemiological field trials in 1998 were performed to examine a relationship between MISP days, leaf blight incidence in small plots, and sporangia release into the air stream. Out of 14 MISP days, in only one situation the expected disease outbreak was not observed, probably due to a preceding period with very high temperatures that caused a desiccation of most lesions in the field.

In addition, MISP situations corresponded well with the onset of spore release periods. Spore trap results therefore confirmed the relevance of the MISP model for the prediction of late blight outbreaks. Increases in the number of sporangia caught in the air stream were usually observed one to two days after MISP situations. We therefore hypothesise that contact fungicides might give a sufficient protection from potato late blight infections if treatments were applied until the day after a MISP situation was observed.

So far, we only have limited spore trap results. Nevertheless, in combination with disease monitoring data, they gave strong indications to follow the MISP approach. However, the 1998 disease incidence results require for a fine tuning of the MISP model with functions that take the influence of high temperatures on the spore and lesion survival into consideration.

References

Cao, K.Q., M. Ruckstuhl, and H.R. Forrer, 1997. Crucial weather conditions for *Phytophthora infestans*: A reliable tool for improved control of potato late blight? *In:* E. Bouma and H. Schepers (eds.), PAV-Special Report no.1, January 1997, 1:85-90.

Cooke, L.R., and G. Little, 1998. Use of Smith periods and risk monitors in potato late blight forecasting in Northern Ireland. *In:* H. Schepers and E. Bouma (eds.), PAV-Special Report no.3, January 1998, 3:173-181.

Goeminne, M., P. Vanhaverbeke, and G. Ampe, 1998. Late blight warning service in Flanders: experiences in 1997. *In:* H. Schepers and E. Bouma (eds.), PAV-Special Report no.3, January 1998, 3:182-187.

Gutsche, V., 1998. Usage of model SIMPHYT in frame of the project PASO in Germany from 1994 to 1997. *In:* H. Schepers and E. Bouma (eds.), PAV-Special Report no.3, January 1998, 3:104-110.

Ruckstuhl, M. and H.R. Forrer, 1998. Main infection and sporulation periods (MISPs): towards its use in an event-based DSS to control potato late blight. *In:* H. Schepers and E. Bouma (eds.), PAV-Special Report no.3, January 1998, 3:67-76.

Schlenzig, A., and J. Habermeyer, 1998. Is formation on latent infection and sporangial movement of *Phytophthora infestans* in potato crops useful in support of forecasting systems? *In:* H. Schepers and E. Bouma (eds.), PAV-Special Report no.3, January 1998, 3:40-48.

Table 1. Daily assessments of late blight development and sporangial concentration in the air, compared with recordings of MISP conditions and its related periods of expected disease outbreak, respectively. Data were collected from an artificially inoculated trial site with different varieties (mainly Bintje and Agria) at Zurich-Reckenholz from June to August 1998.

Date	MISP Conditions [1]	Symptoms Expected [2]	Leaflets [3]	Aerial Sporangia [4]
ne				
1			---	0
2			---	0
3			---	0
4			0	0
5			0	0
6			0	0
7	MISP 2		0	0
8			0	0
9			0	0
10	MISP 3		0	0
11	MISP 4		0	0
12			0	0
13			0	0
14		Exp 2	2	0
15	MISP 5		0	0
16			0	2
17		Exp 3	1	2
18		Exp 4	11	0
19			1	5
20			1	7
21		Exp 5	396	17
22			289	3
23			0	0
24			25	3
25			10	5
26	MISP 6		8	1
27			35	15
28			11	6
29			39	1
30			17	7

	MISP Conditions [1]	Symptoms Expected [2]	Diseased Leaflets	Aerial Sporangia [4]
July				
1		Exp 6	1921	8
2	MISP 7		1212	1
3			415	41
4			133	182
5			169	65
6			54	59
7			41	17
8		Exp 7	3121	4
9			383	25
10			193	9
11			124	11
12			55	13
13			45	5
14			8	4
15			4	2
16	MISP 8		0	1
17			7	32
18			1	7
19			0	10
20			0	2
21	MISP 9	Exp 8	405	3
22			44	1
23			3	4
24	MISP 10		0	1
25			0	1
26		Exp 9	183	0
27	MISP 11		8	1
28			1	1
29		Exp 10	2	2
30			1	2
31	MISP 12		37	2
August				
1	MISP 13	Exp 11	1215	2
2	MISP 14		34	12
3			2	20
4			10	65
5		Exp 12	307	15
6		Exp 13	2370	6
7		Exp 14	---	---

[1] days with fulfilled MISP conditions were numbered from 1-14

[2] days at which late blight symptoms were expected depending on the varying length of the latent period (Exp 1-14)

[3] number of leaflets with newly developed blight symptoms per 3 m^2 (12 plants); Bintje in June, July; Agria in August

[4] number of sporangia per day caught in an air volume of 10 l/min.

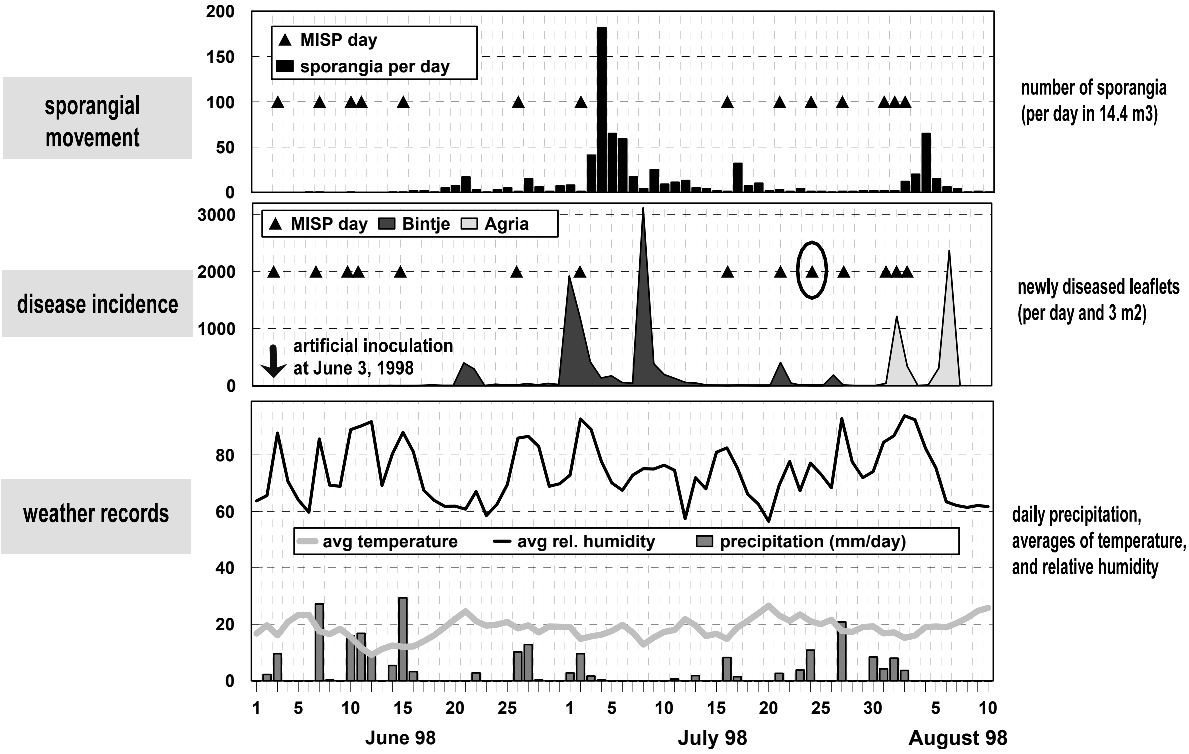


Figure 1. Comparison of aerial sporangia movement (top graph) with observations on the late blight development (central graph), in relation to weather records (bottom graph) at Zurich-Reckenholz from June to August 1998. Disease incidence was measured in unsprayed plots of Bintje (in dark shade) during June and July, or Agria (in light shade) during August, respectively. Triangles mark days with fulfilled MISP conditions, of which MISP 10 (circled) was not followed by a related peak of newly diseased leaflets (see text).

Third Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

Blight forecast and chamical control in Spain, experience in 1998

R. MARQUINEZ

Servicio de Semillas y Plantas de Vivero
Vicente Goicoechea 6-6º
01008 Vitoria-Gasteiz, Spain

Summary

Blight control in Spain was based in application of chemical fungicides once the disease was present in the field. Blight forecast is an important instrument to advice growers on the correct treatment timing. Two forecast systems were compared, but weather was not good for blight development. Fungicides performance under local conditions for late blight control was studied.

Keywords: Forecast, fungicides, Plant-Plus, potato late blight, Smith periods.

Introduction

Potato late blight is a very variable disease in Spain. It depends on the area and the time of the year when the growing period takes place. From south to north, potatoes are grown almost all the year around. Spain devotes to potato crop 167.000 hectares. An important part of the crop, the early crop is grown in quiet warm and dry conditions and blight is not a problem. Other potato growing areas are quiet wet and temperatures are milder as the South and Mallorca in spring time and the North is summer time. These areas may suffer severe blight. The Basque Country is situated in the north cost close to the Pyrenees. Potatoes are grown in the south province, Alava. Due to climatic variability blight epidemics do not occur every year, but blight is always present. It severity goes from a few scattered fields affected to widespread yield losses.

Due to this variability on the blight development, potato growers tend to relax after one or two seasons without problems or tend to overreact after a epidemic season using fungicides when it is not necessary.

Blight forecast in this area is just in the first steps, but technicians and potato growers agree about the need to develop this working instrument to rationalise the use of fungicides and to improve the crop management. Last two years Smith periods (Smith, 1956) have been used to predict the occurrence of late blight on potato. In 1998 Plant-Plus system has been tried.

Materials and Methods

Meteorological data

A weather station net has been created by the Meteorological Service for different purposes. Five meteorological stations (Zambrana, Espejo, Gauna, Salvatierra and Navarrete) were selected as representatives of the different potato growing areas in the region. These stations record weather data (temperature, rainfall, relative humidity, wind direction and wind sped among other parameters) every 10 minutes.

Smith periods were determined from meteorological data from these five locations every day. Plant-Plus system was tested with data from two of them (Salvatierra and Navarrete). Data from the two stations were produced and checked every day and sent to Dacom in Holland to be run by the program.

Crop data

Potatoes are grown in Alava region from May to September . Each station had an untreated field (100m^2)to follow the epidemic occurrence. These fields were visited once a week after emergence took place and its biological data were recorded. The rest of the field was treated following our recommendations based in Smith periods. Salvatierra y Navarrete fields were divided by two. One part of the field received treatments following Plant-Plus advice and the other following our advice.

Table 1. Crop data for Plant-Plus:

LOCATION	CULTIVAR	PLANTING DATE	EMERGENCE	GROUND COVERAGE 100%
Salvatierra	Kennebec	20/5/98	12/6/98	17/7/98
Navarrete	Red Pontiac	25/5/98	15/6/98	17/7/98

Fungicides field trial

Fungicides efficacy was tested in a comparative field trial in 1997 and 1998. Tubers of Spunta cultivar were planted the 15th of May both years in Gauna. This was carried out following a complete randomised design with nine treatments and four replications (Hickey ed., 1986). Each plot had twenty plant in two rows. Between plots one row of plants from the same variety was planted intended to be inoculated once the first treatments were applied. Each plant in the infector rows was inoculated spraying 12.5 ml of a suspension from a local isolate of *Phytophthora infestans* resistant to Metalaxyl, containing 30.000 sporangia /ml. One hour of irrigation was provided every morning to increase the chance of blight development.

Table 2. Fungicides included in the trial.

Nº	ACTIVE INGREDIENT	COMMERCIAL COMPOUND	DOSAGE	INTERVAL
1	Metalaxyl + Mancozeb	Ridomil MZ	2.5 kg/ha	12 days
2	Metalaxyl+ TMTD thiram	Agrilaxil	2 l/ha	12 days
3	Propamocarb + Mancozeb	Tattoo	4 l/ha	12 days
4	Dimetomorf + Mancozeb	Acrobat MZ	2.5 l/ha	12 days
5	Cymoxanil + Mancozeb	Curzate M	3 kg/ha	8 days
6	Cymoxanil + Famosate	Equation Pro	0.4 kg/ha	8 days
7	Vegetal oil extracts	Triac	1.5 l/ha	12 days
8	Fluazinam	Ohayo	0.5-0.3 l/ha	8 days
9	Mancozeb	Vondozeb	3.5 kg/ha	8 days

First treatment took place 18th of June and inoculation was carried out 8 hours later.

Table 3. Treatment dates

Nº TREATMENT	DATE	FUNGICIDE

1	18/6/98	All
2	25/6/98	5,6,8,9
2	29/6/98	1,2,3,4,7
3	2/7/98	5,6,8,9
4	9/7/98	5,6,8,9
3	10/7/98	1,2,3,4,7

Results

Summer 1998 was not a good year to work with blight in Spain. Weather was not favourable for *P. infestans* development.

Four warnings were communicated to the potato growers according to Smith periods and whether forecast. The first one only affected to the south of the province were potatoes were close to 100% ground coverage. Blight was detected 4 days after in Zambrana unsprayed field. The other three warnings concern to all areas in the province.

Table 4. Warning dates and first detection of potato blight in untreated fields.

WARNING DATE	FIELD	BLIGHT DETECTION
10/6/98	Zambrana	15/6/98
1/7/98		
24/7/98		
13/8/98	Gauna Navarrete	24/8/98 26/8/98

Late blight did not occurred in two of the five potato unsprayed plots (Table 4). Summer 1998 was quiet warm with some hot periods and low temperatures at night (below 10 ºC)(Table 5). There were some heavy storms but in some field there was a lack of rainfall (Table 6).

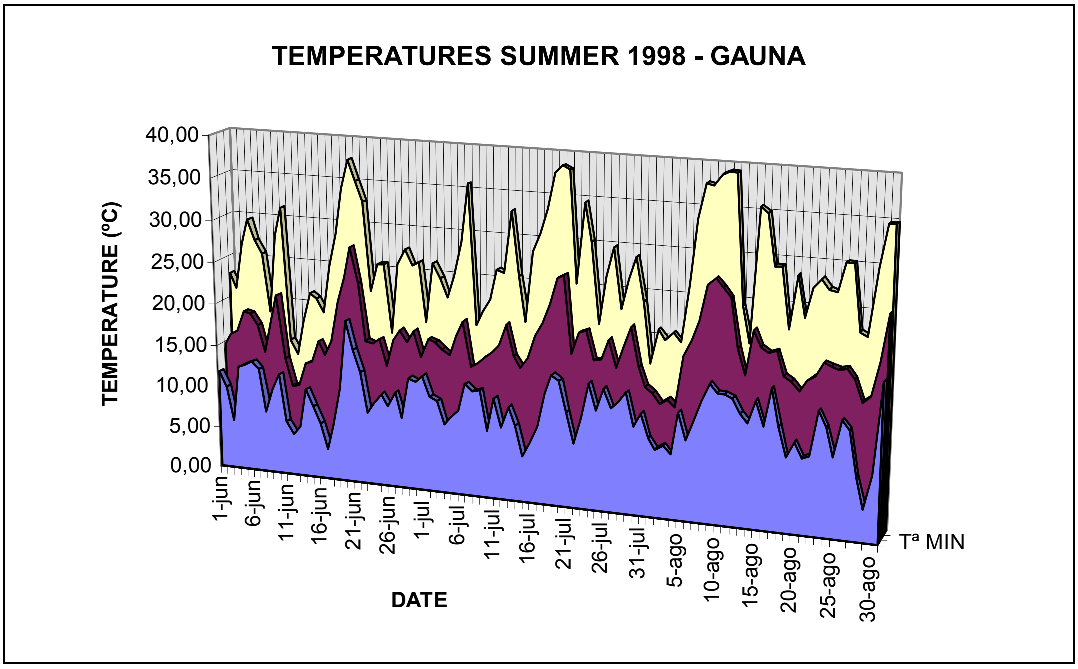
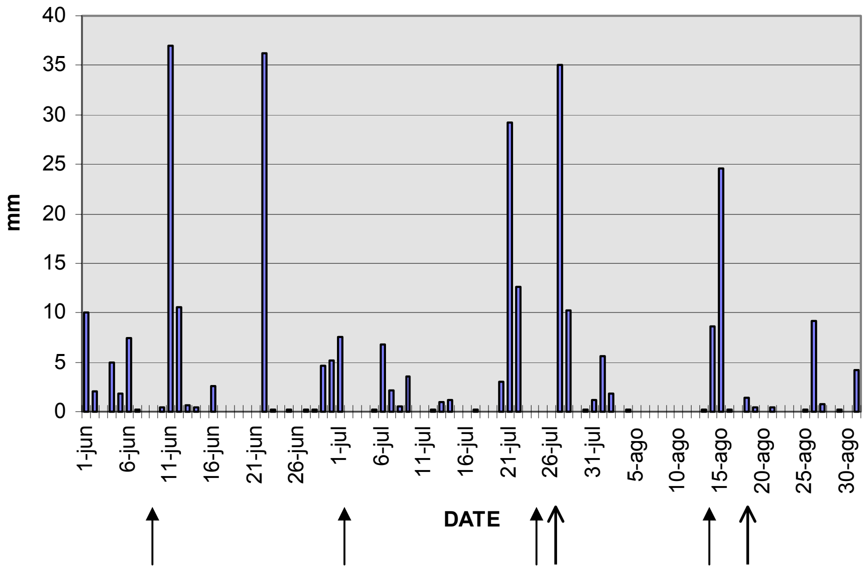


Figure 1. Minimal, mean and maximum temperature in Gauna 1998.



→ Late blight warning based in Smith periods (10/6/98, 1/7/98, 24/7/98, 13/8/98).

→ Late blight warning based in Plant-Plus (23/7/98, 17/8/98).

Figure 2. Rainfall June to August 1998

No blight was detected in one of the fields where both warning systems were compared, nor in the untreated area.

Only Navarrete field showed blight symptoms in the untreated area on the 26th of August. No blight was found in the area where treatment were based in Smith periods. On this plot three systemic treatments were applied. Only two infected leaves were found in the area where treatment were based in Plant-Plus advice. This field received two contact treatments.

Fungicide efficacy was evaluated after three or four treatments according to fungicides persistence. Table 7 records results from last two years field trial. A good control of foliage blight was obtained with Ridomil MZ, Tattoo, Curzate M, Equation Pro, Ohayo and Vondozeb. There was a significative difference between the performance of the two metalaxyl formulations.

Acrobat MZ showed a poor blight control compared with its performance in 1997. Triac, the vegetal oil extracts compound, did not protect the potatoes against late blight.

Fluazinam was used in 1997 at 0.5 l/ha. and a high foliage growth development was observed. In 1998 the fungicide was used at the recommended dose (0.3 l/ha) and this effect was not observed. Its blight control was similar in both years.

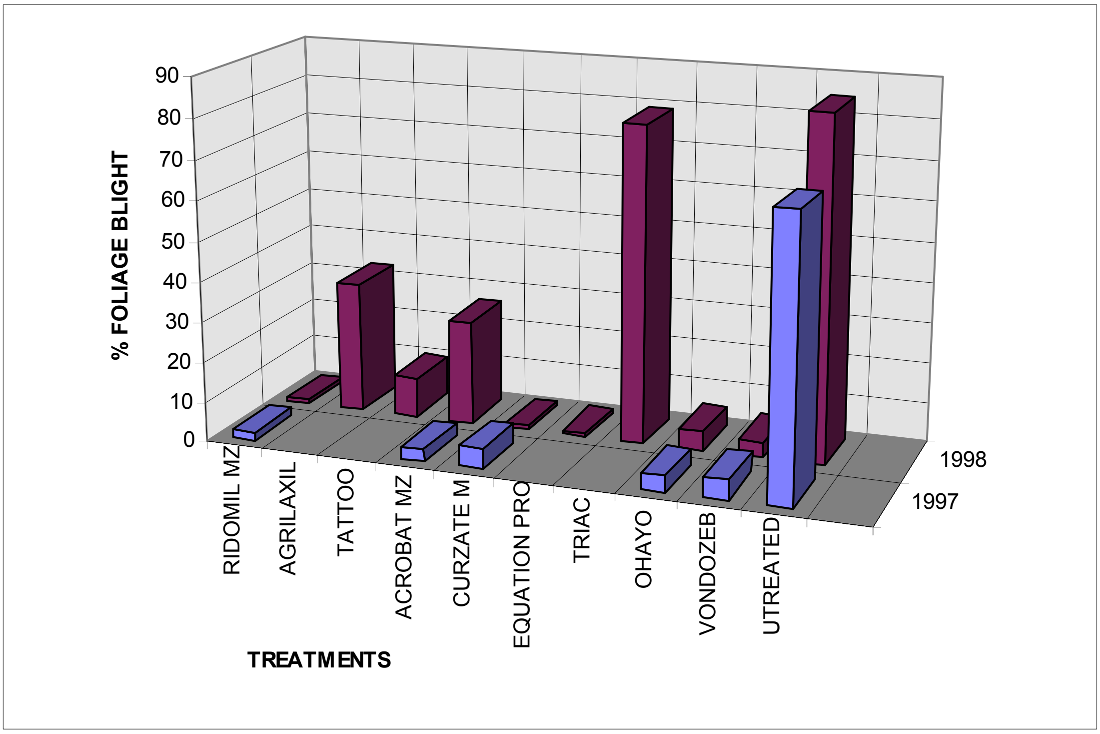


Figure 3. Percentage of foliage blight.

Discussion

Weather data transmission from some of the stations was disrupted at some point by storms and some data were lost. This problem interferes with the warning systems and should be corrected for the next future.

Smith periods generated a mean of three late blight warnings during the summer, but only in three locations up to five, blight was detected in untreated fields. Treatments on the 1/7 and 24/7 proved to be on the limit because no blight was detected in most of the untreated fields until the end of August.

Plant-Plus advice reduced treatment to two contacts fungicides and proved to be enough to control late blight in Navarrete. As the other field did not develop infection, any conclusion may be extracted from it. More work should be done to test this late blight model, especially under high blight pressure.
Plant-Plus requires routine field visits to record crop growth and infection scout, but includes advice on the fungicide choice what it is a great help.
This blight model may be interesting for Spanish potato growers due to the disease variability from one year to the other, and from one area to the other.

Fungicides performance was good compared with the untreated plots, apart from the vegetal oil extract compound.
It was interesting to see the good performance of Ridomil MZ against a resistant isolate. This is not the case for other Metalaxyl based compound. The only objective reason to make the difference is the contact fungicide Mancozeb versus TMTD thiram. Mancozeb obtain a better disease control than TMTD thiram. Fluazinam showed a good blight control and it will be introduced in the Spanish market this autumn. Tattoo was included in the trial for the first year and its performance was not as good as other compounds as Ridomil MZ or Curzate M. Mancozeb based fungicides continue been a good instrument for blight control.

References

Hickey, K.D. ed. 1986. Methods for evaluating pesticides for control of plant pathogens. The American Phytopathological Society. 312 pp.

Smith, L.P. 1956. Potato late blight forecasting by 90% humidity criteria. Plant Pathology, 5, 83-87.

Workshop of an European Network for Development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9 September - 13 September 1998

Potato late blight in Latvia and management of forecasting and warning

INARA TURKA

Latvia University of Agriculture
Liela, 2, Jelgava,
Latvia, LV 30001

Summary

In 1995 the Dept of Plant Protection of Latvia University of Agriculture and the State Plant Protection Station (SPPS) including 11 Forecasting and Diagnostic units all over the country commenced forecasting of potato late blight using the NegFry model and the State Hydrometeorological Centre data obtained not automatically but by fax or Email. The first attempts were made to verify model using historical data 1992-1997 (research project with Swedish University of Agricultural Sciences). The obtained promising results were the cause of another project with Danish Institute of Agricultural Sciences to create the system of automaticall weather stations using the NEGFRY model. Earlier, SPPS Service for the timing of the first spraying used a simple noncomputerised model. Calculation for subsequent fungicide applications was not made thus causing many of unnecessary fungicide applications.

Keywords: potato late blight, NEGFRY model, historical data.

Introduction

Potato is the second important crop in Latvia and the area covered with potatoes is about 70 thsd. ha. It is 8% from the total sown area. Potato late blight *Phytophthora infestans (Mont.) de Bary* is the most serious potato disease, occurring not every year.

For the forecasting purposes very important is the time of potato emergence. Depending on meteorological conditions the planting of potato can be variable. The most common time for potato planting is late April or early May. Potato emergence continues from late May till early or middle June. Totally 17 varieties were tested and it was observed that susceptibility of different varieties to potato late blight is different (Fig.1).

All potato varieties grown in Latvia are devided in three susceptibility groups. This classification is very relative. On favourable years some relative resistant varieties are susceptible to potato late blight.
Most susceptible are some early varieties, which have had exceptions. Early varieties mature in 55-60 days. This may be the result of one or none - fungicide treatment for early varieties in some years.

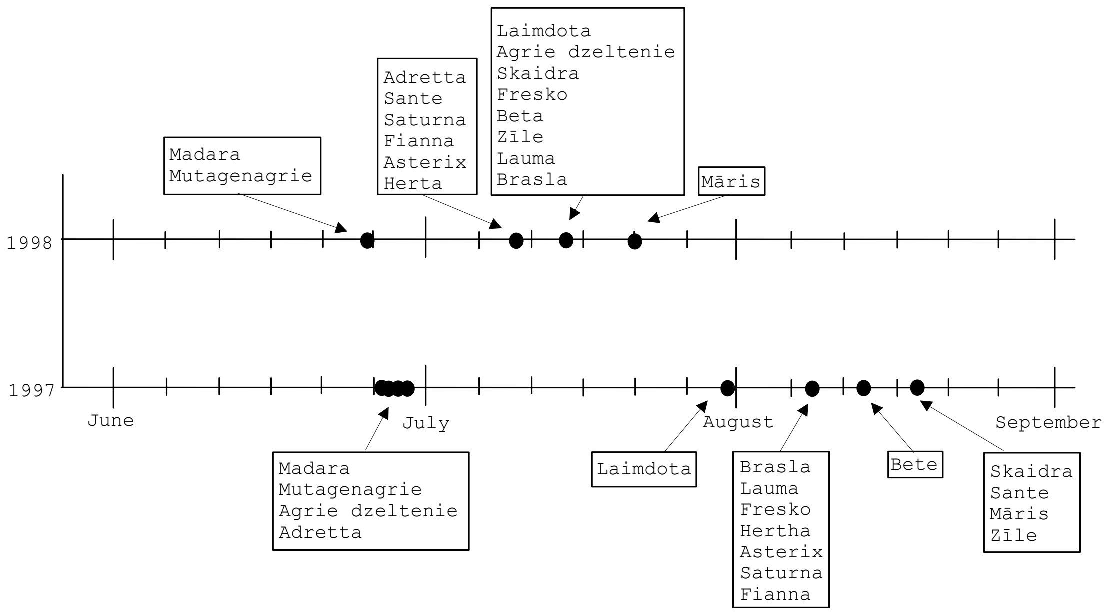


Figure 1. Primary attack of potato late blight 1997, 1998.

Materials and methods

Until recently, the control of potato late blight in Latvia has been performed through routine recommendations. The first field treatment was made with some of the registrated fungicides* either at row closing or after a general warning by radio. Subsequent, regular treatments each 10-14 days were made. If Latvian farmer can economically afford this system, potato plantings are treated 4 times, but in conventional potato growing farms - sometimes even to 6- 8 times.

Attempts to forecast the attack and spread of potato late blight using new technologies were started in 1995.
Observation for the primary attack are made by eleven diagnostic and warning units which are located all over the country including the Latvia University of Agriculture, which is situated in the central part of the country. The results summarised at the State Plant Protection Centre. Each week warnings by radio are made on the basis of calculation using the NegFry model

The most used fungicides* in Latvia are systemic/contact (S/C)fungicides, containing *dithiocarbamate mancozeb*:

- Acrobat (*dimetamorph+mancozeb*);
- Tatoo (*propamocarb* + *mancozeb*);
- Ridomil MC (*metalaksil* +*mancozeb*);
- Sandofan M8 (*oksadiksil* + *mancozeb*).

The common sequence of fungicide application is SSCSC or SSCC.

Results

Research gives evidence that a number of fungicide treatments in some years can be reduced, if both the time of potato emergence and exact local meteorological data are recorded and analysed. The time of the primary observed attack of potato late blight is very different during different years. Some years it has occurred in late June, some years - in late August (Figure 2).

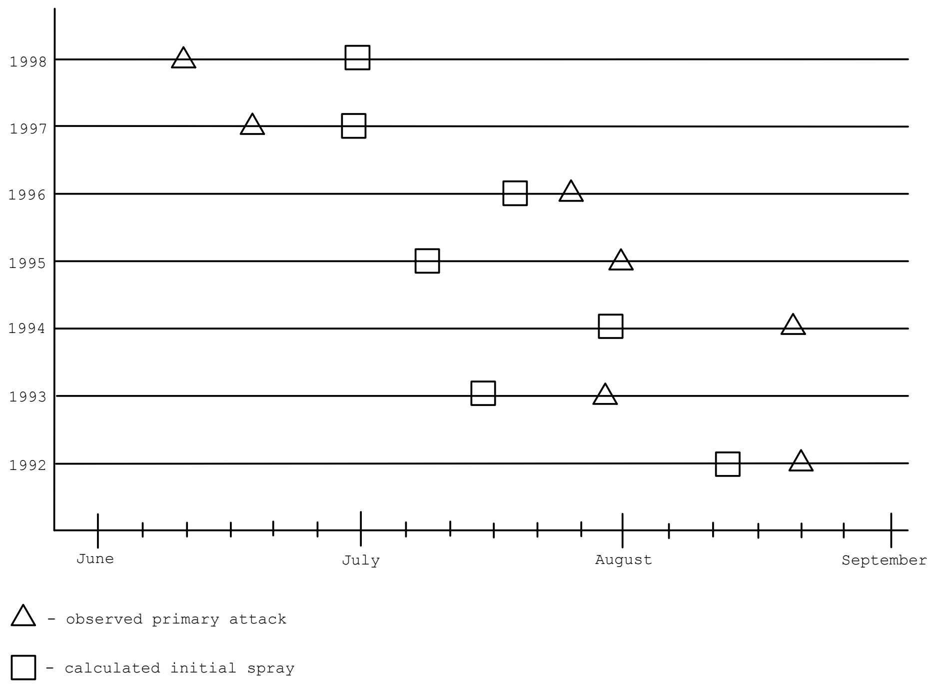


Figure 2. The primary observed attack and calculated initial spray of potato late blight, Priekuli, 1992-1998.

Therefore advise for the initial field treatment and the timing of fungicide applications during the season has a noteworthy economic profit and quality promise.

The number of fungicide application has been very different during 1992-1998 (Fig.3). There have been 1-7 treatments. Very seldom 8 fungicide applications were made in Latvia.

Figure 3. Number of fungicide applications, 1992-1998.

It was the reason why some NegFry versions from the Danish Institute of Agricultural Science (DIAS) have been tested on the Projects level by the Swedish University of Agricultural Sciences (1995-1997) and DIAS since 1998.

Beginning from 1998 five Hardi MetPoles have been used for the weather registration and the testing of the NegFry .

Recordings of primary attacks are compared with the forecast for primary attacks.

The primary observed attack of potato late blight and the calculated risk value in different years are shown in Fig.4. Analysing historical data of Priekuli Experimental and Breeding Station during 1992-1998 (Andersson B., SUAS) the calculated initial spray by the NegFry was before the first symptoms appeared in the field, except 1997 and 1998 .

The primary attack of potato late blight was observed earlier in the last two years (Fig. 1,4.) as compared with the period of 1992-1996. The first symptoms of late blight on moderately resistant varieties usually were observed early August or in middle August. In the 1998 the primary attack of potato late blight was observed in both, moderately resistant and resistant varieties in the middle of July (Fig.4). It was not a common situation in Latvia before, but the tendency of early attacks is observed now.

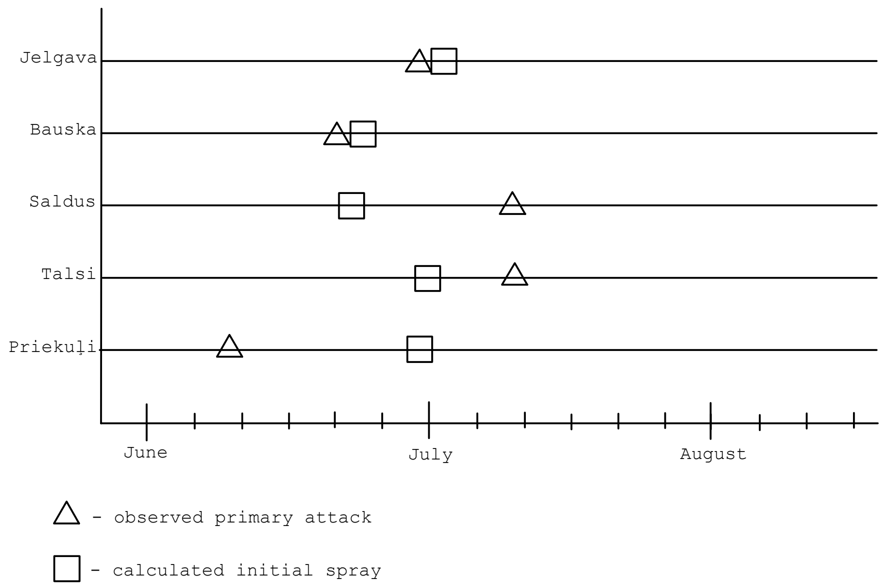


Figure 4. Primary observed attack and calculated initial spray in different regions , NegFry model, 1998.

Discussions

The analysis of historical data showed promising results for further research and using the NegFry model. During the last seven years only one year (1998) was very favourable for late blight . The primary attack of the disease was observed very early and totally seven sprayings were needed. In other years only 2-4 sprayings were necessary so routine sprayings will not be acceptable in potato growing technologies.
Possibilities to reduce the fungicide applications to moderate resistantly varieties did not give satisfactory. It still needs further testing.

References

Gans, P., W. D. Carson & L.L.Owen. 1995. Exploiting cultivar resistance to control potato blight (*Phytophtora infestans*). In: Phytophtora 150, L.J.Dowley et.al. (eds). Proceedings of EAPR Pathology Section Conference, Dublin 1995; 345-350.

Hansen, J. G. 1993. The use of meteorological date for potato late blight forecasting in Denmark. In: Workshop on Computer - based DSS on Crop Protection Parma, Italy, 23-26 November 1993 (Eds.B.J.M.Secher, V.Rossi & P.Battilani), pp 183-193. Danish Institute of Plant and Soil Science. SP Report no 7.

Hansen, J.G. 1995. Meteorological dataflow and management for potato late blight forecasting in Denmark. In: Proceedings of the Workshop on weather information and plant protection. Eds. J.G.Hansen & R.Sigvald. Danish Journal of Plant and Soil Science. SP Report no 10, 57-63.

Third Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

Phytophthora infestans: pathotypes, mating types and fungicide resistance in Germany

BÄRBEL SCHÖBER-BUTIN

Biologische Bundesanstalt für Land- und Forstwirtschaft, Institut für Pflanzenschutz in Ackerbau und Grünland, Messeweg 11/12, D-38104 Braunschweig

Summary

This paper gives a survey of the development of Phatophthora infestans pathotypes during the past decades, on the occurence of mating type A2 and on the situation of fungicide resistance in Germany.

Key words: Potatoes, phenylamides, dimethomorph, fluazinam

Introduction

In many parts of the world the production of potatoes is restricted by *Phytophthora infestans* (Mont.) de Bary that causes rotting of leaves and tubers of the potato plant. The aim of the breeders was and is to create a resistant plant, but the fungus has overcome very fast the specific resistance which has been dominant. Nowadays it has been replaced by the unspecific resistance. On the other hand the fungus has also changed and some parts of this change will be presented.

Materials and Methods

Leaves from infected potato plants were collected in the field and cultivated in the laboratory until the formation of sporangia. The sporangia were then transferred onto potato tubers slices. The pathotype was identified by means of the differentials of Black et al. (1953). Mating types were tested by combining the isolates with the known A1 and A2 types on a rye agar (Ribeiro 1978). The resistance of the isolates against fungicides was tested on leave discs floating on fungicide solution. All tests were done at a temperature of 15 °C and if necessary under light incubation.

Results

Since 1960, the pathotype spectrum has been recorded at a 10-year intervals. However this interval were changed to five years starting in 1980. The results of the last 40 years are given in table 1.

Table 1. Evolution of pathotypes of ***Phytophthora infestans.***

1950	0, 1?
1960	0, 1, 4, 1.4, 1.2.3.4
1970	1, 4, 1.4, 1.3.4, 1.2.3.4
1980	1.4, 1.3.4, 1.2.3.4, 1.3.10, 1.4.10, 1.3.4.10, 1.3.4.7.8.10.11
1985	1.4, 1.3.4, 1.4.10, 1.4.11, 1.3.4.7, 1.4.8.10, 1.2.3.4.11, 1.3.4.7.8, 1.2.3.4.7.8, 1.3.4.7.8.11, 1.2.3.4.7.10.11
1990	1.2.3.4.7.8, 1.2.3.4.7.8.10.11, 1.2.3.4.5.7.10.11, 1.2.3.4.5.7.8.10.11, 1.3.4.7.10, 1.3.4.7.8.10, 1.3.4.6.7.8.10.11, 2.3.4.7.8.10.11, 3.4.7.8.10.11
1995	1.2.3.4.7.8, 1.2.3.4.5.7.8.10,1.2.3.4.6.7.8.10, 1.2.3.4.7, 1.3.4.5.7.8.10, 1.3.4.6.7, 1.3.4.7.8.10.11, 1.3.4.5.6.7.10.11, 1.2.3.4.5.6.7.8.9.10.11, 1.3.4.7, 3.4.7

Two pathotypes are shown for 1950 that could only be tested after the differentials had been developed. The table shows a clear shift of the spectrum in the period from 1980 to 1985 when a considerable increase in the number of virulence genes of the pathogen was found. Pathotypes with a low virulence like those found in 1950 do no longer exist. At the moment the main pathotype in Germany is 1.3.4.7.8.10.11.

Table 2 shows the occurence of A1 and A2 mating types of the tested samples. In 1985, the A2 type was observed for the first time in Germany. All isolates from the strains collected at the institute from 1970 to 1985 proved to be A1.

Table 2. Mating types of *Phytophthora infestans.*

Year	Checked	A1	A2

	isolates		
1985	31	29	2
1986	12	12	0
1987	58	34	24
1988	90	63	27
1989	30	20	10
1990	64	50	14
1991	13	12	1
1992	9	9	0
1993	31	24	7
1994	57	53	4
1995	39	34	5
1996	16	16	0
1997	159	134	25

Depending on the year the ratio A1:A2 is varying, but never a ratio 1:1 or 1:2 was found. Even in the worse late blight year 1997 the ratio was 5:1. Very seldom oospores could be found in the soil.

Table 3 demostrates the amount of isolates resistant against phenylamides. In 1979 fungicides containing these active substances were introduced in Germany and the first resistant isolate of the fungus appeared in 1980. Since that time every year resistant strains could be isolated from infected potato plants. So far no resistance against cymoxanil was found.

Table 3. Resistant isolates of *Phytophthora infestans*

Year	Checked	Phenylamid
	isolates	resistant
1985	31	3
1986	12	3
1987	58	18
1988	90	50
1989	30	13
1990	64	24
1991	13	8
1992	9	6
1993	31	28
1994	57	40
1995	39	25
1996	16	10
1997	159	94

Besides the phenylamides fungicides other fungicidescontaining dimethomorph or fluazinam were tested but till now no resistance couod be found.

Discussion

In Germany, monitoring of pathotypes started in the twenties of this century. A correct classification of the isolates was only possible after international differentails had been established. Before 1950, the pathotype 0 was dominant and the pathotypes 1 and 4 came up later. The less complex pathotypes 1.4, 1.3.4 and 1.2.3.4 were still dominant at the end of the seventies (Schöber 1975), today the pathotype 1.3.4.7.8.10.11 is dominant. A stabilising selection of these highly complex pathotypes seems hardly possible. Most of the cultuvars do not possess a resistance gene at all. According to van der Plank (1968) the pathotype 0 should be still dominant and be the fittest of all pathotypes.

In 1985, mating type A2 was found in Germany for the first time (Schöber und Rullich 1986). Meanwhile this mating type is stably established in the population of the fungus. It was possible to detect oospores in the field but further investigations have to be done to find out their influence on the formation of pathotypes and the outbreak of epidemics.

To assure the efficiency of the systemic fungicides strategies are necessary not to apply them too often in the field. The farmers are told to change the active substances between fungicide applications. Till now this system is working and the phenylamids are still under use.

References

Black, W., Mastenbroek, C., Mills, W.R. & Peterson, L.C. 1953. A proposal for an international nomenclature of races of *Phytophthora infestans* and genes controlling immunity in *Solanum demissum* derivatives. Euphytica **2**, 173 - 240.

Ribeiro, O.K. 1978. A source book of the genus Phytophthora. A.R. Ganter-Verlag KG, Vaduz.

Schöber, B. 1975. Das Auftreten von Pathotypen von *Phytophthora infestans* (Mont.) de Bary in der Bundesrepublik Deutschland. Potato Research **18**, 130 - 132.

Schöber, B. 1984. Resistenz von *Phytophthora infestans* (Mont.) de Bary gegen Metalaxyl in der Bundesrepublik Deutschland. Nachrichtenbl. Deut. Pflanzenschutzd. (Braunschweig) **36**, 121 - 124.

Schöber, B. & Rullich, G. 1986. Oosporenbildung von *Phytophthora infestans* (Mont.) de Bary. Potato Research **29**, 395 - 398.

Third Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

Current status of blight population in Finland
Preliminary results

A. HANNUKKALA

Agricultural Research Centre
Plant Production Research, Plant Protection
FIN-31600 Jokioinen, Finland

Summary

The changes in late blight (*Phytophthora infestans*) population have been monitored since 1990 in Finland using metalaxyl resistance, mating type and major R-gene pathotype as indicators. Blight epidemics in recent years have started in general 2 week earlier than in the beginning of 1990's. The proportion of metalaxyl resistant strains has fluctuated rapidly from year to year. Both mating types have been present on most fields since 1993. High number of different pathotypes and recent early blight attacks in potato fields indicate that sexual reproduction and soil borne inoculum contribute to the present blight epidemics.

Key words

late blight, *Phytophthora infestans*, metalaxyl resistance, mating type, pathotype

Introduction

The new *Phytophthora infestans* population consisting of both mating types A1 and A2 may have severe consequences for potato late blight control. 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 borne source of inoculum (Tooley *et al*. 1986, Spielman *et al*. 1991, Fry *et al.* 1992, Drenth *et al*. 1993, Andrivon 1995).

Indications of sexual reproduction of the pathogen in different parts of Europe including Nordic countries has been reported (Shattock *et al*. 1990, Drenth *et.al*. 1993, Sujkowski *et al.* 1994, Hermansen and Amundsen 1995, Kankila *et al.* 1995, Andrivon 1998). Recently late blight infection was probably initiated by oospores in a field in Sweden (Andersson *et al.* 1998).

In current situation it is important to monitor different aspects of changes in *Phytophthora* population. The aim of this paper is to describe shortly some major changes in rather isolated blight population in Nordic climate in Finland.

Materials and methods

Phytophthora infestans isolates for the survey were obtained mainly from untreated potato plots (Cv. Bintje). Potato leaflets with single visible lesions were collected from major potato producing areas in Finland and send to Agricultural Research Centre by mail. Samples were collected at the onset of the epidemic, 10-14 and 20-28 days thereafter. The survey system has been described in detail by Hannukkala (1994).

The response to metalaxyl was tested immediately after the collected leaflets had produced enough spores for the test. Metalaxyl resistance survey was done according to the guidelines of Williams and Gisi (1992) using floating leaf disk method (Sozzi *et al*. 1992). Leaf disks were obtained from leaves of potato cv. Bintje grown in greenhouse for 4-5 weeks. Six leaf disks were placed on Petri dishes (5 cm diameter) each containing 7 ml distilled water or metalaxyl (Ridomil 25 WP, CGA 48988) in 0.1, 1.0, 10.0 and 100.0 ppm concentrations.

The virulence races were determined using floating leaf disk. The British differential set obtained from the Scottish Crop Research Institute was used. The S.C.R.I. British set consisted of 19 clones, but only clones containing single R-gene were used in tests. Clone containing R9 was not included in the set. Six leaf disks of each potato clone was floated in distilled water in 5 cm plastic Petri dishes and 20 μl of sporangial suspension containing 100000 sporangia/ml was pipetted in the centre of each leaf disk. After seven days incubation at 15°C leaf disks were examined with a dissecting microscope for sporulation. If sporulation was observed, the interaction was rated compatible: if no sporulation was observed, the interaction was rated incompatible.

The isolation of *P. infestans* was done according to the methods described by Tantius *et al.* (1986) and Shattock *et al.* (1990). In stead of rye seeds the rye agar was prepared from rye porridge flakes. The isolation media was amended with 200 ppm vancomycin, 100 ppm rifamycin, 500 ppm nystatin and 100 ppm neomycin sulphate after autoclaving.

Before 1997 mating type testing was done on rye agar. Mycelial plugs with growing hyphal tips of the isolates were paired with the known A1 and A2 tester isolates on separate 90 mm plates of rye agar. After 10 - 18 days of incubation at 18 °C in darkness, the plates were microscopically 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 tester isolate.

Table 1. Number of *P. infestans* isolates included in different tests in 1990-1998.

Test	1990-1996	1997	1998
		number of isolates	
Metalaxyl resistance	1830	590	585
Mating type	204	446	203
R-gene compatibility	558*)	66	not yet tested

*) only 203 isolates were tested for complete differential set.

In 1997-98 mating type testing was mainly done on floating potato leaf disks to avoid laborious isolation of the pathogen onto agar. The mating type determination was possible to do immediately after collecting the isolates from field. A spore suspension containing 100000 spores/ml was made from field isolates and known A1 and A2 tester isolates grown on potato leaves (cv. Bintje).

Two leaf disks were placed on water into Petri dishes and one droplet of spore suspension (20 µl) of the field isolate was pipetted on each leaf disk. Another droplet of known tester isolate (20 µl) was pipetted 2 mm apart. Pairings with A1 and A2 tester were done in separate Petri dishes to avoid any reactions between the known A1 and A2.

After 14 days incubation at 15 °C the leaf disks were carefully removed on object glass, crushed under the cover glass and examined under microscope. If a leaf disk contained oospores the test isolate was rated as the opposite mating type of the tester isolate.

In 1990-98 over 3000 isolates were tested for their metalaxyl resistance, 850 isolates for their mating type and over 600 isolates for their R-gene pathotype. Only 269 isolates were tested with complete differential set due to lack of leaf material of certain R-gene clones (Table 1). Most of the isolates were included in 2-3 consecutive tests.

Results

In 1998 the blight epidemic started very early and the disease progress in untreated susceptible variety was very rapid. Observations from Jokioinen in 1990-98 indicate that the disease progress at he end of 1990's in general has been much faster than in the beginning of the decade (Figure 1).

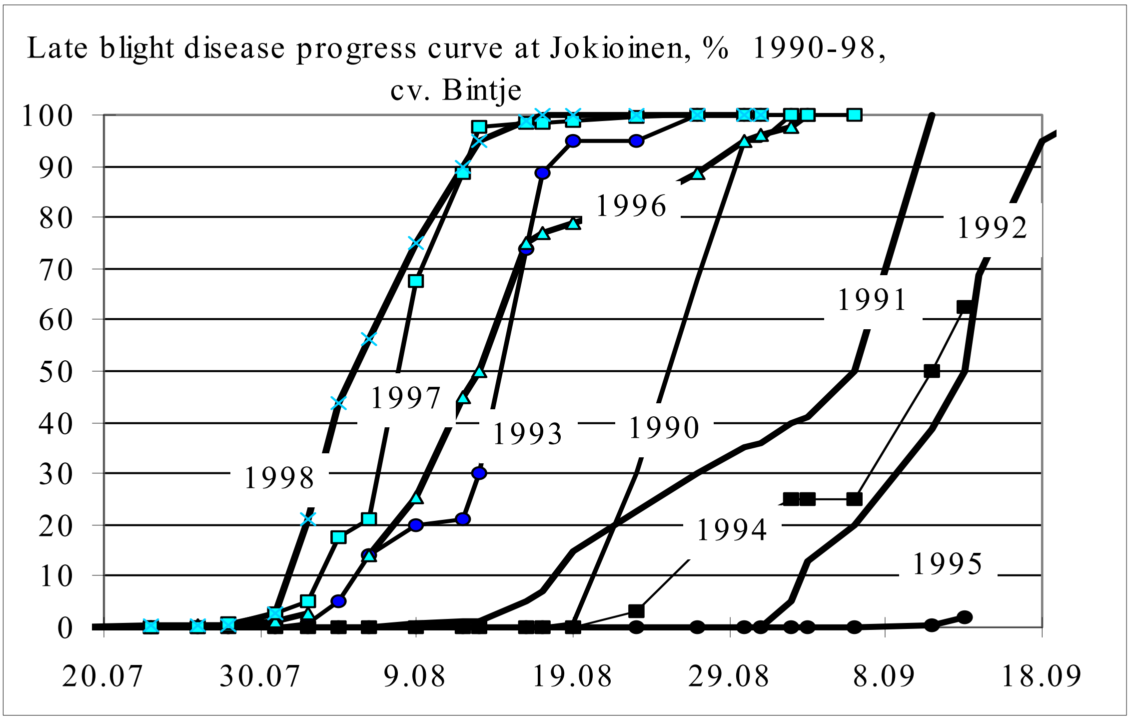


Figure 1. Progress of late blight (*Phytophthora infestans*) as measured by % of defoliated leaf area in a susceptible cv. Bintje at Jokioinen in 1990-1998.

Mating types

A2- mating type was found in 1992 in Finland in a frequency of 3 %. The average proportion of A2- type has stabilised to 20 % of the population. The proportion of A1/A2 has been very variable between individual fields. In recent years both mating types have been observed on the majority of the monitored fields. In 1998 both mating types were found also in isolates collected from one single plant. Therefore it is obvious that oospores are produced in field situations.

Most of the fields, where the proportion of A2- type was high were very isolated home gardens surrounded by forests. A2- mating type was extremely rarely found in northern potato seed production areas in Finland.

Table 2. Occurrence of A1 and A2 mating-types of *P. infestans* in monitored fields in Finland in 1992-1998.

Year	A1 and A2	A1 only	A2 only	No of fields monitored
	number of fields observed			
1992-96	9	4	0	13
1997	14	1	0	15
1998	9	6	2	17

Pathotypes

All pathotypes overcoming a single resistant gene (R1-R11; R9 not studied) has been found in Finland in 1990-97. Most races are capable to infect potato clones with R1, R3, R4, R7. R10 and R11 gene. Pathotypes overcoming R2, R5 and R6 were rare and the two former types were totally absent before 1992. The number of races overcoming genes R8, R10 and R11 have increased clearly during the study (Figure 2).

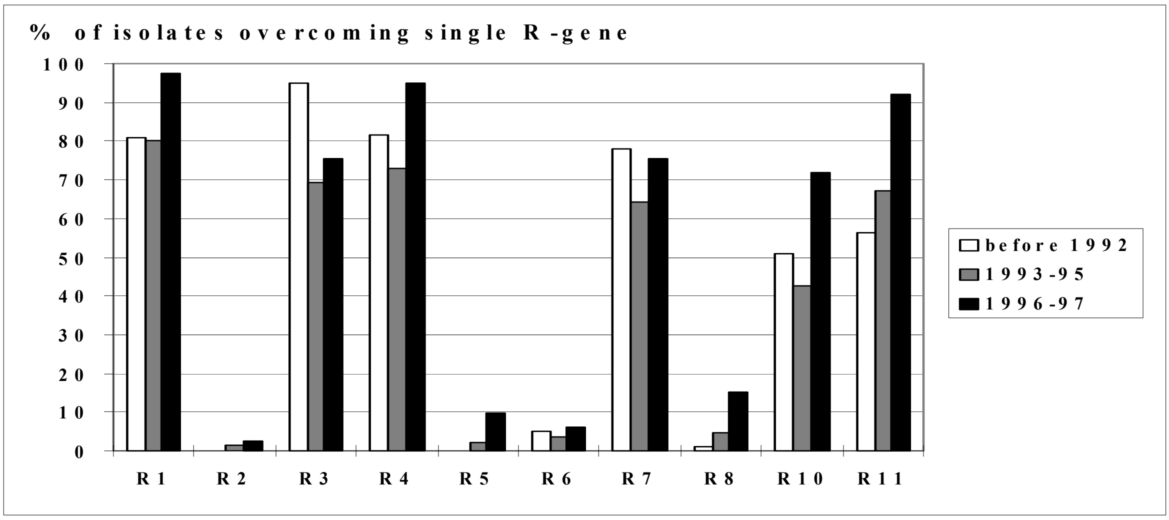


Figure 2. Occurrence of P. infestans pathotypes overcoming single major R-genes in potato differential set in Finland in 1990-97.

During the study more than 60 different virulence pathotypes were found. The most common pathotype (1,3,4,7,10,11) contributed 36 % of the population. Almost 70 % of the population consisted of 10 different pathotypes and the rest of the pathotypes were found only once or twice.

Metalaxyl resistance

In early 1990's the majority of *P. infestans* isolates were resistant to metalaxyl. In 1994 and 1996 the proportion of resistant isolates was low. In 1997 and 1998 the proportion of resistant isolates has been 20 %. Especially in 1998 the proportion of isolates tolerating low dosages of metalaxyl has clearly increased (Figure 3).

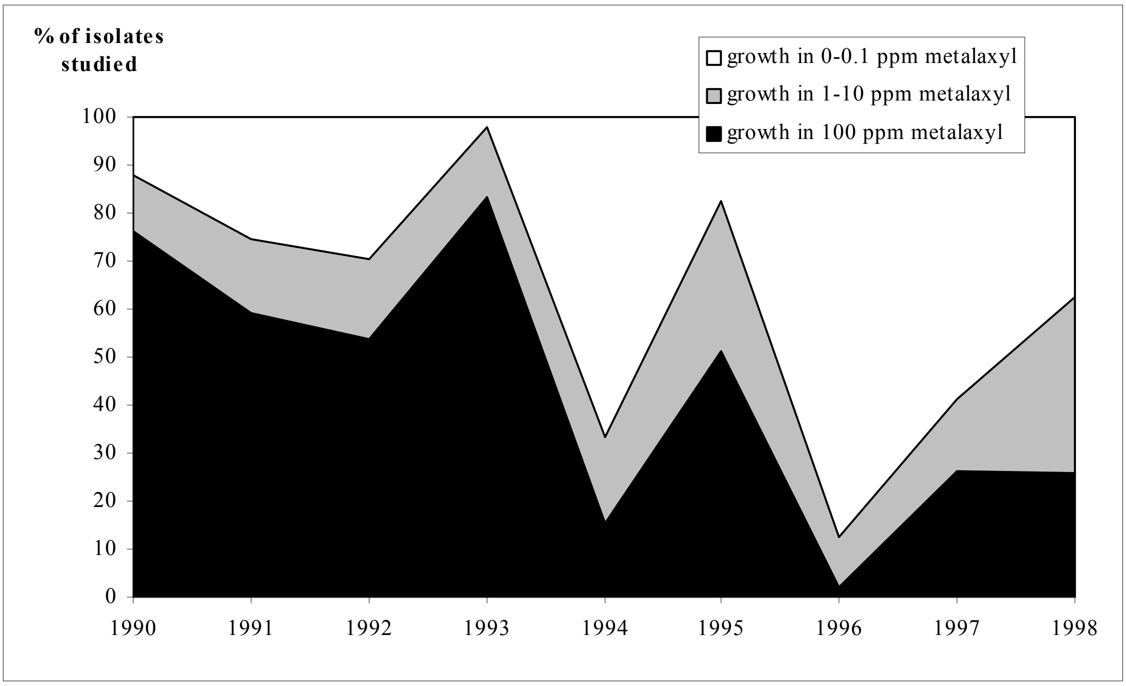


Figure 3. Proportion of *P. infestans* strains growing and sporulating in different concentrations of metalaxyl in 1990-98 in Finland.

The fluctuation in proportion of metalaxyl resistant strains in recent years is difficult to explain with the use of metalaxyl fungicides. Since 1992 the sales of metalaxyl containing fungicides has been extremely low. In addition most of the metalaxyl resistant strains originate from the northern seed production area, where metalaxyl has never been used excessively. Since 1994 the use of metalaxyl has been forbidden in seed production.

Discussion

Potato late blight epidemics in late 1990's have started earlier than in the beginning of the decade. Early attacks of *P. infestans* have recently reported from several European countries (Schepers 1998). This can partly be explained by weather conductive to blight, but at least in Northern Europe soil borne oospores might play a role in the onset of the epidemic especially if soil is wet after sowing (Andersson *et al*. 1998).

A2 mating type was found in Finland in the beginning of 1990's. Unfortunately there are no older Finnish *P. infestans* isolates available to study the situation before 1990. The proportion of A2 has stabilised around 20 % of the population. It is higher than in most South European countries (Andrivion *et al.* 1994), but in the range of that in other Scandinavian countries (Hermansen and Amundsen 1995, Andersson *et al*. 1998, Bodger *et al*. 1998). There has not been any decrease in proportion of A2 during the monitoring period in the contrary of the studies of Griffin *et al*. 1998. It is possible that A2- mating type is somehow more fit in cool than in warm climate.

All pathotypes overcoming single resistant genes R1-R11 were found in population. Over 60 different combinations of virulence were found among 269 isolates tested with complete differential set. The variation and population structure is in the range of that reported by Andrivon *et al.* 1994 and Griffin *et al.* 1998. There was considerable number of isolates giving sometimes negative and sometimes positive reaction especially in compatibility to R- genes 10 and 11, which has also reported by Stewart (1990). These isolates are not included in the 60 different virulences in the report.

R-gene containig potato cultivars are not widely grown in Finland. There should not be any selection pressure towards virulences that have increased recently. The most common pathotype in Finland is also common in France (Andrivon *et al.* 1994).

Metalaxyl resistant strains were very common in the beginning of 1990's. There was an excessive use of metalaxyl- mancoseb mixture in the end of 1980's. The farmers used the fungicide curatively and non contact fungicide were sprayed afterwards (Hannukkala 1994). The antiresistance strategies to control metalaxyl resistance was started in the beginning of 1990. The use of metalaxyl product decreased rapidly and it was hardly not used after 1994. It is difficult to explain the fluctuation of metalaxyl resistant isolates by the use of fungicides in 1995-98. The increase in metalaxyl intermediate strains recently may be a cosequense of sexual reproduction.

Conclusions

Both mating types are present in most fields though A2- type seems to be very rare in northern parts of Finland. It is obvious that sexual reproduction has an important contribution to the genetic composition of Finnish blight population. The number of different virulence races is very large though the population is clearly dominated by a few races. The proportion of isolates rated as intermediate in their sensitivity to metalaxyl have increased during 1990's.

The significance of soil borne inoculum in the epidemic and the consequenses of sexual repruduction should be studied in detail also in Nordic climate.

References

Andersson B, Sandström M & Strömberg A, 1998. Sexual reproduction of *Phytophthora infestans* on potato in Sweden. In: Schepers H, Bouma E, eds.Proceedings of the Workshop on the European network for development of an integrated control strategy of potato late blight. Carlow, Ireland 24 September-27 September 1997. PAV-Special Report no 3, 92-96.

Andrivon, D. 1995. Biology, ecology and epidemiology of the potato late blight pathogen *Phytophthhora infestans* in soil. Phytopathology 85:1053-1056.

Andrivon, D. 1998. Variation for pathogenicity in old and new populations of Phytophthora infestans. In: Schepers H, Bouma E, eds.Proceedings of the Workshop on the European network for development of an integrated control strategy of potato late blight. Carlow, Ireland 24 September-27 September 1997. PAV-Special Report no 3, 49-55.

Andrivon, D., Béasse, C. & Laurent, C. 1994. Characterisation of isolates of Phytophthora infestans collected in northwestwern France from 1988 to 1992. Plant Pathology 43:471-478.

Bϕdger, L., Kidmose, R., Hansen, J. G. & Holm S. 1998. Kartoffelskimmel for og nu. 15 Danske Plantevaernskonference, Sygdomme og skdedyr. DJF rapport Markbrug nr. 3:81-87.

Drenth, A., Turkensteen, L. J. & Govers, F. 1993. The occurrence of A2 mating type of Phytophthora infestans in the Netherlands; significance and consequences. Netherlands Journal of Plant Pathology Supplement 3. 99:57-67.

*Fry, W.E., Goodwin, S.B., Matuszak, J. M., Spielman, L. J.,Milgroom, M. G. & Drenth, A.*1992. Population genetics and intercontinental migrations of *Phytophthora infestans*. Annual Review of Phytopathology 30:107-129.

Griffin, D., O'Sullivan, E., Harmey, M. A. & Dowley, L. J. 1998. Distribution of metalaxyl resistance, mating type and physiological races in Irish populations of Phytophthora infestans; a preliminary report. In: Schepers H, Bouma E, eds.Proceedings of the Workshop on the European network for development of an integrated control strategy of potato late blight. Carlow, Ireland 24 September-27 September 1997. PAV-Special Report no 3, 153-159.

Hannukkala, A. O. 1994. Metalaxyl resistance in Finnish strains of *Phytophthora infestans*. p.183-186. in: Heaney, S., Slaweson, D., Hollomon, D. W., Smith, M., Russell, P. E. & Parry, D. W. (eds.). Fungicide resistance. BCPC Monograph No 60. Farnam, Surrey, UK. 418 p.

Hermansen, A. & Amundsen,T., 1995. Mating types of *Phytopthora infestans* in Norway. p.77-82 in: Dowley, L. J., Bannon, E., Cooke, L. R., Keane, T. & O´Sullivan, E. (Eds.) Phytophthora infestans 150. Boole Press Ltd. Dublin, Ireland. 382 p.

Kankila, J., Hannukkala, A. O., Rokka V.-M. & Pietilä, L. 1995. Screening Phytophthora infestans populations and breeding for resistance in Finland. p.261-267 in: Dowley, L. J., Bannon, E., Cooke, L. R., Keane, T. & O´Sullivan, E. (Eds.) Phytophthora infestans 150. Boole Press Ltd. Dublin, Ireland. 382 p.

Schepers, H. T. A. M. 1998. The development and control of Phytophthora infestans in Europe in 1997. In: Schepers H, Bouma E, eds.Proceedings of the Workshop on the

European network for development of an integrated control strategy of potato late blight. Carlow, Ireland 24 September-27 September 1997. PAV-Special Report no 3, 7-10.

Shattock, R. C., Shaw, D. S., Fyfe, A. M., Dunn, J. R., Loney, K. H. & Shattock, J. A. 1990. Phenotypes of Phytophthora infestans collected in England and Wales from 1995 to 1988: mating type, response to metalaxyl and isoenzyme analysis. Plant Pathology 39:242-248.

Sozzi, D., Schwinn, F. J. & Gisi, U. 1992. Determination of the sensitivity of *Phytophthora infestans* to phenylamides: a leaf disk method. Bulletin OEPP/ EPPO Bulletin 22:306-309.

Spielman,L. J., Drenth, A., Davidse, L. C., Sujkowski, L. J., Gu, W., Tooley, P. W. & Fry, W. E. 1991. A second world-wide migration and population displacement of *Phytophthora infestans* ? Plant Pathology 40:422-430.

Stewart, H. E. 1990. Effect of plant age and inoculum concentration on expression of major gene resistance to Phytophthora infestans in detached potato leaflets. Mycological research 94:823-826.

Sujkowski, L. S., Goodwin, S. B., Dyer, A. T. & Fry, W. E. 1994. Increased genotyoic diversity via migration and possible occurrence of sexual reproduction of Phytophthora infestans in Poland. Phytopathology 84: 201-207.

Tantius, P. H., Fyfe, A. M., Shaw, D. S. & Shattock, R. C. 1986. Occurrence of the A2 mating type and self-fertile isolates of *Phytophthora infestans* in England and Wales. Plant Pathology 35:578-571.

Tooley, P.W. , Sweigard, J. A. and Fry, W. E. 1986. Fitness and Virulence of *Phytophthora infestans* from Sexual and Asexual Populations. Phytopathology 76:1209-1212.

Williams, R. J. & Gisi, U. 1992. Monitoring pathogen sensitivity to phenylamide fungicides: principles and interpretation. Bulletin OEPP/ EPPO Bulletin 22:299-306.

Third Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

Experiences with Plant-Plus in 1998

J.HADDERS

Dacom Automatisering bv, Postbus 2243
NL–7812 HZ Emmen, The Netherlands

Introduction

Plant-Plus is a Decision Support System, which helps farmers to keep Phytophthora infestans (late blight) out of their fields. The program is based on a communication system that takes care of exchanging relevant (crop) data all over the world.

Farmers and scouts collect and record all relevant data about their crops (such as date of emergence, plant growth, and sprayings). They can get weather data and forecasts, information about infected plots and other necessary information from a central databank. The program then calculates the infection chances and advises the farmer to spray or not. If the program is used correctly and all data are correct the farmer will only spray when it is necessary. The farmer will save money and the crop will be healthier.

After 1997, the year 1998 was an even more hectic year in the late blight protection. From around the 10th of June late blight expanded very fast over the country. Information about late blight, gathered by farmers and scouts, was publicized weekly in journals and magazines. In this way potato growers could be informed about the late blight situation in their region.
The farmer using Plant-Plus, was often advised to spray more than once a week. The savings of money were less than in 1995 and 1996 but the qualities of the yields were higher than those of farmers who didn't use the Plant-Plus program.

In the Netherlands over 500 participants are working with the program. More than 70 weather stations provide the farmers with weather data. There are more than 12000 consults per month. Also in other countries Plant Plus is used and trials have been laid out. In Austria, Australia, Germany, Spain, South Africa, Sweden, United Kingdom and the USA farmers use the system.

Weather data play a very important role in Plant-plus. The development of Phytophthora is calculated based on temperature, relative humidity, wind speed, wind direction, radiation and rainfall. The different stages in the life cycle of Phytophthora infestans are influenced in different ways by those factors. In 1998 PLANT-Plus worked with approximately 70 weather stations in the Netherlands. The weather stations the program uses are manufactured by Pessl and Adcon (AU), Skye Instruments, ELE and Delta T (UK) and Opticrop (NL). The sensors are frequently calibrated so that they are accurate and reliable. Every day all weather stations (also in foreign countries!) are checked if and how they work

The advisory module of Plant-plus can be split up in two main parts:
1. the (un)protected part of the crop
2. the disease cycle of the fungus

ad 1. There are two factors, which determine the protected part of the crop:
   a. New growth of leaves. This is affected by time and growthrate.
   b. Deterioration of sprayed product (protection decreases). This is determined by wash off by rain and/or irrigation and deterioration by radiation.

ad 2. The disease cycle can be summarized to:
   a. spore growth (sporulation)
   b. ejection and dispersal of spores
   c. germination and penetration
   d. incubation

The spraying advice is mainly based on one graph that shows all the information the farmer needs. With just one look at the graph the farmer can decide how to handle. An example of such a graph is shown in figure 1.

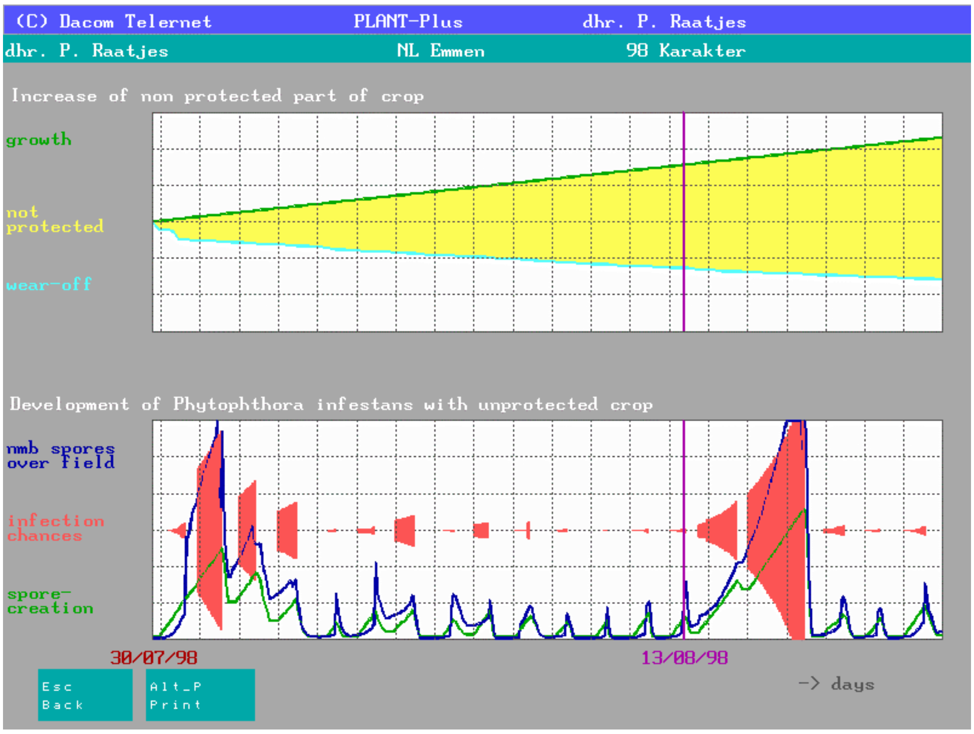


Figure 1. Spraying advice in PLANT-plus.

This graph shows the situation for the specific crop and starts with the date of the last spraying. The vertical purple line indicates the present moment. The left side of the purple line is the period from the date of the last spraying until the present moment. The historical data are collected by the weather station, which is connected to the crop. The weather forecast is used to calculate five days ahead, which is shown at the right side of the purple line. The top part of the graph shows the unprotected part of the crop. Unprotection of the crop is caused by growth of new leaves and the deterioration of used product.

The bottom half of the graph shows the infection possibilities of Phytophthora. Three stages of the fungus are visualized here: the formation of spores, the airborne of spores and the germination of spores. If the last step has been completed successfully with a substantial amount of spores, PLANT-Plus indicates an infection possibility. When there is also a great amount of unprotected leaves PLANT-Plus advises to spray.

The latest version of PLANT-Plus (version 1998) divides the infection of spores in different phases, so an even more accurate advice can be given to the users

The different phases are shown in figure 2.

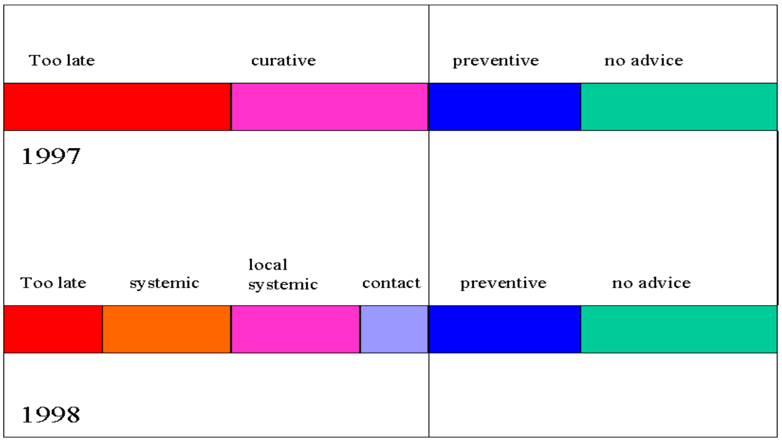


Figure 2. The different treatments advised by PLANT-Plus, based on the moment of infection.

The vertical line in the figure indicates the present moment. If an infection occurred in the recent past (< approx.12 hours) or is expected in the near future the program will advise the user to spray with a contactfungicide (e.g. Shirlan, Maneb Tin).
If the infection took place within the last (approximately) 48 hours, a spraying with a local systemic fungicide (e.g. Curzate M, Turbat) will be recommended. If the infection took place between 48 hours and 5 days before the present moment, a systemic product (e.g. Tattoo C, Ridomil) will be advised to use. The exact lengths of the different infection phases are depending mostly on temperature.
The improved version of PLANT-Plus resulted in less use of curative products. These products are usually more expensive and environmentally unfriendly than the preventive fungicides.
Figure 3 shows the use of preventive and curative fungicides over the last three years at the field trial ‘t Kompas.

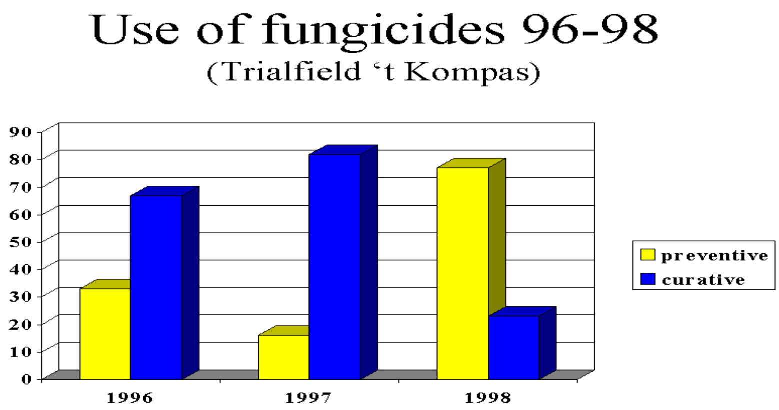


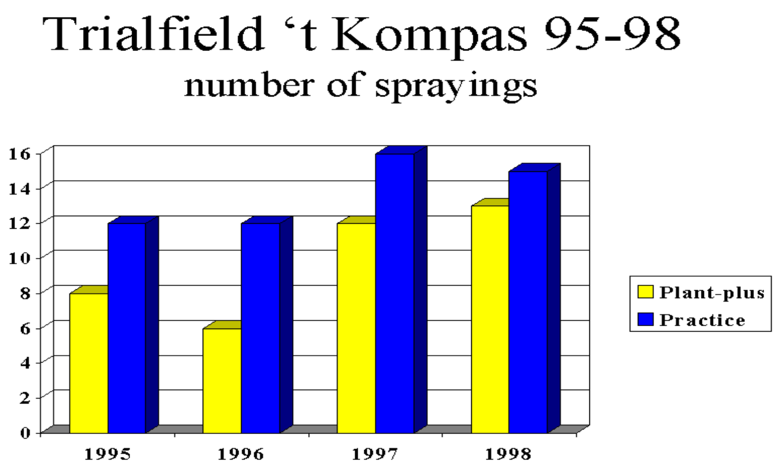
Figure 3. The use of fungicides on fieldtrial 't Kompas during 1996-1998.

Fieldtrial

In 1998 field trials were conducted at Research Centre 't Kompas to compare standard practice (weekly treatments with a contactfungicide) with PLANT-Plus.

Figure 4 shows the number of applications at the fieldtrial 't Kompas over a period of four years. PLANT-Plus advised 13 treatments last year, while the standard practice sprayed 15 times. It is clear that the last two years where more difficult than 1995 and 1996.

Even in difficult years like 1997 and 1998 it is possible to save on products and money using PLANT-Plus.



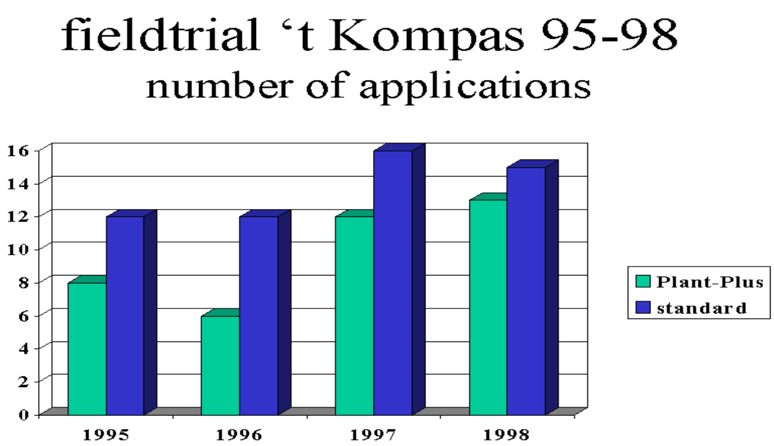


Figure 4. The difference between the number of applications on fieldtrial ‘t Kompas with PLANT-Plus and standard practice during 1995-1998.

Future

In 1998 different projects were started in South Africa, Australia and Sweden. The online Internet connection is ready to use, so it is possible to access data from all over the world. This means PLANT-Plus can be used all around the world in a very simple way.

Third Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

The effecy of lesion age and temperature regime during growth on sporulation of *Phytophthora infestans* lesions

H.P. SPIJKERBOER[1,2], J.E. BENIERS[1], H.J. SCHOUTEN[1] &
W. VAN DER WERF[2]

1. CPRO-DLO Droevendaalsesteeg 1, P.O. Box 16, 6700 AA Wageningen
2. Department of Theoretical Production Ecology, Wageningen Agricultural University, Bornsesteeg 47, P.O. Box 430, 6700 AK Wageningen

Summary

We carried out an experiment to measure spore production per unit of lesion area that has not sporulated before. We let lesions grow under dry conditions, thus preventing sporulation, under three different temperature regimes and let some sporulate four days and others 6 days after inoculation. We found no consistent effect of temperature regime or lesion age on spore production. This supports the use of a temperature and lesion age independent spore production per unit of lesion area in models. However, there was significant interaction between temperature and lesion age and conclusions should be interpreted with care.

Key words: *Phytophthora infestans*, sporulation intensity, humidity, infectious lesion area

Introduction

In the framework of a project that aims to quantify infection pressure of distant sources of *Phytophthora infestans* and its consequences for disease management at the tactical and strategic level, we needed information on spore production by the fungus. The number of spores that are produced on a lesion is generally modelled as the area that sporulates times the number of spores produced per unit of sporulating lesion area (sporulation intensity). To make a model of sporulation both the area that sporulates and the sporulation intensity and the factors that influence them have to be known.

In existing epidemiological models of *Phytophthora infestans*, only conditions during sporulation affect the sporulation intensity (Bruhn and Fry, 1981; Michaelides, 1985). In both models sporulation is assumed to take place on the entire lesion area.

In none of the existing models the conditions before sporulation are taken into account. The effects of conditions before sporulation on the sporulation intensity have not been measured before. We asked the question if lesion age or temperature regime before sporulation have an effect on spore production per unit of lesion area.

Material and Methods

We used 18 plants of cultivar Bintje that were grown from tuber pieces. Eight weeks after emergence, ten leaflets per plant were inoculated with isolate 655-2A obtained from L. Turkensteen (IPO-DLO, the Netherlands). After inoculation, plants were incubated in a climate cabinet for 1 night at 90 to 100 % relative humidity and 15 ^{0} C. After that the plants were kept in three climate cabinets with temperature regimes (day/night) of 15/10, 20/15 and 25/20 ^{0} C. Relative humidity was kept at 70%, which prevented sporulation. On day four and six, the infected leaflets of three plants per treatment were cut off and the sizes of the lesions were measured. We allowed the leaflets to sporulate in test tubes with water agar in the dark at 100% relative humidity at 20 ^{0}C for 16 hours. After that the spores were washed off the leaflets and counted with a Coulter® counter model Z2.

Lesions grown at d:15/n:10 °C were quite small after four days and the number of spores produced per lesion was low, leading to large relative errors in measurements of both lesion size and sporulation. To reduce errors, we calculated the total number of produced spores and total lesion area per plant. Further analyses were carried out with data aggregated in this way.

Results and discussion

Sporulation intensity was not statistically different after 4 and 6 days of lesion growth under dry conditions (Fig. 1; main effect in ANOVA N.S.). Neither was there a consistent effect of temperature (Fig. 1; main effect in ANOVA N.S.). Therefore, the overall result of this experiment suggests that it is indeed reasonable to use a temperature- and lesion age independent sporulation intensity in models of *Phytophthora infestans*. However, there was a significant interaction between temperature and lesion age ($p<0.005$). At 20 °C the older lesions had the higher sporulation intensity, whereas at the other temperatures, the younger lesions had the higher sporulation intensity. Therefore, the above conclusions should be interpreted with care. A repetition of the experiment would be required to confirm the results.

Figure 1. Sporulation intensity after four and six days on lesions grown at different temperature regimes.

Conclusions

We did not find consistent differences in sporulation intensity between *Phytophthora* lesions of different age or grown at different temperatures under dry condition. These overall results support the use of a temperature- and lesion age independent sporulation intensity in models. There was, however, a statistically significant interaction between temperature and lesion age, so that this conclusion should be interpreted with care.

References

Bruhn, J.A. and W.E. Fry, 1981: *Analysis of potato late blight epidemiology by simulation modeling.* Phytopathology. **71**: 612-616.

Michaelides, S.C., 1985: *A simulation model of the fungus Phytophthora infestans (Mont) De Bary [potato]*. Ecological Modelling. **28**: 121-137.

Third Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

Experiences of oospore germination and formation in potato cultivars with different levels of resistance to leaf late blight

ANITA STRÖMBERG

Swedish University of Agricultural Research
Department of Plant Biology
P.O. Box 7080, S-75007 Uppsala

Summary

Oospores from *Phytophthora infestans* were induced by mixing sporangial suspensions of mating types A1 and A2. Germination of young oospores was low but stimulated at 10 and 15°C and 10% soil extract. Oospore production at 5,10, 20 and 30°C was higher in medium resistant cultivars in all tested potato cultivars except in Asterix.

Keywords: *Phytophthora infestans*, oospores, cultivar resistance

Introduction

The late blight disease of potato is caused by the heterothallic oomycete *Phytophthora infestans* (Andrivion 1995). Interaction between hyphae of opposite mating type can thus result in sexual reproduction and the production of oospores. Oospores give the pathogen possibilites to survive without its host, and presumably starting blight epidemics when conditions is favourable. This paper present results about conditions for oospore germination and formation on potato cultivars, used in Sweden, with different levels of resistance to leaf late blight.

Material and Methods

Cultivars

Pot plants of *Solanum tuburosum* were grown in a greenhouse under standard conditions with 16-hr-day and 8 hr-dark period. Plants were used for experiments 6-8 weeks after planting. Leaf discs (18mm Ø) were prepared from 8 cultivars with different level of general resistance (fig.1b)

Inoculum production

Scandinavian A1 and A2 isolate of *P. infestans* of recent origin were used in the experiments. Sporangial suspension was prepared from *P. infestans* cultured on ray A agar incubated for 2 weeks at 15 °C. A1 and A2 sporangial suspensions of 10000-50000 sp/ml were mixed and chilled for 2-3 h at 5 °C to encourage zoospore release.

Oospore germination

Oospores were produced on cv. Bintje by incubating detached leaves in 10°C and 18h light-8h-dark. Oospore were extracted from leaf tissue by treating the leaves in DW (destilled water) in an Ultra turrax with 8000 rpm for 2 minutes. The oospores were collected on the 20 µm net in 10 ml SDW (sterile destilled water). To nullify zoospores, sporangia and mycelia the oospores were incubated for 36 hour in 18□C (dark) with 0.01gr Novozym and then washed with SDW 4 times by centrifugation in 2000g for 3 min. The germination tests were performed in tissue culture plates. To suppress bacteria 10 µg/ml rifampicin and 100 µg/ml ampicillin was added to the oospore suspension. Soil extracts were produced by mixing equal amount of loamy soil and DW for at least one hour. The solution was centrifuged in 3000g for 5 minutes and the supernatent (soil extract) autoclaved. Germ tube formation was observed with an inverted microscope after 12 days.

Oospore formation in different cultivars

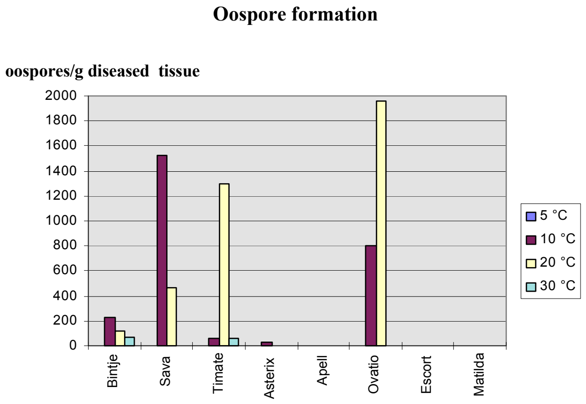
Leaf discs 18mm Ø were inoculated on the abaxial side with 20 µl spore drops. After 10 days incubation at temperatures from 5,10, 20, and 30 °C leaf discs were dried and stored at room temperature. The dried leaf discs were weighed, blended with a mortar and a pestle in 2 ml of DW. Oospores were counted in each of four 20 µl drops with a heamocytometer. The total number of oospores extracted per leaf disc and grams dry diseased tissue was calculated.

Results

Figure. 1a

Figure. 1b

Oospore formation in potato cultivars with different level of resistance to late blight



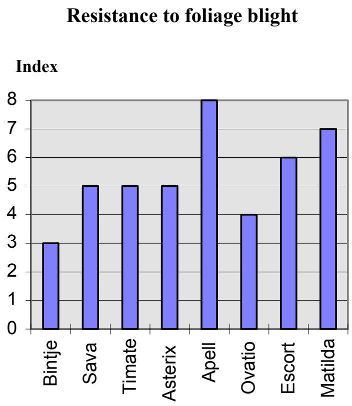


Figure 1 shows the oospore formation in 8 different cultivars with various degree of general resistance. At 5°C and 30°C no oospores were formed. In these experiments cultivar Bintje is considered suceptibel, cvs. Sava, Timate, Ovatio and Asterix medium resistant, cvs. Apell, Matilda and Escort resistant.

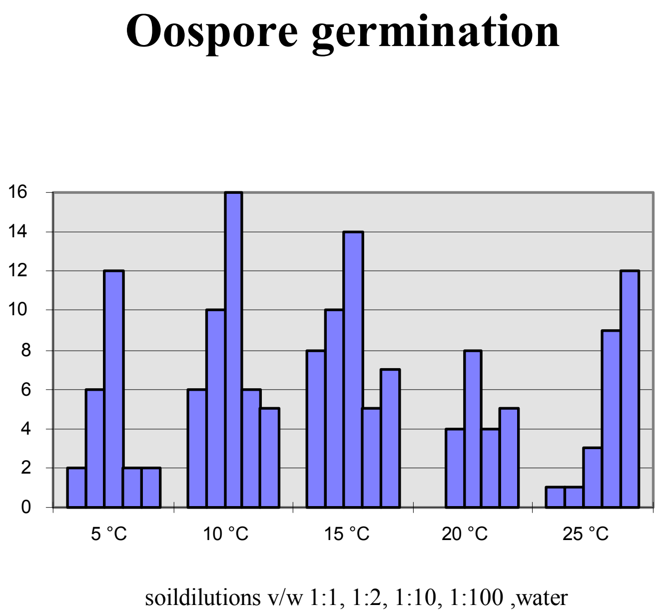


Figure 2.

Figure 2 shows the percentage germination of oospores from *P. infestans* at various temperatures in different concentrations of soil extract. The soil extracts were diluted with water (1:1-1:100) as shown in the stapels read from left to the right.

Discussion

The germination of oospores from *Phytophthora infestans* was low, but stimulated at 10 and 15 °C with 10% soil extract. Oospores were young (10 days old) in these experiments, while oospores have a period of dormancy, like its host, the germination may increase if older oospores are tested.

The oospore formation was more intense on medium resistant cultivars Sava, Timate and Ovatio then on susceptible cv. Bintje and resistant cvs Matilda, Apell and Escort which agrees with results from Drenth *et al*. 1995 and Hanson and Shattock 1998. Drenth *et al*. concluded 1995 that more oospores were formed in resistant than in susceptible cultivars because former showed delayed detoriation. In these experiments the medium resistant cv Asterix show a different behavior. In this cultivar only one leaf disc with oospores was found from altogether six experiments in different incubating conditions. This indicate that oospore production not only is influenced by delayed detoriation of late blight affected tissue, but also some other factor, for instance nutrients, influence the oospore formation.

References

Andrivon, D. 1995. Biology, Ecology, and Epidemiology of the Potato Late Blight Pathogen *Phytophtora infestans* in Soil. Phytopathology 85, no.10, 1053-1056.

Drenth A., Jansson E.M., Govers F, 1995. Formation and survival of oospores of *Phytophthora infestans* under natural conditions. Plant Pathology 44, 86-94.g

Hanson K., Shattock R.C., 1998. Formation of oospores of *Phytophthora infestans* in cultivars with different levels of race-nonspecific resistance. Plant Pathology 47, 123-129.

Acknowledgement

This work was supported by the Swedish Council for Forest and Agricultural Research.

Third Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

Factors influencing potato tuber infection by *Phytophthora infestans*

R. A. BAIN [1] & K. MÖLLER[2]

[1] Department of Plant Biology, Plant Science Division, SAC, Auchincruive, Ayr KA6 5HW, UK.

[2] Lehrstuhl für Phytopathologie, Technische Universität München, 85350 Freising

Key words: *Phytophthora infestans*, tuber blight, late blight

Introduction

There is a considerable amount of information in the literature relating the risk of spread of foliar late blight to specific factors. This information has been used to develop many systems that identify or forecast weather conditions that constitute a high risk period for the development and spread of foliar blight. Although there is some information on what factors predispose potato crops to tuber infection by *P. infestans*, this information is inadequate and generally has not been used to identify the periods when conditions are most favourable for tuber infection. This review of the literature does not cover the role of oospores in tuber infection is not included in this review.

Literature review

The severity of blight on the haulm

The risk of tuber infection is not related to the risk of foliar infection as indicated by the number of Smith Periods per growing season (Bain, unpublished).

Hirst *et al*. (1965) and Ullrich (1967) observed that in untreated plots of potatoes, the first tuber infections occurred when the severity of foliar blight was 1 to 2% whereas in fungicide-treated plots up to 5% foliar blight was required. A similar result was obtained by Fairclough (1995). Fehrmann (1963) concluded that very low sporangia concentrations were enough to result in tuber infection. Lapwood (1977) and Hirst *et al*. (1965) concluded that, in general, the initial infection of tubers occurred when rain coincided with 1 to 5% foliar blight. Most tuber infection occurred before half of the foliage was killed by blight. Lacey (1962) found that soil was most infective between 25% and 75% foliar blight. Fehrmann (1963) concluded that under certain conditions a little foliar blight could be responsible for a large amount of tuber blight.

Although there was frequently a strong relationship between the severity of haulm blight (within a limited range) and tuber blight incidence, there have been reports of high incidences of tuber blight at harvest in the apparent absence of foliar symptoms (Murphy, 1927; Grainger, 1957; Hirst & Stedman, 1962; Lacey, 1962; Boyd, 1972). Also, many authors commented on low incidences of tuber blight after a strong foliar blight epidemic (Skaptason *et al*., 1949; Gray, 1958; Fehrmann, 1963; Hirst *et al*., 1965; Ullrich, 1967; Bochow *et al*., 1979). Most of them concluded that a strong development of foliar blight with a fast haulm death resulted in a short period during which tubers were at risk from infection (Fehrmann, 1963; Ullrich, 1967; Croxhall & Smith, 1976; Bochow *et al*., 1979).

Cultivars with a greater degree of foliar resistance, for which the foliar epidemic progresses more slowly, may provide a higher risk of tuber infection because sporangia tend to be produced over a longer period of time and therefore their production is more likely to coincide with a rainfall event (Toxopeus, 1958). The same phenomenon is frequently observed in fungicide-treated plots in which the epidemic on the haulm is slower than in comparable untreated plots and yet the incidence of tuber blight is higher. Cox & Large (1960) considered the rate of foliage destruction to be the most important factor because they thought there were more opportunities for tuber infection in slow epidemics.

There is some evidence about the importance of stem blight in tuber infection. It has been demonstrated that in the absence of leaf lesions, *P. infestans* inoculum produced on lesions located at the base of potato stems can infect daughter tubers when washed into the soil. Lapwood (1964) reported 30% tuber blight in field plots of King Edward in which there were few blight lesions on the leaves but abundant stem lesions. He also found that most of the blighted tubers were clustered around the stem bases. Lacey (1967a) also observed a high incidence of tuber infection close to the stems in pot-grown potato plants. This is evidence supporting the idea that the sporangia on stem lesions can be readily transported in water channelled down the stems to infect the tubers. Lacey

(1962) noted that much rain water was channelled down the stems of upright cultivars. In contrast, sporangia washed from foliar lesions are more likely to land on the soil surface and the barrier of soil between them and the progeny tubers will limit infection. Lapwood (1977) reported that in late or slowly developing attacks, stem lesions became more numerous and larger than in fast, early attacks and were prolific sources of sporangia on some, but not all, cultivars. Water was channelled down the stems and while these were upright, water was deposited around the stem bases (Lacey 1967a). In years when stem lesions were prevalent, water channelled down the stems could account for many infected tubers clustered around the stem bases (Lapwood, 1964) and for the frequency of infected tubers close to the stems (Lacey 1966, 1967a). Bain *et al*. (1997) reported that the incidence of tuber blight was more closely related to the incidence of stem infection than to the severity of foliar blight.

The canopy architecture of a cultivar also influences the incidence of tuber infection: the proportion of sporangia or zoospores which reached tubers depended on how the lesions were distributed on the leaves or stems, by the way water was shed onto the ridge by the canopy of each cultivar, and whether water was channelled down the stems to the tubers (Lapwood, 1977).

Rainfall

The main role of rain (or irrigation water) in the tuber infection process is to wash sporangia or zoospores from leaf or stem lesions into the soil and onto progeny tubers. Lapwood (1977) found that 8 mm of rain were needed for tuber infection but that infection was greatest after about 25 mm of rain or more had increased soil moisture above field capacity around the tuber. Lacey (1962, 1965) observed that at least 6 mm of rainwater was required to cause tuber infection. Nineteen millimetres of rainfall made soil infective to a depth of 15 cm (Lacey, 1965). Hirst *et al*. (1965) reported that at least 5 mm of rainfall were necessary for tuber infection, but for a large number of infections at least 13 mm were required. Hirst *et al*. (1965) didn't find a strong correlation between rainfall and tuber blight. The effectiveness of rain in transporting the pathogen from the haulm to the progeny tubers is influenced by other factors. For example, infection is greater when a rainfall event occurs shortly after a period of profuse sporulation on the haulm. Hirst *et al*. (1965) observed that most infections followed rainfall of more than 13 mm coinciding with profuse sporulation on the foliage. Lapwood (1977) found the best relationship between tuber blight and rainfall between 0.1 and 75% foliar blight.

Rain or irrigation also increases the soil moisture content, which can influence the incidence of tuber infection. The relationship between soil moisture content and infection can be complex and depends on how and where the tubers were inoculated and whether infection precedes or follows the soil moisture treatment. Fairclough *et al.* (1993) found that higher soil moisture contents reduced infection when tubers were wound inoculated but the opposite was the case when tubers were infected *in situ*. Lapwood (1965) observed that 20% soil moisture content was the lower limit required for tuber infection. However, Stewart *et al.* (1993) observed that tubers from drier compost were significantly more susceptible to infection by *P. infestans* than those from wet or moist compost.

Soil factors

The soil acts as a barrier to tuber infection but the barrier is often incomplete. The effectiveness of a soil in preventing sporangia and zoospores reaching the progeny tubers is influenced by several factors. Sporangia washed down the stem are more likely to reach the tubers than those deposited on the ridge because there is often a channel formed between the stem and soil, created by the stem rocking in the wind (Zan, 1962). Zan (1962) also considered that cracks in the soil surface were necessary for extensive tuber infection. The greater the depth of soil over tubers, the greater the protection from infection by sporangia and zoospores washed down from the foliage. Movement of spores is facilitated in soils with larger particles and therefore larger pore sizes. Lacey (1962) and Zan (1962) reported that *P. infestans* passed more freely through vertical columns of sand than corresponding clay columns. Pore size is generally increased when the moisture content of a soil is increased.

It is commonly believed that *P. infestans* has poor saprophytic ability in soil (Malajczuk, 1983). This limited persistence in soil is generally attributed to the inactivation and rapid degradation of sporangia and mycelium by soil micro-organisms. Murphy (1922) and Lacey (1965) observed that mycelial growth of the pathogen was good in sterilised soil, but was severely impaired in non-sterile soil. These results were confirmed by observations of Andrivon (1994). Two mechanisms shaped the survival of *P. infestans* sporangia in soils: fungistasis (Lockwood, 1964) and lysis of fungal organs (Andrivon, 1994).

Soils contaminated with *P. infestans* sporangia remained infective to potato tubers for 15 to 77 days, depending on soil type, moisture content and pH (Murphy, 1921, 1922; Zan, 1962; Lacey, 1965; Bogulavskaya & Filippov, 1977; Sato, 1980; Andrivon, 1994). Zan (1962) found a maximum persistence of infectivity of sporangia of 77 days in a clay soil at 25% water-holding capacity and 15ºC. Murphy (1922) found that *P. infestans*-infested soil could retain its infectivity for up 40 days, depending on soil type and moisture content: clay soil retained infectivity longer than sand, and moist soil longer then very wet. As a rule, sandy soils lost their infectivity faster than clay or loam soils, and moist soils, i.e. at 20-25% of the water-holding capacity, remained infective longer than either water-saturated or dry soils (Murphy, 1922; Zan, 1962; Lacey, 1965). Zan (1962) didn't observe any link between tuber blight and soil pH in the range 4.8 to 8. Similar results were obtained by Fehrmann (1963).

Susceptibility of progeny tubers

Tubers can become infected through eyes, lenticels, wounds (Müller, 1957; Zan, 1962; Lacey, 1967b; Lapwood, 1977), bud initials, stolons (Müller, 1957) and directly through the periderm if tubers are immature (Walmsley-Woodward & Lewis, 1977). However, this last pathway was rejected by many authors (Müller, 1957; Zan, 1962; Lacey, 1967b). Müller (1957) reported that periderm tissues are commonly regarded as effective barriers against infection by pathogenic micro-organisms, the unbroken skin being impenetrable to fungi or bacteria. As soon as the young tuber had undergone two cell divisions in periderm formation, infection through the skin no longer took place (Müller, 1957). Hirst *et al*. (1965), citing Zan (1962), Lacey (1967b) and a personal communication from Lapwood, concluded that in general intact skin is immune. Lapwood (1977) reported that lenticels and eyes were the most frequent sites for tuber infection prior to harvest. The susceptibility of tubers between initiation and harvest generally declines with maturity (Bonde *et al*., 1940; Boyd & Henderson, 1953; Boyd, 1960). Boyd & Henderson (1953), Zeck (1957), Lemke (1962), Zan (1962), Hirst *et al*. (1965), Lacey (1967b) and Walmsley-Woodward & Lewis (1977) all found an increase in the resistance of lenticels to *P. infestans* with increasing tuber maturity but there was some variation between years. The relationship between tuber maturity and the resistance of eyes is less clear cut but

Hirst *et al*. (1965) reported that eyes may become slightly more susceptible as tubers mature. Higher soil moisture contents increased the number of lenticels per tuber and also caused the lenticels to proliferate (Cutter, 1978). Lacey (1962) and Adams (1975) suggested that proliferation might increase the susceptibility of lenticels to infection. Fairclough (1995) observed more lenticel infection on tubers incubated in soils with high moisture contents prior to inoculation.

Cultivars differ considerably in resistance to tuber blight but tuber susceptibility is generally not closely related to foliar blight susceptibility (Wastie, 1991). There is some evidence that the relationship between stem blight and tuber blight is closer (Bain *et al*., 1997). Some cultivars may escape tuber infection either temporally, i.e. those whose tubers bulk early, or spatially, i.e. tubers are not produced near the soil surface or on short stolons close to the stems.

Temperature

Tuber infection is more likely where lower ambient temperatures encourage indirect germination of sporangia. Sato (1979) concluded that limited tuber blight in Japan, in spite of extensive foliar blight and heavy rainfall, was due to soil temperatures during the growing season remaining above 18 ^{o}C. Zoospores are more likely to penetrate through soils to reach tubers than much larger sporangia. Zan (1962) noted that zoospores of *P. infestans* penetrated further into the soil profile than did sporangia when washed down by rain.

Alternative pathways of progeny tuber infection

(a) from infected progeny tubers

P. infestans can spread underground from infected to healthy progeny tubers on the same plant (Lapwood 1962; Lacey, 1962, 1967a) or neighbouring plants (Jones *et al*., 1912; Murphy & McKay, 1924; Murphy, 1927; Lapwood, 1961; Fairclough *et al*., 1993; Adler, personal communication). Lapwood (1962) and Lacey (1962, 1967a) reported the spread of *P. infestans* over a distance of 1.3 cm between progeny tubers on the same plant. Spread from inoculated progeny tubers on one plant to those on neighbouring plants up to 60 cm away was observed but only when the soil moisture content was high, i.e. 75% of field capacity, for a prolonged period (Fairclough *et al*., 1993). Jones *et al*. (1912), Murphy & McKay (1924), Murphy (1927) Lapwood (1961b) and Lacey (1962) observed active sporulation by *P. infestans* on the eyes and lenticels of progeny tubers in growing crops of several cultivars.

Sporulation by *P. infestans* on artificially inoculated tubers incubated under laboratory conditions at 15ºC was greatest between 8 and 13 days (Lapwood, 1962) Sporangia production was reduced if tubers were incubated in soil. The optimum soil moisture content for sporangia production was greater than 20% by weight (Lacey, 1967a). Fairclough *et al*. (1993) observed that sporangia production was greater on tubers from soil with a high moisture content (79% of field capacity).

Spread from infected progeny tubers to healthy tubers during handling at harvesting may also occur. Viable sporangia have been detected on the surface of recently harvested tubers (Murphy, 1927; Lapwood, 1961a, b, 1962, 1965; Hirst & Stedman, 1962; Lacey, 1962; Boyd, 1972). Dowley & O'Sullivan (1991) reported that viable sporangia of *P. infestans* were produced on infected potato tubers during storage and that these could infect healthy tubers during handling.

(b) Directly from seed tubers

Sporulation has been observed on blighted seed tubers up to 65 days after planting in soil in the glasshouse (Fairclough *et al*., 1993). The blighted seed tubers were kept in soil at 39 or 59% of field capacity for 58 days and sporulation observed 7 days after the moisture content was increased to 79%. It may not be necessary for tuberisation to have occurred for this pathway of infection to be occasionally important because stolons can be infected by *P. infestans* (Müller, 1957).

Fungicides

Partial control of foliar blight with fungicides can often lead to high numbers of sporangia being deposited on the soil surface (Hirst *et al*., 1965). Fehrmann (1963) reported less tuber blight in the unsprayed plots of her experiments than in the fungicide-treated plots. Bochow *et al*. (1979) reported that it was not only the intensity of foliar blight that was important for tuber blight but also the period during which tuber infection can take place. A prolonged period with foliar blight means also a long period with the possibility of tuber infection by a relatively small number of sporangia. He observed that as a result of fungicide treatment the severity of foliar blight was low, but tuber infection could take place over a longer period of time and tuber blight incidence in such plots was sometimes higher than in plots without any treatment.

Schepers & van Soesbergen (1995) assumed that fungicides could affect tuber blight in three ways: by preventing or reducing sporulation on the foliage, thus reducing the number of sporangia/zoospores that can be washed down into the soil; by directly or indirectly decreasing the viability of the sporangia/zoospores on the leaves; by the repeated application of fungicide to the foliage resulting in fungicide on the ridge. This fungicide present in the soil can prevent the germination of sporangia (Schepers & van Soesbergen (1995) citing Cetas & Leach, 1969) or may impair the motility of zoospores.

The phenylamide metalaxyl, when applied to the foliage, has been reported to protect tubers from infection by *P. infestans* (Bhatia *et al*., 1979; Smith, 1979; Cooke *et al*., 1981; Bruin *et al*., 1982; Bhatia & Young, 1983; Easton & Nagle, 1985). Where the proportion of phenylamide-insensitive *P. infestans* in the population was low, two or three applications of phenylamide-based fungicides applied during rapid haulm growth provided good control of tuber blight (Bain, unpublished). Metalaxyl significantly reduced the sporulation capacity of leaf lesions (Bruck *et al*., 1980) and inhibited the germination of zoospores (Coffey & Young, 1984). Bock (1981) proposed that the protection of tubers was due to metalaxyl dramatically reducing the number of zoospores being produced on foliar lesions. However, Bruin *et al*. (1982) and Barak *et al*. (1984) detected biologically active residues of metalaxyl in tubers following foliar applications.

Fentin hydroxide and fentin acetate can be very effective at controlling tuber blight (Last, 1961; Holmes & Storely, 1962; Pieters, 1962; Jarvis *et al*., 1967; Bock, 1981; Bain & Holmes, 1990). The fentin fungicides control tuber blight by several methods. They are reported to inhibit sporulation by *P. infestans,* and fentin hydroxide inhibited the release and germination of zoospores (Schwinn & Margot, 1991). Treatment with fentin hydroxide, compared with mancozeb, significantly reduced the development of stem blight and the incidence of tuber blight in field experiments (Fairclough, 1995; Bain, unpublished). Fentin hydroxide substantially reduced the number of foliar lesions that expanded down the petiole to cause stem lesions (Fairclough, 1995). Applications of fentin acetate to the soil significantly reduced tuber blight but in only one out of two years

(McIntosh 1965, 1966) and in only one out of two experiments conducted during 1962 by Bruin (Bock, 1981).

Fluazinam can also be very effective in preventing tuber blight. Fluazinam strongly inhibits sporangia production, indirect germination and cystospore germination (Anema *et al.*, 1992). Schepers & van Soesbergen (1995) observed that fluazinam at very low concentrations inhibited the motility and germination of zoospores. They explained the lower infectivity of soil in potato plots treated with fluazinam in terms of this property.

Agronomic practice

Potato tubers may become infected in the field before lifting or during harvest when they come into contact with diseased haulm. Lacey (1966) found that most blighted tubers were within 5 cm of the ridge surface. The deeper the tuber, the more penetrating had to be the rain to ensure infection. This demonstrates that an adequate depth of soil cover over progeny tubers is essential to maximise protection from infection.

Murphy (1921) first obtained experimental proof of infection at lifting, and Murphy & McKay (1924, 1925) later published data showing the reduction of tuber blight obtained by lifting when the haulm was dead, as compared with lifting when blight was active on the haulm. Müller (1957) also reported that many infections by *P. infestans* occurred around harvest time, when the soil was wet and contained a high proportion of infective spores, and where wounds have been inflicted during lifting. Bochow *et al.* (1979) reported reduced tuber blight when lifting was delayed until the second and third week after haulm death; even after 4 weeks tuber blight decreased. They concluded that a period of at least 3 weeks between haulm killing and lifting was necessary to avoid tuber infection. Hirst *et al.* (1965) reached a similar conclusion. Murphy (1927) reported that most sporangia lost their viability in 3 to 4 weeks. He found no effect from a delay in harvest of 5 days, but much less tuber blight after one of 10 days, although tubers sometimes become infected after a delay of 39 days. Lacey (1965) reported that the surface soil remained infective for at least 32 days after haulm killing, but the concentration of viable spores declined to a small value during the first week after killing. Murphy (1921) found catastrophic losses of tubers from blight after lifting tubers when the foliage was still alive and the soil contained many viable spores. Jones *et al.* (1912) considered that, in the field, a delay of as little as 7 days was sometimes enough to decrease tuber infection at lifting. Murphy (1921) recommended an interval of 10-14 days between the haulm dying and lifting tubers. Lacey (1965) reported that when deeper soil became infective it retained its infectivity for a very short period in contrast to the surface soil. He interpreted this in terms of only zoospores being washed deep into the soil and sporangia being retained in the surface layers.

References

Adams, M.J. (1975) Potato tuber lenticels: development and structure. *Annals of Applied Biology* **79,** 265-273.

Andrivon, D. (1994) Dynamics of the survival and infectivity to potato tubers of sporangia of *Phytophthora infestans* in three different soils. *Soil Biology and Biochemistry* **26**, 945-952.

Anema, B.P., Bouwman, J.J., Komyoji, T. & Suzuki, K. (1992) Fluazinam: a novel fungicide for use against *Phytophthora infestans* in potatoes. Proceedings Brighton Crop Protection Conference, 1992, 663-668.

Bain, R.A., R.W. Fairclough; S.J. Holmes & G.L. Ligertwood (1997) The role of *P. infestans* inoculum from stem lesions in the infection of tubers. Proc. of the workshop on the European network for development of an integrated control strategy of potato late blight. PAV-Special Report no. 1, 98-105.

Bain, R.A. & Holmes, S.J. (1990) Phenylamide insensitivity in *P. infestans* and control of potato late blight with fungicides. *Proceedings of the British Crop Protection Conference - Pests and Diseases, 1990*. Brighton: BCPC, 1121-1126.

Barak, E., Edgington, L.V. & Ripley, B.D. (1984) Bioactivity of the fungicide metalaxyl in potato tubers against some species of *Phytophthora*, *Fusarium* and *Alternaria* related to polyphenoloxidase activity. *Canadian Journal of Plant Pathology* **6,** 304-308.

Bhatia, S.K., Young, R.J. & Pencis, S.I. (1979) Detection of fungitoxic activity in potato tubers field-treated with CGA 48988 - a systemic fungicide. *Phytopathology* **69 (5),** 534 (abstract).

Bhatia, S.K. & Young, R.J. (1983) Detection of antifungal activity in potato tubers field-treated with metalaxyl, a systemic fungicide. *Plant Disease* **67,** 1075-1079.

Bochow, H., Krochert, R. & Tarnow, W.(1979) Hinweise auf einige das Auftreten und die Bekämpfung der Kartoffelbraunfäule (*Phytophthora infestans*) betreffende Zusammenhänge. *Nachrichtenblatt Pflanzenschutzdienst DDR* **24**, 225-229.

Bogulavskaya, N.V. & Filippov, A.V. (1977) Survival rates of Phytophthora infestans (Mont.) de Bary in different soils. Mykologiya i Fitopatologiya **11**, 239-241 (in russian). Cited by: Andrivon, D. (1994): Dynamics of the survival and infectivity to potato tubers of sporangia of *Phytophthora infestans* in three different soils. *Soil Biology and Biochemistry* **26**, 945-952.

Bock, R. (1981) Triphenyltin compounds and their degradation products. *Residue Review* **79,** 1-230.

Bonde, R., Stevenson, F.J. & Clark, C.F. (1940) Resistance of certain potato varieties and seedling progenies to late blight in the tubers. *Phytopathology* **30,** 733-748.

Boyd, A.E.W. (1960) Size of potato tubers and natural infection with blight and pink rot. *Plant Pathol.* **9**, 99-101.

Boyd, A.E.W. (1972) Potato storage diseases. *Plant Pathology* **51(5),** 297-321.

Boyd, A.E.W. & J. M. Henderson (1953) Susceptibility of immature potato tubers to blight. *Plant Pathol*. **2**, 113-116.

Bruck, R.I., Fry, W.E. & Apple, A.E. (1980) Effect of metalaxyl, an acylalanine fungicide, on developmental stages of *Phytophthora infestans. Phytopathology* **70,** 597-60.

Bruin, G.C.A., Edgington, L.V. & Ripley, B.D. (1982) Bioactivity of the fungicide metalaxyl in potato tubers after foliar sprays. *Canadian Journal of Plant Pathology* **4,** 353-356.

Cetas, R.C. & S.S. Leach (1969) *Phytophthora infestans* sporangial germination and tuber rot reduced by soil residues of fungicides. *Am. Pot. J.* **46**, 174-181. Cited by: Schepers, H.T. & van Soesbergen, M.A. (1995) Factors affecting the occurence and control of tuber blight. In: Dowley, L.J., Bannon, E., Cooke, Louise R., Keane, T. & O´Sullivan, E.: Phytophthora infestans 150. Published by European Association for Potato Research. Pages 171-176.

Coffey, M.D. & Young, L.H. (1984) Responses to metalaxyl of sensitive and resistant isolates of *Phytophthora infestans*. *Phytopathology* **74,** 615-620.

Cooke, L.R., Clifford, D.R. & Holgate, M.E. (1981) Control of potato late blight (*Phytophthora infestans*) with systemic fungicides. *Pesticide Science* **12,** 678-684.

Cox, A.E. & Large, E.C. (1960) *Potato blight epidemics throughout the world*. United States Department of Agriculture; USDA publication no. 174 (Agriculture Handbook Series).

Croxall, H.E. and L.P. Smith (1976) The epidemiology of potato blight in the East Midlands 1923-74. *Ann. Appl. Biol.* **82**, 451-466.

Cutter, E. (1978) Structure and development of the potato plant. In: Harris, P.M., ed. *The Potato Crop*. NewYork: Chapman & Hall, 70-147.

Dowley, L.J. & E. O´Sullivan (1991): Sporulation of *Phytophthora infestans* (Mont.) de Bary on the surface of diseased potatoes and tuber to tuber spread of infection during handling. *Potato Research* **34**, 295-296

Easton, G.D. & Nagle, M.E. (1985) Timing and root absorption affecting efficiency of metalaxyl in controlling *Phytophthora infestans* on potato in north-western Washington State. *Plant Disease* **69,** 499-500.

Fairclough, R. W. (1995) An investigation of factors influencing the incidence of potato tuber blight caused by *Phytophthora infestans* (Mont.) de Bary. PhD thesis: University of Glasgow.

Fairclough, R., R.A. Bain & S.J. Holmes (1993) The effect of soil moisture content on the infection of daughter tubers by *Phytophthora infestans* and subsequent disease transmission. *Proc. Crop Protection in Northern Britain 1993*, 325-330.

Fehrmann, H. (1963) Untersuchungen zur Pathogenese der durch *Phytophthora infestans* hervorgerufenen Braunfäule der Kartoffelknolle. *Phytopath. Z*. **46**, 371-408.

Grainger, J. (1957) Blight - The potato versus *Phytophthora infestans. Agricultural Review (London)* **3(5),** 10-26.

Gray, E.G. (1958): The control of blight in potato crops. *Scottish Agric*. **38**, 46-47.

Hirst, J.M. & Stedman, O.J. (1962) The infection of potato foliage and tubers by *Phytophthora infestans*. *Rothamsted Experimental Station Report for 1961.* Harpenden: Rothamsted Experimental Station, 113-114.

Hirst, J.M., O.J. Stedman, *J. Lacey & G.A. Hide* (1965) The epidemiology of *Phytophthora infestans*. IV. Spraying trails, 1959 to 1963, and the infection of tubers. *Ann. appl. Biol*. **55**, 373-395.

Holmes, T.D. & Storely, I.F. (1962) Comparative trials of copper, dithiocarbamate and organo-tin fungicides for potato blight control in Lincolnshire, 1958-61. *Plant Pathology* **11**, 139-146.

Jarvis, R.H., Short, J.L. & Shotton F.E. (1967) Copper, dithiocarbamates and organotin compounds for the control of potato blight, 1962-65. *Plant Pathology* **16,** 49-53.

Jones, L.R., Giddings, J. & Lutman, F. (1912) Investigations of potato fungus *Phytophthora infestans*. *Bull. Vt. agric. Exp. Stn.,* no. 168.

Lacey, J. (1962) The activity of *Phytophthora infestans (Mont.) de Bary* in soils. Ph.D. Thesis. University of Reading.

Lacey, J. (1965) The infectivity of soils containing *Phytophthora infestans*. *Ann. appl. Biol.* **59**, 363-380.

Lacey, J. (1966) The distribution of healthy and blighted tubers in potato ridges. *Eur. Potato J.* **9,** 86-98.

Lacey, J. (1967a) The role of water in the spread of *Phytophthora infestans* in the potato crop. *Ann. appl. Biol*. **59**, 257-264.

Lacey, J. (1967b) Susceptibility of potato tubers to infection by *Phytophthora infestans*. *Annals of Applied Biology* **59**, 257-264.

Lapwood, D. H. (1961a) Haulm and tuber resistance to *Phytophthora infestans*. *In: Rothamsted Experimental Station Report for 1960.* Harpenden: Rothamsted Experimental Station, 123.

Lapwood, D. H. (1961b) Sporulation of blight on potato tubers within ridges. *Plant Pathology* **10**, 40.

Lapwood, D. H. (1962) Soil activity of *Phytophthora infestans* and haulm and tuber resistance to blight. *In: Rothamsted Experimental Station Report for 1961.* Harpenden: Rothamsted Experimental Station, 115-117.

Lapwood, D. H. (1964) Haulm and tuber resistance to *Phytophthora infestans*. *In: Rothamsted Experimental Station Report for 1963*. Harpenden: Rothamsted Experimental Station, 111-112.

Lapwood, D. H. (1965) Tuber susceptibility to potato blight *In: Rothamsted Experimental Station Report for 1964*. Harpenden: Rothamsted Experimental Station, 129-131.

Lapwood, D.H. (1977) Factors affecting the field infection of potato tubers of different cultivars by blight (*Phytophthora infestans*). *Ann. appl. Biol.* **85**, 23-45.

Last, F.T. (1961) Results of spraying trials for *Phytophthora infestans*. *In: Rothamsted Experimental Station Report for 1960.* Harpenden: Rothamsted Experimental Station, 152-155.

Lemke (1962) Erfahrungen mit Kartoffelfäulen. *Kartoffelbau* **13**, 200-202.

Lockwood (1964) Soil fungistasis. *Annual Review of Phytopathology* **2**, 341-362.

Malajczuk, N. (1983) Microbial antagonism to *Phytophthora*. In: Erwin, D.C., Bartnicki-Garcia, S. and Tsao, P.H. (eds). The American Phytopathological Society, St. Paul, M.N. Pages 197-218.

McIntosh, A.H. (1965) An experiment on control of potato tuber blight. *Proceedings of the British Crop Protection Conference -Pests and Diseases, 1965*. Brighton: BCPC, 199-207.

McIntosh, A.H. (1966) Fungicides. *Rothamsted Experimental Station Report for 1966*. Harpenden: Rothamsted Experimental Station, 184.

Müller, K.O. (1957) Wound healing of the potato tuber in relation to infection by *Phytophthora infestans* (Mont.) de Bary. *Australian J. of Biol. Sci*. **10**,2 S. 189-196.

Murphy, P.A. (1921) The sources of infection of potato tubers with blight fungus, *Phytophthora infestans*. *Sci. Proc. R. Dublin Soc*. **16**, 353-368.

Murphy, P.A. (1922): The bionomics of conidia of *Phytophthora infestans*. *Sci. Proc*. R. *Dublin Soc*. **16**, 442-466.

Murphy, P.A. (1927): Some further cases of the production of diseased shoots by potato tubers attacked by *Phythophthora infestans* and a demonstration of alternative sources of foliage and tuber infection. *Sci. Proc. Roy. Dublin Soc*. Vol. **17**, 413-422.

Murphy, P.A. & R. McKay (1924) The development of blight in potatoes subsequent to digging. *J. Dep. Lds. Agric., Dublin* **24**, 103-116.

Murphy, P.A. & R. McKay (1925) Further experiments on the sources and development of blight infection in potato tubers. *J. Dep. Lds. Agric., Dublin* **25**, 10-21.

Pieters, A.J. (1962) Triphenyltin hydroxide- a fungicide for the control of *Phytophthora infestans* on potatoes, and some other fungal diseases. *Proceedings of the British Crop Protection Conference-Pests and Diseases, 1962*. Brighton: BCPC, 461-470.

Sato, N. (1979) Effect of soil temperature on the field infection of potato tubers by *Phytophthora infestans*. *Phytopathology* **69**, 989-993.

Sato, N. (1980) Sources of inoculum and sites of infection of potato tubers by *Phytophthora infestans* in soil. *Ann. Phytopath. Soc. Japan* **46**, 231-240.

Schepers, H.T. & van Soesbergen, M.A. (1995) Factors affecting the occurence and control of tuber blight. In: Dowley, L.J., Bannon, E., Cooke, Louise R., Keane, T. & O´Sullivan, E.: *Phytophthora infestans 150*. Published by European Association for Potato Research. Pages 171-176.

Schwinn, F.J. & Margot, P. (1991) Control with chemicals. In: Ingram, D.S. & Williams, P.H. eds. *Advances in Plant Pathology vol. 7*. London: Academic Press, 225-265.

Skaptason, J.B., L.C. Peterson & F.M. Blodgett (1940) The copper content of Long Island soils in relation to tuber rot of potatoes caused by *Phytophthora infestans* (Mont.) de Bary. *Amer. Pot. J.* 17, 88-92.

Smith, J.M. (1979) The use of metalaxyl for the control of downy mildew diseases. *Proceedings of the British Crop Protection Conference- Pests and Diseases, 1979*. Brighton: BCPC, 331-340.

Stewart, H.E., Wastie, R.L. & Bradshaw, J.E. (1993) The effect of the moisture level of potting compost on the susceptibility of glasshouse-grown tubers to late blight. *Potato Research* **36,** 29-33.

Toxopeus, H. J. (1958) Some notes on the relations between field resistance to *Phytophthora infestans* in leaves and tubers and ripening time in *Solanum tuberosum* subsp. *tuberosum*. *Euphytica* **7,** 123-130.

Ullrich, J. (1967) Die Braunfäule der Kartoffel (*Phytophthora infestans* [Mont.] de Bary). *Nachrichtenblatt Deut. Pflanzenschutzd. (Braunschweig)* **19**, 55-59.

Walmsley-Woodward, D. J. & Lewis, B.G. (1977) Laboratory studies of potato tuber resistance to infection by *Phytophthora infestans. Annals of Applied Biology* **85***, 43-49*.

Wastie, R.L. (1991) Breeding for resistance. In: Ingram, D.S. & Williams, P.H. eds. *Advances in Plant Pathology vol. 7*. London: Academic Press, 193-224.

Zan, K. (1962): Activity of *Phytophthora infestans* in soil in relation to tuber infection. *Trans. Brit. Mycol. Soc.* **45**, 205-.

Zeck, W. (1957) Untersuchungen über Infektionsverhältnisse bei der *Phytophthora*-Knollenfäule und über deren Beeinflussbarkeit durch Kupferdüngung. *Phytopath. Z.* **29**, 233-264.

Third Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

Experiments on stem late blight (*Phytophthora infestans*) control in Poland

J.S. KAPSA, J. OSOWSKI

Plant Breeding and Acclimatization Institute, Branch Division Bonin,
Department of Plant Protection
76-009 Bonin, Poland

Abstract

For the last few years, an increase in incidences of potato stem blight symptoms was observed among potato breeding clones and cultivars. In laboratory, greenhouse and field conditions efficacy of chemical control of that form of late blight was examined.

In laboratory experiments an addition of fungicides to rye medium (in equal to field doses) gave good inhibition of *Phytophthora infestans* isolates growth. In greenhouse, a good efficacy in decreasing the plant number with stem blight symptoms, after spraying them with fungicides 7 and 2 days before *Phytophthora infestans* inoculation was observed. In field trials there were not significant differences in efficacy of fungicide programmes in stem blight control.

Keywords: potatoes, stem form of late blight, chemical control.

Introduction

Potato is one of the most important agricultural crops in Poland. Since the year 1980 the potato acreage has decreased slowly but still remains at a very high level (table 1.)

Table 1. Area of the potato crops in Poland.

Year	Potato area/ha	% of the all seedings
1980	2.344.000	16,1
1990	1.835.000	12,9
1991	1.733.000	12,3
1993	1.761.000	13,1
1995	1.522.000	11,8
1997	1.342.000	10.5
1998	ab. 1.300.000	ab. 10

Phytophthora infestans causing potato late blight, is one of the main fungal pathogens in Poland. In most of the potato growing areas the late blight is present every year, but not always in an epidemic form, affecting haulm and reducing tuber yields. First appearance of the late blight is commonly recorded at the end of June or at the beginning of July, under Polish meteorological conditions. First symptoms of the disease are generally observed on the leaflets and petioles. Under favourable weather conditions (high humidity) late blight develops very intensively, destroying leaves, later stems and finally whole plants. High air temperature (about 30 °C), during growing season, stops very often development of typical late blight and may eliminate it completely.

Changes in the occurrence of the first potato late blight symptoms have been noted in some regions of Poland. First symptoms of the disease are confined to stems. The next step of the disease development is the infection of leaves. In case of this form of late blight the process of stopping rather than the total elimination of the disease which could be related to the higher air temperatures was observed (Clayson, Robertson, 1956). When weather conditions became more favourable for the disease, the late blight had started to develop epidemicly again (Bain et al, 1996). Field observations undertaken at Bonin (North of Poland) showed that most of the registrated in our country fungicides were not effective in controlling of stem late blight when they were used according to the standard Polish recommendation. For early potatoes, the first fungicide treatments should be applied as the tops are well met along the row but before they meet across the row. For maincrop cultivars, the first fungicide application is recommended when the late blight is noticed in early potatoes.

Materials and methods

1. *Description of stem late blight incidence on potato*

Prior to 1994, an appearance of stem late blight in potatoes in Poland was rare. There have only been occasional reports of the occurrence of this form of late blight on potato crops. In the years 1995-1998, in Bonin, observation on this subject were made among advanced potato breeding clones and cultivars in state trials. Each year we assessed occurrance of the stem blight on 80-85 genotypes.

In 1997 survey of potato crops was undertaken to give an information on incidence of stem blight around Poland. Personnel from the Advisory Service collected information mostly from the commercial potato fields. Observations were made on 148 potato crops, giving many very usefull additional informations.

2. Experiments on stem blight control

A/ Laboratory tests

The main purpose of the laboratory tests was to obtain an information on fungicide efficiency in growth inhibition of *Phytophthora infestans* isolates. Isolates of the fungus were collected from naturally infected stem and foliage of two potato cultivars (Jasmin and Van Gogh). All isolates were maintained in Petri dishes on rye agar media containing different fungicides (10 plates/2replications/combination). Ten fungicides, differing with their mode of action were chosen from the registered in Poland fungicides.

Table 2. Fungicides tested in laboratory conditions.

Product	active integrient	Mode of action	Rate/ha
Altima 500	fluazinam	protectant	0,4 l
Bravo 500	chlorothalonil	protectant	2,0 l
Bravo Plus	chlorothalonil + Zn	protectant	2,0 l
Dithane M-45	mancozeb	protectant	2,0 kg
Acrobat MZ 69	dimethomorph + mancozeb	translaminar	2,0 kg
Curzate M 72,5	cymoxanil + mancozeb	translaminar	2,0 kg
Invader 742	dimethomorph + mancozeb	translaminar	2,0 kg
Tanos*	being Registered	translaminar	0,4 kg
Tattoo 550	propamocarb hydrochloride + mancozeb	systemic + protectant	4,0 l
Ridomil MZ 72	metalaksyl + mancozeb	systemic + protectant	2,0 l

Each of them was applied to rye agar medium in two doses: equivalent to field dose and dose 10 times lower. Radial growth after 21 days of incubation at 17 °C was measured.

B/ Glasshouse experiments

Purpose of the study was to determine the timing of the first fungicide application to control stem late blight in plant tests. Potato plants were grown in soil in 10 cm diameter pots. Replicated plants (cv Ruta) were fungicide treated at doses equivalent to recommended in fiel conditions. The following fungicides were applied: chlorothalonil (Bravo 500), propamocarb hydrochloride + mancozeb (Tattoo550) and metalaksyl + mancozeb (Ridomil MZ 72). Fungicides had been applied 7 and 2 days before potato plants were inoculated with *Phytophthora infestans*, at inoculation day and 2 days after inoculation. Date of inoculation of the plants was set as date 0. Following inoculation plants were incubated at 20 °C and 60% humidity under a 12 h light/dark regime. The number of stems with late blight infection was monitored every 72 h for 4 weeks.

C/ Field trials

In the years 1997-1998 field experiments were conducted in Bonin, to determine the effectiveness of 4 fungicide spray programmes for potato stem late blight control. All trials were carried out in replicated (number of replicates 4) plots (each – 15 m^2) for all treatments in a randomized complete block design. Two replications were relied on natural infection. The next two replications were exposed to infection from artificially – inoculated infector plants. Fungicide sprays started very early in the season (in mid – June) and were repeated up to mid – August. Treated plots were protected with fungicide applications for 3 months. Following fungicide programmes were compared:

- Chlorothalonil (Bravo 500 SC) – 8 sprays;
- Propamocarb hydrochloride + mancozeb (Tattoo 550 SC) – 6 sprays;
- Dimethomorph + mancozeb (Invader 742 WP) – 6 sprays;
- Fungicide sequence – Bravo 500 SC, Tattoo 550 SC, Curzate M 72,5, Dithane M-45 WP, Altima 500 SC, Altima 500 SC, Brestan – 7 sprayings.

Control plots were without any chemical protection. At the beginning of the season, plot were carefully inspected several times a week in order to detect the first stem late blight infections. When these had been spotted visual ratings were made at weekly intervals to assess disease progress until the end of the season.

At harvest, tuber yields and percentage of diseased tubers were assessed.

Results and discussion

1. The field observations undertaken in Bonin, in the years 1995-1998 showed each year increasing number of cultivars and breeding clones infected with stem late blight (table 3). The largest number of genotypes with stem blight symptoms was observed among very early clones. The year 1998 was an exception. High air humidity at the beginning of July was a reason that the first symptoms of late blight were observed mainly on leaflets.

   From the survey of 148 potato crops from accros Poland, an information about incidence of stem blight in Poland was obtained. In 1997 year, 81,5% of observed crops was affected with stem blight. The first symptoms of stem blight were observed mainly on the middle parts of the potato plants – 51,6%, more rarely at the top – 35,5% and only about 12,7% of stem infection started at the bottom of the plants.

Table 3. Incidence of stem blight infection on the potato breeding clones and cultivars in state trials in Poland.

Years	Number of observed clones/cultivars	% of clones/cultivars affected with stem blight
1995	82	25,6
1996	85	36,5
1997	80	51,3
1998	80	26,3

2a/. All fungicides tested in laboratory conditions (in Petri dishes) gave 100% efficacious inhibition of the mycelium growth of *Phytophthora infestans* isolates, when were added to rye media in concentration equal to field dose. Only fluazinam added in dose ten times lower than field dose, did not gave 100% efficacy in inhibition of the fungus mycelium. Although, its efficacy was also significantly better as compare to combination without fungicide (table 4). The reason why the fungicide has not been efficient was too lower dose in b – combination (=0,04 l per ha).

Table 4. Inhibition growth of *Phytophthora infestans* isolates with fungicides added to medium (laboratory conditions).

Fungicide	Dose	Size of mycelium/mm/after 21 days			
		L_J	S_J	L_{vg}	S_{vg}
Without fungicide	-	44,8	53,4	45,6	59,3
Altima 500	A	0	0	0	0
	B	15,1	19,7	0	2,2

Bravo 500	A B	0 0	0 0	0 0	0 0
Bravo Plus	A B	0 0	0 0	0 0	0 0
Dithane M-45	A B	0 0	0 0	0 0	0 0
Acrobat MZ 69	A B	0 0	0 0	0 0	0 0
Invader 742	A B	0 0	0 0	0 0	0 0
Curzate M 72,5	A B0	0 0	0 0	0 0	0 0
Tanos*	A B	0 0	0 0	0 0	0 0
Tattoo 550	A B	0 0	0 0	0 0	0 0
Ridomil MZ 72	A B	0 0	0 0	0 0	0 0

Doses: A = field dose L – isolates of Ph.inf. from leaves (cvs. Jasmin or Van Gogh)

B = 10 times lower than field dose S – isolates of Ph.inf. from stems (cvs. Jasmin or Van Gogh)

2b/. In greenhouse conditions a very good efficacy in decreasing the number of potato plants with stem blight symptoms of all tested fungicides were observed. All the fungicides acted efficiently as they were applied at the day of inoculation and even better when the potato plants were protected 7 or 2 days before infection. The stem blight control of systemic fungicide treatments was clearly superior to that in the contact fungicide treatment. 2 days after inoculation only propamocarb hydro-chloride was significantly efficacious in limiting of stem late blight as compare to the rest of products (figure 1).

Figure 1. Efficacy of protection against stem blight in greenhouse conditions.

Results of greenhouse experiments showed that control of stem late blight is possible at potato crops if the first spray would be applied before infection of *Phytophthora infestans*.

2c/. In 1997 field trials performed in natural infection conditions there were not significant differences in efficacy of all tested fungicide programmes in the stem blight control at two cultivars (Bryza and Cisa) – figure 2.

Figure 2. Inhibition of stem blight development in natural infection conditions – Bonin 1997.

Generally, tuber yield was not very high in 1997 year. Differences in tuber yield between plots protected with fungicide programmes and untreated plots were statistically significant. Tuber yields of treated plots were 47,0 – 65,8% higher compared to unprotected combination (table 5).

Table 5. Influence of the fungicide protection programmes on potato tuber yield; Bonin, 1997.

Treatment	Natural conditions		Infectors	
	Yield t/ha	% of unprotected	Yield t/ha	% of unprotected
Unprotected	11,7	100,0	11,9	100,0
Bravo 500	17,9	153,0	16,7	140,3
Invader	18,5	158,1	14,7	123,0
Tattoo 550	17,2	147,0	14,1	118,5
Fungicide sequence	19,4	165,8	15,3	128,6
LSD = 3,4 t/ha				

Conclusions

1. Laboratory, glasshouse and field trials showed that effective control of potato crops against stem late blight is possible, decreasing the number of infected stems and increasing tuber yields.
2. Control should start with preventive spraying using systemic or translaminar fungicides and should be provided during three months or even longer.
3. The scheme of potato crops protection as given above acts very well also in control of typical potato late blight.

References

Bain R.A., Fairclough R.W., Holmes S.J., Ligertwood G.L., 1996 The role of P.*infestans* inoculum from stem lesions in the infection of tubers. Proceedings of the Workshop on the European Network for Development of an Integrated Control Strategy of potato late blight. Lelystad, The Netherlands, 30.09-3.10.1996, 98-105

Clayson A.M., Robertson N.F., 1956. Survival of *Phytophthora infestans* in potato stem lesions. Plant Pathology 5, 30-31.

Third Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

Use of Fluazinam in potato late blight control: Sensitivity and field performance

L. R. COOKE[1,2] G. LITTLE[1] & D. G. WILSON[1]

[1]Applied Plant Science Division, Department of Agriculture for Northern Ireland
[2]Department of Applied Plant Science, The Queen's University of Belfast
Newforge Lane, Belfast, BT9 5PX, UK

Abstract

Fluazinam, a non-systemic protectant fungicide, has been used for the control of potato late blight in Northern Ireland since 1994 and is currently applied to *c*. 20% of the crop area. A zoospore motility assay was used to test the sensitivity to fluazinam of isolates of *Phytophthora infestans* obtained from Northern Ireland potato crops between 1993 and 1998. All isolates proved very sensitive to fluazinam with zoospore motility inhibited by 20 - 80 μg fluazinam/litre. There was no consistent trend in sensitivity between isolates obtained from crops in different years. Fluazinam sensitivity was not affected by use of fluazinam on the crops from which isolates were obtained. *In vivo* sensitivity to fluazinam was demonstrated in field trials inoculated with Northern Ireland isolates of *P. infestans*. Fluazinam programmes achieved good control of foliage and tuber blight, better than mancozeb at the same interval. The most effective programme was where the fluazinam treatments were preceded by three applications of metalaxyl + mancozeb.

Keywords:*Phytophthora infestans*, potato late blight, fungicide sensitivity, fluazinam

Introduction

The non-systemic fungicide fluazinam has been approved in the UK since 1994 exclusively for the control of potato late blight. Fluazinam is very effective in protecting foliage from attack by *Phytophthora infestans* and has achieved excellent control of tuber blight (Tucker *et al*., 1994), which is of particular importance to potato growers in wetter regions such as Northern Ireland.

Fluazinam is marketed in formulations containing no other active ingredient and these are recommended for season long use on potatoes, with a maximum of 10 applications per crop. The possibility of the development of fungicide resistance is of particular concern in the case of *P. infestans*. It is a rapidly reproducing air-borne pathogen, which has frequently demonstrated its ability to respond to environmental selection pressures such as host-plant resistance or fungicide usage. Subjecting it to repeated applications of a single fungicide within one season has the potential to select for fungicide resistant strains if viable, fit strains can develop. Zeneca have developed a technique for monitoring the sensitivity of *P. infestans* isolates to fluazinam based on inhibition of zoospore motility. In view of the increasing use of fluazinam on potato crops in Northern Ireland, it was decided to test the sensitivity of *P. infestans* isolates collected from Northern Ireland potato crops over the last six years and to evaluate the field performance of fluazinam against known isolates.

Materials and Methods

Source of Phytophthora infestans isolates

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 as previously described (Cooke & Penney, 1992). Isolates were derived by bulking together the sporangia obtained from all foliage samples within a single crop. A few isolates were obtained from infected tubers. At the end of each season, Potato Inspectors provided estimates of fungicide usage for all seed potato crops in their areas.

Characterisation of isolates for phenylamide resistance and mating type

For 2-3 months after receipt, isolates were maintained on detached glasshouse-grown potato leaflets free from fungicide treatment. During this time, they were tested for phenylamide resistance using the floating leaf disc technique (Cooke, 1986) on 100 and 2 mg metalaxyl/litre. Isolates were designated resistant if they sporulated on 100 mg metalaxyl/l-treated discs. Isolates were subsequently transferred into pure culture and tested for mating type (Cooke *et al*., 1995).

Field trials 1996-97

Tubers of the maincrop potato cv. Up-to-date were planted on 10 May 1996 and 23 April 1997 at Newforge, Belfast in fully randomised blocks with five replicate plots per treatment. Each plot (2.8 x 3.0 m^2) contained four rows of ten tubers. Pairs of rows of unsprayed plants adjacent to each treated plot served as an infection source. Plants in these rows were inoculated (4 July 1996, 3 July 1997) with phenylamide-resistant and phenylamide-sensitive isolates of *P. infestans* (50% of leaves inoculated with a mixture of three resistant isolates and 50% with three sensitive isolates obtained from the previous season's Northern Ireland blight samples). The plots were misted daily after inoculation for 2-3 h at dawn and dusk to encourage spread of blight.

In both years, three programmes containing fluazinam (150 g/ha as 'Shirlan') were compared with a standard programme of mancozeb (1275 g/ha as 'Dithane DF') followed by fentin hydroxide (266 g/ha as 'Du-ter 50'). Metalaxyl + mancozeb was used as 'Fubol 75 WP'(150 g + 1350 g/ha). Spray intervals and numbers are shown in Table 1. Spray programmes started on 24 June 1996 and 9 June 1997. Foliage late blight was assessed twice weekly during July and August. Plots were desiccated with diquat (23 August 1996, 1 September 1997) and tubers lifted three weeks later. After lifting, tubers were graded and the numbers and weight of tubers with blight (>35 mm) from each plot recorded.

Table 1.Fungicide programmes evaluated for control of potato blight, 1996-1998.

Product (spray interval in days in brackets)			No. of sprays		
Early-season	Mid-season	End-season	1996	1997	1998
———mancozeb (10)———		fentin hydroxide (7)	5/3	nt	nt
———mancozeb (7)———		fentin hydroxide (7)	nt	8/3	7/2
———fluazinam (10)———			7	9	nt
———fluazinam (7)———			9	11	nt
metalaxyl+mancozeb (10)	———fluazinam (7)———		3/5	3/7	4/4

nt = not tested

In 1998, a similar field trial was carried out (disease and yield data not reported), which included mancozeb/fentin hydroxide and metalaxyl + mancozeb/fluazinam programmes (Table 1). Foliage blight samples were collected from each plot of these treatments on 27 August (after completion of the spray programmes). Single lesion isolates were obtained (up to 3 per plot) from these and tested for fluazinam sensitivity as described below.

Sensitivity of isolates to fluazinam

The sensitivity assay was modified from an unpublished protocol developed by the University of Wageningen for Zeneca and now used by Zeneca as their standard protocol. Sporangial suspensions (*c*. 10^5 sporangia/ml) were prepared from rye agar cultures of *P. infestans* isolates maintained at 15°C. Suspensions were incubated at *c*. 5°C for 2-3 h to stimulate zoospore release.

Isolates were tested against final concentrations of 70, 60, 50, 40, 30 and 20 µg fluazinam/litre (prepared from 'Shirlan') in 96-well ELISA plates. Two replicate wells per isolate were used for each concentration and water controls were included. Plates were incubated at 5°C for 1 h before assessment of zoospore motility; this was found to be the optimum time to achieve reproducible results (Cooke *et al*., 1998). Results were expressed as the minimum inhibitory concentration (MIC), defined as the lowest concentration which completely inhibited zoospore motility. Each isolate was tested at least twice. Isolates where zoospores were motile at 70 µg fluazinam/litre were re-tested at 100, 90 and 80 µg fluazinam/litre.

Results

Fluazinam usage on seed potato crops

Fluazinam was not used on commercial potato crops in Northern Ireland before 1994. Since then, usage has increased annually (Table 1). In 1997, just under 20% of seed crops received fluazinam applications for most of the spray programme. Additionally, other seed crops may have received one or two applications of fluazinam in mixed blight control programmes. This is borne out by data from the Survey of Pesticide Usage in Northern Ireland. In 1996, the most recent year surveyed, approx. 23% of seed crops, 9% of early ware and 17% of maincrop ware received one or more fluazinam applications (Jess *et al*. 1998).

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

Fungicide applied	Growers (%) using fungicides in				
	1993	1994	1995	1996	1997
mancozeb alone	70	69	63	61	60
fluazinam	0	5	13	16	19
phenylamide + mancozeb	17	14	14	14	12

other	13	12	10	9	9

Field trials 1996-97

Fluazinam achieved significantly better control of foliage blight caused by a 50/50 phenylamide-resistant/phenylamide-sensitive *P. infestans* population than did the standard mancozeb/fentin hydroxide programme at the same interval (Figure 1). Fluazinam performed significantly better when applied at 7 d rather than 10 d intervals. The best foliage blight control was obtained with the programme which started with three applications of metalaxyl+mancozeb. Performance in controlling foliar infection was reflected in the yield, particularly of healthy tubers, and in the effect on tuber blight (Table 3).

Table 3. Yield assessments: weight and number of total, total excluding chats and total healthy.

Treatment	Weight (kg) tubers >35 mm per plot				Blighted tubers	
	Total tubers		Healthy tubers		(% by number)	
	1996	1997	1996	1997	1996	1997
mancozeb/fentin hydroxide	23.8	45.2	19.1	12.0	16.1	64.2
fluazinam 10 d	33.1	53.0	28.0	18.6	19.6	56.5
fluazinam 7 d	30.5	53.3	23.0	29.4	9.6	36.2
metalaxyl+mancozeb/-fluazinam	33.6	69.0	32.0	49.9	0.7	19.6
L.S.D. (P<0.05)	3.92	11.89	4.70	11.80	8.82	16.43

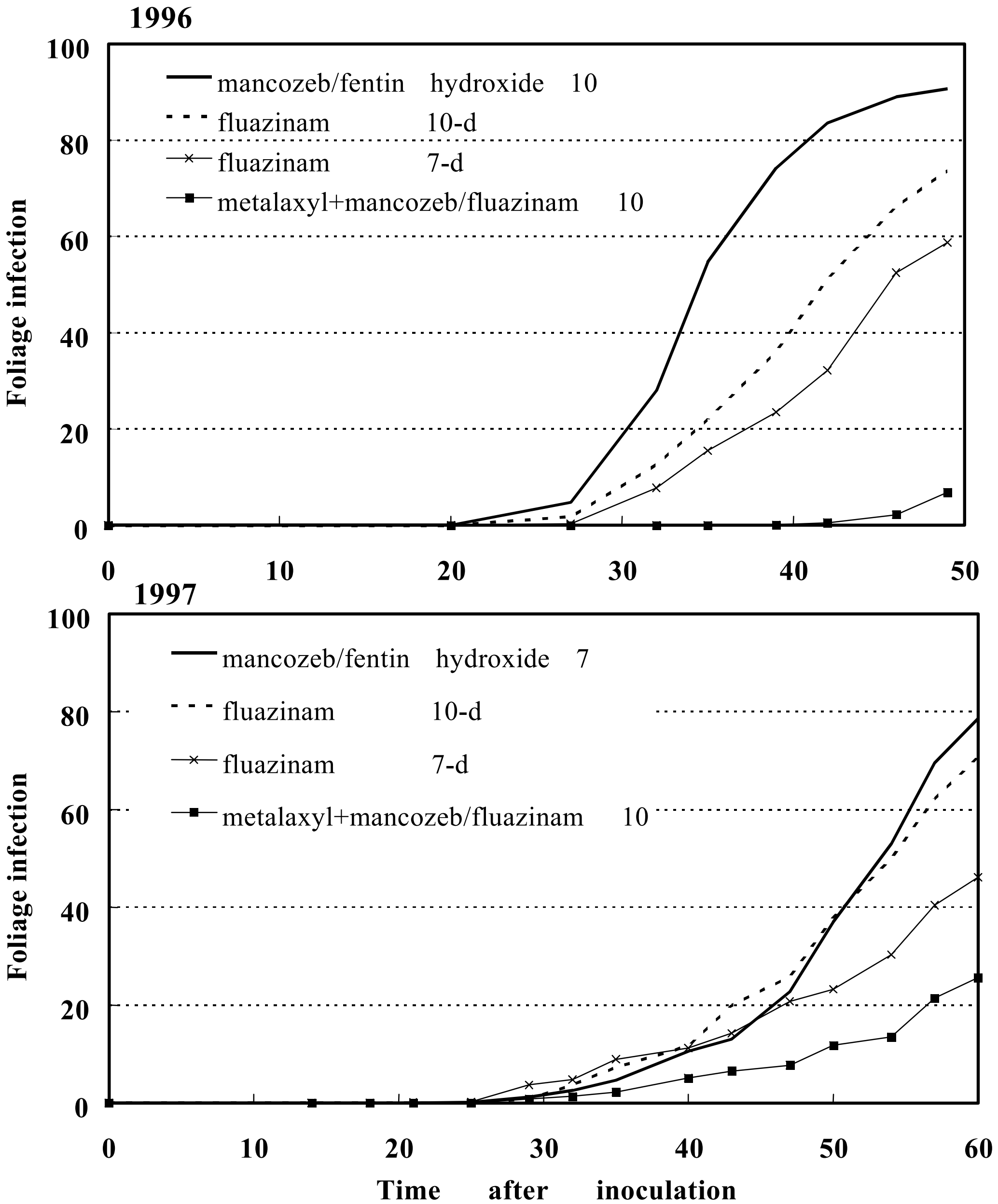


Figure 1. Effect of fungicide programmes on foliage blight development, 1996-1997.

Sensitivity to fluazinam of zoospore motility of field isolates of Phytophthora infestans from Northern Ireland, 1993-1998

A collection of 132 isolates of *P. infestans* obtained from Northern Ireland crops between 1993 and 1998 was tested for sensitivity to fluazinam. The mean MIC values for individual isolates ranged from 20 to 80 μg fluazinam/litre. There was no evidence of any trend in sensitivity between isolates obtained from potato crops in different years (Table 3), although a few isolates which gave higher MIC values (70-80 μg/litre) were obtained in 1998.

Table 4. Sensitivity to fluazinam of Northern Ireland *Phytophthora infestans* isolates collected in different years.

Year isolated	No. of isolates tested	MIC value (μg/l)	
		Range	Mean
1993	6	20 - 30	23
1994	27	20 - 50	28
1995	18	20 - 60	28
1996	24	20 - 50	38
1997	15	20 - 50	31
1998	43	20 - 80	31
Total	133	20 - 80	31

The sensitivity of isolates obtained from crops which had received one or more fluazinam applications was very similar to those from crops treated with other fungicides (Table 4). There was also no association between phenylamide resistance and fluazinam sensitivity.

Table 5. Sensitivity to fluazinam of Northern Ireland *Phytophthora infestans* isolates: the effect of fungicide usage and phenylamide resistance.

Character	No. of isolates tested	MIC value (μg/l)	
		Range	Mean
<u>Fungicide usage</u>			
No fluazinam	113	20 - 80	31
Fluazinam	20	20 - 70	29
<u>Phenylamide resistance</u>			
R	33	20 - 80	32
S	99	20 - 70	31

Isolates of the A2 mating type of *P. infestans* are infrequent in Northern Ireland (Cooke *et al*., 1995) and all but three were of the A1 mating type. The A2 isolates (obtained from two 1993 crops and one 1994 crop) had a mean MIC value of 23 μg fluazinam/litre (range 20-30 μg/l).

Sensitivity to fluazinam of isolates of Phytophthora infestans from fungicide-treated plots, 1998 field trial

It was intended to test at least two isolates from each treated plot, to give a minimum of ten for each treatment. However, whilst nine isolates were obtained from the mancozeb/fentin-treated plots, only five were successfully isolated from lesions from fluazinam-treated plots (Table 5), suggesting that, although sporulating lesions were present, spore viability had been impaired. Analysis of variance of plot means indicated that there was no difference in fluazinam sensitivity between the isolates from the two treatments ($P > 0.05$).

Table 6. Sensitivity to fluazinam of *Phytophthora infestans* isolates from 1998 field trial.

Treatment	No. of isolates tested	MIC value (μg/l)	
		Range	Mean
mancozeb/ fentin hydroxide	9	20 - 80	44
metalaxyl+mancozeb/ fluazinam	5	20 - 70	40

Discussion

Fluazinam is currently the only diarylamine fungicide in widespread use, so it is not possible to extrapolate the likely risk of resistance development from the behaviour of related fungicides. Its application to potatoes for late blight control, as a sole active ingredient with a recommendation for season-long use, provides a strong selection pressure. However, mancozeb has been used in a similar way for the past 30 years with no recorded cases of resistance. Practical fungicide resistance leading to disease control problems has generally occurred with single-site inhibiting, systemic fungicides. Fluazinam is non-systemic and acts as an uncoupler of fungal oxidative phosphorylation (Guo *et al*., 1991). It has been proposed that, as its action is non-specific, selection of resistant strains is extremely unlikely (Tucker *et al.*, 1994). Nonetheless, monitoring of the sensitivity of *P. infestans* populations exposed to fluazinam is desirable.

The zoospore motility test provides a rapid method for sensitivity testing. The test is best-suited to use with *P. infestans* isolates in pure culture; use with isolates maintained on potato tissue is more problematic since motile contaminants may confuse the assessments. To ensure consistent results, in our tests, it was found crucial to ensure that that all suspensions and ELISA plates were kept chilled to *c*. 5°C, otherwise zoospore motility rapidly declined.

In the Netherlands, where fluazinam has been used intensively since 1992, *P. infestans* isolates collected between 1993 and 1995 were tested using this technique and all proved very sensitive to fluazinam (Anon., 1997). In the tests reported here, zoospore motility of all isolates tested was highly sensitive to fluazinam with MIC values most commonly between 30 and 40 μg/litre, in agreement with the figure of 40 μg/litre reported by Tucker *et al*. (1994). There was no evidence of any change in sensitivity over time or association with any other factor.

In vivo sensitivity to fluazinam was demonstrated in the field trials inoculated with isolates of *P. infestans* obtained from Northern Ireland crops in the preceding seasons. Fluazinam programmes achieved good control of foliage and tuber blight, better than mancozeb at the same interval. The most effective programme was where the fluazinam treatments were preceded by three applications of metalaxyl + mancozeb. Phenylamide-resistant strains of *P. infestans* have been found in less than 50% of isolates tested for the last four years (1995-98) and, under these circumstances, there is benefit from starting the spray programme with a phenylamide-containing formulation, which provides systemic protection while the foliage is growing most rapidly.

Acknowledgements

We thank Zeneca for the protocol for fluazinam sensitivity testing and for financial assistance.

References

Anon.1997. In *Fungicide resistance in potato pathogens: potato blight* Phytophthora infestans. Slawson D D (ed), British Potato Council, FRAG-UK, pp 10.

Cooke, L.R. 1986. Acylalanine resistance in *Phytophthora infestans* in Northern Ireland. *Proceedings of the 1986 British Crop Protection Conference - Pests and Diseases* **2**, 507-514.

Cooke, L.R., Little, G. & Wilson, D.G. 1998. Sensitivity of *Phytophthora infestans* to fluazinam and its use in potato blight control in Northern Ireland. *Proceedings 1998 Brighton Crop Protection Conference - Pests and Diseases*, **2**, 517-522.

Cooke, L.R. & Penney, R.E. 1992. Phenylamide resistance in *Phytophthora infestans* in Northern Ireland - a changing situation. *Proceedings 1992 Brighton Crop Protection Conference - Pests and Diseases*, **1**, 201-206.

Cooke, L.R., Swan, R.E. & Currie, T.S. 1995. Incidence of the A2 mating type of *Phytophthora infestans* on potato crops in Northern Ireland. *Potato Research*, **38**, 23-29.

Guo, Z.J., Miyoshi, H., Komyoji, T., Haga, T. & Fujita, T. 1991. Uncoupling activity of a newly discovered fungicide, fluazinam [3-chloro-N-(3-chloro-2,6-dinitro-4-trifluoromethyl-phenyl)-5-trifluoromethyl-2-pyridinamine]. *Biochimica et Biophysica Acta*, **1056**, 89-92.

Jess, S., Kidd, S.L.B. & McCallion, T. 1998. Pesticide Usage Survey Report 146, Northern Ireland Arable Crops 1996. HMSO, Belfast, in press.

Tucker, R.P., Leaper, D. J, & Laidler, S.T. 1994. Fluazinam - control of potato late blight - UK experience 1992-3. *Proceedings 1994 Brighton Crop Protection Conference - Pests and Diseases*, **1**, 295-300.

Third Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

PCR techniques used for detection of Phytophthora infestans latent infections in potato

N. ADLER, J. HABERMEYER, V. ZINKERNAGEL

Lehrstuhl für Phytopathologie,
TU München-Weihenstephan, D-85350 Freising, Germany

Abstract

Knowledge about the epidemiology of a fungus is necessary for a fast and well working forecasting system. It is favourable for these systems and for the control of propagation to know where the pathogen can be located before a sudden outbreak occurs. The PCR method allows the detection of small amounts of mycelium inside an organism. Therefore the PCR technique seems to be an accurate method to identify *Phytophthora infestans* in latently infected plant material before the fungus shows visible symptoms.

Keywords: *Phytophthora infestans*, Late blight, latent infections, PCR, detection limit, ELISA

Introduction

Late blight, caused by *Phytophthora infestans* has been a threatening disease of potatoes for more than 150 years. A high number of systems exists in order to forecast the outbreak of the disease. Therefore the following question arises: When and where does the first inoculum of *P. infestans* appear in a field?

The improved knowledge on the epidemiology of the fungus and its behaviour enables better forecasting systems and economising the use of fungicides.

A lot of preparation work in PCR has been done by different scientific groups to design specific primers for the *P. infestans* detection (Niepold and Schöber-Butin, 1995, Tooley et al., 1997, Trout et al.,1997). We hope that the methods described here could be used for a more sensitive detection than it is possible with the ELISA test (Schlenzig, 1997).

Material and Methods

PCR. The detection method for latent infection with *P. infestans* was carried out by PCR according to a varied method of Tooley et al. (1997). This method has been modified in the concentration of the PCR components and in the temperature run of the thermocycler (MG Research, PTC 200). The used primers ITS3 and PIN F2 showed an 456bp amplification product.

Field design

The described experiments were performed in the year 1997.

Weihenstephan

In the examined potato field in Weihenstephan seed potatoes were grown, which originated from an organic field (cultivar *Christa*). The tubers were planted in twelve rows with nearly 100 tubers. After emergence the plants were numbered and one stem of each potato was taken for the assay.

Munich

In the experiment at the LBP in Munich certified seed potatoes (cultivar *Agria*) were used. The tubers were planted in beds containing different kinds of soil. Some of the seed tubers were artificially inoculated with 5-10 zoospores of *P. infestans* (isolates *S41* and *Dür*) per tuber (Fig.2) by a syringe. Two stem samples were taken from each plant after emergence but before visible outbreak.

A assumption exists that soil type and humidity have an influence on primary inoculum. For this reason the experiment was planed including different parameters. As the trial shows (Fig. 2) there were differences in the number of planted tubers, in the number of artificially infected tubers, in the amount of the irrigation water in each plot and at last in soil type (loam, silt and sand), in order to find out, which parameters influence the primary infection.

A hose was used for irrigation, so that only the soil was irrigated.

Tested Tubers. The examined tubers were obtained from different fungicide untreated fields in Bavaria.

Sample preparation. From each stem DNA was isolated using a DNeasy Plant Mini Kit (QIAGEN, Hilden, Germany). As a rule the lowest 3 cm of the stem were used for the sample preparation.
For the tuber preparation the whole tuber was washed, freeze-dried, crushed by mortar and pestle and afterwards DNA was extracted by an NaOH method according to Wang et al. (1993).

ELISA. The ELISA test used is described by Schlenzig (1997). The *Phytophthora infestans*-antiserum derived from the Scottish Research Institute.

Results

By changing the PCR conditions a method was created that was 20 times more sensitive than the originally one (Fig.1). Based on this PCR method some experiments were realised.

500ng 50ng 5ng 500pg 50pg 5pg 500fg negative standard

Figure 1. Dilution series of *P. infestans* DNA (isolate S41) according to a modified method of Tooley et al. (1997)

At first some 1200 potato plants of the cultivar Christa were grown in a field at Freising-Weihenstephan. The potatoes were arranged in twelve rows with 100 tubers each. The date of planting was April 23rd. The first plants emerged in the end of May. The stem samples were taken on the first of July. Approximately one week later visible

Phytophthora stem and leaf symptoms were detected in the field. Six times a positive PCR signal was found in the stems taken one week before the outbreak. This represents an infection rate of 0.5%.

The experiment at the Landesanstalt (Fig.2) showed more accurate the distribution of the latently infected stems throughout the plots.

Figure 2. Experimental plots at the LBP (Munich) 1997

Two stem samples from each plant were examined with the PCR technique after emergence. The date of planting was June 19^{th}. The potato plants grew very fast so that the date of sampling was the July 16^{th}. The PCR examinations gave the following results:

13 out of 174 potatoes did not emerge and 7 stems showed latent infection, which corresponds a percentage of 4. The high rate of losses in the 45 planted artificially infected tubers (nearly 25%) is conspicuous.

From the artificially inoculated plants which emerged only 2 had a positive PCR reaction (5.8%). This occurred only in one of the two sampled stems per plant.

From the tubers without artificial inoculation only two plants did not grow (1.5%). These emerged potato plants showed 5 latent infected stems which results in a rate of 3.9%.

In order to find a higher level of sensitivity in disease detection by PCR in comparison with the ELISA test, a first visibly diseased stem was chosen which seemed to be the first inoculum source in a field at the time of the *Phytophthora* outbreak. The stem was cut into 1 cm pieces and subsequently DNA and proteins of each piece were extracted. The results are shown in Fig. 3.

We could notice by ELISA test that the fungus was present in the whole stem except in the middle of the stem part. The grey bars show the stem parts where *P. infestans* could be located by means of PCR. There is also a lack of mycelium detection, but it is smaller.

Figure 3. ELISA and PCR examination of a stem with blight disease (initial infthe field; cv. *Linda*).

Experiments with potato tubers were made also, because the PCR method was originally developed to detect Phytophthora in tubers. The plots at the LBP experiment showed different developments of the disease. It seemed that the amount of inoculum has influenced the tuber infection enormously. In order to know which potential of theoretical incidence exists in the next year, untreated hand harvested potato tubers from different fields were examined. They were cut into slices, freeze-dried and then the DNA was extracted. The PCR examination produced the results shown in Table1.

Table 1. Infection potential in tubers of different cultivars (stored 6-8 month) at 6°C.

	number of examined tubers	visible infected	latent infected detect with PCR	total infected
Amigo 1	**118**	4 **(3.4%)**	10 **(8.5%)**	14 **(11.9%)**
Amigo 2	**124**	1 **(0.8%)**	0 **(0.0%)**	1 **(0.8%)**
Agria 1	**150**	2 **(1.3%)**	4 **(2.7%)**	6 **(4.0%)**
Agria 2	**110**	8 **(7.2%)**	11 **(10.0%)**	19 **(17.2%)**
Producent	**110**	12 **(10.9%)**	9 **(8.2%)**	21 **(19.0%)**
Florijn	**101**	2 **(1.9%)**	2 **(1.9%)**	4 **(3.9%)**
Maxilla	**86**	3**(3.4%)**	2 **(2.3%)**	5 **(5.8%)**

A high number of latently infected tubers were found in the material examined.

In order to get answered what is gowing on with the daughter generation of infected plants and artificially infected tubers, we examined the harvested tubers from our experiment at the Landesanstalt, as well (Fig. 4). The foliage of the plants had a total infestation August 7^{th}.

Immediately after harvesting tubers were frozen. Most of the latently infected tubers were found in loamy soil. The total number of examined tubers was 400. In 17 of these tubers a latent infection could be detected, which means an infection rate of 4.3%.

Figure 4. *P. infestans* tuber infection at the LBP plots 1997 (cv. *Agria*).

Discussion and Conclusions

The results of the field experiment at Weihenstephan agree with those achieved by Schlenzig (1997) obtained with the ELISA test.

The amount of the stems which were infected is very low (0.5%). But there is needed only one outbreak from an inoculum source in a field to infect 1 km^2 potato plants (van der Zaag, 1956).

We presume that the low number of infected emerged stems can be attributed to a kind of dilution effect. Out of a high potential of infected tubers the mycelium has the possibility to grow into the stem, as our experiments confirm. Tuber buds which are very close to the inoculum area in the tuber do not emerge, stems which are too far from the infection site get not infected. Therefore it needs a defined distance in the tuber for the latent mycelium growth into the stem.

The results from the experiment at the Landesanstalt in Munich give information about the fact that other factors can also have an influence on the primary infection.

It is remarkable, that the latently infected stems were mostly found in the irrigated plots. Further more it was spectacular that latently infected plants were either in the neighbourhood of artificially infected tubers or between them. It is presumed, that under advantageous weather conditions and enough soil water an infection from one tuber to another should be possible. This assumption is ascertained by the infection of neighbouring tubers which is specially predominant in the irrigated plots.

The results of the stem piece examination with ELISA and PCR (Fig.4) show that *P. infestans* can most likely grow into the stem.

Further on the conclusions can be drawn that the PCR method is more sensitive than the ELISA test. Consequently it seems to be a question of detection limit of a method whether a latent infection can be detected or not.

The examination of the hand dug potato tubers showed that there is a high potential of latently infected tubers within the crop (0.8 to 19 %). It seems that there is neither a correlation between *Phytophthora infestans* disease and potato variety nor between visible and latent infection.

But a high rate of latent infection after 6-8 months storage involves a high potential of inoculum in the field by the seed.

The results are supported with the observations of the plots at the LBP in Munich (Fig.4) where a rate of 4.3% of latently infected tubers was found. These results point out that it is wrong to set the number of visible infected tubers in any relation to the amount of the latent infection.

Further on it is a proof that more infected seed potatoes exist as previously assumed and reported.

Acknowledgement

We want to thank the Bayerischen Landesanstalt für Bodenkultur und Pflanzenbau (LBP) for the equipment, needed for use of the PCR.

References

Niepold,F., and Schöber-Butin, B., 1995: Application of the PCR technique to detect *Phytophthora infestans* in potato tubers and leaves. Microbiol. Res. **150**: 379-385.

Schlenzig A., 1997: Epidemie und latenter Primärbefall von Phytophthora infestans an Kartoffeln sowie Charakterisierung von Freilandisolaten des Erregers. Thesis, Technical University of Munich at Weihenstephan.

Tooley, P.W., Bunyard B.A., Carras M.M., Hatziloukas E., 1997: Development of PCR Primers from Internal Transcribed Spacer Region 2 for Detection of *Phytophthora* Species Infecting Potatoes. Appl. And Environm. Microbiol. 1467-1475.

Trout C.L., Ristaino J.B., Madritch M., Wangsomboondee, T., 1997: Rapid detection of *Phytophthora infestans* in Late Blight-Infected potato and tomato using PCR. Plant Disease Vol.**81** No.9 1042-1048.

van der Zaag, D.E., 1956: Overwintering en Epidemiologie van *Phytophthora infestans*, tevens enige nieuwe Bestrijdingsmoelijkheden. T.Pl.ziekten, **62**, 89-156.

Wang H., Qi M., Cutler A.J., 1993: A simple method of preparing plant samples for PCR. Nucleic Acids Res. **21**: 4153-4154.

Third Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

The epidemic development of Phytophthora infestans in Northern France in 1998

S. DUVAUCHELLE*, L. DUBOIS**
*S.R.P.V. Nord Pas-de-Calais, BP47 - 62750 Loos-en-Gohelle, France
**F.R.E.D.E.C. Nord Pas-de-Calais, BP74 -Loos-en-Gohelle, France

Abstract
Like in 1996, the epidemic of *P. infestans* reached very high levels. Though very good fungicide protections were performed, some attacks in fields were noticed. Difficulties in controlling focuses in fields are encountered.

A rapid break out of the epidemic
The monitoring of the data given by the model GUNTZ-DIVOUX for triggering the first application showed that from 2 June, all shot fields had to be protected with fungicides. This date corresponded to the third generation necrosis occurrence, the first disease symptoms could be seen on the fields. Indeed, the first cases of late blight on waste piles were reported on 4 June. From 8 June onward, both regions of Nord Pas-de-Calais and Picardy experienced fierce storms and showers. The epidemic was then launched.
As for the models MILSOL and GUNTZ-DIVOUX, the contamination and sporulation came out one after the other.
At the agricultural warning level, products possessing a good resistance to the rainfastness were recommended (fluazinam, dimetomorphe, propomocarbe). The products containing oxadyxil (systemic) were also recommended during this period of vegetation active growth.
The first cases of late blight in fields were recorded around 16 June. This contamination was mostly due to the presence of waste piles nearby the fields.
Violent storms took place on 12 June, the difficulties in carrying out applications (no protection for 4 to 5 days) accumulated with the presence of late blight in the environment were the main causes of the occurrence of first serious cases of late blight in fields. These

late blight symptoms appeared mostly on fields which were only protected with dithiocarbamate before the storms of 12 June.

In late June, some fields were destroyed from 30 to 50%, and some completely-destroyed plants were noticeable in the middle of the field. No other symptom of late blight was observed all around these destroyed plants. The cause of these attacks is still to be determined.

In the contaminated fields, the growers had difficulties to stop the epidemic. The wet weather conditions promoted the fungus development. In order to eradicate the disease in fields, strategies of 3 applications at a three-day interval were recommended.

The first application was carried out with a tin salt (BRESTAN) or a fluazinam. The second one with a curzate and the third one with a fluazinam. These applications at short intervals aimed at overprotecting the vegetation which was still green and reducing the sporulation.

If we compare the model MILSOL outputs between 1997 and 1998, we can notice that the epidemic develops more rapidly in 1998. It also reaches higher levels of risk. The weather conditions of July remained favourable to the contamination. There were not new serious cases of late blight in fields, nevertheless, during the visits on the observation plots, new symptoms of late blight appeared in spray-line couplings. During this period, the slightest digression in the fungicide protection (spray-line coupling...) could bring about contamination in fields. These attacks can be stopped easily.

A lull in the weather seems to come back together with high temperatures, however, the mists in the morning may keep a certain risk level.

Having to face again in 1998 with difficulties in controlling the late blight, we are urged to investigate about the strain agressiveness, problems of resistance, and the presence of the strain A2. Additional studies on samples collected in the North of France are in progress presently in the laboratory of the Regional Plant Protection Service of Nord Pas-de-Calais in Loos-en-Gohelle.

Third Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

Possibility of a combined use of IPI and MISP forecasting models for late blight warnings

R. Bugiani, P. Govoni, L. Cobelli

Servizio Fitosanitario - Regione Emilia-Romagna,
Via Corticella 133, 40129 I, Bologna (Italy)

Abstract

IPI model is widely 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 any information about the subsequent sprays. MISP criteria proved to be a reliable tool for the determination of infectious events in Switzerland. The validation of MISP criteria over 4 years in the potato growing area of Emilia-Romagna region is presented along with the possibility to use a combination of both systems to provide farmers with a more precise warning system able to save useless sprays against potato late blight. The analysis of both criteria is then compared with the seasonal concentration of *P.infestans* airborne sporangia in 4 stations over 4 years.

Keywords: Late blight, Potato, DSS, IPI model, MISP model.

Introduction

Late blight is the most important disease affecting potato and tomato in Emilia-Romagna (Italy). The onset of the disease in our environment is particularly related to rainy events especially during May and June. However, despite the several chemical applications carried out by farmers the disease does not occur every year. This results in useless treatments. In order to determine the risk of blight onset in the field the negative prognosis I.P.I. (Infection Potential Index) model was developed in 1990 (Cavanni, P. *et al.* 1990). 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, originally developed for tomato crop (Bugiani, R. *et al.* 1993), was then validated for potato crop (Bugiani, R. *et al.* 1997) and its use extended the following years within a territorial warning service (Bugiani, R. *et al.* 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.

MISP criteria is able to determine on the basis of hourly meteorological data of temperature, relative humidity and precipitation, rain-driven blight infection period (Cao, K.Q. *et al.,* 1997; Rucksthul, M. *et al.,* 1998).

The aim of this work is to compare with historical data of four years both criteria in order to verify MISP's reliability in our region and evaluate the possibility to use it in combination with I.P.I. so as to time correctly the subsequent sprays once IPI Index reaches the threshold for the first spray.

Materials and methods

Hourly (for MISP criteria) and daily (for IPI criteria) historical meteorological data of 8 weather stations located within the potato growing areas of Emilia Romagna region, from 1995 to 1998 (April to end of July) were elaborated. In particular the following weather stations were considered:

C.S.Pietro, Palata Pepoli, Crevalcore, S.G.Persiceto, Budrio, Molinella, Castenaso and Altedo in 1995; C.S.Pietro, Crevalcore, Molinella, S.G.persiceto, Longara, Budrio, Castenaso and Altedo in 1996; C.S.Pietro, Budrio, Crevalcore, Molinella, S.G.Persiceto, Mezzolara, Anzola and Altedo in 1997; Sala, S.Agata, Casola, Budrio, Mezzolara, Sasso Morelli, Altedo and S.P.Capofiume in 1998.

For MISP criteria, all the conditions favourable for sporulation and infection (24 hours with at least six hours with precipitation at air temperature ≥ 10°C, even non consecutive, and at least further six consecutive hours during which relative humidity is ≥ 90%) (Cao et al., 1997; Rucksthul, 1998) were considered. Moreover, little modifications of MISP such as 5-6 hours of rainfall with temperature ≥ 10°C and further 5-6 hours with relative humidity ≥ 90% within 24 hours (MISP-m), were also considered.Warnings obtained by either criteria were then compared with the historical late blight onsets in unsprayed potato plots measuring 100 m^2 and located near the weather stations. Surveys were carried out twice a week and sometimes weekly. Crop emergence (green rows indicating the 75-

80% of plant emerged) occurred in the first days of April for all the years considered. Volumetric Hirst-type sporetraps measuring the concentration of airborne sporangia during the season were also placed within some unsprayed plots (Castenaso and Altedo in 1995 and 1996 respectively; Mezzolara in 1997 and 1998). For these stations, daily and cumulated IPI index, MISPs and daily concentration of airborne sporangia, were calculated and plotted against the disease occurrence in the field.
Furthermore, two final prospects, the former showing either IPI values and MISPs over the same years yet considering every weather station and the latter the number of treatments following each different criteria were elaborated.

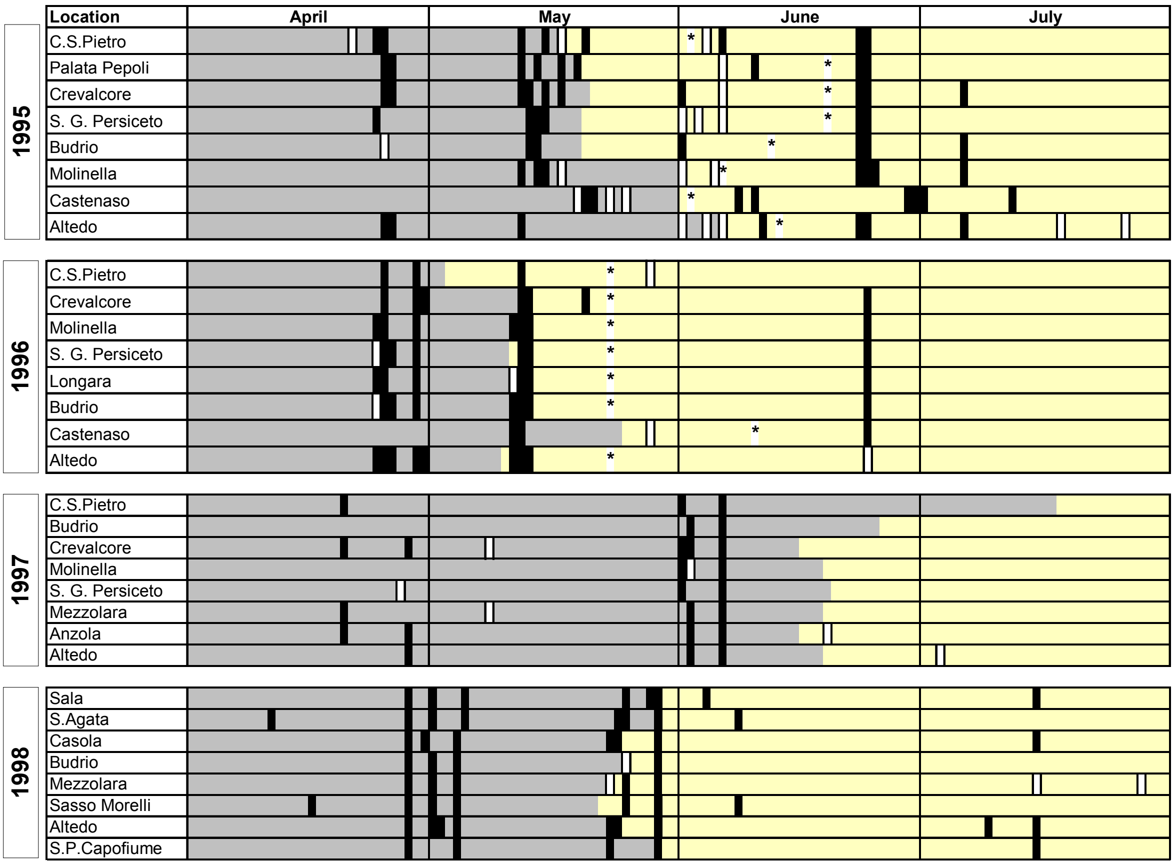


Figure. 1. Late blight warnings elaborated by IPI, MISP and MISP-m forecasting models in 8 locations over the years 1995-1998. ■: IPI blight-free period; *: disease occurrence; ■: MISP warning; □: MISP-m warning.

Results

<u>Global analysis</u> (FIG. 1)

1995. Year 1995 can be considered at high blight risk. In fact, the disease occurred in all the unsprayed plots of the potato growing areas in Bologna province. However, differences between the dates of blight outbreaks may be observed. Disease occurred in the first week of June in unsprayed plots located in Castenaso, Molinella and C.S.Pietro, in the second decade of June in unsprayed plots located in P.Pepoli, Crevalcore and S.G.Persiceto. Disease occurred between these two periods in unsprayed plots located in Budrio and Altedo. Generally, IPI index reached the blight risk threshold close to mid-May, 15 to 30 days before the disease onset in the field. In Altedo and Molinella, disease occurred a week after IPI index reached risk threshold, while in Castenaso first symptoms of the disease have been detected only two days after IPI threshold was reached. In this case warning might result not early enough for the farmer to protect the crop efficiently. MISP model in April detected several blight conducive events but no disease occurred. In May MISP periods were very close or at most coincided with the IPI risk threshold. After that, MISP periods seems to indicate precisely the blight infection event, in that in most cases disease symptoms appear 7 to 10 days after. This results may further improved if MISP-m are considered (4 cases out of 8).

1996. Year 1996 may be considered at blight high risk also. Disease occurred throughout the potato growing areas of the province on every unsprayed plot (7 out of 8) on 19 May, probably due to the uniformity of the blight conducive precipitation. IPI index reached the risk threshold averagely 10 days before the occurrence of the first symptoms of the disease in the field. Like the previous year MISP periods in April were not followed by the blight occurrence. IPI index reached the risk threshold in coincidence with the only MISP period in May. Such MISP period was common to every station, therefore proving to be exactly the blight infection event. The only exception is represented by Castenaso station. In this location late blight was detected only 20 days after the common disease occurrence in the area. However, in this location IPI index reached the risk threshold later and MISP periods subsequent to that of 10-12 May were given.

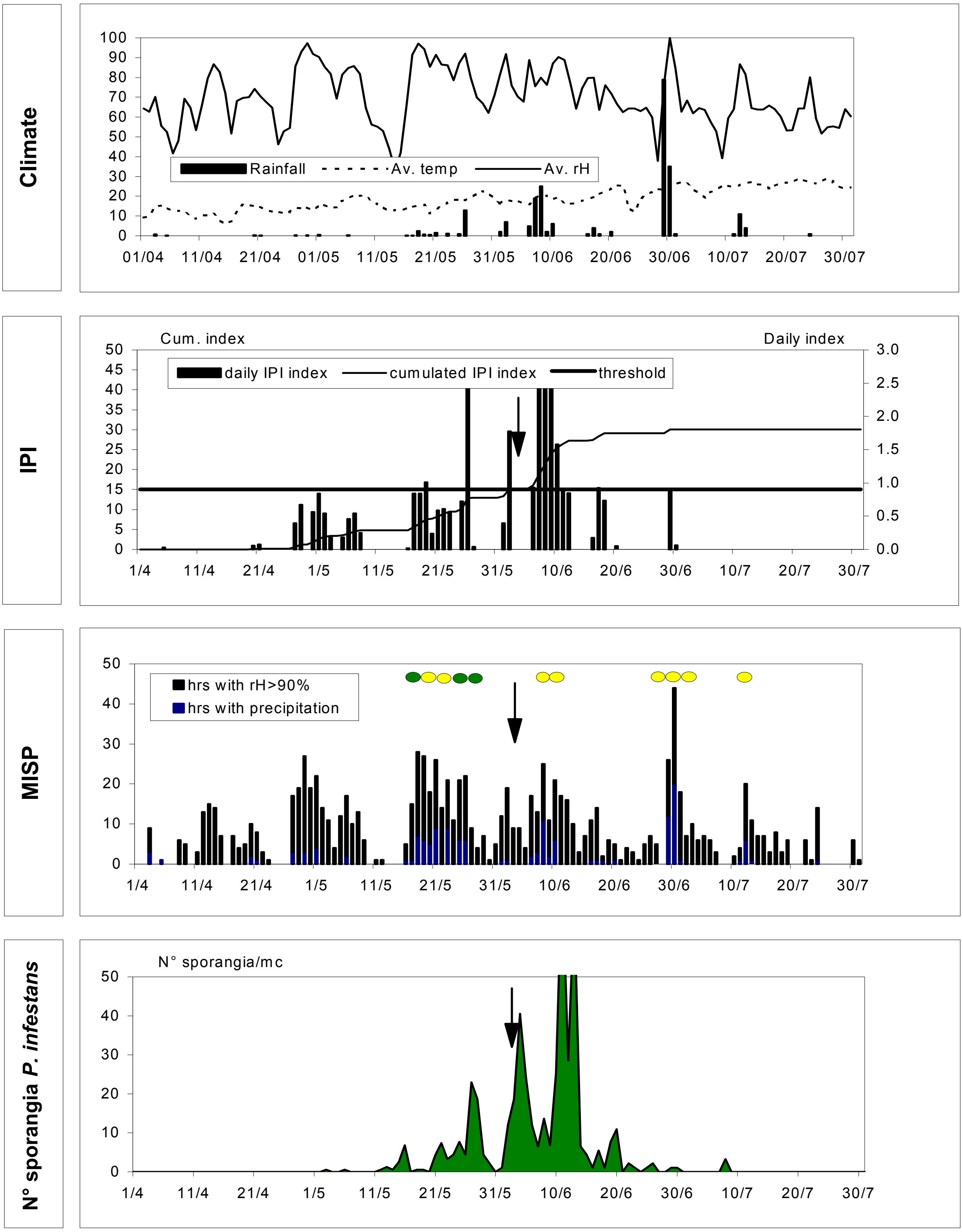
1997. Year 1997 was at low blight risk. No disease occurrence has been detected in the potato unsprayed plots. IPI index generally reached the risk threshold in mid-June, except C.S.Pietro station. In this location IPI index reached the risk threshold very late in mid-July when the plants, at the end of the season, are less susceptible to blight infection due to particularly dry climate and crop senescence. Even in 1997, MISP model gave some warnings in April (even though less than the previous years) but without any following disease occurrence. May was characterised by the lack of MISP and MISP-m periods, while on the contrary 2 to 3 MISP and/or MISP-m warnings were given in June yet without any following disease occurrence in the field. It is interesting to notice that most the MISP and MISP-m periods occurred before IPI index reached the risk threshold. After that few MISP periods only were given in two stations (Altedo and Molinella).

1998. Year 1998 also was characterised by lack of blight occurrence on potato crops, even though climate in April and May seemed to be conducive for the disease. Accordingly, IPI index reached the risk threshold at the end of May, in coincidence with one or more MISP and MISP-m periods. After the IPI risk threshold was reached, MISP periods were relatively few in June. MISP warnings in July were not considered because the crops, at the end of the season, already showed symptoms of senescence.

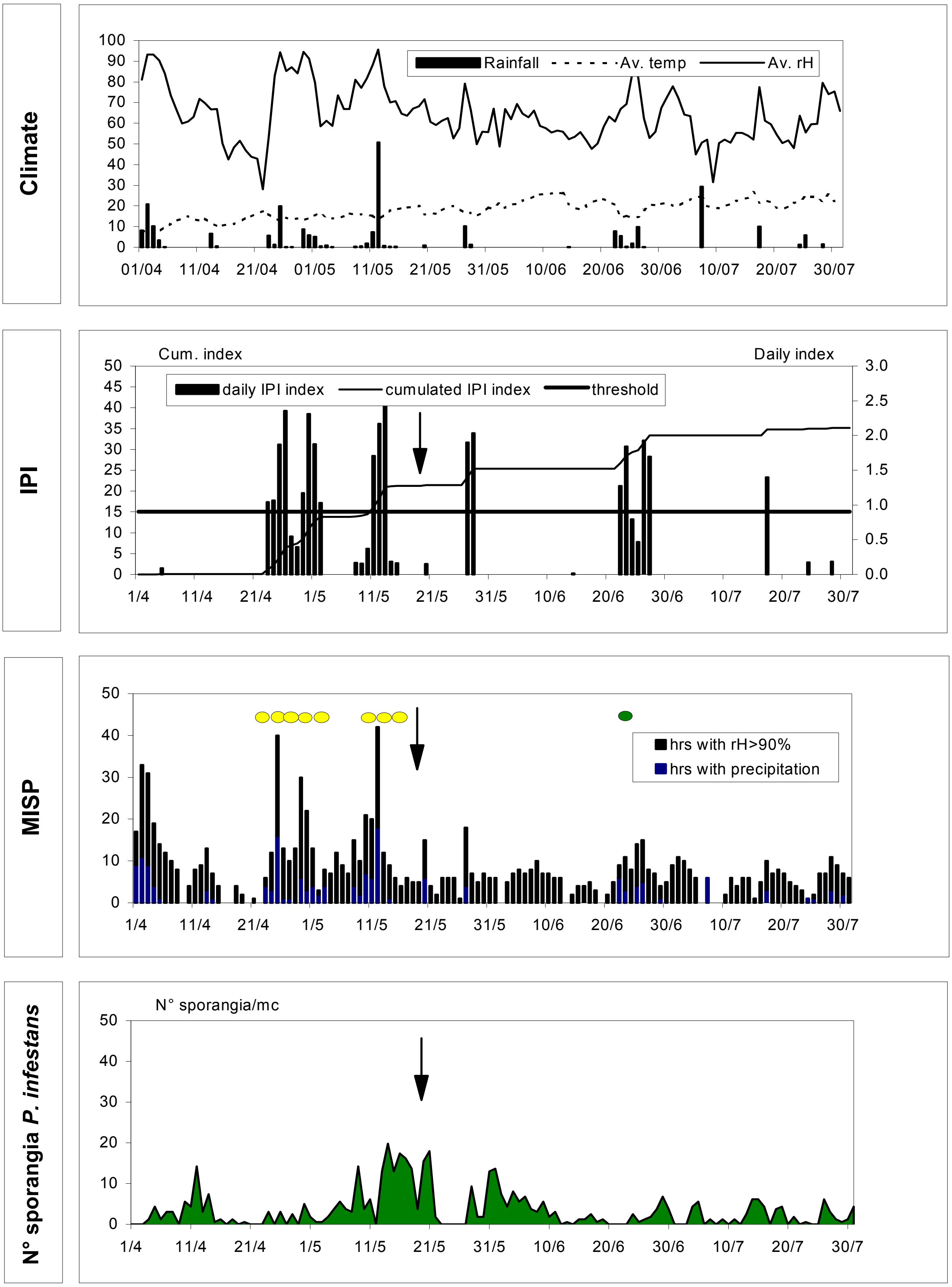
Single location analysis

One station per year are taken into consideration in detail where climate (mean temperature, r.H. and precipitation), daily and accumulated IPI index, MISP and MISP-m periods along with the n° of hour with precipitation and r.H.≥90%, and finally daily average *P.infestans* sporangia concentration are showed.

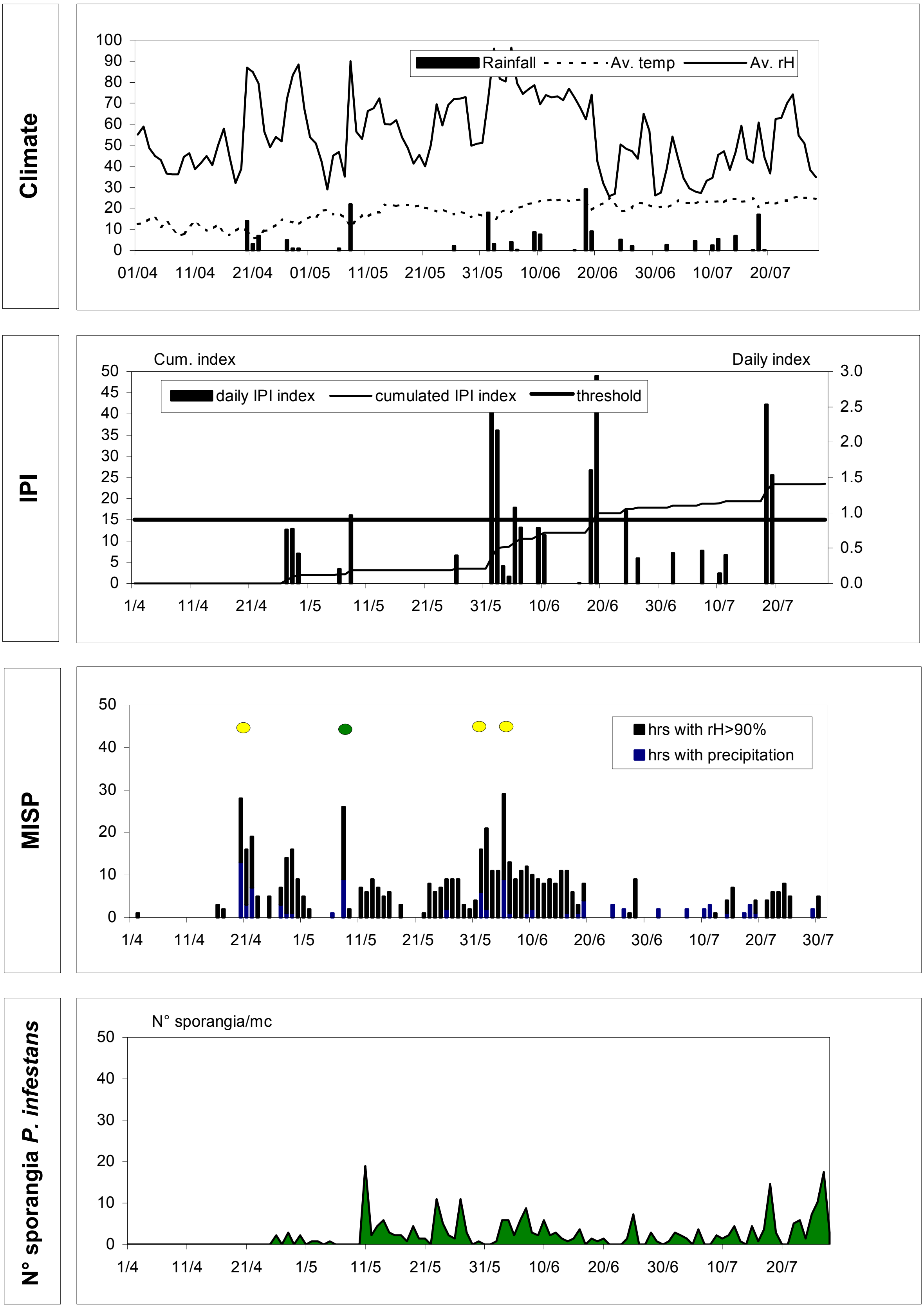
Castenaso 1995. This is the case in which IPI index did not reach the risk threshold early enough compared with the first disease occurrence in the field (2 days). From climate analysis the delay was due primarily to the precipitation in May always below 1mm. Such kind of precipitation that MISP model did not consider, might be underestimated by IPI model too. Such underestimation was then cumulated during the season therefore resulting in a delayed warning compared with other locations. On the contrary, several blight conducive events either as MISP and MISP-m periods have been observed on 20 May positively correlated with the disease onset in the field on 2 June. The blight risk period starting from 15-20 May onward has been confirmed by the peaks of airborne spore concentration (Graph. 1).



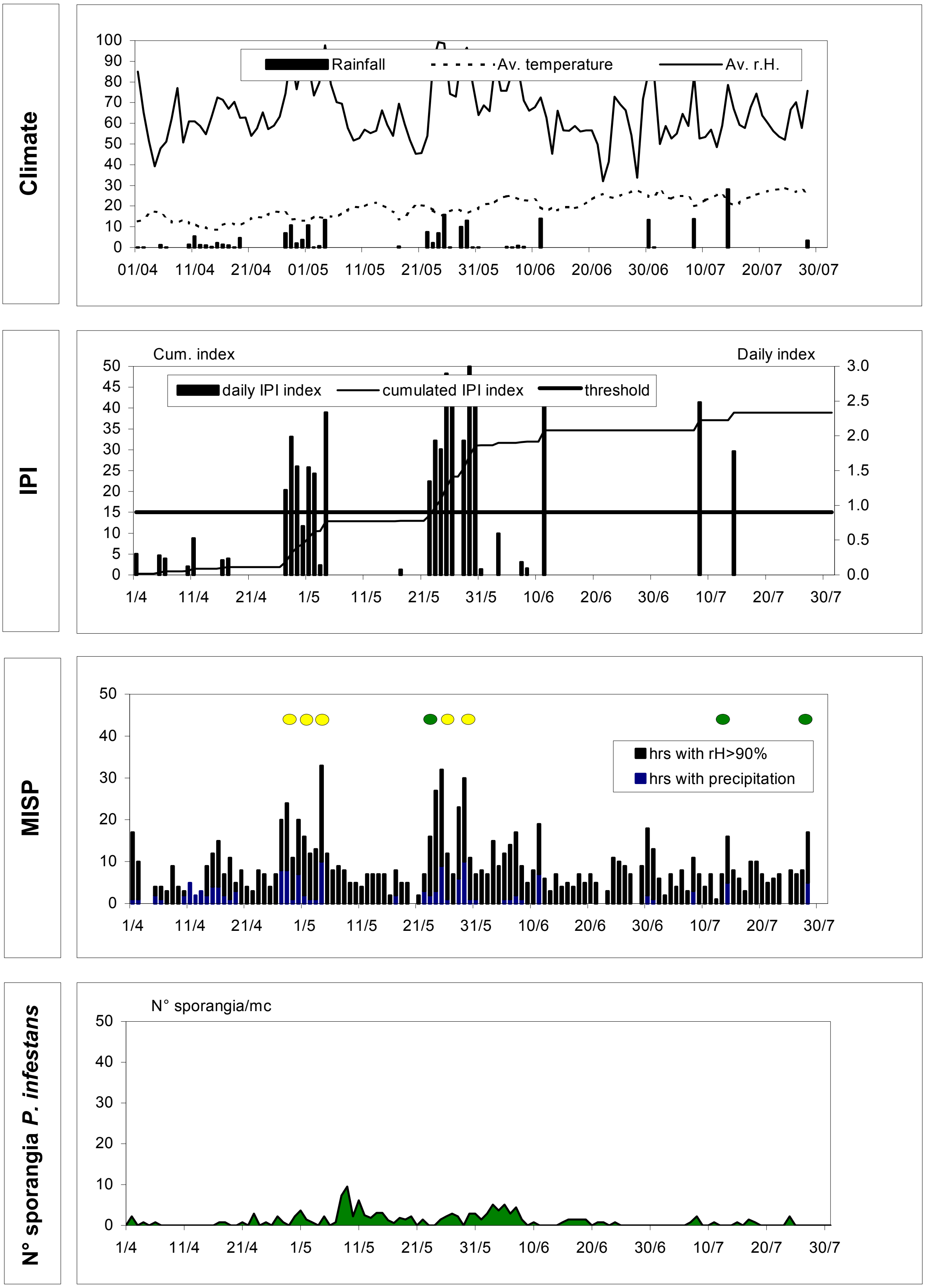
Graphic 1. Climate, (🡻) disease occurence, (■) daily and (-) accumulated IPI index, (■)spore concentration and (○)MISP and (●)MISP-m blight conducive periods in Castenaso station in 1995.



Graphic 2. Climate, (↓) disease occurence, (■) daily and (-) accumulated IPI index, (■)spore concentration and (O)MISP and (●)MISP-m blight conducive periods in Altedo station in 1996.



Graphic 3. Climate, (🡇) disease occurence, (■) daily and (-) accumulated IPI index, (■)spore concentration and (**O**)MISP and (●)MISP-m blight conducive periods in Mezzolara station in 1997.



Graphic 4. Climate, (↓) disease occurence, (■) daily and (-) accumulated IPI index, (■)spore concentration and (**O**)MISP and (●)MISP-m blight conducive periods in Mezzolara station in 1998.

Altedo 1996. This location may well represent the blight situation in the whole province. Precipitation at the end of April and those close to 10 May were blight conducive. In these two particular periods IPI index increased importantly and MISP model showed several blight conducive events. MISP periods on 11, 12 and 13 May conducive for the disease onset in the field, coincide whit the overcome of IPI risk threshold. As in 1995 in Castenaso, peak of airborne spore was detected before the first symptoms of the disease occurred in the unsprayed plot. Further peaks of 20 sporangia/m^3 air were further observed after rainfall occurred at the beginning of May and on 11 and 12 May (Graph.2).

Mezzolara 1997. Disease failed to occur in all the unsprayed plots. IPI index reached the risk threshold on 19 June. Before that, only 3 MISP periods and 1 MISP-m period have been observed. However, MISP-m period (due to the rainfall on 18 May) is particularly interesting because coincide with the only peak of spores (20 sporangia/m^3 air) observed during the whole season. (Graph. 3). MISP-m should also be considered for a more precise blight warning. Spore concentration was very low throughout the season therefore confirming the low blight risk in 1997.

Mezzolara 1998. No disease occurred on potato crops. However, compared with the previous year, IPI index reached the risk threshold one month before (22/5). MISP periods occurred before or at most at the same time IPI index reached the risk threshold. Only 2 MISP-m periods occurred afterwards (in the third decade of July), yet when the crop was close to harvest and showed symptoms of senescence. Like in 1997, the low airborne spore concentration throughout the season confirmed the lack of blight conducive events in the IPI blight high risk period. (Graph. 4).

Discussion

Results showed that IPI model confirms to be a reliable “negative prognosis” model for the environmental condition of Emilia-Romagna region. It is able to warn correctly for the first occurrence of potato late blight. However, sometimes it warns too early (up to one month before), therefore leading farmers to waste chemical applications, particularly in those years climatically unfavourable to the disease. In fact, IPI index reaches the risk threshold every year, and sometimes very early, as in 1998. On the whole, IPI model is a valid tool to determine the low blight risk period and therefore save fungicides applied early in the season. However, it fails to give information about blight conducive events in high blight risk periods and therefore correctly apply fungicides in the right moment. The analysis of the single locations shows that once the risk threshold is overcome, the accumulated IPI index is not correlated with the real risk of infection. In fact, its final value was higher in 1998 (low blight risk) compared with 1996 (high blight risk).

MISP model proved to be a reliable tool in forecasting the blight conducive events in years favourable to the disease. MISP event was considered reliable if occurring 10 to 12 days before the detection of the first symptoms of the disease in the unsprayed potato plots (a certain delay in the detection is possible in that monitoring was carried out twice a week). MISP model proved to be a good forecaster also considering MISP-m periods which at least in Italian climatic condition should be taken into account. MISP model used alone seems to be too prudential because over the four years considered it always warned for blight conducive events in April and at the beginning of May yet without any disease occurrence. In this case MISP may lead farmers to spray early in the season when there would be no risk.

The combined use of both forecasting models in different moment seems to give promising results. IPI model might be used in early season until IPI index reaches the blight risk threshold so as to warn for the first fungicide application. Up to this moment, MISP warnings may not be taken into account, therefore saving chemicals applied early in the season.

MISP and MISP-m warnings only should be taken into consideration after IPI index reached the risk threshold. In this case chemicals are applied only when they really need, and a further reduction of treatment is achieved particularly in blight-free years. MISP and MISP-m blight conducive events after the disease occurrence were not taken into consideration because ad-hoc experimental trials are needed for their evaluation. The number of fungicide applications carried out from crop emergence to disease occurrence or close to harvest in blight-free years might be reduced to 1, 2 and 3 in 20, 10 and 1 cases respectively (Table. 2).

Table 2. Theoretical number of fungicide applied until disease occurrence or harvest following IPI, MISP and a combined use of both forecasting models in 8 locations over the years 1995-1998.

Year	Location	IPI	MISP	IPI + MISP
1995	C.S.Pietro	3	3	1
	Palata Pepoli	4	4	2
	Crevalcore	4	5	2
	S. G. Persiceto	4	4	2
	Budrio	3	3	2
	Molinella	1	2	1
	Castenaso	1	2	1
	Altedo	1	4	1
1996	C.S.Pietro	3	3	2
	Crevalcore	2	4	2
	Molinella	2	3	1
	S. G. Persiceto	2	3	1
	Longara	2	3	1
	Budrio	2	3	1
	Castenaso	3	2	1
	Altedo	2	3	1
1997	C.S.Pietro	0	2	0
	Budrio	3	1	1
	Crevalcore	4	4	1
	Molinella	4	1	1
	S. G. Persiceto	4	2	1
	Mezzolara	4	3	1
	Anzola	4	4	1
	Altedo	4	3	2
1998	Sala	7	4	2
	S.Agata	7	6	2
	Casola	7	4	1
	Budrio	7	3	1
	Mezzolara	7	4	1
	Sasso Morelli	8	5	3
	Altedo	7	5	2
	S.P.Capofiume	7	4	1

Results showed that the combined use of both IPI and MISP forecasting models might be extremely useful for the rationalisation of late blight control strategy. This system will allow to save 60 to 80% of fungicide applications compared with calendar strategy still commonly applied in the Po Valley.

References

Bugiani, R., Cavanni, P. and Ponti, I. 1993. An advisory service for the occurrence of *P.infestans* on tomato in Emilia-Romagna region. Bulletin OEPP/EPPO Bulletin, 23, 607-613.

Bugiani, R., Govoni, P. and Cobelli, L. 1997. Comparison of different prediction criteria for the occurrence of potato late blight in Northern Italy. In: E.Bouma and H.Schepers (eds.), PAV-Special Report no.1, January 1997, 69-78.

Bugiani, R., Govoni, P. and Cobelli, L. 1998. First large scale application of IPI model for potato late blight prediction in the Po Valley. . In: E.Bouma and H.Schepers (eds.), PAV-Special Report no.3, January 1998, 188-199.

Cao, K.Q., Rucksthul, M., and Forrer, H.R. 1997. Crucial weather conditions for *Phytophthora infestans*: A reliable tool for improved control of potato late blight? In: E.Bouma and H.Schepers (eds.), PAV-Special Report no.1, January 1997, 1:85-90.

Cavanni, P., Ponti, I. and Marinelli, M. 1990. Modello previsionale per la peronospora del pomodoro. Informatore Fitopatologico, 6, 1990, 17-25.

Rucksthul, M., Forrer, H.R. 1998. Main infection and sporulation periods (MISP): towards its use in an event-based DSS to control potato late blight. In: E.Bouma and H.Schepers (eds.), PAV-Special Report no.3, January 1998, 67-76.

Third Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

Research on physiological races of Phytophthora infestans in Italy

CRISTINZIO G. AND TESTA A.

Dept.Arb.Bot. and Plant Pathology, University of Napels "Federico II", Italy.
E-mail: cristinz@unina.it

Summary

Thirty eight physiological races of *Phytophthora infestans* are identified among 60 potato an tomato isolates from different Italian rgeions. The majority of races are complex. The most common are (0) on tomato (4, 7, 10, 11) on potato plants.

Introduction

After more than 150 years from its first appearance in Europe, the late blight caused by *Phytophthora infestans* (Mont.) de Bary is still of the most serious problems affecting cultivated potato.

The populations of *P.infestans* are evolving thoughout the world and we are currently witnessing a rapid spread of new an even more virulent strains (Spielmann et al. 1991; Fry et al. 1993, Goodwin et al. 1995). Over the last 2-3 years, a number of serious late blight attacks have been reported in Italy in several areas where potato is a traditional crop. After taking a few samples of diseased plant tissue in these areas, we isolated several strains of *P.infestans* with the A_2 sexual compatibility. Until the early '80s, these strains could be found only in Mexico. Furthermore, we have identified a number of isolates showing a homothallic or self-fertile behaviour (Cristinzio and Testa 1997).

Material and methods

All *P.infestans* strains were grown in Petri dishes on V-8p agar at 20°C. Pathogenicity testing was with the leaf disks method (Toolley et al. 1989). Plants of *Solanum tuberosum* carrying different genes for resistance derived from *Solanum demissum*: 800986 (R1), 800987 (R2). 800989 (R4), 800991 (R6), 800987 (R7), 800993 (R8), 800995 (R10),

800996 (R11) and 702514 (r), were obtained from the CIP (International Center of Potato – Lima, Perù). The plants were first grown *in vitro* and subsequently transplanted in a greenhouse and sprayed as needed to control pests.
Inoculum was obtained by washing sporangia with 10 ml of sterile distilled water from 15 to 20-day-old cultures, and the concentration was adjusted to circa 40.000/ml with a hemacytometer. A 50 ml-drop of sporangial suspension was placed on each leaf disk in overturned Petri dishes containing a bottom layer of agar-water at 2%. During the first 24 hours the dishes were kept in a dark place at a temperature of 20 °C. They were then uninterruptedly exposed to light while remaining at the same temperature.
After 5 days we analyzed the disks with an optical microscope. The fungus-plant interaction was rated compatible only if at least three out of four inoculated disks showed a sporulation.

Results

We identified 38 physiological races out of 60 isolates from potato and tomato plants, almost all of which with a very low rate of presence (Table 1). The most common are (4, 7, 10, 11) and (1, 4, 6, 7, 10) on potato and (0) on tomato. About eighty percent are complex and there is also a race (1, 2, 4, 6, 7, 8, 10, 11) capable of attacking both the susceptible genotype and all the other genotypes endowed with the resistance genes used. The physiological race structure of the population with prevailing those with two or more genes could be a consequence of the fungus sexual recombination, which can now take place also in Italy, or it simply may be due to the natural expansion of the new populations of *P.infestans*, considering that it is spreading all over the world. Another possible theory is that the above phenomenon is the result of both factors.

References

Cristinzio G. and Testa A. 1997 – Occurrence of the A2 mating type and Self isolates of *Phytophthora infestans* in Italy. Journal of Plant Pathology, 79, 121-123.

Fry W.E., Goodwin S.B., Dyer A.T., Matuszak J.M., Drenth A., Tooley P.W., Sujkowski L.S., Koh Y.J., Cohen B.A., Spielmann L.J., Deahl K.L., Inglis D.A., Sandlan K.P. 1993 – Historical and recent migration of *Phytophthora infestans*: chronology, pathways and implications. Plant Disease, 77, 653-661.

Goodwin S.B., Sujkowski L.S. and Fry W.E. 1995 – Rapid evolution of pathogenicity within clonal lineages of the potato late blight disease fungus. Phytopathology, 85, 669-676.

Spielmann L.J., Drenth A., Davidse L.C., Sujkowski L.S., Gu W., Tooley P.W. and Fry W.E. 1991 - A second world-wide migration and population displacement of *Phytophthora infestans*. Plant Pathology, 40, 422-430.

Tooley P.W, Therrein C.D. and Ritch D.L. 1989 – Mating type, Race composition, nuclear DNA content, and isozyme analysis of peruvian isolates of *Phytophthora infestans*. Phytopathology, 79, 478-481.

Table 1.

Races	Frequency	Potato	Tomato
0	15	1,7	13,3
1	1,7	1,7	
1.2	1,7	1,7	
1.2.4.6.7	1,7	1,7	
1.2.4.6.7.8.10.11	3,3	3,3	
1.2.4.6.7.8.11	1,7	1,7	
1.2.4.6.10.11	1,7	1,7	
1.2.4.7.8.10.11	5	3,3	1,7
1.2.4.7.8.11	1,7	1,7	
1.2.4.7.10	1,7	1,7	
1.2.6	1,7	1,7	
1.4.6.7.8.11	3,3	3,3	
1.4.6.7.10	5	5	
1.4.6.10	1,7	1,7	
1.4.6.10.11	1,7	1,7	
1.4.7.11	3,3	3,3	
1.6.7.8.10.11	1,7	1,7	
1.6.10	1,7	1,7	
1.7	1,7	1,7	
1.7.8.10	1,7	1,7	
1.10	3,3	3,3	
1.11	1,7	1,7	
2.4.6.7.8.10.11	3,3	3,3	
2.4.6.10.11	1,7	1,7	
2.6.7.8.11	1,7	1,7	
2.7.11	1,7		1,7
2.10	1,7	1,7	
4	1,7	1,7	
4.6.7.8	1,7	1,7	
4.6.7.8.10	1,7	1,7	
4.6.7.11	1,7	1,7	
4.7.8.10.11	5	3,3	1,7
4.7.10.11	6,7	6,7	
6.7.11	1,7	1,7	
7	1,7		1,7
7.8	1,7	1,7	
7.11	1,7		1,7
10.11	1,7	1,7	

Third Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

CDI:
A flexible tool for import and control of weather data in DSS's

POUL LASSEN AND JENS GRØNBECH HANSEN

Danish Institute of Agricultural Sciences, Department of Agricultural Systems
Research Centre Foulum, P.O. Box 50, DK-8830 Tjele, Denmark
E-mail: Poul.Lassen@agrsci.dk, JensG.Hansen@agrsci.dk

Abstract

For many Decision Support Systems in the area of plant protection, the availability of updated and high quality weather data is essential. A Climate Data Interface (CDI) was developed with features to import weather data from different sources, including transformation, quality control, interpolation of missing data and merging of data from different sources. At the present time the CDI can read data from The Danish Meteorological Institute, the Hardi Metpole and ASCII-files. The use of object-oriented methods facilitates the implementation in the use of new data sources. The CDI component can be used by any PC-program running on the Windows 32-bit platform.

If the CDI or a similar component could develop into an EU standard, it would facilitate the transport of models and DSS systems between countries. Further improvements of the CDI could include potential use of more data sources, extended quality control of weather data and implementation of a CDI version for use in Internet server applications.

Design

The CDI was developed as a DLL-file for Windows 32-bit operating systems, i.e. Windows 95 and Windows NT. In this way the CDI.DLL file is accessible to all programming environments using the Windows operating systems. The CDI.DLL was compiled with the Borland C++Builder, Version 1. Interface for C++ is available in a header file (CDI.H). Interface for Delphi is available in a unit file (CDI.PAS).

Transformation

The first step in the CDI is the transformation of the original data to a standard format. At present the CDI is able to read data from the AMIS system at the Danish Meteorological Institute (DMI), from a Hardi Metpole database, and from ASCII files (Figure 1)

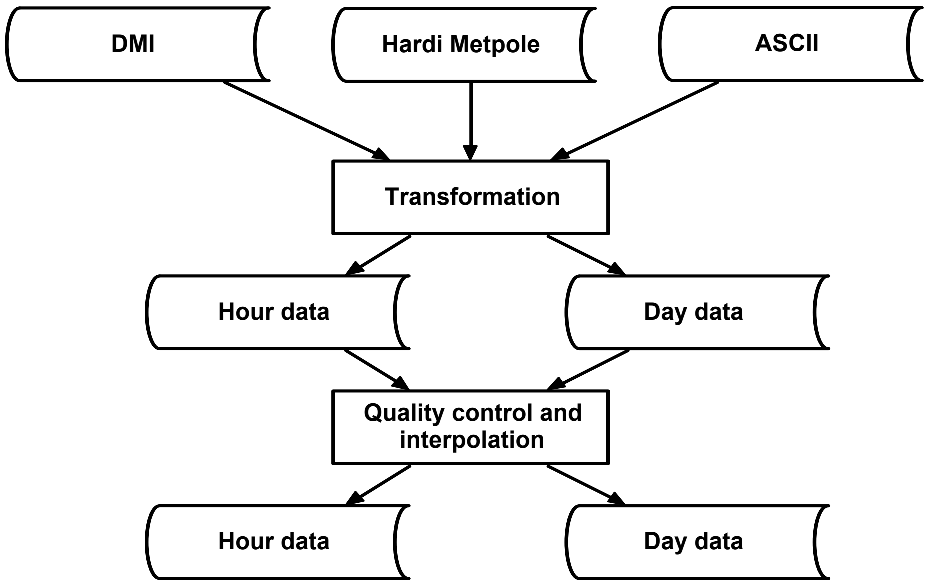


Figure 1. Data flow diagram showing the transformation of data from different sources to a standard hour and day data file format.

Grid interpolated weather data (10*10 km) are available at the Danish Meteorological Institute (DMI). The data are transferred to a local PC via the Internet using a communication DLL (AMIS.DLL) developed by DMI. The CDI transform the DMI-coded files to standard files with daily and hourly data.

The **Hardi Metpole** data are stored in a Paradox® database. The CDI access the Paradox table directly through a Borland Database Engine alias named SpyData. Data are transformed from half hourly values to hourly and daily values in standard format.

Several formats of **ASCII files** with data in columns can be read by the CDI. The format of ASCII files can be specified by the user, e.g. in NegFry via the Weather data tab page.

For each data source the CDI creates a binary file containing data for one year. This file has the extension ".cdi" and the size is approximately 1.3 MB. Table 1 lists the predefined climate variables in the CDI hour data.

Table 1. List of climate variables included in the CDI hour data.

Wind speed	Air temperature	Air humidity	Precipitation
Wind direction	Crop temperature	Crop humidity	Farm precipitation
Farm wind speed	Soil temperature, high	Surface humidity	Evaporation
Farm wind direction	Soil temperature, deep	Soil humidity, high	Radiation
		Soil humidity, deep	

Interpolation

After transformation a linear interpolation will take place replacing missing values with estimated. Only periods with less than a given number of missing values are linear interpolated. Otherwise data are defined as missing value. Period length and figure for missing value are defined by the user

Quality control

The CDI reports for each climate variable the total number of missing values before interpolation. If there are series with consecutive hours of missing values, the CDI reports the start date and number of subsequent hours in these series.

Merging

Using the CDI, it is possible to merge weather data from different sources. Local weather stations like the Hardi Metpole may have missing values e.g. caused by lightening. In Denmark farmers used grid interpolated data from the Danish Meteorological Institute to compensate for missing values in local Hardi Metpole data.

Object oriented class hierarchy

The functionality of the CDI is implemented in the programming language C++, using the Borland C++Builder, Version 1. Object oriented methods are used, and figure 2 shows a part of the class hierarchy. One of the most important aspects of using object-oriented programming is the ease of extendibility. To include a data from new sources a new child class of the class "trans" must be implemented. This class must include a method to read data and put it into the standard CDI data format. All other functionality is still working; that is initialising, interpolation and quality control. If further functionality is implemented e.g. interpolation this will work for all data sources.

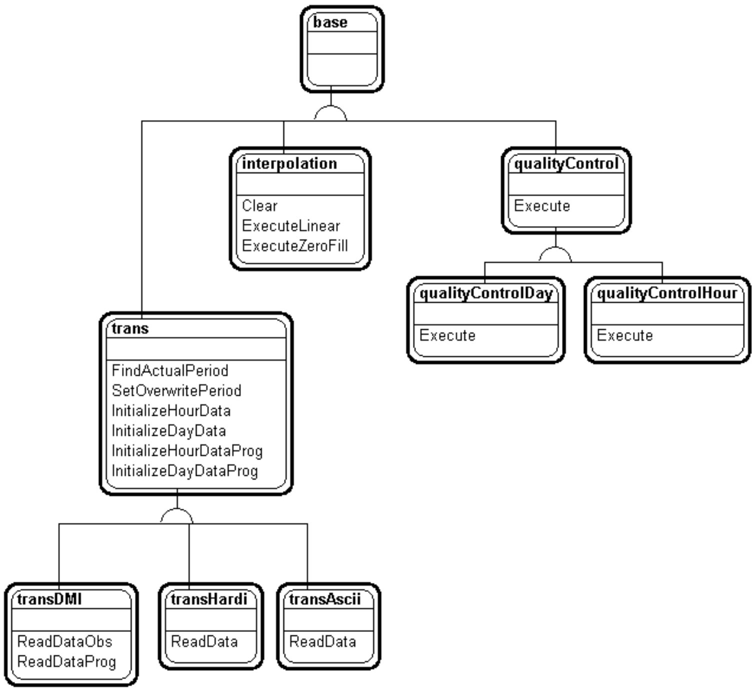


Figure 2. Class diagram showing some of the classes in the CDI.DLL.

The functionality of the CDI is implemented in the programming language C++, using the Borland C++Builder, Version 1. Object oriented methods are used, and figure 2 shows a part of the class hierarchy. One of the most important aspects of using object-oriented programming is the ease of extendibility. To include a data from new sources a new child class of the class "trans" must be implemented. This class must include a method to read data and put it into the standard CDI data format. All other functionality is still working; that is initialising, interpolation and quality control. If further functionality is implemented e.g. interpolation this will work for all data sources.
In table 2 functions for communication between a PC-program and the CDI is listed.

Table 2. List of the most common function calls in the CDI.DLL.

MergeCDIData	Merge at maximum 3 datasets to one dataset by priority. For each climate variable a value from a data set with lower priority will replace a value with higher priority if this variable has the value of missing value after the interpolation has been done.
LoadCDIData	Loads the merged dataset from disk to memory.

GetCDIValue	Returns the value of a given climate variable at a given date and time from the merged data set in memory.
GetDMIData	Gets data from the AMIS system at the Danish Meteorological Institute from a given grid number and a given date interval.
GetHardiData	Gets data from the Hardi Metpole from a given pole serial number and a given date interval.
GetAsciiData	Gets data from an ASCII file from a given ID number and a given date interval.

Additional functions exist for reading prognosis data from the DMI AMIS system and functions for specifying the format of ASCII files. The calling sequence is as follows:

1. Each call to the three functions: GetDMIData, GetHardiData and/or GetAsciiData create a CDI-file.
2. A call to MergeCDIData determines the priority of the data sources and creates a special CDI-file containing the merged data.
3. A call to LoadCDIData will load the merged CDI-file into memory.
4. Any call to GetCDIValue can fetch a climate variable at a given time.

Use in NegFry

The CDI.DLL was developed as a general tool for use together with decision support systems. However NegFry 5 was used as a test application for the CDI. Other prototypes of applications developed at the Danish Agricultural Advisory Centre have used the CDI.

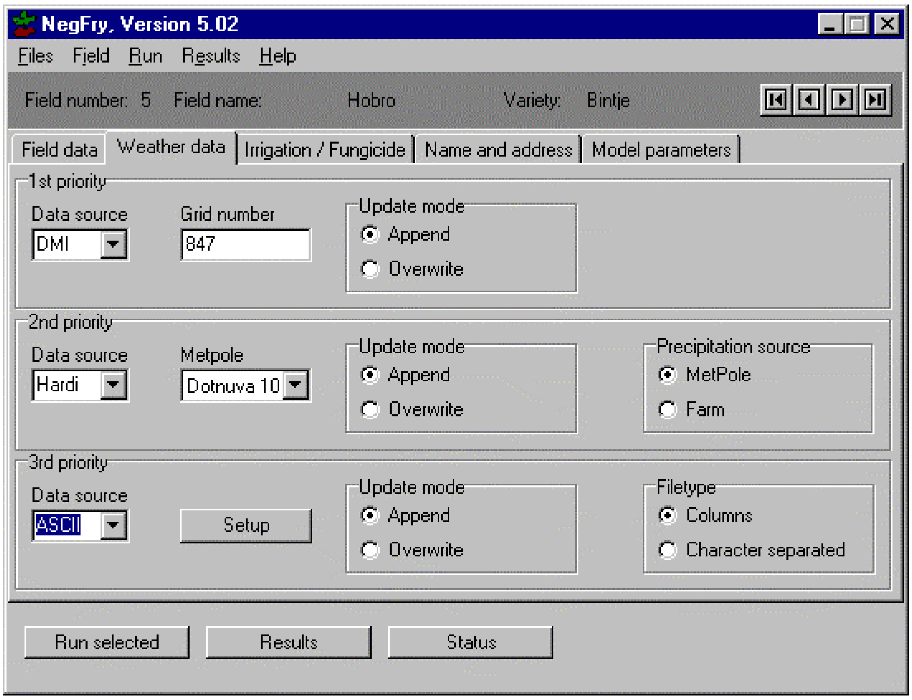


Figure 3. Input dialog box used in NegFry 5.02 to select data sources for running the model.

Figure 3 shows the weather data tab page from NegFry 5.02. This tab page is used as interface between NegFry and the CDI. In this example all possible data sources are used. For each data source the program ask for control figures necessary for reading weather data. When pressing the Setup button for the ASCII data source another dialog box is shown where specific definitions of the ASCII file format are entered. Start and end dates for model calculations are entered on the Field data tab page.

Distribution of mating types of *Phytophthora infestans* in Sweden

MAGNUS SANDSTRÖM AND BJÖRN ANDERSON

SLU Department of Applied Plant Protection
P. O Box 7044, SE-750 07 Uppsala, Sweden

The potato late blight problem has taken a new turn with the introduction of the possibility of sexual reproduction of *Phytophthora infestans*. It is difficult to say exactly how this will affect the disease, but in Sweden oospore formation and probably also infection from oospores have been observed in some fields. This means that late blight on potato has become a soil borne disease and has to be dealt with accordingly. Sexual reproduction also results in increased genetic variation, and there are good reasons to suspect that late blight will change its appearance under field conditions. The aggressiveness of the pathogen, its ability to attack varieties that now show good resistance and the efficacy of fungicides are examples of factors that might change.

At the Department of Applied Plant Protection at SLU a survey of the distribution of the mating types of *Phytophthora infestans* is conducted. From the results from 1997 and 1998 we can se that both mating types are present in all of Sweden. There is also a surprisingly high proportion of places where both mating types can be found in the same field.

Tabel 1. Mating types of *Phytophthora infestans*, number of fields per county 1997.

County	AB	AC	C	E	I	M	N	Total
A1	0	1	2	1	1	1	3	9
A2	1	1	0	0	0	2	1	5

Tabel 2. Mating types of *Phytophthora infestans*, number of fields per county 1998.

County	AB	AC	BD	C	E	G	H	I	K	M	N	O	S	Y	X	Total
A1	1	8	2	15	0	1	2	1	3	9	2	8	1	1	2	56
A2	0	2	1	16	4	0	1	1	0	8	5	3	0	1	2	44
A1/A2*	0	3	1	1	1	0	0	0	0	2	0	0	1	1	1	11

Tabel 3. Mating types of *Phytophthora infestans* in 7 specific fields in 1998.

	South Sweden				Mid Sweden			North Sweden
	Field 1	Field 2	Field 3	Field 4	Field 1	Field 2	Field 3	Field 1
A1	8	2	4	6	9	72	4	4
A2	1	2	0	5	1	5	5	2
A1/A2	0	0	0	1	1	0	0	2
Oospores found	No	Yes	Yes	Yes	-	Yes	-	-

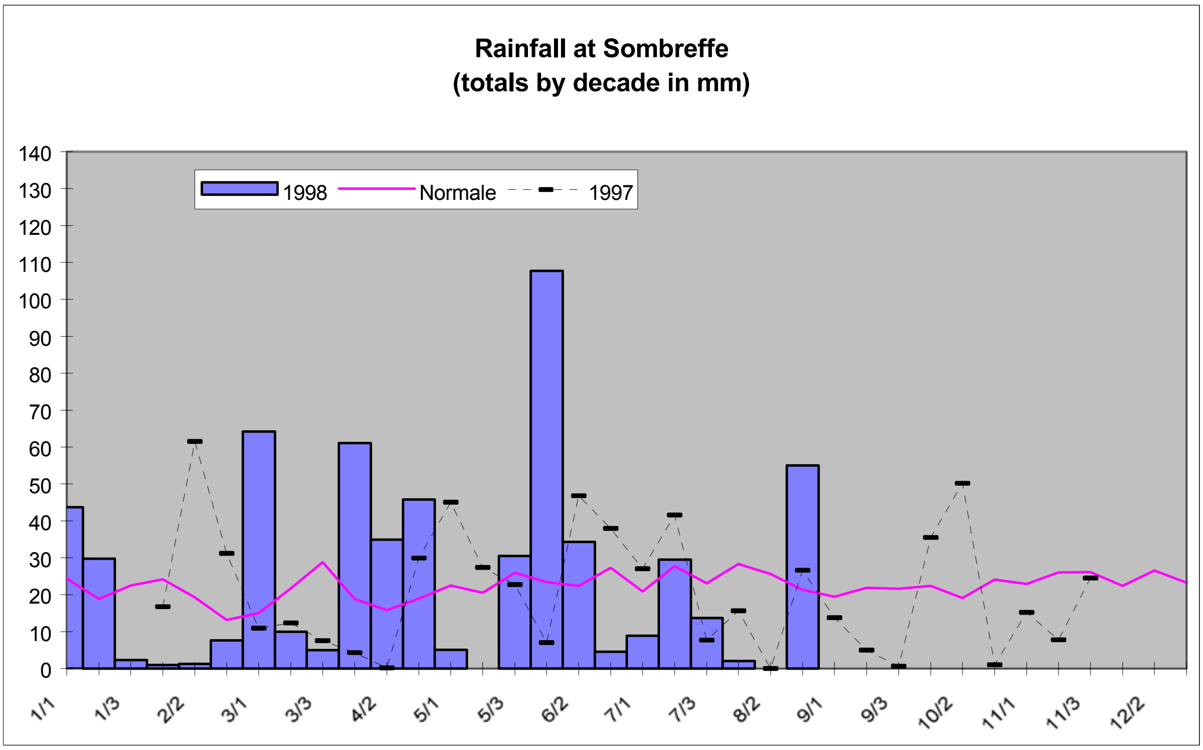
In the counties C, M and N the amount of samples is greater due to suspicion of soil borne inoculum. In some fields in these areas observations of early infections are believed to originate from oospores in the soil. Looking at the results of the surveys of 1997 and 1998 we can conclude that both A1 and A2 are present in all potato producing areas in Sweden. It is also shown that there are examples of fields where both A1 and A2 have been present at the same time. In a total of four fields oospores have been found in foliage. These surveys will be carried out also during 1999 and 2000.

Third Workshop of an European Network for development of an Integrated Control Strategy of potato late blight
Uppsala, Sweden, 9-13 September 1998

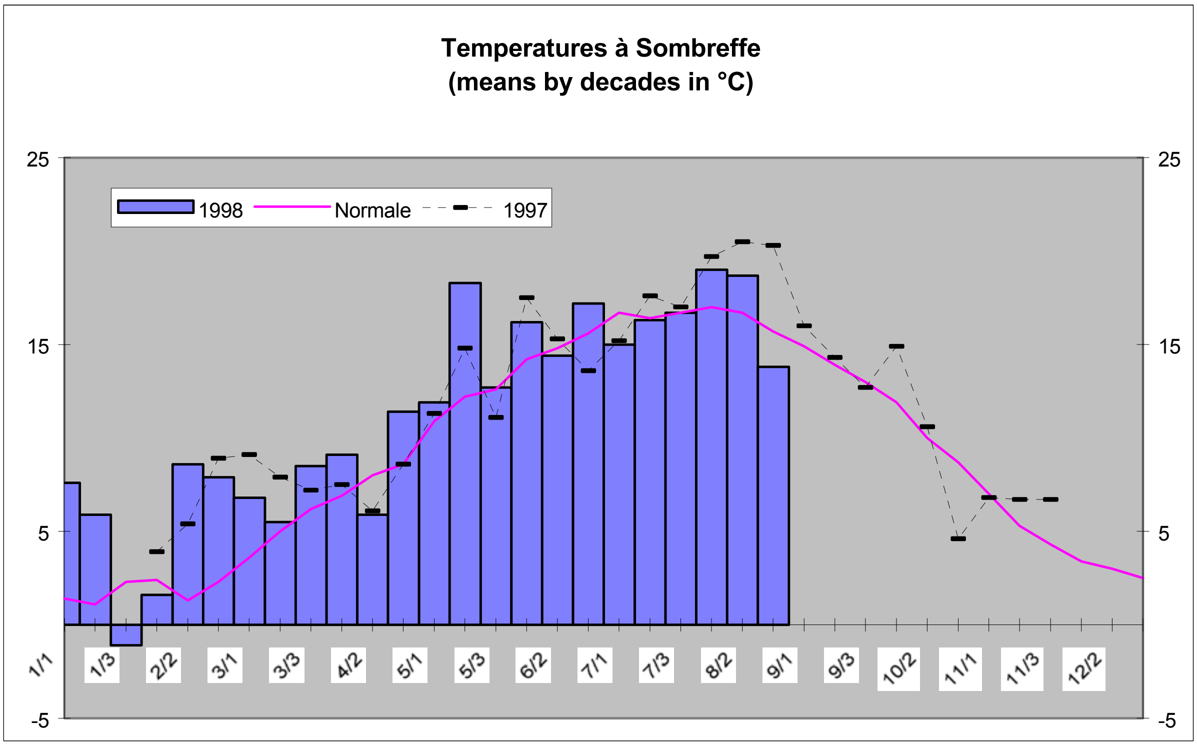
LATE BLIGHT FORECAST AND CONTROL IN WALLONIE

MICHELANTE, D., ROLOT, J.L., VERLAINE, A.

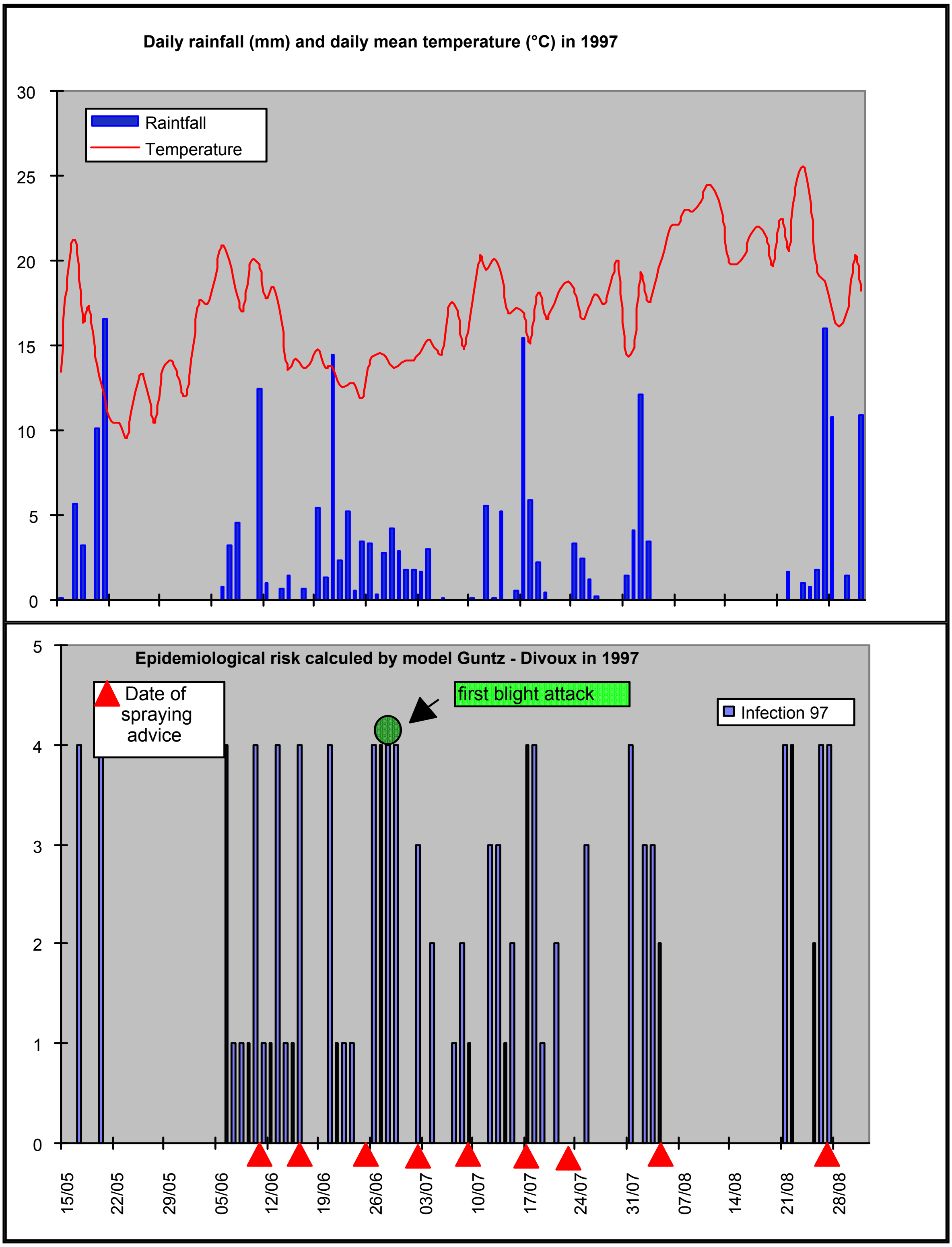
Département de Production Animale et Systèmes Agricoles, Rue Serpont 100, B-6800 LIBRAMONT,
Tél : 32 61 23 10 10, Fax : 32 61 23 10 28



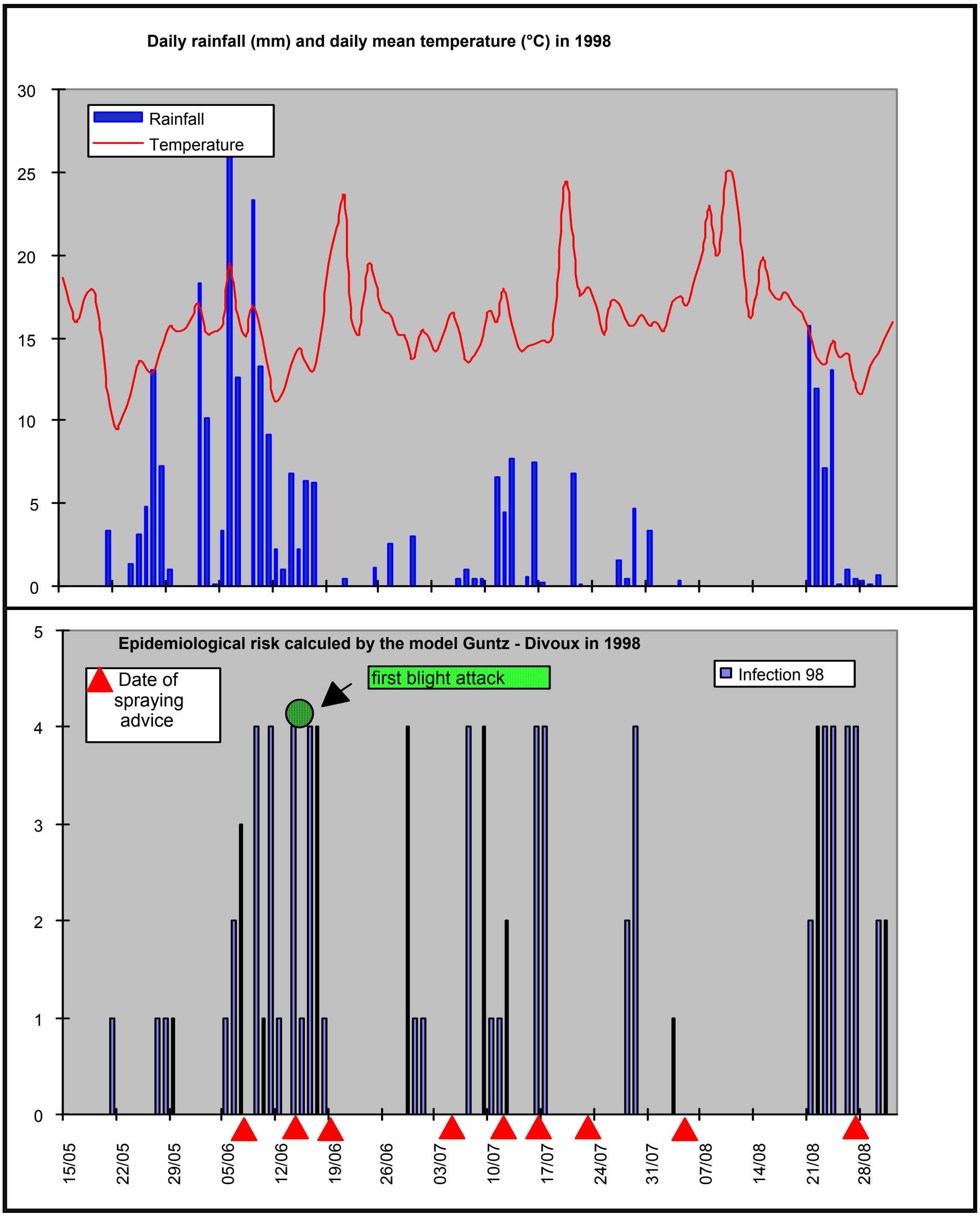
Potato late blight modelling and recommendations for spraying 1997



Potato late blight modelling and recommendations for spraying 1998

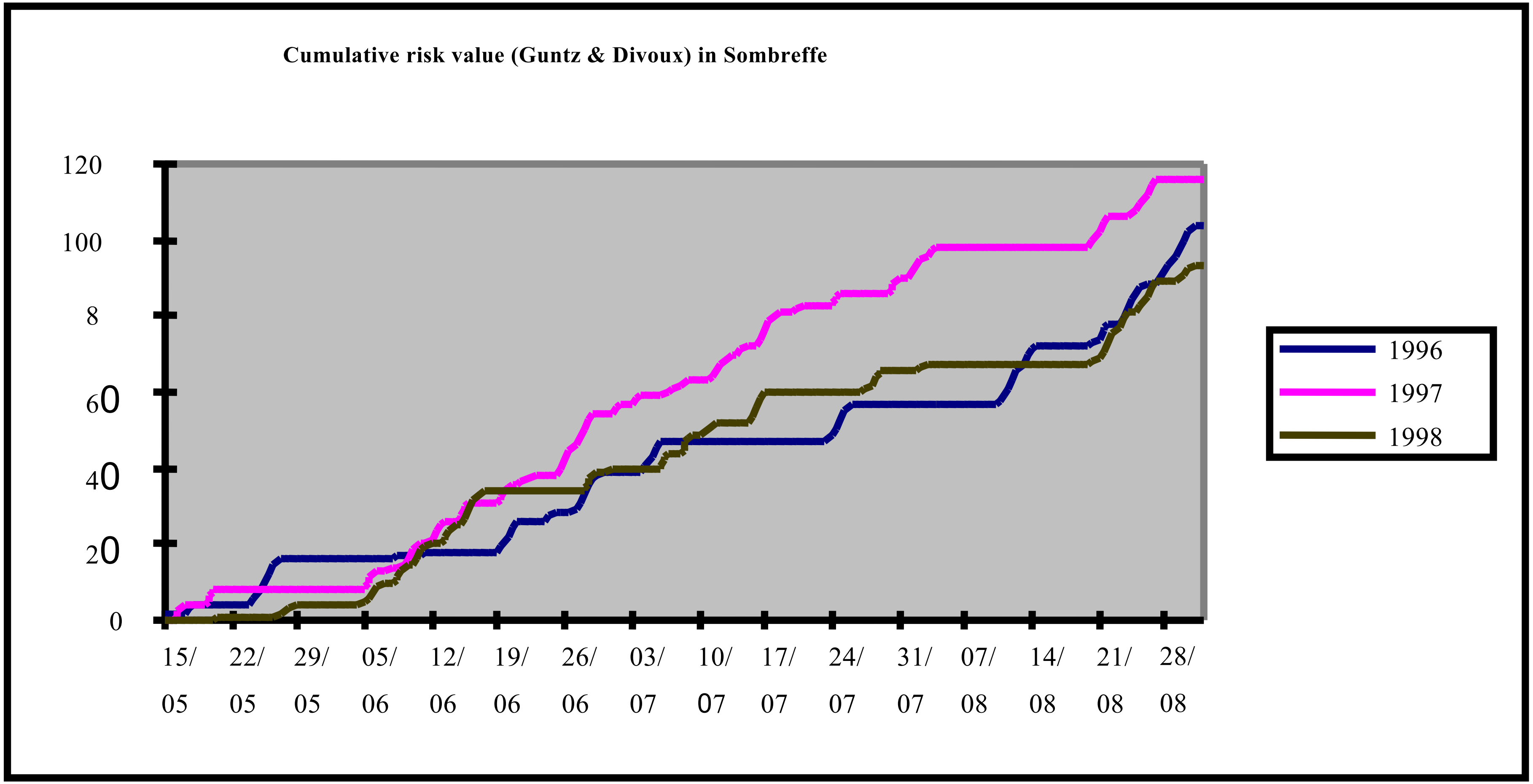

Daily rainfall (mm) and daily mean temperature (°C) in 1997
Raintfall
Temperature
30
25
20
15
10
5
0
Epidemiological risk calculed by model Guntz - Divoux in 1997
Date of spraying advice
first blight attack
Infection 97
5
4
3
2
1
0
15/05
22/05
29/05
05/06
12/06
19/06
26/06
03/07
10/07
17/07
24/07
31/07
07/08
14/08
21/08
28/08

Crop emergence	19-5-93					
Treatment				**Infection**		**Rain**
N°	**Date**	**Fungicide**	**Days**	**Type**	**Date**	
				Very serious	05-05-93	
				Minor	13-05-93	
				Very serious	17-05-93	
				Very serious	20-05-93	
1	10-06-93	contact		Very serious	06-06-93	
2	15-06-93	enetrating actio	5	Very serious	10-06-93	16
3	24-06-93	systemic action	9	Serious	20-06-93	30
4	01-07-93	contact	7	Very serious	28-06-93	19
5	08-07-93	contact	7	Moderate	02-07-93	7
6	16-07-93	contact	8	Moderate	12-07-93	12
7	22-07-93	enetrating actio	6	Very serious	17-07-93	24
8	03-08-93	enetrating actio	12	Very serious	31-07-93	28
9	26-08-93	contact+stannic	23	Very serious	21-08-93	5
10	31-08-93	contact+stannic	5	very serious	26-08-93	28



Daily rainfall (mm) and daily mean temperature (°C) in 1998
Rainfall
Temperature
30
25
20
15
10
5
0
Epidemiological risk calcuIed by the model Guntz - Divoux in 1998
Date of spraying advice
first blight attack
Infection 98
5
4
3
2
1
0
15/05
22/05
29/05
05/06
12/06
19/06
26/06
03/07
10/07
17/07
24/07
31/07
07/08
14/08
21/08
28/08

Crop emergence :	5-6-94					
Treatment				**Infection**		**Rain**
N°	**Date**	**Fungicide**	**Days**	**Type**	**Date**	
				Minor	20-05-94	
				Minor	26-05-94	
				Minor	27-05-94	
				Minor	28-05-94	
1	08-06-94	contact		Moderate	05-06-94	
2	14-06-94	enetrating actio	6	Very serious	10-06-94	56
3	18-06-94	systemic action	4	Very serious	15-06-94	15
4	03-07-94	contact	15	Very serious	29-06-94	7
5	10-07-94	contact	7	Very serious	06-07-94	2
6	14-07-94	enetrating actio	4	Very serious	11-07-94	19
7	21-07-94	enetrating actio	7	Very serious	15-07-94	15
8	02-08-94	contact	12	Very serious	28-07-94	10
9	26-08-94	enetrating actio	24	Moderate	20-08-94	48
10	04-09-94	contact+stannic	9	Moderate	28-08-94	


Cumulative risk value (Guntz & Divoux) in Sombreffe
120
100
8
60
40
20
0
15/ 05
22/ 05
29/ 05
05/ 06
12/ 06
19/ 06
26/ 06
03/ 07
10/ 07
17/ 07
24/ 07
31/ 07
07/ 08
14/ 08
21/ 08
28/ 08
1996
1997
1998