PAGV-Special Report no 1
January 1997

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

Lelystad, The Netherlands 30 September - 3 October 1996

Erno Bouma & Huub Schepers (eds.)

issn: 1386-3126

Research Station 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

Lelystad, The Netherlands 30 September - 3 October 1996

E. Bouma & H.T.A.M. Schepers (editors)
Research Station 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

PAGV-Report no. 1 January 1997

Publisher: **Research Station 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)

Workshop, Lelystad, 1996

This report contains the papers and posters presented at the Workshop on the European network for development of an integrated control strategy of potato late blight held in Lelystad, The Netherlands 30 September-3 October 1996. The Workshop was the first 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 coördinate ongoing research in order to avoid duplication of efforts.
* survey the state of the art on control of *Phytophthora infestans* and indicate information gaps as 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 this Proceedings give a survey of the state of the art in controlling *Phytophthora infestans* in potatoes in Europe. During the Wokshop sub-groups were formed on epidemiology, fungicides and Decision Support Systems. In these sub-groups first steps were made towards on indication of information gaps and coördinating 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 & E. Bouma

Telephone +31 320 291111
Telefax +31 320 230479
E-mail bouma@pagv.agro.nl
http://www.agro.nl/appliedresearch/pav/

Contents

First Workshop of an European Network for Development of an
Integrated Control Strategy of potato late blight
Lelystad, The Netherlands, 30 September - 3 October 1996

1STATE OF THE ART OF PHYTOPHTHORA INFESTANS CONTROL IN EUROPE

H.T.A.M. SCHEPERS, E. BOUMA, C.B. BUS
Research Station for Arable Farming and Field
Production of Vegetables (PAGV),
P.O. Box 430, 8200 AK, Lelystad,
The Netherlands

Introduction

From 30 September to 3 October 1996 a Workshop was held in the framework of the concerted action "European network for development of an integrated control strategy of potato late blight" in Lelystad in The Netherlands. Experts in the field of control of *Phytophthora infestans* (Table 1) were together with the objective to present the state of the art of control stategies and in discussions define information gaps and recommend on further research. In this paper the presentations of the participants are summarized on registered fungicides, estimated use of fungicides to control *P. infestans* and the decision support systems.

Fungicides registered

Table 2 shows the fungicides registered in Europe for control of *Phytophthora infestans* in potato. The fungicides are divided in three groups: protectant, translaminar and systemic fungicides. With the protectant fungicides it is remarkable that in Italy a number of fungicides are registered such as anilazin, dichloran and thiram, that are considered not particularly effective against late blight. However, although these fungicides are registered, they are hardly ever used by farmers. In France the highest number of protectant fungicides is registered (15), in Sweden the lowest number (3). Fluazinam was introduced in Europe several years ago, only in Denmark and Italy it is not yet registered.

The translaminar fungicides cymoxanil and dimethomorph are registered in several combinations with protectant fungicides. The Scandinavian countries Denmark, Sweden and Norway

Special PAGV-report 1. (1996), 7-12

are the only countries were these translaminar fungicides are not registered. Dimethomorph is not registered in Austria.

The systemic fungicides are always registered in combination with a protectant fungicide. Benalaxyl is not registered in Scandinavia and The Netherlands. Metalaxyl is not registered in Denmark. Oxadixyl is not registered in Denmark, Sweden and The Netherlands. Ofurace is only registered in Belgium, Ireland and the UK. Propamocarb is registered in all countries with the exception of Austria and Italy.

Estimated use of fungicides

Table 3 shows the estimations of the experts present at the Workshop on fungicides used to control *Phytophthora infestans*. The number of sprays per season and the use of kg active ingredient per hectare per year are given. Since most of the data are estimations, a (wide) range exists in the number of sprays and kg a.i./ha/year. The use of fungicides depends on the intensity of potato culture in a specific region, combined with the climatic conditions, the susceptibility of the potato varieties grown and the registered fungicides. This probably explains the low number of sprays per season in Norway and the north of Sweden, whereas in the more intensively grown potato crops in countries with favorable climatic conditions for the development of *P. infestans,* a higher number of sprays is necessary to control the disease. The number of sprays and fungicide input is highest in France and lowest in Norway and Sweden. The kg a.i. used does not only depend on the number of sprays but can also reflect the specific fungicides used. One application for example of fluazinam is 200 g a.i./ha whereas one application of copperoxychloride is 3000 g a.i./ha.

Decision Support Systems

Table 3 also shows the Decision Support Systems (DSS) that are in operation or under development in Europe. In the UK recommendations for critical days are formulated according to the Smith periods. However, a DSS that includes other factors than weather parameters is not yet available. In various countries DSS are in operation like NEGFRY in Denmark and Sweden, Prophy and Plant-Plus in The Netherlands, Guntz-Divoux in Belgium and France, PhytoPRE in Switzerland, Simphyt in Germany and the Negativ-Prognosis in Austria and Germany. Details on these different systems are already published or will be mentioned in this Proceedings.

2 Report of the discussions of the subgroup Epidemiology

D. ANDRIVON

Participants

The group was composed of the following participants:
B. Andersson, D. Andrivon (chairman), R. Bain, K. Cao, A. Cassells, L. Cobelli, L.R. Cooke, M. Goeminne,
J. Hadders, A. Hermansen, K. Möller, H. Schepers, E. Schiessendoppler, B. Schöber-Butin, D. Spykerboer.

The purpose of the discussion was to briefly review topics related to late blight epidemiology important for the development and operation of decision support systems (DSS), and to identify knowledge gaps and areas where research of further information is needed for the improvement of these systems.

Three major areas were covered by the discussions:

- determination of weather thresholds and/or relationships with epidemiological parameters for current isolates of the late blight fungus;
- inoculum sources: nature and quantification;
- role of the plant. Pathogen variability was also considered a major topic, but could not be discussed in any detail because of time shortage.

Determination of weather thresholds and or relationships for current isolates of *P. infestans*

Participants agreed that a lot of information is available on disease/weather relationships concerning late blight, but pointed to the fact that most of the data have been gathered during the first decades of the century. This raises the question of the precision and reliability of data,

Special PAGV-report 1. (1996), 12-14

but also of their relevance regarding the new genotypes of the fungus currently present in Europe (as opposed to the 'old' genotypes used in the before mentioned experiments). For instance, the experience of some of the participants tends to indicate that both the minimum and maximum temperature thresholds used in DSS models for infection, growth or sporulation might need revision. Furthermore, the group noted that most of the information available deals with leaf infection, but that no data are available regarding stem infections, which could be of great epidemiological significance.

Some work on these topics is currently being done, or is planned, by the research teams of several participants, mainly in the Netherlands and Norway. The group encouraged these investigations, and recommended that:

- coördination between teams involved in these experiments (and of teams willing to get involved) be undertaken, regarding testing procedures, isolates and cultivars used;
- a compilation of data available be produced. H. Schepers agreed to prepare it.

Inoculum sources: nature and quantification

The group recognized that oospores, refuse piles and infected seed potatoes are the major inoculum sources, but that current experience indicates that volunteers are probably not a major source of inoculum. The epidemiological importance of the various inoculum sources probably depends of the agro-ecological situation considered (seed borne inoculum considered as the major source in Nordic countries, but not in the Netherlands, UK or France where refuse piles are probably the main contributors to initial disease outbreaks). Work is underway in several countries (notably the Netherlands, Austria, Norway and the UK) concerning the formation, survival and importance of oospores, but much information is lacking yet and the current data do not allow for inclusion of oospores in any DSS model. Similarly, the role and detection of latent seed infection is as yet unexplored, as is the impact of seed crop management (homegrown seed, organic seed, certified seed) on the proportion of diseased or latently infected tubers. Quantification of sources (for both primary and secondary inoculum) is currently made using a number of criteria (number of infected leaves/plants per ha; location of the source from nearest crop; scale ratings -single focus vs generalized infections for instance), but at the moment, no difference is made between stem and leaf lesions.

The group therefore:

- recommended that monitoring of populations for the presence and frequency of the two mating types be continued in the participating countries;
- encouraged the continuation and broadening of investigations related to the quantification of the epidemiological consequences of the various inoculum sources currently underway;
- will analyse the knowledge gathered during current studies (some being now running towards their end) to propose future research in the areas where information is still missing.

Role of the plant

Potato growth and development models have been developed. The group wondered whether these could be usefully integrated in current DSS models to provide a better forecasting of disease development. This would require that information be available on the disease susceptibility of the plant at the various stages of its development (e.g., on different leaves of the same plant or on leaves of different ages). Conflicting information is reported in the present literature, and clarification would be helpful.

Overall, the group held a lively and fruitful discussion, but found it difficult to be precise in its recommendations because the demands from DSS builders were unclear for most participants. The lack of time to discuss aspects of pathogen variability and population structure and evolution (as assessed by pathogenicity and fungicide resistance as well as neutral markers) and its consequences on forecasting and DSS models was regretted; these topics will hopefully be tackled during contacts between members, so that a report can be presented at the next workshop.

3**Report of the discussions of the subgroup Decision Support Systems**

J.G. Hansen

Participants

The group was composed of the following participants: Jens Grønbech Hansen (DK, chairman), Erno Bouma (NL, vice chairman), Lesley Dowley (IE), Roland Sigvald (SE), Riccardo Bugiani (IT), Markus Ruckstuhl (CH), Nigel Hardwick (UK), André Verlaine (BE), Rosemary Collier (UK), Wim Nugteren (NL), Pieter Vanhaverbeke (BE), Ludovic Bubois (FR) and J. Raatjes (NL).

Warning methods:

In the concerted action focus will be on integrated control strategies as computerized DSS´s, but it will be relevant to compare the DSS output with national warning systems and methods. In some countries on farm computerized late blight DSS is of minor relevance at this moment. Late blight warning systems and methods can be categorized in four groups:

A. Integrated Control Strategy, non-computerized
B: Regional warning system based on networks of ordinary met-stations
C: Computerized Late Blight DSS
D: Late Blight DSS as a part of a larger system

Goals in EU.NET.ICP Sub-group DSS:

1. Step (until next workshop)

Description of DSS and validation results should be collected by E, Bouma in a compendium to all participants. DSS systems are: Dacom, Prophy, Negfry, Milsol, Guntz Divou (and Simphyt ?). Other integrated control strategies and warning methods or systems in operation like Smith and Försund Rules should be included. Choose one or two key articles (or short report)

Special PAGV-report 1. (1996), 15-19

of each system and include an updated list of literature. Categorize descriptions in A, B, C and D.

To compare the systems a suggestion for standardized systems description will be made by W. Nugteren to E. Bouma

Each national contact person (see list below) is responsible for collecting key articles and making a standardized descriptions of national warning methods and DSS´s. Descriptions are send to E. Bouma before December 1., 1996.

The DSS systems (Dacom, Prophy, Negfry, Milsol, Guntz Divou (and Simphyt ?)) are validated based on historical data from different sites of Europe. High quality met and biological data from one or two locations and for the last three years are needed from all participating countries. Met data and biological data are send to Jens G. Hansen before February 1. These will be located on an FTP server in Denmark or send by diskette to each model/DSS/system group. Name the data files (for Denmark) as:

DK.met	: Meteorological data
DK.bio	: Biological data
DKread.me	: Explanation (ASCII file)

Met data needed: Hourly or three hourly data in column formatted ASCII files.
Describe how the data are measured (height, equipment (type and position) etc. in the read.me file.

Met data as minimum:	Temperature, Relative humidity, Precipitation
Met data additional (if possible):	Wind speed and direction, Global radiation
Biological data as minimum:	Crop emergence, End of season, Variety and variety resistance index, Irrigation (date and amount)
Biological data additional:	Crop growth, phenology, ground coverage

----

The DSS output will be: Risk of first occurrence of late blight (or date of first spray). Number and date of applications from crop emergence to end of season

Together with national met data, output from national warning systems on the same data are send to Jens G. Hansen before February 1. 1997. The DSS output with use of data from all participating countries are send to Jens G. Hansen before June 1, 1997. A summary report of all results are send to participants before 1.August

DSS output results will be compared with observations on late blight development on the second workshop.

Contact (and responsible) persons in each country:

Switzerland: M. Ruckstuhl
Italy: R. Bugiani
France : L. Dubois
Belgium: P. Vanhaverbeke
UK (incl. wales & Jersey): N. Hardwick
The Netherlands: E. Bouma
Germany: B. Schöber & V. Gutsche
Austria: E. Schiessendoppler
Scotland: R. Bain
Ireland: L. Dowley
Northern Ireland: L. Cooke
Denmark: J.G. Hansen
Norway: A. Hermansen
Sweden: B. Andersson

Dead lines	Issue	From	To
96.11.01	Method for standard description of methods and systems	W. Nugteren	E. Bouma
96.12.01	Key articles and reports on operational late blight methods and systems and validation results	National contact persons	E. Bouma
97.02.01	Meteorological and biological data for DSS validation on historical data. Including output from national warning system on the same data.	National contact person	J.G. Hansen
97.06.01	DSS output results	DSS responsible	J.G.Hansen
97.08.01	DSS output results	J.G. Hansen	All Participants

A Report on availability of meteorological data (Cost actions) will be send to all participants

2. step (Second workshop)

Discussion of validation results and components in DSS systems

Presentations from sub-group DSS at the next workshop:

- Validation results
- Availability of meteorological data
- The use of different sources of met data in DSS and warning systems
- Standards for validation of DSS and warning systems

3. step (Third workshop)

Results on field validation of submodels and systems

DSS represented: Dacom, Prophy, Negfry, Milsol, Guntz Divou, (Simphyt)

Description and validation of the systems.

- Make a list of publications describing the systems.
- Describe for every system:
  - Objectives
  - Computer language
  - Components and submodels
  - Input data needed
  - Output
  - Constraints and gaps in systems
  - National conditions taken into account
  - Availability
  - Constraints for operational use
  - etc.

Major constraints and gaps in existing DSS:

- Submodels are based on old data.
- Availability and use of weather data
- Quantification of fungicide rainfastness and (photochemical) breakdown
- Standardization of descriptions of crop resistance

Weather data:

Important issues about the use of weather data to be discussed during this concerted Action

Availability of weather data (for research, central operations, farmers)

Advantages and constraints in the use of micro/macro climate data ?

Model sensitivity to variation in met-data or by use of non accurate met-data

Implementation of weather forecasting data in DSS

Common interface/platform to read data from different sources.

Standardization in quality control procedures and interpolation procedures (time and space)

Coordination with EU.NET.DSS and COST actions

Use of the Internet to exchange knowledge and data ?

Validation trials and demonstration

Experimental design and standardisation of validation trials and demonstrations was suggested as a topic for the second workshop in Ireland

Initiation development of EU ICS/DSS

There should be a focus on submodels. Validation of submodels and systems during the second part of the concerted action if possible.

See also Webpage http:/www.sp.dk/afa/eu_net_icp/sub_group_dss.html

4**Report of the discussions of the subgroup Potato late blight fungicides**

N.J. Bradshaw

Participants

Participants: N.J. Bradshaw (chairman) (UK), G. Little (UK), S. Mathiassen (DK), G. Ampe (B), S. Duveauchelle (F), R. Hafskjold (N), A. Vermazeren (NL), F. Heuts (NL), K. Bus (NL).

Objectives: Within the context of an Integrated Control Strategy for potato late blight the objectives of the fungicides sub-group were:

1) to discuss the current state of knowledge of potato late blight fungicides, their properties and activity in the field as indicated by the subject areas below,
2) to identify where information was lacking,
3) to make recommendations for further research in the following subject areas.

Subject areas:

1) Properties of fungicides
- preventive/curative activity and effectiveness
- fungicide breakdown/degradation by UV radiation, temperature and rainfall
- effect of weather conditions on fungicide activity eg rainfastness, redistribution within the canopy

2) application strategies
- fungicide programmes ie start of spraying, frequency,
- fungicide choice
- reduced fungicide rates
- interaction between fungicides and host resistance
- application technology

Special PAGV-report 1. (1996), 20-24

– duration of activity and effectiveness in relation to spray intervals
– influence of infection pressure on fungicide efficacy
– effect of crop growth
3) fungicide resistance management
– phenylamide resistance

1) Properties of fungicides

The sup-group considered that information on the properties of late blight fungicides was available mainly from the agrochemical companies and also from the various research institutes/organisations represented at the workshop.

Due to commercial considerations there was concern about the availability of such information and also its' comparability as different techniques would have been used to generate such information eg the relative merits of field vs laboratory techniques. If information on the attributes of different fungicides was to be included in a Decision Support System, it was consider important that data on fungicide properties should be obtained using the same methodology eg experiment design, assessment of blight and analysis of data. It was therefore agreed that there should be a harmonisation of methodologies within Europe for fungicide evaluation for late blight control and that a standard protocol should be adopted. Such a protocol would be based on EPPO Guidelines but would also incorporate the experience and expertise of the workshop participants.

When evaluating properties such as the protectant and curative activity of fungicide in vitro, it was agreed that the conditions used for these tests should be chosen to reflect those in the major potato producing regions of Europe and that potato cultivars representative of those most commonly grown in the EU should be used. The laboratory/glasshouse facilities necessary to conduct in vitro studies on fungicides were already available in Denmark, The Netherlands and the UK, and that such a large project would need to conducted at more than one research centre.

Before undertaking such an extensive programme of work, it was considered necessary to collate and evaluate existing information on fungicide properties from all possible sources. M Duvauchelle agreed to prepare a draft questionnaire asking specific questions relating to fungicide efficacy and other properties but also including details of the methodologies industry and to reach agreement on the selection and presentation of data, the draft questionnaire would be circulated not only to participants and but also to agrochemical companies for comment.

The questionnaire would then be sent by participants to all agrochemical companies with registered potato blight fungicides and to another research institutes in the various countries holding information on the properties of potato blight fungicides. M Duvauchelle agreed to collate the information on behalf of the sub-group and report back at the next meeting of the Concerted Action in 1997.

Action: S. Duvauchelle

2) **Application strategies**

Discussions in this section focused choice and spray programmes, the potential for evaluating reduced doses and the use of new application technologies.

Fungicide programmes

All countries currently advised a 'programme approach' to fungicide use for late blight control whereby sprays of one or more products were applied at regular intervals throughout the season, starting either at a particular crop growth stage or according in the choice of products used at different stages of crop development.

In The Netherlands farmers tended to use one product throughout the season changing to another product as the risk increased. Other countries also recognised the level of blight risk at different times during the season and used their knowledge of a fungicides' properties in relation to risk. France advised dithiocarbamate fungicides for the early crop development phase, changing to systemic materials as risk increased and when crop growth was rapid or remaining with dithiocarbamates in low risk conditions. Intervals between application for 2-way phenylamide mixtures recommended at 10 days whereas this was extended to 12-14 days for 3-way mixtures. The UK preferred products with known systemic or partially systemic properties to be used at the start of a spray programme when crop growth was rapid, changing to protectant materials once the canopy had become established but also tayloring product choice also according to blight risk.

There was general agreement that little independent information existed on 'best fungicide' choice and that this sort of information was difficult to generate. Blight infection often appeared at different stages of crop development and this made interpretation of field trials results difficult. Within the context of a Decision Support System it was accepted that fungicide choice may eventually have to be limited to those defined as having either protectant or curative properties.

Reduced fungicide doses

The interaction between reduced fungicide doses, cultivar resistance and application intervals has already been investigated in the UK by Gans. The results have indicated the potential to reduce the rate of fungicide used for varieties possessing good foliar blight resistance but further confirmation onder a wider range of conditions is required. Before these principles could be included in a Decision Support System, it would be necessary to generate the dose response activity of the most commonly used blight fungicides. The incorporation of reduced dose recommendations in a DSS would need to clearly indicate the potential risks of poor and if necessary carry a disclaimer. Such an approach may therefore only be suitable for the more technologically aware farmers or for well defined geographical areas identified as low risk each year by weather models.

It was considered unlikely that sufficient data existed to construct robust dose response curves and that a considerable research effort would be needed using an agreed standard protocol. Although some dose rate data would already have been generated by agrochemical companies during the pre-registration product development phase in order to set label rates, it was consider insufficient to derive the Area Under the Disease Progress Curves (AUDPC) for a wide enough range of fungicides and doses.

Such a research programme would need to take account of a number of variables in addition to cultivar resistance and application interval, eg fungicide formulation properties, the need for standard inoculum pressure. However, it was suggested that preliminary investigation could be made in the field by including a range of fungicide doses in national fungicide testing programmes. **Action:all Participants**.

Application technology

The consensus view was that much work had already been done with conventional sprayin systems and that volume rates generally used by farmers throughout Europe were in the range of 200-300 l/ha. No further work was envisaged on conventional spraying systems although the potential of dropleg technology in be investigated further. The need to investigate to role of application technologies in order to achieve a reduction in fungicide contamination of water courses was also considered important.

3) Fungicide resistance management

Discussions focused on phenylamide resistance and resistance management strategies, and highlighted the different approach used in The Netherlands compared with elsewhere. In most countries phenylamide fungicide use was limited to a maximum of two or three applications, usually during early crop development.

However, in The Netherlands a different strategy was adopted by some farmers where phenylamide fungicides were only used in high risk conditions. This often meant that phenylamide fungicides were applied when foliar blight was present in a crop and was contrary to the FRAC Guidelines.

It was agreed that fungicides resistance management considerations should form an integral part of a Decision Support System.

5POTATO LATE BLIGHT: DEVELOPMENT OF A WARNING SERVICE AT THE "STATION DE HAUTE BELGIQUE"

ROLOT J.-L. (1) - VERLAINE A. (2) - MEEUS P. (3)
(1) Rolot J-L : Assistant, CRAGx, Station de Haute Belgique, Libramont
(2) Verlaine A. : Agricultural scientist, asbl Pameseb, Station de Haute Belgique, Libramont
(3) Meeus P. : Director a.i., CRAGx, Station de Phytopharmacie, Gembloux

Abstract

This paper describes the setting up and operation of a Warning service for potato growers in Wallonia (Belgium). This Service is to recognize the periods in which potato late blight (Phytophtora infestans) is likely to spread and let the farmers know when preventive fungicide treatments are to be carried out.
The risk is determined according to the GUNTZ and DIVOUX model (weather factors) and to the particular risks linked to the environment and the state of development of the crops.

Keywords*:* warning, potato, late blight, fungicides, humidity, temperature, pluviometry, network of agrometeorological stations

Introduction

Potato late blight caused by *Phytophtora infestans (Mont.) de Bary* is observed all over the world. The lower yield and quality that result from this disease account for great economic losses. It should not be necessary to evoke here the catastrophic social consequences of potato late blight for the Irish people in the nineteenth century; as a matter of fact Ireland then lost more than one and a half million inhabitants due to famine and emigration.

Nowadays frequent fungicide sprayings are carried out in order to combat the occurrence and the spread of this disease. In Belgium, where the area of potatoes amounts to 55,000 ha, sprayings frequencies of 10 to 15 treatments per growing season may be regularly observed.

At this rate of spraying the maximum amount of synthetic products spread on the crops equals 2,000 tons.

In spite of such intensive treatments, some plots are still found to be infected. In view of increasing the efficiency of potato late blight contrond avoiding the waste of active compounds it is absolutely necessary to know in what conditions the disease comes about and which moments are the most convenient for spraying.

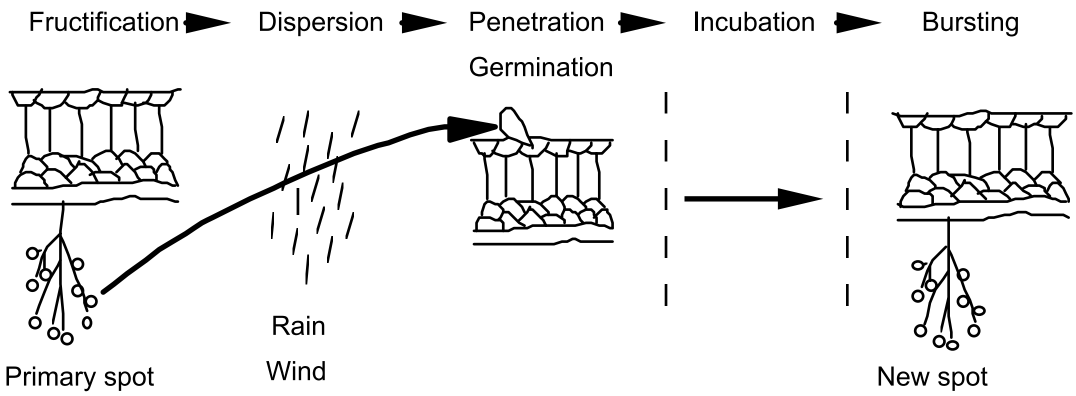
So, the main assignment of a Warning Service is to decide on the periods of time that are the most risky with respect to a presumable infection of crops and to incite farmers from that moment on to proceed to the spreading of a fungicide cover on their plants, out of precaution. When there is no risk, the Service should convince farmers not to proceed to any treatment. The advantages of this control strategy are obvious : increasing the efficiency of the control by means of well-considered treatments and cutting down production costs, but also minimizing the negative impact on the environment by avoiding unnecessary spraying.

The reproduction cyclus of potato late blight: developing conditions

Potato late blight epidemies are the result of a succession of reproduction cycles during which the infecting capacity of the disease may vary quickly increase according to a geometrical progression of 10^4.

The various stages of this cycle are :

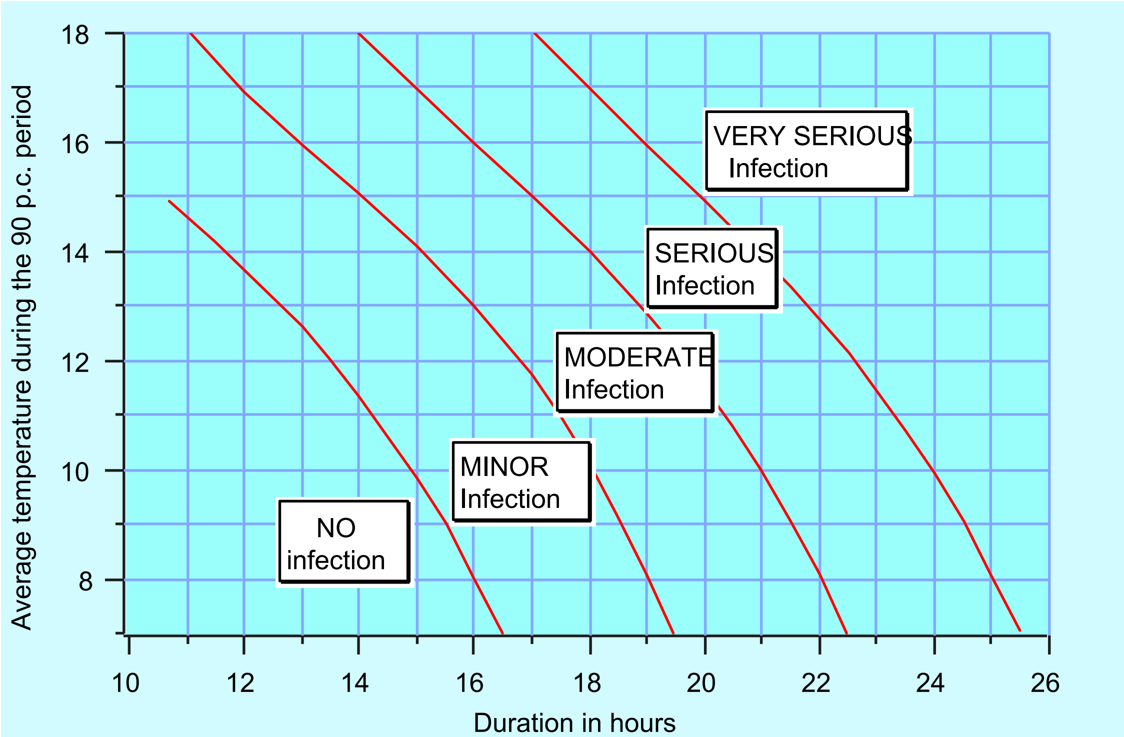
- *contamination*, i.e. the dispersion of spore-cases, the setting free of spores, the deposit of spores on plants and their germination and penetration into plant tissues (infection).
- *incubation*, consisting of the invisible development of the fungus inside leaves or stems.
-*bursting*, the period during which the characteristic symptoms of the disease appear. At this time the fungus develops its fructiferous system (sporangiophores bearing the spore-cases containing the spores) on the surface of leaves or stems. The cycle is completed by the sporulation (i.e. the release of spore-cases and spores into the environment).



The reproduction cycle

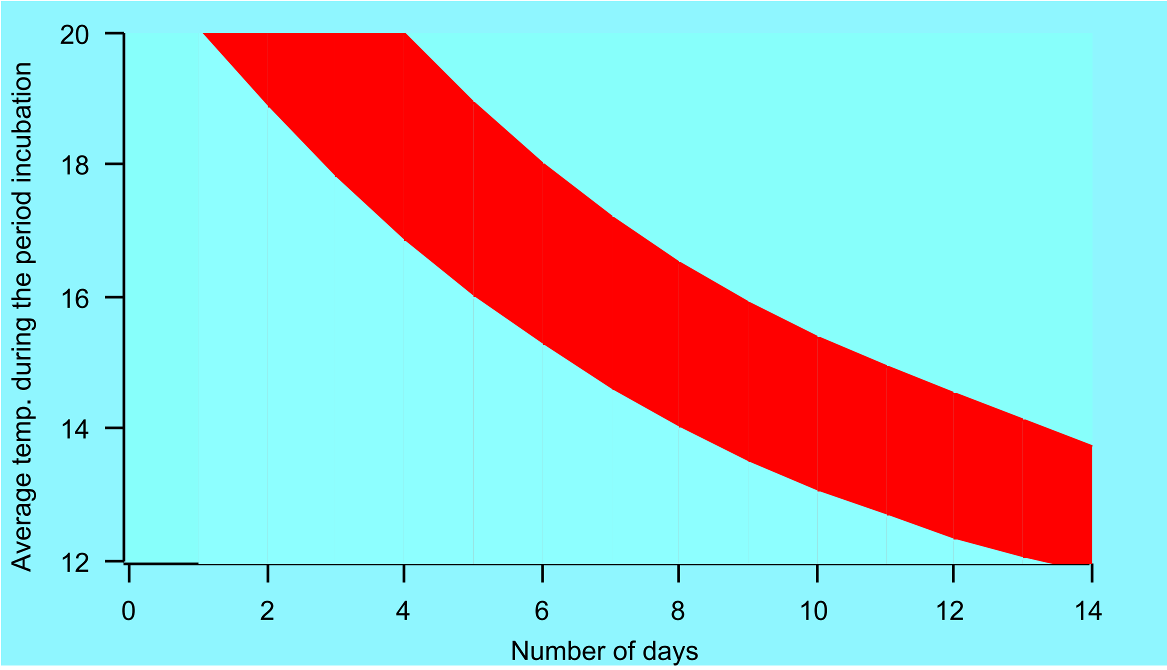
As early as the 20s several scientists tried to establish a link between the various stages of development and prevailing weather conditions (Van Everdingen,1926 - Beamont,1934 - Ducomet and Foex, 1939 - Wallin, 1949 - Thran, 1952 - Bourke,1953 - Guntx, 1960 - Divoux, 1961 ...). The relative humidity, the wetting of foliage, the pluviometry as well as the temperature are the most important weather parameters that determine the development of the disease.

Guntz adopted the findings made by Bourke (requirement of a 12 hour period with a HR of more than 90%. with rain or a 16 hour period with no rain to make contamination possible): he made out a scale in which the gravity of the infections is linked to the complex of relative humidity and temperature.



Guntz and Divoux Scale

Moreover, with the aim of estimating the duration of the incubation period and admitting the fact shown by Thran that this duration varies according to temperature, he defined incubation evolution units that are based upon the average daily temperatures; these units, that were added up day after day, make it possible to estimate the bursting and sporulation period (added value nr 7). From that time on, it is possible to predict the exact moment at which crops should possibly be treated in order to avoid a new contamination.



Duration of the incubation period in terms of the average temperature according to Thran

Evolution Units according to Divoux

An average daily temperature		
of less than 10°C	is equivalent to	0.00 evolution units
between 10,1 °C and 12 °C	is equivalent to	0.25 evolution unit
between 12,1 °C and 14°C	is equivalent to	0.50 evolution unit
between 14.1°C and 16°C	is equivalent to	1.00 evolution unit
between 17.1°C and 20 °C	is equivalent to	2.00 evolution units
of more than 20°C	is equivalent to	1.00 evolution unit

Evolution units according to CONCE

An average daily temperature		
of less than 8°C	is equivalent to	0.00 evolution units
between 8.1°C and 12°C	is equivalent to	0.75 evolution unit
between 12.1°C and 16.5°C	is equivalent to	1.00 evolution unit
between 16.6°C and 20°C	is equivalent to	1.50 evolution units
between 20.1°C and 30°C	is equivalent to	1.00 evolution unit
of more than 30°C	is equivalent to	0.00 evolution units

The production of sporangiophores and spore-cases requires at least 8 hours of high humidity for a range of temperatures between 3 and 26 °C , the optimum level being comprised between 18 and 22 °C (Crozier, 1934). So, the possibility of a serious or very serious infection ought not to be taken into account when the short-term weather forecasts allow to presume that the wheather will be dry for some time (limited fructification and no new infections possible).

In a dry and and warm atmosphere the viability of the spores is limited. To enable them to germ the foliage should be moistened during 4 hours at least. Germination is possible between 3 and 30 °C, the optimum being comprised between 10 and 14 °C.

So, the weather conditions that are very favourable to contamination and to the spread of the disease are those that accompany thundery wheather. Then the rainfall, which is preceded by a period of high dampness and temperature that are definitely favourable to fructification, is followed by a fall in temperature which favours the inoculation of the wetted leaves. The repeating of such periods under thundery weather brings about the further evolution of the reproduction cycles again and again as well as the fast spread of the disease as a result of its extraordinary potential rate of increase.

The disease always seems to start from the presence of infected tubers in which the fungus has been able to survive to winter conditions as a mycelium. Only a few infected tubers are enough to bring about an epidemy under appropriate circumstances.

Yet, at the beginning of the season there is a latent phase with very topical and hardly visible symptoms (a few spots per plot) which precedes the phase of very rapid epidemic spread of the disease. The epidemic threshold is reached when the highly topical occurrence of the disease around primary outbreaks develops into a spread at the regional level. From that time on crops are in great danger : the success of any warning system will depend on its ability to recognize exactly that moment, i.e. the time at which the first recommendation to treat crops is to be diffused.

Observations on the phenology of the plant are required. For a particular area, the general emergence of the crops should be followed immediately by the calculation of the various possible infection cycles. Until tuberization takes place, i.e. during the stage of full vegetative growth, the regular appearance of new unprotected leaves should be taken into account.

The surroundings of the crops and the specific risks these may imply, should be known. Kitchen gardens and primeur fields are e.g. known to act as reservoirs of inoculum for agricultural crops. Plots surrounded by hedges or trees and plots in low valleys are under the influence of a damp microclimate that is favourable to the development of the disease.

At the end of mild winters the tubers that were left in the ground at harvest have not been destroyed by frost : in spring these tubers will give numerous volunteer plants which may contain significantly more inoculum than usually.

Precipitation results in the eluviation of active compounds. These reduce the residual efficiency of the previous treatment and should therefore be taken into account.

All these principles are to be considered when making decisions. So, the bringing about of a warning system is a very delicate operation which requires an all-embracing understanding of the situation in a given area.
On the other hand, growers must also have a good knowledge of the particular risks involved for their plots to be able to adjust their control strategy. The devices used to measure weather parameters must reflect in the best possible way the variability of the weather conditions in the area.

The Potato Late Blight Warning System set up by the "Station de Haute Belgique"

The Phytophtora warning set up by the Station de Haute Belgique is based upon the method worked out by Guntz and Divoux and adjusted to the particular conditions of the Station. The elements taken into account simultaneously are: temperature, hygrometry, added up pluviometry, former infection conditions and plant phenology.

From 1960 to the early 70s field trials have been carried out in order to verify the findings of Guntz and Divoux in the growing conditions prevailing in this area. Since then, the leading principles of the warning system may be summed up as follows:

* From the time of general emergence of all crops in a given area the Service lays down the possible infections and their incubation periods after gathering data on weather parameters,

* the first recommendations for treatment is generally given at the end of the incubation of the 3rd serious infection cycle. Such a recommendation could however be diffused as soon as at the end of the second serious infection cycle when conditions are very favourable to the disease (mild winters, infected earlies, high pluviometry and dampness, ...)

* given the continuous development of new leaves until the stage of tuberization, the treatment should be repeated at the end of the next possible very serious, serious or even moderate infection,

* an added up precipitation of about 20 mm, and especially when it has a high intensity, is being considered as having eluviated the active compound present on the leaves; a new treatment is recommended as soon as a new possible serious infection is perceived,

* a request to apply fungicides is being made when the added up incubation is as near as possible to the values of 5.5/6. As it is, treatments that are done too early may be washed out by the rain before the next infection occurs.

* the type of the active compound that is recommended varies according to the stage of growth of the crop :
  - *a.i. acting by contact, having a preventive effect :*

these remain on the surface of the cuticle; their acting on certain parts of the respiratory chain prevents the spores from germinating.
Dithiocarbamates are rather appropriate for treatments up to and including flowering.
Organic stannics should be applied at the end of the growing season.
Combinations of dithiocarbamates and organic stannics, chlorothalonil and fluazinam may be used at any time of the season.
Products on the basis of copper are more appropriate for hobby growers as they are growth-inhibiting.

- *a.i. with a systemic action :*
these compounds penetrate into the plants and have curative effects in an early stage of incubation. Because of their characteristics they may be recommended especially at the start of the season (during the vegetative growth stage) when possible serious to very serious infections succeed to one another at a high rate and when the weather conditions do not allow the use of sprayers at the proper time. These active compounds (ofurace, metalaxyl, oxadixyl, benalaxyl) belong to the phenylamids group and should always be used together with a contact active compound because of the risks of resistance involved by their very specific way of action.

- *a.i. with a penetrating and translaminary action (local systemic action)* generally have a curative action although this is more limited. They are recommended when it has been impossible to carry out treatments at the proper time. Treating with a penetrant within 48 hours may possibly allow to "catch up" with an infection that has already come about in the tissues. These active compounds are also sold always as a combination with other products.

In most cases the recommendations with respect to the active compound bear on the use of contact active ingredients with a preventive action.

* at the end of the season, weather conditions are generally very appropriate for the development of the disease. At that time warnings are being diffused for all serious infections in accordance with the recorded rainfall. In this period (mostly September) crop protection becomes laborious and it is recommended to proceed to haulm destruction in fields where

potato late blight has been found to occur. At this time the loss of one or two percent of dry matter and some kilograms of yield is preferable to encumbering the quality of the crop at harvesting. At the same time farmers are invited to maintain protection until all haulms have disappeared.

Organization and operation of the Service

From 1970 to 1992

In the early 70s the Service was set up in co-operation with the Plant Protection Service of the Ministry of Agriculture. This warning service covered the whole southern part of the province of Luxemburg including three distinct agricultural areas :

- the Jurassic area with 4 weather stations (in Schockville, Vance, Sommethonne and Chassepierre)
- the Ardennes with two stations (in Framont and Libramont),
- the Famenne with one station (in Aye).

Each station is equipped with the measuring devices that are required to record hygrometry, temperature and rainfall.

Recordings are made each morning by voluntary observers and sent to the analysing and decision-making center in Libramont by postcard.

All parameters are then plotted on graphs and the occurrence of infections is made out on the basis of the Guntz and Divoux scale (with minor adjustments). The daily incubation units are defined on the basis of the average daily temperature ((Max + Min)/2).

In the immediate surroundings of each of the stations there are check plots that are treated according to the recommendations which makes it possible to verify the reliability of the system.

When all the data have been analysed appropriate recommendations with respect to prevention may be defined for each of the stations.

Treatment recommendations are sent to the participating farmers by post and the same information is recorded on an answering machine.

The Service applied this method until 1992 to the satisfaction of the farmers of the southern part of Luxemburg. On an average, 4 to 6 treatments are recommended to the farmers; during the same period the number of systematic treatments was estimated at 10 to 12.

The main restraints linked to this system are :

- the human factor, i.e. the fact that volunteers are to record the weather informations and send them by post to the Station in Libramont, regardless of their other duties. Because of this restraint it is not possible to consider a significant extension of the geographical area under observation.

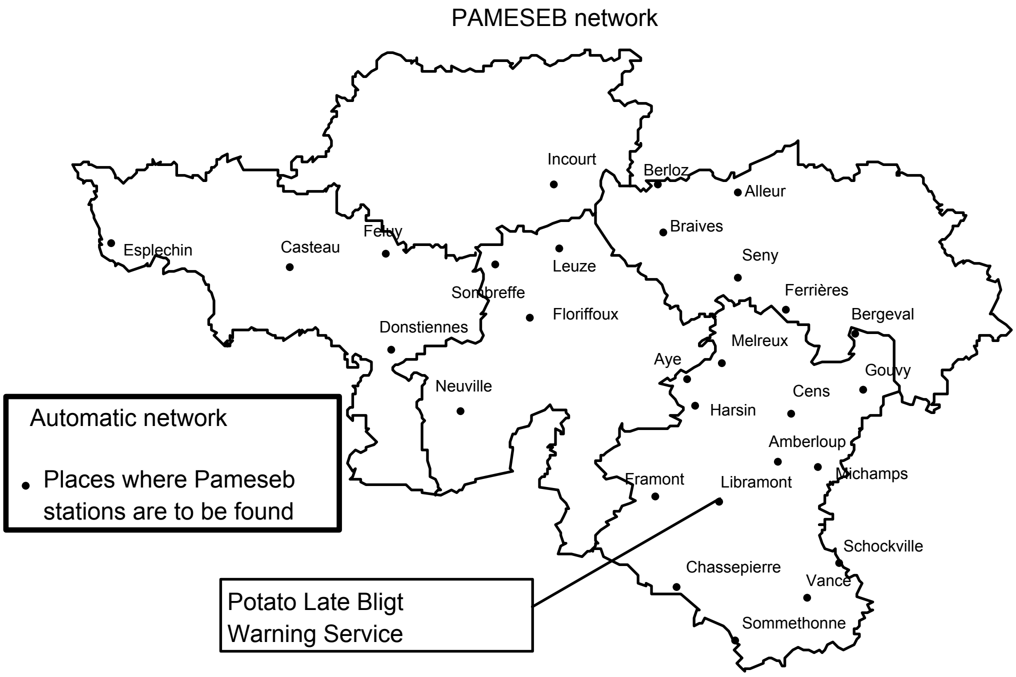
- the slow transmission of information to the decision-making center and, in return, the slow transmission of treatment recommendations to the farmers. As a matter of fact there is no mail delivery in weekends and on bank holidays. This complicates the work of the specialists who have to allow for possible delays with respect to the availability of information and the transmission of recommendations.

From 1990 to 1995. Development of the PAMESEB network.
1989 marks the start of the project on the promotion of agricultural meteorology in South-East Belgium - PAMESEB , an iniatative of the "Unité d'Enseignement et de Recherche en Génie rural" (Agricultural Engineering Training and Research Unit) of the University of Louvain-la-Neuve.

The aim of PAMESEB is to set up and maintain an automated network of agricultural weather stations, to receive and to send informations on the weather conditions to all interested institutes and persons. For farmers this instrument has several advantages; more particularly, it makes it easier for them to manage crop protection by means of the Warning Systems. For the existing Warning System for potato late blight PAMESEB was an opportunity to avoid the hereabove mentioned drawbacks and to extend its activity to a larger geographical area.

Initially, the network is limited to the area that was covered by the former system. The new automatic stations are built nearby the former stations with a view to reliability.

Later on new stations have been connected to the network which now consists of 37 stations spread all over Wallonia. Twenty-seven of these stations which are really representative for the potato growing area, are used for the purpose of potato late blight warning.



Description and operation of the PAMESEB potato late blight warning system

Weather stations

The agricultural weather stations are to be found all over the territory of Wallonia at places that are appropriate for recording meteorological information, mostly not far away from a farm.

A field station has eight sensors and a local data collection unit marketed by C2MS. Only three of them are needed with respect to the potato late blight situation : dry temperature, wet temperature, pluviometry.

The data collection unit is connected to the power network (220 volts transformed into 12 volts DC) or runs on a battery (12 volts DC) that is recharged by means of a solar panel. With a view to data transmission the unit is connected to the telephone network by means of a modem; it may also be connected to the farmer's computer by means of a RS232 connection.

The sensors that are used are :

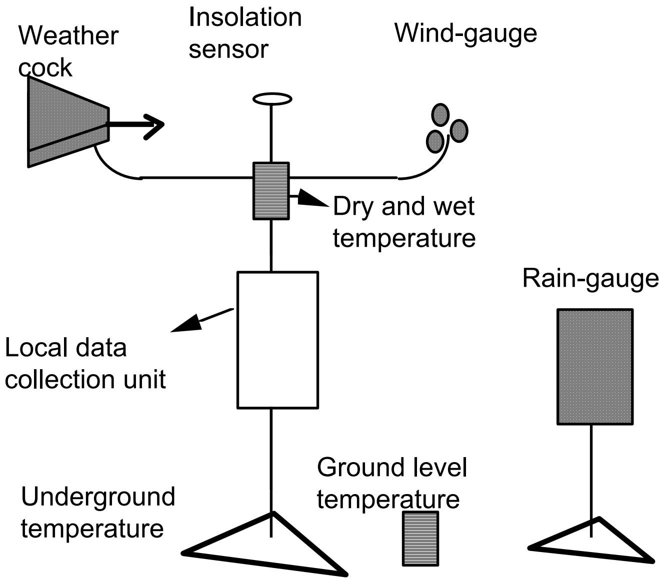


Diagram of a station with all its sensors

Telemeasuring

This device is programmed in such a way that it records the measurements at regular intervals of time (every hour). The values measured at the outlet of each sensor of the station are electric tensions (i.e. unprocessed data). These are put into the memory of the local data collection unit and will be transmitted afterwards by means of the telephone lines to the central unit in Libramont.

The central unit consists of a computer and a programme including a set of functionalities that are required to manage the network:

* the teleconfiguration of the field posts makes it possible to consult, to extend and to change the characteristics of one or more field posts;

* the consulting of field posts with the aim of :

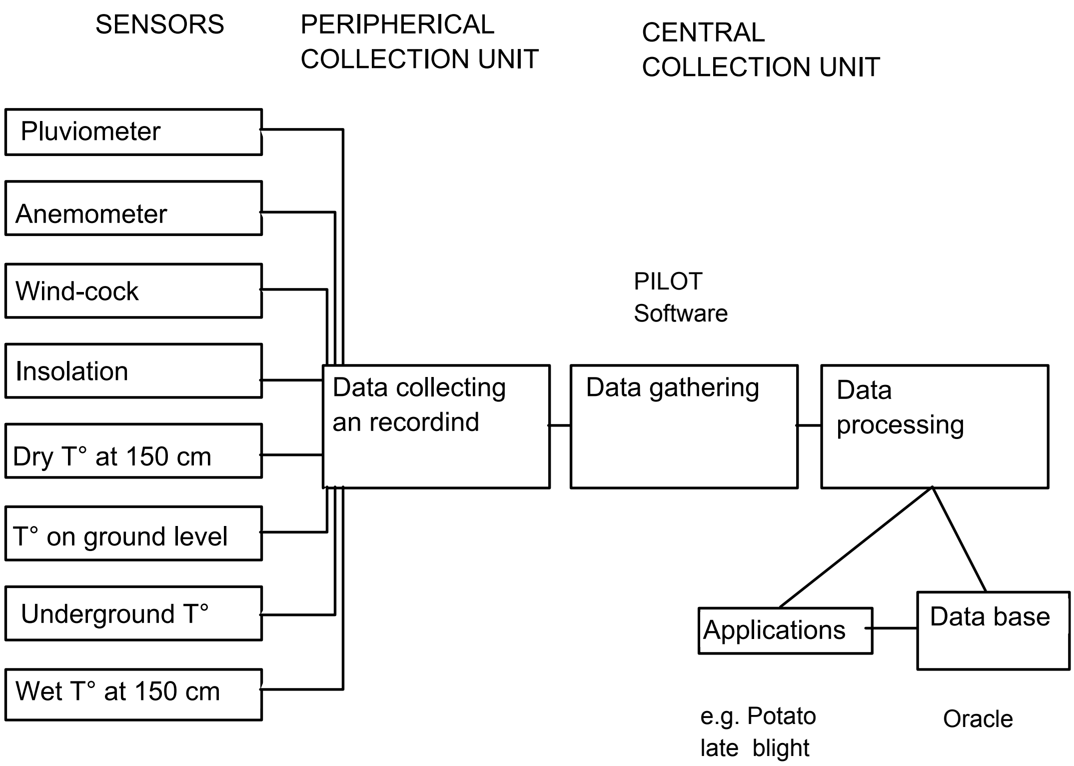
  - direct reading of the measurements which makes it possible to check the working of the equipment with respect to measure-taking;
  - transferring data;

* the visualisation of these data;

* the making of automatic calls; this programme makes it possible to drain the stations at any time set by the user.

By means of specific conversion equations for each of the measured parameters the unprocessed data are transformed into physical data within a system of known units (% RH, °C, mm, H20, ...).

The physical data are then checked and ratified. In this way the stations requiring an intervention of the technician may be identified; this intervention may concern the sensors as well as the electronic collection interface and the transferring of unprocessed measurements. The data that have been ratified are stored in a data base (ORACLE).

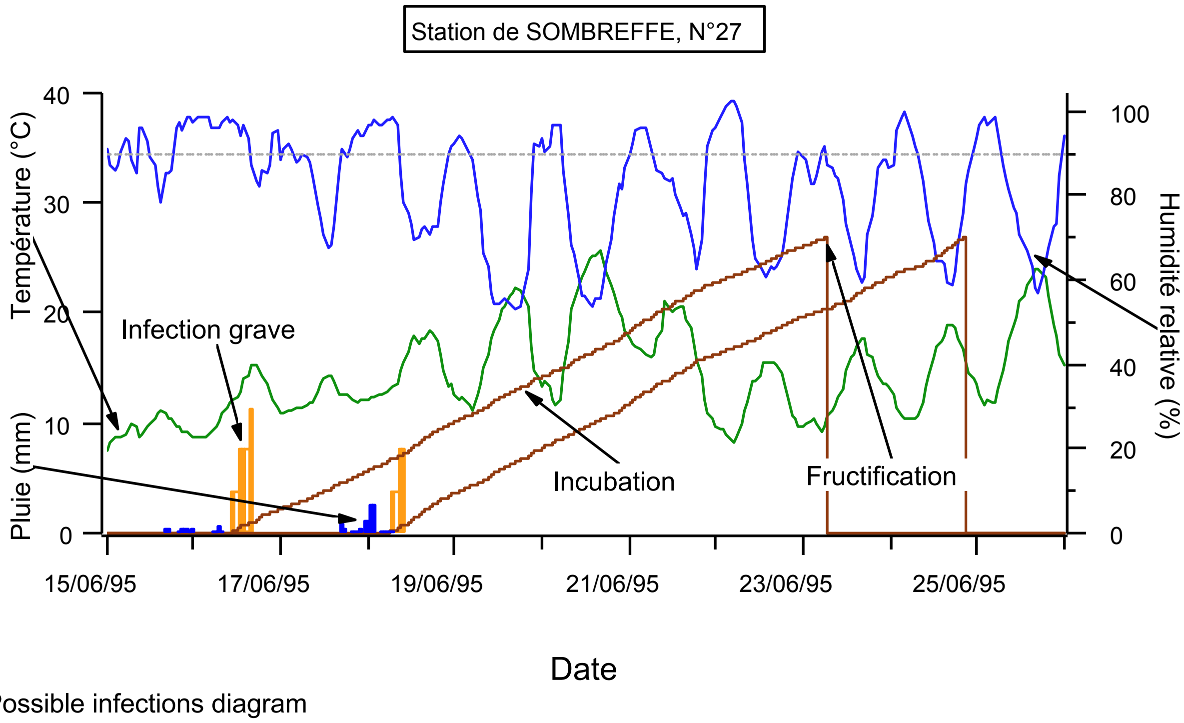


The process of automatic measuring

Potato late blight modelling

In order to make the task of plant pathologists easier and less time-consuming (27 stations are to be analysed each day !) PAMESEB set up the modelling of the evolution of this disease (with the aid of the expert knowledge of Libramont) by designing the computer programme MILDIOU (Potato late blight). This model is based on measured data (RH, temperatures, precipitation) and calculates the possible infections, their seriousness and the incubation evolution curves at the start of each infection, according to GUNTZ and DIVOUX. The data that are processed by the MILDIOU software and the curves representing the relative humidity, the temperature, the amount of precipitation are then visualized in a diagram.

This diagram provides the plant pathologist who is in charge of the warning system with a general picture of the situation at one place and the evolution thereof during some days : it helps him to judge and decide upon the need or absence of need of carrying out a treatment, taking into account the growth stage of the crop and the short term weather forecasts. These forecasts are supplied by the official meteorological services working in Belgium (WING METEO, Institut royal météorologique de Belgique).



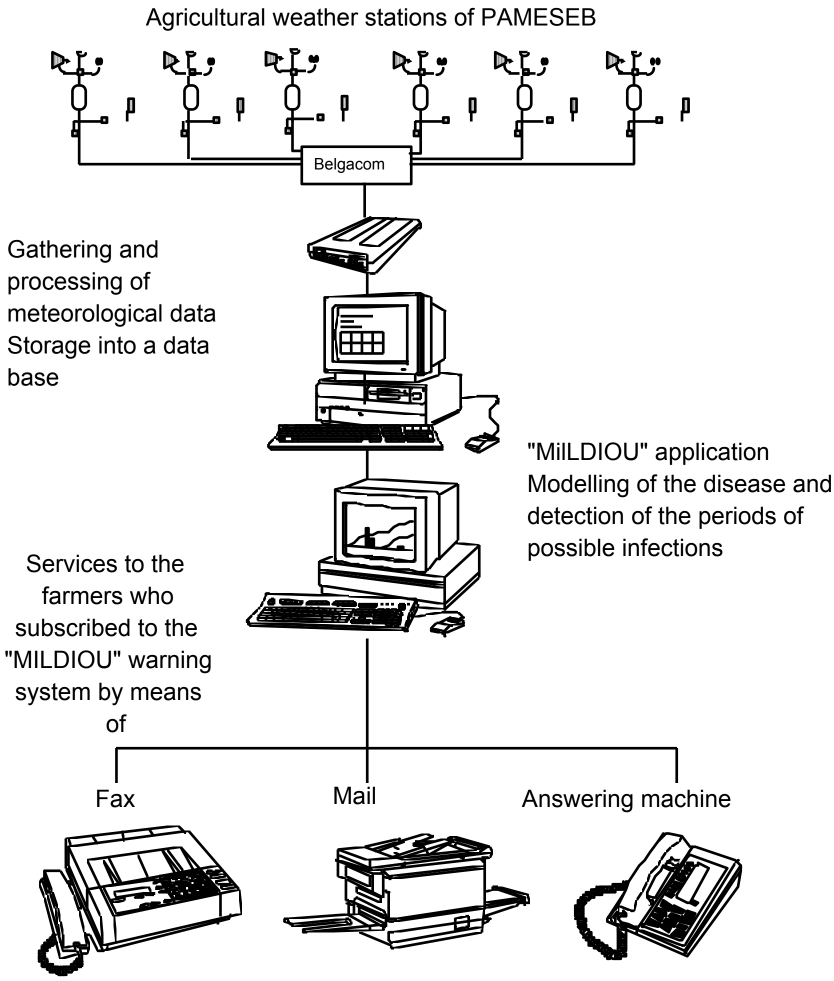
Possible infections diagram

Spreading information

The farmer must subscribe if he wants to have access to the information. The subscription rate varies between 300 and 500 BEF according to his reported area planted with potatoes.

Information is spread in three ways :

- by an answering machine on which has been recorded the information of the day as well as the recommendation with respect to treatment. To have access to the answering machine the subscriber is given a code-number as well as a list of the stations and their telephone numbers where he may get local information.
- by a fax sent to the farm when treatment is recommended.
- by mail, for subscribers who do not have a fax machine.



Further spread of the information

The time schedule of the daily activities required with respect to the Warning System is :

- transmission of the unprocessed data from the local units to the central unit at 5 a.m.
- ratification, storage into the data base
  model defining and graphic representation from 7.30 to 9.30 a.m.

- analysis and decision-making by the plant pathologist for each of the stations from 9.30 a.m. till noon
- deciding on the recommendations till 1.30 p.m.

- the information is recorded on the answering machine as soon as the recommendations have been decided on; if a recommendation for treatment is made the fax messages are made out and transmitted automatically by computer. In most cases the whole operation is accomplished at approximately 3 p.m.

Means of checking
- Reference plots are planted on the land of approximately ten farmers at different places in Wallonia. These plots make it possible to check the efficiency of the warning in each of the areas. In potato crops where classic plant protection schemes are carried out, farmers apply the recommendations made by the Warning system to a part of the area in a very strict way. In this time of geographic extension of the Service the plots also act as an ideal instrument with a view to informing farmers.

- Untreated check plots may possibly enable the expert in charge of the warning to verify the concordance between the possible infection resulting from the model and the actual infection of the fields. The choice of the date of the first treatment may be checked. These check plots also make it possible for the expert to try to improve the system by working out solutions for possible deficiencies of the model (infections in the presence of low temperatures, value attributed to the incubation evolution units according to the temperatures and especially to low temperatures, to recorded average temperature that are higher than those taken into account when defining the model (7 to 18°C, ...).

Conclusions

The Potato Late Blight Warning System set up by the Station de Haute Belgique has become reality in Wallonia and an increasing number of farmers are relying on it. The network of stations established by PAMESEB (a non-profit seeking association) as well as the technical support given with respect to data management and processing have become an essential part of such a large-scale warning system.

In the course of the 1994 season more than 60 messages have been recorded for each of the 27 stations; the answering machine has been called more than 2400 times. According to the station 6 to 9 recommendations for treatment have been spread in this season. The operation was carried out between 27 April and 22 September. In the course of the 1995 season 42 messages have been worded and spread. The operation was carried out from 21 April to 18 September. According to the observation posts 7 to 9 recommendations for treatment have been spread. During the 1996 season 38 messages have been worded and spread as well as 6 to 9 recommendations for treatment, the operation being carried out from 30 April to 11 September.

The response given by the subscribers (approximately 350 in 1996) was positive. The elements that are most frequently put forward in favour of a subscription to the system are:

- the lower number of treatments resulting in considerable savings for large farms (approximately 1,000 BEF/ha/treatment)
- the reliability which appears from the fact that no potato late blight occurred in the fields that were treated in accordance with the recommendations given.

For the plant pathologist in charge the margin of error is however practically zero and all efforts must be made in order to improve and correct possible weaknesses of the system. In this respect the use of new stations on the territory should be considered with an aim to achieving the highest possible representation with respect to weather variability, as well as an improvement of the model, particularly with respect to low temperatures, and the persistence of various fungicides (eluviation due to rainfall, degradation in time).

References

Rigot, N. (1973); La pratique des avertissements de traitements contre le mildiou de la pomme de terre (*Phytophtora infestans*) au poste d'avertissement de Libramont; Revue de l'Agriculture, 26(6): 1391-1414

Fouarge, G., Olivier J. (1979); Les avertissements fongicides et insecticides en pommes de terre, facteurs de fiabilité et d'économie; Revue de l'Agriculture, 32(2) : 439-443

Wijngaert, K., Ampe G., Fouarge G., Meeus P. (1992); Systèmes d'avertissements pour *Phytophtora infestans* en cultures de pommes de terre; Revue de l'Agriculture, numéro hors série 45(6) : 39-49

Persoons, E. (1992); PAMESEB asbl pour la Promotion de l'Agrométéorologie dans le sud-est de la Belgique -Programme de développement intégré 1990-1992; Rapport PDI116

Duvauchelle, S. (1992); Le mildiou de la pomme de terre (*Phytophtora infestans*): aperçu des connaissances; Service Régional de la Protection des végétaux - Fédération Régionale de Défense contre les ennemis des cultures Nord Pas-de-Calais

Harrison, J.G. (1992) Effects of the aerial environment on late blight of potato foliage, a review. Plant Pathology 1992, 41, 384-416

First Workshop of an European Network for Development of an
Integrated Control Strategy of potato late blight
Lelystad, The Netherlands, 30 September - 3 October 1996

6RECENT EXPERIENCES WITH CONTROL OF PHYTOPHTHORA INFESTANS IN THE NETHERLANDS

H.T.A.M. SCHEPERS, E. BOUMA, C.B. BUS & J.K. RIDDER
Research Station for Arable Farming and Field
Production of Vegetables (PAGV),
P.O. Box 430, 8200 AK, Lelystad,
The Netherlands

Abstract
Several aspects that are important in the control strategy of potato late blight (*Phytophthora infestans*) were studied, such as the measurement of weather parameters, the rainfastness of fungicides and the relation between the cultivar resistance and dose rates of fungicides. In the potato crop more hours with a relative humidity above 90% were recorded than 1,5 m above the crop. The rainfastness of a flowable formulation of maneb-fentinacetate was considerably lower than that of a WP formulation of the same active ingredients. In a spray schedule with weekly applications, reductions of 25-50% seem possible in in the highly resistant cultivars Kartel and Aziza. The relevance for inclusion of the results in decision support systems is discussed.

Keywords: fungicides, *Phytophthora infestans*, rainfastness, cultivar resistance, reduced rates

Introduction

In The Netherlands the control of late blight highly depends on the use of fungicides. In 1992 the total input of fungicides in agriculture was 4.2×10^6 kg active ingredient of which 1.8×10^6 kg a.i. was used to control late blight. In the Multi Year Crop Protection Plan goals were set for reductions in the use and dependence of fungicides, and for the emission to the environment. Since control of *P. infestans* requires more than 40% of the total fungicide input, it is important to optimise the control strategy for this disease. The objective of the following research was to investigate several aspects that are important in the control strategy of late blight. In particular the measurement of weather parameters, the rainfastness of fungicides and the relation between the cultivar resistance and dose rates were studied.

Materials and Methods

Measurements weather parameters: In 1994 and 1995 the relative humidity (%) and temperature (°C) were measured in a potato crop (cv Turbo) in Biddinghuizen. During the growing season the relative humidity and temperature were measured with a thermohygrograph in a Stevensons screen placed between the ridges and at 1.50 m above the crop.

Rainfastness fungicides: Potato plants (cv Bintje) were raised in pots and grown under field conditions. Plants were sprayed with fungicides using a laboratory spray track with a spray volume of 250 l/ha. Fungicides used were 0.75 kg/ha Solide (dimethomorph/ fentinhydroxide, 25%/26.6%), 2.5 kg/ha Curzate M (cymoxanil/mancozeb, 4.5%/65%), 2.5 kg/ha maneb-fentinacetate WP (34%/11%) and 2.5 l/ha maneb-fentinacetate Flow (340/110 g/l). Simulated rain was applied to these plants 24 hours after application of fungicides. The rain volume applied was 2 x 5 mm with an intensity of 10 mm h^{-1}, with an interval of 30 minutes between the two rain showers. Leaf samples were taken as soon as plants were dry and treatment effects were evaluated using a bioassay (Schepers, 1997).

Cultivar resistance & reduced rates: Two field experiments were performed: one on clay soil (Munnekezijl) and one on reclaimed peat soil (Valthermond). Each experiment included three cultivars with different ratings of foliar resistance to late blight and three doses of fungicides. The doses used were 100%, 75% and 50% of the maximum recommended dose. The maximum recommended doses and fungicide formulations were 2.5 kg/ha maneb-fentinacetate (maneb/fentinacetate, 33/11%) and 0,4 l/ha Shirlan (500 g/l fluazinam). Fungicides were applied with weekly intervals. The set-up of the trials was the same as described earlier (Bus et al., 1995). Table 1 shows the cultivars at the two locations and their rating for foliage late blight resistance. The level of disease was assessed using the foliar blight assessment key of the Dutch Plant Protection Service (Bus et al., 1995).

Also pot plants grown under field conditions (cvs Bintje, Agria, Aziza) were sprayed with 100% (=2.5 kg/ha), 75% and 50% maneb-fentinacetate WP (34%/11%). The protection of leaflets after 6-14 days after application was assessed using a bioassay.

Table 1. The cultivars used in the experiments, their ratings for foliage blight resistance according to The Netherlands Descriptive list of Cultivars of Field Crops, and the dates of first spraying and haulm killing.

	Location	
	Valthermond	Munnekezijl
Cultivars	Elkana (4.5)[1]	Bintje (3)
	Astarte (5.8)	Agria (5.5)
	Kartel (8.1)	Aziza (7.5)
First spraying	20 June 1996	2 July 1996
Fungicides	maneb-fentinacetate	Shirlan
Haulm killing	10 October 1996	10 October 1996

[1] Resistance to *P. infestans* ranked 2-9; 9 being very resistant and 2 very susceptible.

Results

Measurements weather parameters: In Figure 1 the development of the relative humidity in and above the crop is shown during 24 hours. The data are the average of the measurements of 21 days in 1994 and 24 days in 1995 during cloudy days with low radiation. In the potato crop more hours with a relative humidity above 90% were recorded than above the crop. In many decision support systems the duration of a period with a relative humidity of 90% is included as an important parameter for sporulation. Differences in temperatures were recorded also, but these were not relevant for the development of *P. infestans.*

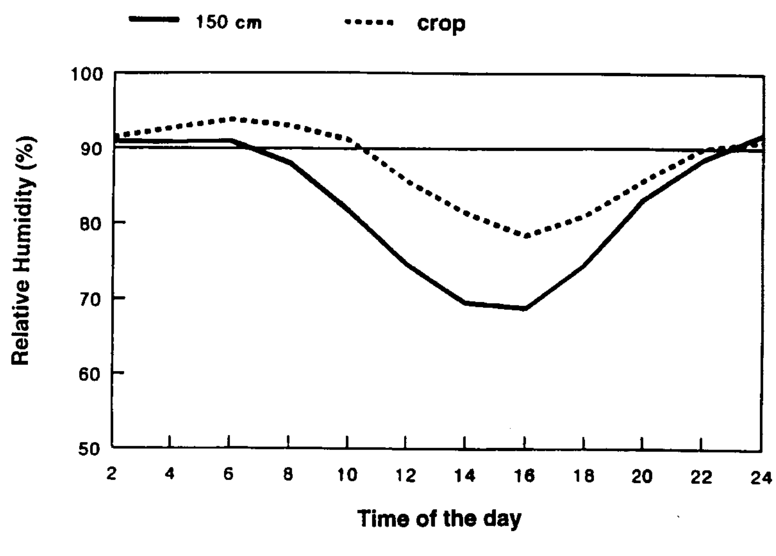


Figure 1. Relative humidity in and above the potato canopy during cloudy days

Rainfastness fungicides: The plants treated with Solide, Curzate M and maneb-fentinacetate WP and subjected to 10 mm of rain after 24 hours, did not show a higher number of infected leaflets than the plants that were not subjected to rain. However, a significant wash-off of the flowable formulation of maneb-fentinacetate was observed. With plants that were not subjected to rain, the number of infected leaflets of plants treated with the flowable formulation of maneb-fentinacetate, was also significantly lower than the number of infected leaflets of plants treated with the other fungicides (Table 2).

Table 2. Percent potato leaflets infected with late blight after application of fungicides followed after 24 hours by 10 mm simulated rain.

Treatment	Potato leaflets infected (%)	
	no rain	10 mm rain
Solide	0 a	2.5 a
Curzate M	0 a	1.3 a
maneb-fentinacetate WP	2.5 a	5.0 a
maneb-fentinacetate Flow	12.5 b	53.8 b

[1] Values in columns followed by the same letter are not significantly different ($p < 0.05$)

Cultivar resistance & reduced rates: In Valthermond the first lesions were observed on 22 August in the untreated plots of cultivar Elkana. On that same day the foliage of all these plots was killed. Treated plots became infected from 12 September onwards (Table 3). Elkana senesced more rapidly than Astarte and Kartel. On 12 September 90% of the leaves of Elkana were already senesced, whereas Astarte and Kartel were still completely green. The epidemic developed slower in cv. Kartel than in cvs Elkana and Astarte. In contrast to cvs Elkana and Astarte there were no significant differences in disease severity in cv. Kartel between the treatments with 100%, 75% and 50% of the recommended dose.

In Munnekezijl the first lesions were observed on 9 September in the untreated plots of the cultivars Bintje and Agria. On that same day the foliage of all these plots was killed. Treated plots became infected from 18 September onwards (Table 4). Despite their different ratings for foliar blight, the disease developed similarly in the cvs. Bintje and Agria. *P. infestans* developed more slowly in the resistent cv. Aziza. In the three cvs. there were only small differences in disease severity between the 100% and 75% treatments. In the 50% treatments of Bintje and Agria the disease severity was clearly higher than in the 75% and 100% treatments.

Two experiments were carried out with pot plants. In the first experiment leaves were detached to test in the bioassay at 7 and 14 days after application, in the second experiment at 6 and 13 days after application. In all three cultivars the leaflets that were detached two weeks after application, had a significantly lower level of protection than the leaflets detached one week after application. The leaflets of Aziza were significantly better protected than the leaflets of Bintje and Agria. The leaflets of Bintje and Agria treated with 100% maneb-fentinacetate tended to have a lower number of infected leaflets than the leaflets treated with a 75% dose. There was also a tendency that the leaflets of Bintje and Agria that were treated with a 50% dose had a higher number of infected leaflets than the leaflets treated with 100% and 75% (Table 5).

Table 3. Infection index of foliar late blight (PD-key) for three application rates of maneb-fentinacetate in 1996 at Valthermond.

Dose	Infection index late blight												
		Elkana		Astarte				Kartel					
	12/9	16/9	23/9	12/9	16/9	23/9	1/10	10/10	12/9	16/9	23/9	1/10	10/10
100%	9.4	9.0	x[1]	9.1	8.3	8.1	7.6	6.5	9.8	9.1	8.6	8.2	7.6
75%	8.9	8.8	x	9.1	8.1	7.7	7.0	5.6	9.5	9.1	8.6	8.1	7.4
50%	8.3	8.0	x	8.8	7.0	6.6	5.9	4.6	9.8	9.1	8.5	8.0	7.2

[1] Elkana was completely senesced

Table 4. Infection index of foliar late blight (PD-key) for three application rates of Shirlan in 1996 at Munnekezijl

Dose	Infection index late blight											
	Bintje				Agria				Aziza			
	18/9	25/9	2/10	10/10	18/9	25/9	2/10	10/10	8/9	25/9	2/10	10/10
100%	9.5	8.1	7.0	6.0	9.5	8.2	6.8	6.0	10	9.0	8.0	7.6
75%	9.3	7.8	6.5	5.5	9.5	8.0	6.4	5.8	10	8.9	7.9	7.6
50%	8.5	7.0	6.0	4.8	8.5	7.1	5.9	4.8	10	8.4	7.6	7.4

Table 5. Percent potato leaflets infected with late blight of cvs Bintje, Agria and Aziza raised as pot plants) that had been treated with 100%, 75% and 50% dose rate of maneb-fentinacetate.

Cultivar	Dose	Potato leaflets infected (%)			
		Experiment 1		Experiment 2	
		7 daa [1]	14 daa	6 daa	13 daa
Bintje	100%	18	45	3	13
	75%	38	80	5	23
	50%	48	88	23	30
Agria	100%	15	58	5	3
	75%	18	58	15	25
	50%	18	98	40	23
Aziza	100%	5	0	0	0
	75%	5	18	0	10
	50%	0	23	0	5

[1] daa: days after application of fungicide

Discussion and conclusions

Weather parameters: The duration of a period with a relative humidity of more than 90% is considered as an important parameter to determine whether *P. infestans* will sporulate or not. In many decision support systems (DSS) the threshold for sporulation is a period of more than 10 hours with a rh>90%. The data on which this threshold is based are derived from investigations in which the relative humidity was measured in the crop (Crosier, 1934) or at 1,50-2 meter in standard meteorological stations (Schrödter & Ullrich, 1967). The results described in this study show that the choice of the position in which the rh is measured, can influence the data considerably. In order to conclude whether the threshold of 90% rh that is included in DSS can be correlated to measurements above the crop or in the crop, more measurements in correlation with crop development are necessary.

Rainfastness: No significant losses of efficacy were observed when plants treated with Solide, Curzate M or Maneb-fentinacetate WP were subjected to 10 mm rain. In previous experiments wash-off of maneb-fentinacetate WP was observed when 10 mm rain was applied 4 hours after application of the fungicide. When plants were subjected to rain 4 days after application, the rainfastness of maneb-fentinacetate was good (Schepers, 1997). The good rainfastness in the experiments described might be caused by the longer drying period of 24 hours compared to the 4 hours in the previous tests. Since the formulation of the maneb-fentinacetate WP was different from the formulations used in the previous tests, it cannot be excluded that this might also have influenced the rainfastness. That formulations can influence the rainfastness considerably was shown by the poor rainfastness of the flowable maneb-fentinacetate formulation when compared to the WP. Kudsk et al. (1991) suggested that with maneb and mancozeb the smaller particle size in flowable formulations is an important factor in the better rainfastness of flowables when compared to wettable powders. In the case of the maneb-fentinacetate formulations tested in this study other formulation ingredients or characteristics seem to be more important than particle size.

Cultivar resistance & reduced rates: Gans et al. (1995) and Bus et al. (1995) showed that an effective blight control with a reduced fungicide input is possible on resistant cultivars. In a spray schedule with weekly applications, reductions of 25-50% seem possible in the highly resistent cultivars Kartel (8) and Aziza (7.5). Spray schedules in which the first spray is only applied when disease is observed in the field or in the region in combination with weekly applications of 25-50% doses and spray schedules that are directed by the DSS Teelt-Plus, are under investigation. The results of the 1996 trials again show that the possibilities for reduction in the moderately resistant cultivars (Agria, Astarte) is limited. In a weekly spray schedule disease control of the 75% dose is similar to that with the 100% dose. When the disease pressure is low it is recommended that in a weekly spray schedule, a 25% reduction of the dose is possible. In integrated farming in The Netherlands, doses are recommended of 75%, 62% and 50% in June/July, when the disease pressure is low, in cultivars with foliage resistance ratings of 3-4, 5-6 and 7-8 respectively. When disease pressure increases, these doses have to be increased to 100%, 80% and 60%, respectively. On a limited number of farms that are intensively visited by extension officers this system has functioned satisfactorily for years already. More experience with reduced rates is necessary before such recommendations can be generalised.

References

Bus, C.B., Ridder, J.K. & H.T.A.M. Schepers. 1995. Experimenting with lower doses of fungicides to prevent late blight in potato cultivars of different susceptibility in The Netherlands. In: Phytophthora 150, L.J. Dowley et al. (eds). Proceedings of EAPR Pathology Section Conference, Dublin 1995: 351-356.

Crosier, W. 1934. Studies in the biology of *Phytophthora infestans* (Mont.) de Bary. Cornell Univ. Agric. Exp. St. Memoir No. 155: 40 pp.

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

Kudsk, E., S.K. Mathiassen & E. Kirknel. 1991. Influence of formulations and adjuvants on the rainfastness of maneb and mancozeb on pea and potato. Pesticide Science 33: 57-71.

Schepers, H.T.A.M. 1997. Effect of rain on efficacy of fungicide deposits on potato against *Phytophthora infestans* . Potato Research (in press).

Ullrich, J. & H. Schrödter. 1966. Das Problem der Vorhersage des Auftretens der Kartoffelkrautfäule (*Phytophthora infestans*) und die Möglichkeit seiner Lösung durch eine “Negativprognose”. Nachrichtenblatt des Deutschen Plfanzenschutz-dienstes 18: 33-40.

.

First Workshop of an European Network for Development of an
Integrated Control Strategy of potato late blight
Lelystad, The Netherlands, 30 September - 3 October 1996

EXPERIENCES WITH LATE BLIGHT WARNING SERVICE IN FLANDERS

7M. GOEMINNE, P. VANHAVERBEKE (*), G. AMPE (**)
(*) PCA – Karreweg 6, B-9770 Kruishoutem, Belgium.
(**) PCA – Ieperseweg 87, B-8800 Rumbeke-Beitem, Belgium.

Abstract

The PCA – Centre for Applied Potato Research – in Flanders (Belgium) started in 1993 with a warning service for potato late blight, providing advice throughout the growing season on optimal time of application and type of fungicide to be used. In 1996 the advices were sent either by mail or by fax to almost 700 farmers, together cultivating about 13500 hectares of potatoes. The PCA warning service makes use of the disease forecasting model of Guntz-Divoux, developed in France and modified in Libramont-Ath (Belgium). To record the necessary meteorological data, the PCA employs a network of 24 automatical weather stations. The theoretical disease model is further complemented with information on actual blight pressure, development stage of the crop and the weather forecast before an advice is drafted. The basic priciple of blight control in the Guntz-Divoux model consists of spraying shortly before the emergence of lesions of a previous infection. The warning service also provides advice on the most suitable type of fungicide to be used with each application. To that aim, the available fungicides are arranged into 5 functional groups. Field trials concerning the control of late blight are carried out every year on several locations. The purpose of these trials is to check the accuracy and security of the advices, as well as to determine to what extent the number of fungicidal applications can be reduced. Finally, an anonymous poll is conducted by the PCA at the end of each growing season in order to gauge the opinion of the farmer, and the impact of the warning service on his current practice.

Special PAGV-report 1. (1996), 52-60

Introduction

The PCA is an independent organisation which aims to support and improve potato cultivation in Flanders (Northern part of Belgium) through applied research and extension. Established in 1992 as a cooperation between the Provinces of West- and East-Flanders, which together account for approx. 30 000 ha of potatoes, its extension now reaches the whole region of Flanders where about 37 000 ha of potatoes are grown or 67 % of the total area in Belgium.

In 1993 the PCA started with a potato blight warning service, providing advice to its members (mostly potato growers) on optimal time of application and type of fungicide for spraying against late blight during the growing season. Before, a similar service for timing of the first spraying already existed since 1978 in the Provincial Centre for Agriculture and Horticulture (Potato Department) in Beitem, West-Flanders. The warning service was further developed in the following years with the support from the Ministry of Agriculture and the European Union, in close cooperation with the "Centre de Recherches Agronomiques" in Libramont and the "Bureau d'Economie Rurale" in Ath, both in the Walloon region.
In 1994 the written advices were sent to about 300 farmers, together cultivating about 5000 ha of ware-potatoes (mostly of the variety Bintje); in 1995 and ‘96 the advices were sent either by mail or by fax to almost 700 farmers, covering approx. 13500 hectares of potatoes.

Methods

Model description

The PCA warning service makes use of the disease forecasting model of Guntz-Divoux, developed in France and modified in Libramont-Ath (Belgium). This model calculates the theoretical development of the disease based solely on weather data, measured at a standard level of 1.50 m. The basic rules of the disease model are as follows:

- A chance of infection occurs when at least 10 ½ consecutive hours with a relative humidity of more than 90 % are measured ; an interruption of this 'humid period' of no more than 4 hours with a relative humidity of more than 70 % is also considered 'humid'. The average temperature of the humid period should be at least 7 °C in order for the infection chance to come about.
- Chances of infection are classified according to their severity: ranging from 0 (no chance of infection) to 4 (very severe chance of infection).

- The incubation or growth of mycelium in the plant's tissue is determined by the mean day temperature (calculated as (T° max + T° min)/2)). Each day a unit of development ranging from 0 to 1.5 is calculated. The fungus emerges at the underside of the leaf at reaching a total of 7 development units after initial infection. The emergence is visible as necrotic lesions on the leaf or stem surface ; on these spots new spores can be produced depending on weather conditions.
- A disease cycle in the model comprises: germination of a spore, penetration in the plant, incubation, emergence at the underside of the leaf and formation of new spores. These cycles are further grouped into disease generations. If during a cycle a new chance of infection occurs *before* emergence, then this new cycle belongs to the same disease generation. If however a new chance of infection comes about *after* emergence of the previous cycle, then a new generation starts: the large amount of spores which are formed on the spots of the previous cycle are able to germinate and penetrate healthy plants during the favorable conditions of this new infection, leading to a strong multiplication of the disease. If successive generations are closely linked, then a very strong development of the disease is possible.

Meteorological data

The PCA has moved from using manually operated thermohygrographers in 6 locations (seasons of 1993, '94 and '95) to a network of 24 automatical weather stations (Mety) to record the necessary meteorological data. Registered hourly data include relative humidity, temperature, leaf wetness and precipitation. These records are transmitted every morning via modem to the PCA office in Kruishoutem and subsequently processed according to the rules of the Guntz-Divoux model, to determine daily chance of infection and incubation rate for each location.

Crop data and other inputs

The theoretical disease model is further complemented with information on:

- growth stage of the crop,
- actual appearance of late blight on refuse piles, in fields or backyards (assessment of primary inoculum or blight pressure),
- cumulative precipitation since previous application of fungicide,
- weather forecast,

and eventually an advice is drafted for timing of application (if any) and type of fungicide to be used.
This advice has a regional character but the timing of application can vary, depending on the location of the weather station.

Implementation

Timing of applications

The basic principle of control of the disease in the Guntz-Divoux model consists of spraying shortly before emergence of the lesions of a previous infection. This way, healthy leaves are protected from infection by the spores which could possibly be formed on these lesions.

After registering a theoretical chance of infection (it is always assumed that inoculum is present) in a weather station on a given day, the development of the fungus in the plant's tissue is tracked and the date of emergence is predicted based on the weather forecast (mean daily temperature). The optimal timing of application is shortly before this date of emergence: spraying too late means that the crop is unprotected against the large amount of new spores which could be formed on the lesions upon emergence ; spraying too early however means that newly formed leaves between application and emergence of the fungus are not protected.
Besides advices based on this principle, other types of advice can be sent to the farmer during the course of the season, e.g. if cumulative precipitation as measured at the weather station has washed off the fungicides of a previous application.

Not all advices require the spraying of a fungicide. Moreover, the close spacing both in time and geografically of very early crops (grown under cover), early varieties, seed potatoes and maincrop varieties (mostly Bintje) in Flanders is not making the task of a warning service any easier. The first advices for spraying are aimed only at the very early and early cultures.
As a rule, the first application for maincrop fields is advised shortly before the end of incubation of the second disease generation for that field, that is the second disease generation recorded after emergence of the plants in that field or its neighborhood. This implies that the location of the field is important with regard to date of first application: if early varieties are grown in the proximity (< 500 m) of the field then the disease could already have developed in that field before emergence of the maincrop. The same goes for refuse piles and backyard gardens situated near maincrop fields.

Type of fungicide

The warning service not only provides advice on optimal timing of applications but also on the most suitable type of fungicide to be used in the prevailing conditions. To that aim, the available fungicides are arranged into 5 functional groups by the PCA. The most important criteria for this subdivision are:

- uptake by the plant or not
- retroactive effect after infection
- rainfastness
- the degree of protection against tuber infection
- risk of developing resistance

Based on these criteria, the following groups of fungicides are formed for the use of the warning service:

♦ **Fungicides not taken up by the plant (protectant or contact fungicides):**

Group 1:	without tuber protection (maneb, mancozeb, copperderivates, chlorothalonil...)
Group 2:	with better protection of the tubers (fluazinam, organotins)

♦ **Fungicides that are taken up by the plant:**

Group 3:	without retroactive effect after infection (propamocarb)
Group 4:	with retroactive effect up to 1.5 incubation-units after infection (cymoxanil, dimethomorph)
Group 5:	with retroactive effect up to 2.5 incubation-units after infection (phenylamides)

Validation

Method

In order to assess the advices given with the warning service, to enhance their accuracy and raise the confidence of the farmers, field trials concerning the control of late blight with cv. Bintje are carried out every year on several locations. The purpose of these trials is to check the accuracy and security of the advices as well as to determine to what extent the number of fungicidal applications can be reduced. To that aim, sprayings considered not strictly necessary are omitted, to find out to what degree this raises the risk of blight infection. Part of the trial is sprayed only with the minimal number of applications considered necessary for effective blight control. Another part of the trial is left unprotected to compare theoretical chances of infection according to the Guntz-Divoux model with actual appearance of late blight infections, and to assess blight pressure in the vicinity of the field.

Spraying on advice of the warning service is also compared to weekly routine applications of fungicides. These weekly sprayings are carried out with a 100 % dose (according to product label) and in turn compared to applications with a dosage of 75 % and 50 %.

Results and discussion

In ‘94, ‘95 and ‘96 sprayings in accordance with advice proved effective. Spraying the minimal number of applications also gave satisfactory protection, taken into account the exceptional high disease pressure on the field due to blight in the unprotected plots.

Field trials in Kruishoutem on late blight control (var. Bintje) with the PCA warning service:

Year	Total number of advices	Number of sprayings on maincrop in accordance with advice	Number of weekly sprayings in same period	Minimal number of advice sprayings	Blight pressure
1994	17	8	11	4	moderate in june, high towards end of august
1995	20	12	13	8	very high during first half of june
1996	17	9	12	6	exceptionally low

Using a lower dosage for the weekly applications can only be done under conditions of very low blight pressure. In a season or spell of higher diasease pressure, the degree of foliage blight was proportionate to the dosage reduction.

Impact of the warning service

The merit of a warning service is ultimately determined by its end-user, the potato grower: what do the advices imply for him, what is their influence on his current practice of spraying and how can the warning service be improved according to him? In order to gauge the opinion of the farmer, the PCA conducts an anonymous poll at the end of each growing season. The response to this opinion poll is very good. Some of the results are discussed below:

- For 78 % of the growers, the current practice of spraying consists of applications with a narrow or wider interval depending on prevailing weather conditions, whereas 17 % preferes routine weekly sprayings.

- As greatest merit of the warning service is mentioned by the growers:
  - 52 % It is a great support and provides a firmer grip on blight control.
  - 14 % The advices determined my schedule of sprayings.
  - 11 % I gained more insight in the fungus' disease cycle and epidemiology.

8 % It allowed me to have an effective blight control at lower cost.

- The requirements which a warning service should meet – assuming it already prevents the development of blight in the fields – are arranged by the farmers as follows (in order of importance):
  1. Give advice for a cheaper blight control by making better use of the protectant fungicides.
  2. Give advice for a cheaper blight control by reducing the number of sprayings.
  3. Provide more insight in the fungus' disease cycle and epidemiology.
  4. Lead to a more environmentally friendly blight control.

- Not less than 88 % of the users declared that the advices incited them to control their fields more frequently and more thoroughly.

- The distance between their field and the nearest weather station is less than 25 km for 79 % of the growers. The majority of them however expresses the feeling that this distance should be at most 20 km to retain enough confidence in the warning service.

- Spraying according to the advices of a warning service does not raise difficulties for the work-planning (92 % of the growers).

- Finally, 91 % of the farmers expresses interest in an advice system with minimal number of applications, and would like to be informed about it by the warning service.

References

Ampe, G., Goeminne, M. : Jaarverslag PCA 1993: Proefveldresultaten : hoofdstuk 4 Aardappelziekte (*Phytophthora infestans*), p. 23-32

Duvauchelle, S., 1992: Le mildiou de la pomme de terre, *Phytophthora infestans*: Aperçu des *connaissances*

Vanhaverbeke, P., Ampe, G., Goeminne, M. : Werkgroep Akkerbouw Vlaanderen: resultaten oogst 1994 aardappelen : p. 60-67

Vanhaverbeke, P., Ampe, G., Goeminne, M., De Temmerman, L.: Werkgroep Akkerbouw Vlaanderen: resultaten oogst 1995 aardappelen : p. 67-76

First Workshop of an European Network for Development of an
Integrated Control Strategy of potato late blight
Lelystad, The Netherlands, 30 September - 3 October 1996

THE CURRENT STATUS OF PHENYLAMIDE RESISTANCE IN *PHYTOPHTHORA INFESTANS* IN NORTHERN IRELAND

L. R. COOKE[1,2], G. LITTLE[1] & D. J. CARLISLE[2]

[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, Northern Ireland, BT9 5PX, UK.8

Abstract

Since 1981, the incidence of phenylamide-resistant *Phytophthora infestans* has been surveyed annually using isolates derived from samples of potato blight collected mainly from seed crops throughout the potato-growing areas of Northern Ireland. The percentage of isolates containing resistant strains peaked at 90% in 1988, but has declined in every year since 1989 (except 1992) and was 27% in 1996. Detailed sampling of 20 crops in 1996 showed that most yielded only phenylamide-sensitive isolates. The selection pressure in favour of phenylamide resistance has been reduced compared with the situation in the mid 1980s, since now those growers who apply phenylamides mostly only use one or two applications per season. Formulations containing phenylamides continue to play a useful role in late blight control in Northern Ireland.

Keywords: *Phytophthora infestans*, potato late blight, fungicide resistance, phenylamide

Introduction

In 1978, a co-formulation of metalaxyl with mancozeb was introduced to the UK market for the control of potato blight. Phenylamide-resistant *Phytophthora infestans* was first detected in Northern Ireland two years later in isolates from blighted tubers of the 1980 crop (Cooke, 1981).

Special PAGV-report 1. (1996), 61-68

In Northern Ireland, between 1978 and 1993, potato blight control relied mainly on two types of formulations, those based on mancozeb alone and those containing a phenylamide plus mancozeb, with fentin-based formulations being used at the end of the spray programme. In 1994, formulations containing three fungicides, new for potato blight control, received UK approval. These were propamocarb and dimethomorph (both formulated with mancozeb) and fluazinam. This has widened the fungicide groups available for potato bligh control.

Phenylamide resistance has been monitored since 1981 (Cooke, 1986). In the late 1980s, resistant strains were detected in the majority of isolates tested (Cooke & Penney, 1992), but in the 1990s, the proportion containing resistance declined (Cooke & Swan, 1994). Here, surveys for the years up to 1996 are reported together with results from detailed sampling of selected crops in 1996.

Materials & Methods

Sampling of potato crops for blight - general survey

Samples of infected potato foliage together with data on sample site, potato cultivar, fungicide usage and disease incidence were obtained (mainly from seed crops) by members of the Department of Agriculture's Potato Inspection Service, as previously described (Cooke & Penney, 1992). Isolates were derived by bulking together the sporangia obtained from all foliage samples within a single crop. At the end of each season, Inspectors provided estimates of fungicide usage for all seed potato crops in their areas.

Detailed sampling of selected potato crops, 1996

Twenty potato crops in which infection was moderately widespread were identified from the potato-growing areas of Cos. Antrim, Down and Londonderry. Individual lesions were sampled (from stems or leaves) and isolates derived from these tested separately for phenylamide resistance.

Tests for phenylamide resistance

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

Results

Fungicide usage on seed potato crops

Potato Inspectors' estimates of the types of fungicide formulation applied for most of the season on seed potato crops for three selected years are shown in Table 1. In 1987, formulations containing phenylamides were used on over 60% of seed crops, but by 1991 usage had declined to 10% with most crops being treated with mancozeb alone. In 1995, although over 60% of crops received mancozeb alone, 14% were phenylamide-treated and the proportion treated with other product types had increased, with fluazinam being the most widely used of the newer fungicides.

Considering crops which had received phenylamide treatments at any time during the spray programme, in recent years 30-40% have been so treated (Fig. 1; data for 1996 not yet available). However, the majority of these crops received only one or two phenylamide treatments (Table 2).

Table 1. Fungicide usage on seed potato crops for most of the season.

Fungicide type	Year		
	1987	1991	1995
mancozeb alone	23	84	63
phenylamide	62	10	14
other	15	6	10
fluazinam	0	0	13

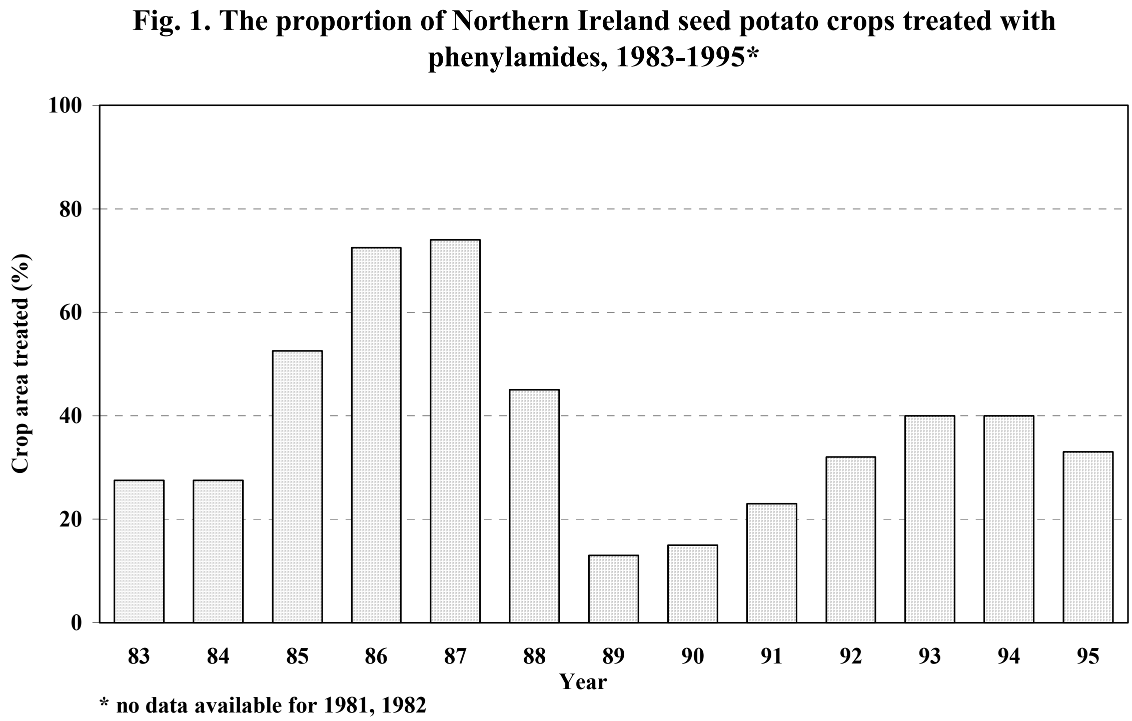


Fig. 1. The proportion of Northern Ireland seed potato crops treated with phenylamides, 1983-1995*.

Table 2. Number of applications used by seed potato growers applying phenylamides, 1992-1995

Number of phen-ylamide applications	Of growers using phenylamides (%) 1992	1993	1994	1995
one	34	25	33	33
two	24	27	29	18
three	30	23	26	25
four	9	18	9	17
five +	4	7	3	7
% growers using phenylamides	26	44	42	38

Fig. 2. The proportion of Northern Ireland *Phytophthora infestans* isolates containing phenylamide-resistant strains, 1981-1996

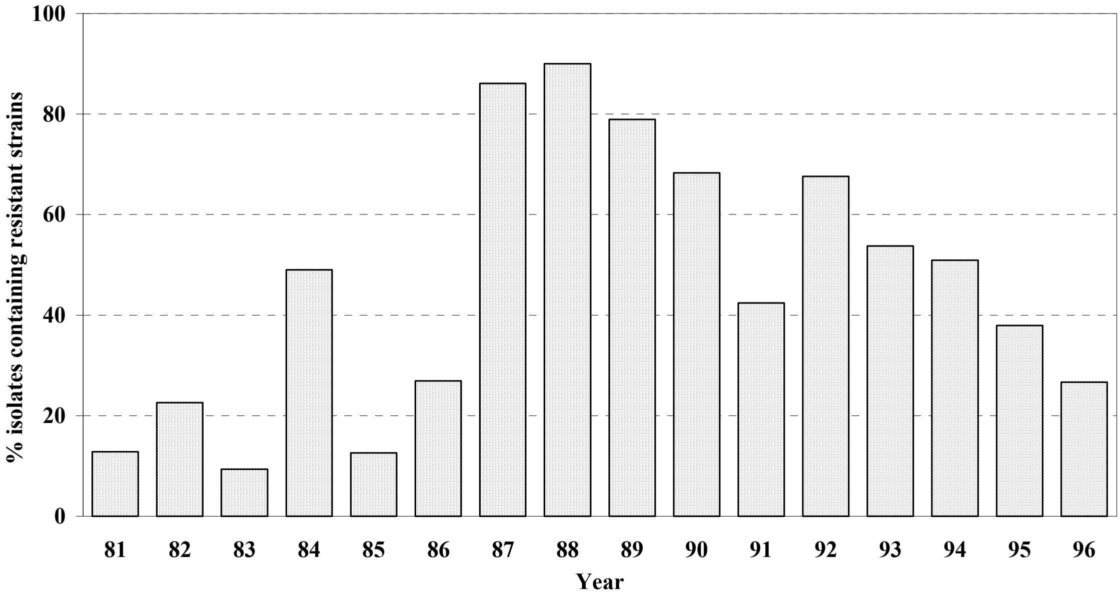


Fig. 2. The proportion of Northern Ireland *Phytophthora infestans* isolates containing phenylamide-resistant strains, 1981-1996.

Incidence of phenylamide resistance

The overall proportion of isolates containing phenylamide-resistant strains of *P. infestans* for the years 1981-1996 is shown in Fig. 2. In 1988, a peak of 90% of isolates containing resistance was reached, but since 1989 the proportion has declined in every year except 1992. In 1996, isolates from 45 different crops were tested, and of these, 11 (27%) contained resistant strains.

When product usage on sampled crops was examined, it was found that those which had received phenylamide applications tended to have a greater proportion of isolates containing resistant strains, but that even crops where only protectant fungicides were used or where no fungicide had been applied often yielded resistant strains (Table 3).

Table 3. Fungicide usage on potato crops sampled for phenylamide resistance survey, 1991-1996

Crop treatment	% crops with resistant strains					
	1991	1992	1993	1994	1995	1996
no phenylamide	29	57	43	36	33	25
phenylamide	65	88	63	81	60	75
all crops*	42	68	54	51	38	27

* includes untreated crops and those where fungicide usage is not known

The incidence of phenylamide-resistant *Phytophthora infestans* within crops, 1996

In the 20 crops selected for detailed sampling in 1996, a greater percentage of isolates from Co. Londonderry than from Cos. Antrim and Down contained resistant strains (Table 4). Fourteen different cultivars were represented in the 20 crops. In 15 crops, all isolates were phenylamide-sensitive, in two all were phenylamide-resistant, while in the remaining three crops a mixture of phenylamide-resistant and phenylamide-sensitive was found.

Table 4. Potato crops sampled in detail, 1996

County	No. of sites (isolates)	Cultivars	Phenylamide resistance by site	%
Antrim	6 (44)	British Queen, Dunbar Rover, Dunbar Standard, Dundrod, Kerr's Pink, Saxon	5 sites 100% S 1 site 5/6 R	11.4
Down	10 (69)	Arran Banner, Cultra, Désirée, Kerr's Pink, Record, Rooster	8 sites 100% S 1 site 1/6 R 1 site 6/6 R	10.1
Londonderry	4 (25)	Kerr's Pink, Pentland Dell, Pentland Ivory, Red Gem	2 sites 100% S 1 site 1/7 R 1 site 6/6 R	28.0

Discussion

In the mid-1980s, 50-70% of the seed crop area was treated with phenylamides and crops often received five or more applications per season. In the 1990s, a substantial proportion of growers appear to be adhering to the Department of Agriculture recommendations for potato blight control (Cooke & Little, 1996). Currently, these are:

- Start the programme with 2-3 applications of a product containing a systemic fungicide (either a phenylamide of propamocarb)
- Continue with a formulation containing either a translaminar fungicide (cymoxanil, dimethomorph) or a protectant alone (e.g. fluazinam, mancozeb)
- Complete the spray programme with at least two sprays of a fentin-based formulation (unless fluazinam has been used for most of the programme and the crop has remained blight-free).

Although phenylamides are used on 30-40% of seed crops, most of these receive only one or two applications in the early part of the season, other product types being used for the remainder of the programme. A greater diversity of fungicide types available for potato blight control has also helped to reduce the selection pressure in favour of phenylamide resistance.

Detailed sampling of crops in 1996 showed that a substantial proportion yielded only phenylamide-sensitive isolates. This contrasts with 1990, when six crops were sampled in detail and all yielded a mixture of phenylamide-resistant and phenylamide-sensitive isolates with five out of six having more than 50% of isolates resistant (Cooke & Penney, 1992). These findings reflect the different overall proportion of isolates containing resistant strains in these two years, with the figures for 1990 and 1996 being 68% and 27%, respectively.

Considering the incidence of phenylamide-resistant *P. infestans* together with the results of field evaluation of fungicide formulations against late blight in Ireland (Cooke *et al.* 1995), it is concluded that formulations containing phenylamide fungicides continue to have a useful role in blight control in Northern Ireland. Restricting their use to a limited number of sprays in the early part of the season appears to have decreased selection for phenylamide resistance. A strategy such as that adopted in some other European countries, where phenylamides are only recommended when there is a high blight pressure, would be inappropriate for Northern Ireland. The changeable weather and frequent prolonged periods of rain would inevitably result in curative phenylamide use, which is specifically prohibited by the Fungicide Resistance Action Group strategy (Urech & Staub, 1985) and by UK phenylamide product labels.

Acknowledgements

The authors thank members of the Department of Agriculture's Potato Inspection Service for supplying samples of potato blight and crop information. Mr. D.G. Wilson and students of the Queen's University of Belfast are thanked for technical assistance.

References

Cooke, L.R. (1981) Resistance to metalaxyl in *Phytophthora infestans* in Northern Ireland. 1981 British Crop Protection Conference - Pests and Diseases, **2**, 641-649.

Cooke, L.R. (1986) Acylalanine resistance in *Phytophthora infestans* in Northern Ireland. 1986 British Crop Protection Conference - Pests and Diseases, **2**, 507-514.

Cooke, L.R., Dowley, L.J., Little, G. & O'Sullivan, E. (1995) Efficacy of fungicide programmes for the control of late blight in Ireland. In *Phytophthora infestans.* Eds. Dowley, L.J., Bannon, E., Cooke, L.R., Keane, T. & O'Sullivan, E. Boole Press, Dublin. pp. 177-184.

Cooke, L.R. & Little, G. (1996) Blight control reminder for potato growers. Farm Trader, Issue 1, p. 24.

Cooke, L.R. & Penney, R.E. (1992) Phenylamide resistance in *Phytophthora infestans* in Northern Ireland - a changing situation. 1992 Brighton Crop Protection Conference - Pests and Diseases, **1**, 201-206.

Urech, P.A. & Staub, T. (1985) The resistance stragey for acylalanine fungicides. EPPO Bulletin, **15**, 539-543.

First Workshop of an European Network for Development of an
Integrated Control Strategy of potato late blight
Lelystad, The Netherlands, 30 September - 3 October 1996

COMPARISON OF DIFFERENT PREDICTION CRITERIA FOR THE FIRST OCCURRENCE OF POTATO LATE BLIGHT IN NORTHERN ITALY

R.BUGIANI, P.GOVONI, L.COBELLI
Centrale Ortofrutticola Cesena
c/o Osservatorio per le Malattie delle Piante (Plant Protection Service) -
Via Corticella, 133 - 40129 Bologna (Italy)9

Abstract

Potato late blight in the north of Italy represents the most dangerous disease. Epidemiological surveys confirmed that the disease does not occur every year but many chemical sprays are routinely applied by farmers without taking into consideration the real blight risk. This preliminary evaluation aimed to compare different potato late blight forecasting models currently used in Europe. Primary blight occurrence prediction models of Smith, Schrödter & Ullrich, NEGFRY, BLITECAST, Winstel and I.P.I. were validated over 3 years (1994-1996) in potato growing areas of northern Italy. Results showed that in italian potato growing areas, I.P.I. and Smith's criteria correctly predict the first blight occurrence in field in 100% of the cases examined. Nevertheless, while the former proved to reduce the number of chemicals in years unfavourable to blight development up to 50%, the latter recommended the first spray very early (1 month before the real blight onset in field) therefore failing to reduce the chemicals applied. Among the other prediction models tested, Guntz-Divouz and Winstel proved to be the most promising because of their low percentage of failure and good spray reduction.

Keywords: *Phytophthora infestans*, Late blight, Potato, Forecasting models

Introduction

In Italy potato crop covers roughly 86,400 hectars and produces averagely more than 20,000 t. of tubers. Potatoes are mainly grown in the south of Italy with early cultivars for export; other potato-growing areas are also in the central and northern part of the country. Different climatic conditions characterizing our country may allow potato crop to have an almost continuos growing cicle over the year. Generalization about all the different phytosanitary problems are not possible but late blight is with no doubt the most dangerous and feared disease in all the environments where potato is cultivated. Emilia Romagna region located in the Po Valley may well represent the tipical potato-growing area of the north of Italy. Here, blight epidemics do not occur every year, vary a lot either in incidence and severity and mainly affect the canopy while on the contrary, symptoms on tubers may be considered a rare event. Besides, most of the potato cultivars grown in Italy are scarcely resistant to late blight (Table 1) and therefore disease control is based mainly on repeated chemical applications throughout the growing season (av. 5-6 sprays per season). Chemical applications usually starts depending on potato crop phenology, calendar date and on farmer's feeling of blight risk. Further treatments are schedully applied or based on precipitations in cases where more evoluted farmers are involved. The interval between a spray and the other depends on type of fungicide used (averagely 8-10 days).

The region has a long tradition in IPM techniques. A regional project to diffuse them was lanched early in the '70 and now transformed in Integrated Production with the aim to improve the quality of the product and consumer health reducing the number of chemical applications in the agricultural environment. One of the most promising tools to rationalize the disease control strategies is represented by the use of forecasting models. With this respect, Emilia Romagna region put several efforts to develope the negative prognosis I.P.I. forecasting model for the prediction of the first occurrence of late blight on tomato, undoubtedly the economically most important crop of the Country. Nowadays, the I.P.I. model is used in north and central Italy and allowed farmers to reduce 30 to 50% of chemical applications on tomato specially in those year not climatically favourable to the disease. The previous experience on tomato late blight made us aware that a considerable saving of chemical applications could be more easily achieved trying to time the first spray as close to the first disease onset as possible.

Table 1. Potato crop in Italy: hectars, cultivars and relative blight susceptibility (Dutch classification) in Italian potato growing regions. Most commonly grown varies are written in bold characters.

Regions	Hectars	Fresh market	Industrial processing	Late blight susceptibility (Dutch classification)	
				leaves	tubers
PUGLIA	11564	Spunta		5	5
SICILY	6821	Mondial		4.5	7
SARDINIA	2874	Nicola		4.5	8
		Sieglinde		-	-
		Timate		5	8
CAMPANIA	17265	Alcmaria		2.5	7
CALABRIA	8864	Jaerla		2.5	6
		Aminca etc.		3	8
			Agria	5.5	7
			Lady Rosetta	3	6
LAZIO	6278	Monalisa		4	6
TUSCANY	2517	Jaerla		3	8
		Spunta		5	5
		Liseta		2	7
		Agata		-	-
EMILIA-ROMAGNA	6570	Primura		2	5
VENETO	3777	Monalisa		4	6
PIEMONTE	3296	Agata		2	7
		Lutetia		2	6
		Liseta		2	7
ABRUZZO	6235	Desiree		5	7
		Avanti		4	8
			Agria	5.5	7
			Asterix	5	8.5

Total: 76061 ha (88% of the potato growing area in Italy (data ISTAT 1994)

In the present work, a validation of the I.P.I. model on potato over the years 1994-1996 and a preliminary comparison of different forecasting criteria most widely used for the prediction of the first blight occurence on potato are reported.

Materials & Methods

The validation of several forecasting models for the prediction of potato late blight was carried out over three years, from 1994 to 1996 in three provinces of northern Italy. All the localities were choosen because of their strategical position within some important potato growing areas. In particular, 9 stations (Altedo, Castenaso, Minerbio, Budrio, Molinella, Castel S.

Pietro, Crevalcore, S. Giovanni Persiceto, Longara) of Bologna district in Emilia-Romagna region, 2 stations (Venturina, S.Vincenzo) of Livorno district in Tuscany region, 3 stations (Fiume, Spilimbergo, Zoppola) of Pordenone district in Friuli Venezia Giulia region (Fig 1).

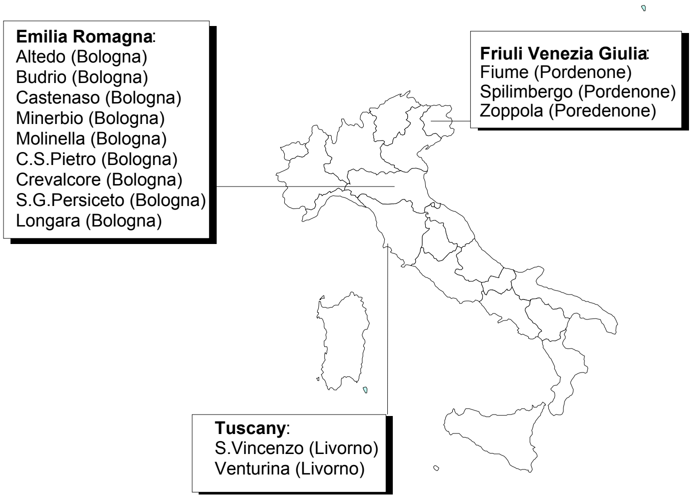


Fig. 1. Distribution of unsprayed potato plots and weather stations.

In the first year's validation only 3 stations in Bologna district were choosen, while in 1995 and 1996 the number of stations was increased to 8 and 10 respectively.

Each station consists of an unsprayed guard plots measuring approximately 100 sqm placed within potato plots belonging to private farms. Potato unsprayed guard plots were sown with cultivars most frequently grown in the north of Italy and particularly susceptible to late blight infection, namely Primura, Monalisa, Lutetia. No fungicide applications were carried out on potato plots until the occurrence of the first symptoms of the disease on the canopy. Subsequent fungicide sprays were applied following a calendar date. On the contrary, insecticides and fertilizers were routinely applied to prevent the plots from pest attacks and physiological stresses.

Hourly meteorological data of temperature, relative humidity and rainfall were provided by automatic weather stations belonging to either private associations (Bologna province) and regional meteorological services (Livorno and Pordenone provinces). Such weather stations used for the validation have their sensors placed at 2 m above the ground and are located within a range of few meters to 5 km maximum from the unsprayed guard plots.

Potato growing season in the north of Italy lasts approximately four months, from April to July. Since crop emergence (80-85% of emerged plants) usually occurring the first week of April, unsprayed potato guard plots are constantly scouted in order to monitor the first symptoms of the disease on the canopy and therefore determine the date of the first blight onset in the field. Field scouting were carried out weekly during the first potato growth stages and every 3 days during the periods of blight risk as dictated by each forecasting models and crop growth stage favourable for the infection.

After file translation, weather data were transferred to PC so as to elaborate the information of blight risk threshold provided by each forecasting model, compare it with the date of the real first blight onset and quantify the model's advance or delay prediction. Blight first occurrence prediction criteria of BliteCast (Krause et al., 1975), Guntz-Divoux (Duvauchelle, 1991), IPI (Bugiani et al., 1993), Smith (1956), Winstel (1992), Neg-Fry (Hansen, 1995) and Ullrich & Schrödter (1967) were validated using Microsoft Excel and Visual Basic.

Results

Late blight occurrences in the potato unsprayed guard plots of Northern Italy used for model validations showed that the disease pressure in our environments varies a lot from year to year.

1994 can be climatically considered unfavourable for disease development since only one blight onset (in Castenaso station on may, 31) was recorded throughout the potato growing area in Bologna province. On the contrary, 1995 and 1996 were at risk for blight development because of the several blight occurrences in all the potato growing areas of northern Italy (Fig 2).

Besides, it is interesting to note that the first symptoms of the disease were not recorded before 50 days from crop emergence calculated as 80-85% of emerged plants and corresponding to the full canopy development.

In 1994, primary blight occurrence dictated by the prediction criteria of Smith and Winstel considerably anticipated the real disease onset in the field in all the stations taken into consideration. Forecasting model of Guntz-Divoux and BliteCast predicted the blight risk after 2 weeks the disease occurrence in the field. The other forecasting models, namely I.P.I., Ullrich & Schrödter and NEGFRY correctly predicted the primary blight occurrence in the field.

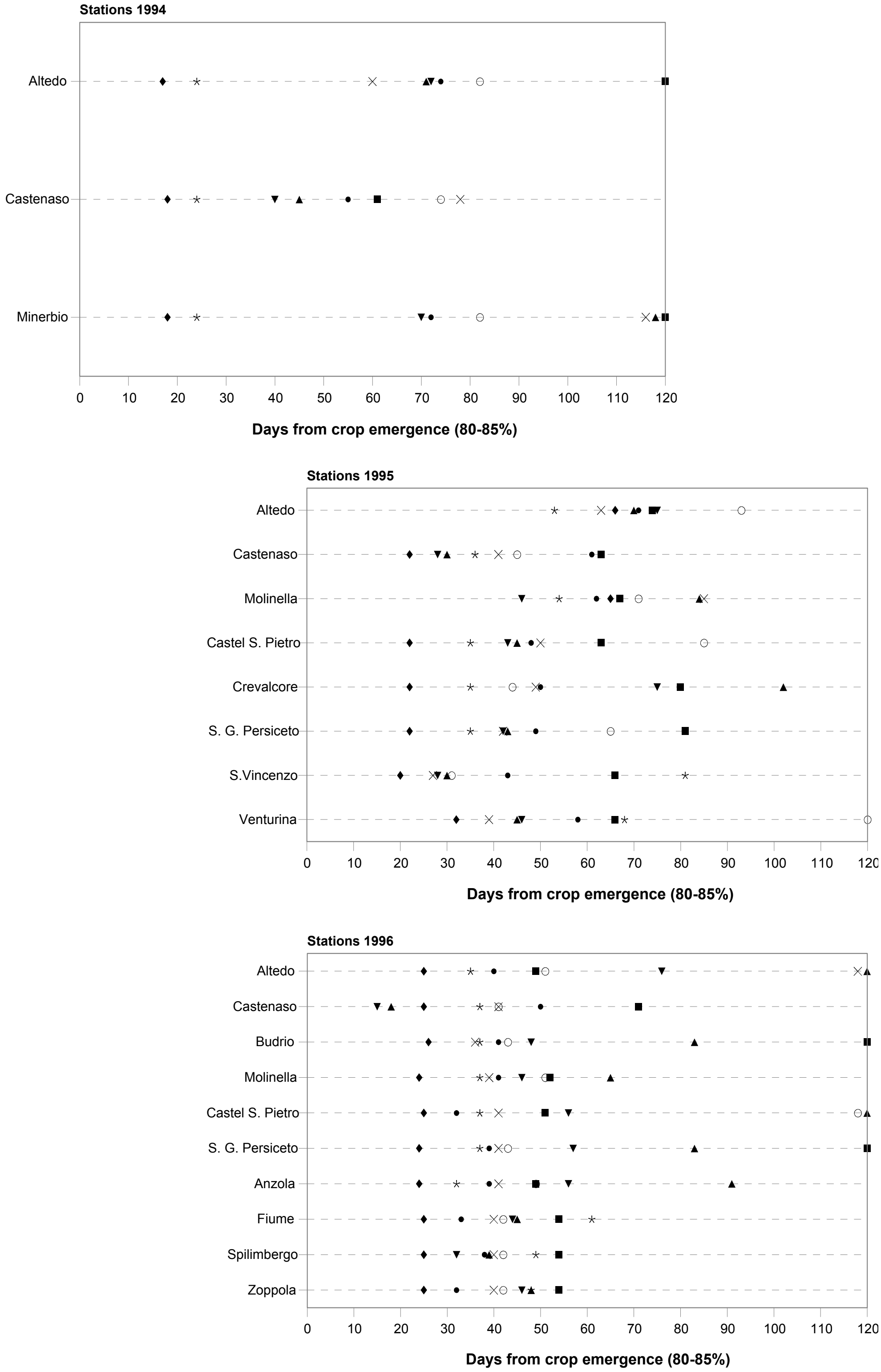


Fig. 2. Initial fungicide sprays calculated with different prediction criteria (▼ Ullrich & Schrödter; ◆ Smith; ▲ Negfry; ✕Guntz-Divoux; ★Winstel; ○ Blitecast; ● i.p.i.) compared to first blight onset (■) in unsprayed plots over 1994-1996. simbols on right side of the graph refer to cases with no disease occurrence or no risk threshold overcoming.

In 1995 the first primary blight occurrences were recorded beginning from June, 2th. Compared to the previous year, predictions provided by all the forecasting models varied considerably among the different localities even though Smith and Winstel's predictions anticipated greatly the real blight onset in field. Among all the forecasting models, only I.P.I. and Smith's criteria always correctly anticipated the real disease onset in all the stations used for validation.

In the third year validation, late blight occurred early compared to previous year beginning from may, 19. In two cases only (Budrio and S.G.Persiceto stations) where no disease was recorded, the potato crop development of the guard plots was delayed compared to the others in the same growing area probably due to waterlogging. Even in 1996, I.P.I. and Smith's forecasting models constantly anticipated the blight onset in all the stations.

The validation of different forecasting models applied in the north of Italy over 3 years shows that only Smith's criteria and I.P.I. forecasting model predicted the primary blight risk in 100% of the cases examined. I.P.I. model proved to be more efficient in that it anticipates the real blight onset of averagely 2 weeks compared to Smith's prediction which averagely anticipates of about 1 month. On the other hand, BliteCast proved to be the least reliable model tested in our environment, in that its predictions were delayed in 50% of the cases. Guntz-Divoux, Winstel, Ullrich & Schrödter and NEGFRY showed a percentage of failure of 12, 18, 24, 35 respectively (Table 2).

Table 2. Prediction reliability of tested forecasting models compared to disease onset in field.

Prediction Model	Frequency of delay (%)	Frequency of advance (%)	Av. N° days of delay	Av. N° days of advance
BliteCast	47	53	23.4	19.8
Guntz-Divoux	12	88	45.5	19.5
Smith	0	100	0	33.4
I.P.I.	0	100	0	14.8
Winstel	18	82	8	23
Neg-Fry	35	65	39.7	21.7
Ullrich & Schrödter	24	76	10	22

Assuming that chemical sprays after the first spray warning dictated by each forecasting model are schedully applied, among the most promising prediction models in our environment, that is I.P.I., Smith, Guntz-Divoux and Winstel, the first one allowed farmers to apply the least number of fungicide. The considerable anticipation of the predictions dictated by Smith's forecasting criteria led to apply too many chemical sprays, more than those routinely carried out throughout the growing season. Finally, the validation shows that in those years favourable to blight development (1995-1996), the use of Guntz-Divoux and Winstel's forecasting models allowed farmers to save as many sprays as I.P.I., but their predictions in few cases failed to correctly anticipate the real blight onset in field (Fig. 3).

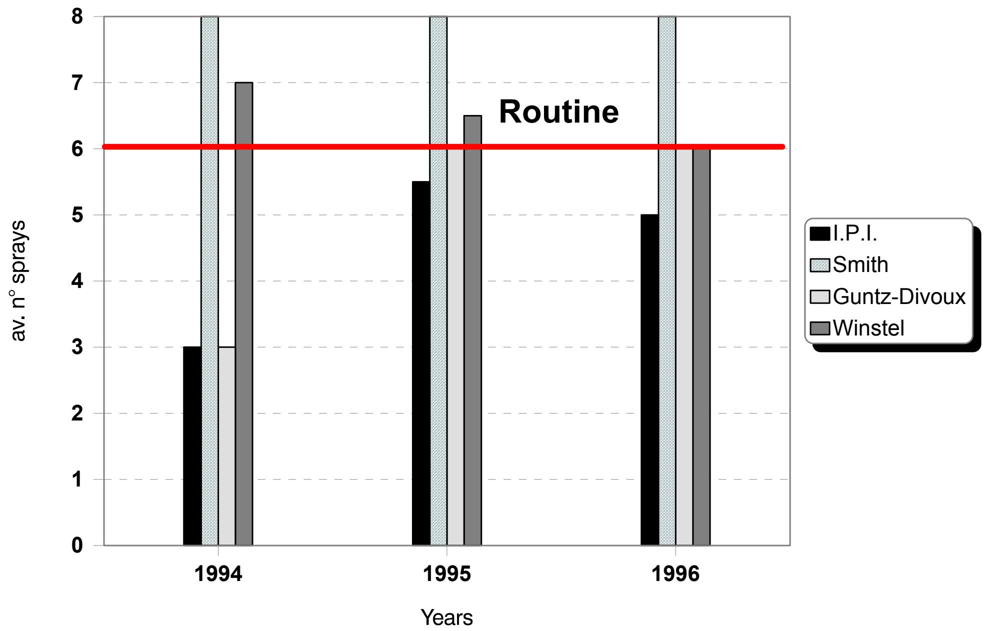


Fig. 3. Average number of chemical sprays using the most promising prediction models compared to those routinely applied in Emilia-Romagna (1994-1996).

Conclusions

The validation performed over 3 years in potato growing areas of northern Italy showed a certain uniformity in epidemic development in that disease averagely occurred simultaneously in the different areas. Therefore there are good possibilities to find a forecasting model that fit the climatic environments in the whole north of Italy.

This preliminary overall evaluation of different forecasting models for the prediction of potato late blight primary occurrence currently used in Europe demonstrates that the I.P.I. forecasting model elaborated in Emilia-Romagna region for tomato late blight can be considered the most valid blight risk prediction model in the north of Italy. In fact, it correctly predicts the first blight occurrence of averagely 2 weeks therefore allowing to save up to 50% of chemical sprays in years unfavourable to disease development.

Even though the other forecasting models did not gave similar results, model refinements will be taken into account in order to adapt them for italian environment and compare them to I.P.I. model.

Among the simplest and most promising ones, are Guntz-Divoux and Winstel's criteria for their low percentage of failure and good spray reduction.

The project will continue in the future and will concentrate on further refinements for the primary blight occurrence prediction model, the study and integration of the crop growth stage into the model, and investigations on criteria for timing the subsequent sprays.
This study aims to set up a Potato late blight Warning Service similar to that already operative for the prediction of tomato late blight in Emilia-Romagna region (Fig. 4).

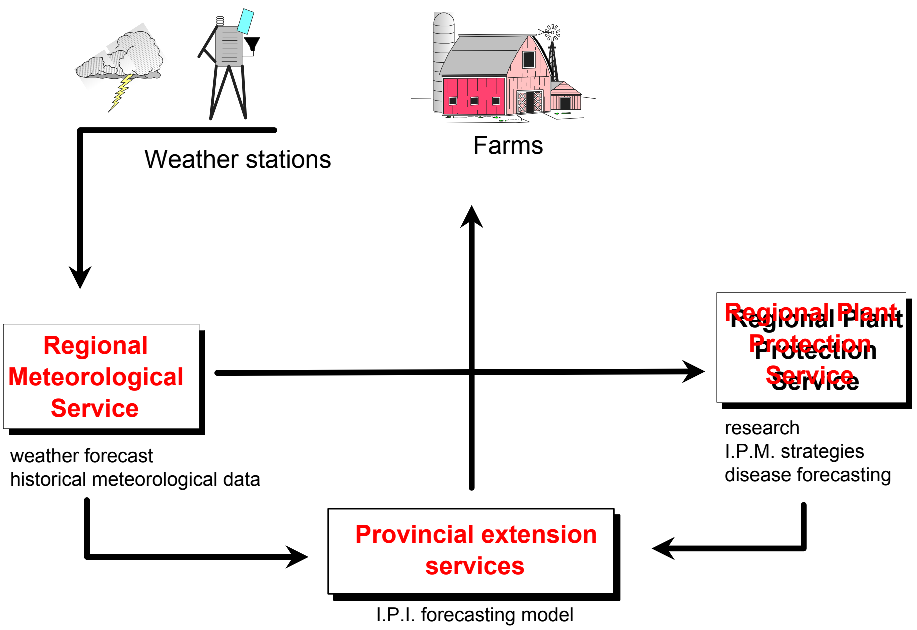


Fig. 4. Data flow for the potato late blight warning service in Emilia-Romagna.

The warning service will work at provincial scale. Each province will manage meteorological data provided by automatic weather stations of the Regional Meteorological Service and analyze them to elaborate the warning messages. These will be diffused to the farmers by means of bulletins, telephone answering machines and fax messages. The Regional Plant Protection Service will collect meteorological and epidemiological data so as to set up a DataBank useful for any further model refinements.

Acknowledgement

We wish to thank Hansen J.G. of the Danish Institute of Plant and Soil Science for providing us with NEGFRY PC-programme to validate in Italian potato growing environments.

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.

Duvauchelle, S. 1991. Lutte contre le mildiou de la pomme de terre en France: modèles de prévision pour les avertissements agricoles et stratégie d'utilisation des spécialités contenant des matières actives sistémiques face à la résistance. Bulletin OEPP/EPPO Bulletin, **21**, 49-55.

Hansen, J. G. 1995. Meteorological dataflow and management for potato late blight forecasting in Denmark. SP-Report, Danish Institute of Plant and Soil Science, **10**, 57-63.

Krause, R. A., Massie, L. B. & Hyre, R. A. 1975. Blitecast: a computerized forecast of potato blight. Plant Disease Reporter, **59**, 95-98.

Schrödter, H. & Ullrich, J. 1967. Eine mathematischstatistische Lösung des Problems der Prognose von Epidemien mit Hilfe meteorologischer Parameter, dargestellt am Beispiel der Kartoffelkrautfäule (*Phytophthora infestans*). Agricultural Meteorology, **4**, 119-135.

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

Winstel, K. 1992. Kraute und Knollenfäule der Kartoffel - eine neue prognosemoglich keit. Gesunde-Pflanzen, **44**, 12, 414-415.

First Workshop of an European Network for Development of an
Integrated Control Strategy of potato late blight
Lelystad, The Netherlands, 30 September - 3 October 1996

LATE BLIGHT WARNING IN NORWAY

ARNE HERMANSEN & TERJE AMUNDSEN
The Norwegian Crop Research Institute
Plant Protection Centre
N-1432 Ås NORWAY**10**

Abstract

In Norway late blight warning based on Førsund-rules is dissiminated through a voice board system TELEVIS. Validation trials have been carried out in 1994-1996. Treatments based on these warnings were reliable in most areas and years, but not in all. The number of sprays were reduced by 0 - 3 compared to routine treatments.

Keywords: Førsund-rules, late blight, *Phytophthora infestans*, TELEVIS, validation trials, warning.

Introduction

Phytophthora infestans (Mont.) de Bary is an important plant pathogen in Norway. The use of fungicides against late blight in potato represents about 50 % of the overall amount of fungicides used every year. In most of the potato growing areas late blight is present every year, but not always epidemic. In northern Norway, low temperature is the limiting factor for the occurrence of *P. infestans*.

In 1995 potato was grown on approx. 17000 ha. About 70 % of this area is cropped by potato for consumption.

Stortinget, the Parliament of Norway, stated in 1989 an intention to reduce the usage of pesticides in Norway, although no specific limit of this reduction was decided. The use of a

Special PAGV-report 1. (1996), 79-84

reliable late blight warning system for better timing of fungicide treatments represents an useful tool in this work.

This paper presents some facts about late blight warning in Norway and results from some validation trials.

Late blight warning

Late blight warning was initiated in Norway in 1957 (Førsund 1958) and run by the Plant Protection Service.

The service was revised in 1965 and from that year the warning was distributed by the Norwegian Meteorological Institute (NMI). The warnings were disseminated to the press and Norwegian Broadcasting System (Førsund 1983). Later on weather-telephone also was used.

The Førsund-rules from 1965 had four basic criteria on a daily basis (Førsund 1983):

1) Maximum temperature between 17 and 24 °C

2) Minimum temperature ≥ 10 °C

3) Relative humidity ≥75 % at 12.00 a.m.

4) Rainfall ≥0.1 mm in the period.

In 1995 two of the criteria in the Førsund-rules were adjusted according to results from validation trials and field observations:

1) Maximum temperature between 16(15) and 24 °C

2) Minimum temperature > 8 °C.

A network of 52 automatic weather stations was deployed in agricultural areas in 1990 - 94. In 1992 a PC-based advisory system, including dissemination of plant protection warnings through a voice board system TELEVIS, was started by the Norwegian Crop Research Institute (Magnus & Ligaarden 1991). In 1994 late blight warnings based on Førsund Rules were put into operation via TELEVIS. The warnings are given for the area surrounding each weather station, both for the last 5 days based on «historical» weather data, and for 2 days ahead based on local weather prognoses, prepared by NMI.

In 1994 potato growers in two districts were asked about warning systems (Sæthre & Hofsvang 1995). Late blight warnings from radio and other media were used by 16.7 %, 10.2 % used a phone-answerer at the local advisor, and 7.4 % had called TELEVIS.

In 1996 about 1400 phone calls were registered listening at the TELEVIS late blight warnings (Ligaarden, pers. comm.). Some of these calls were from local advisors who use the information from TELEVIS in their local advisory work.

In Norway, the number of fungicide applications against potato late blight varies from 0 to 7, with an approx. mean of 3 treatments per season.

Validation trials

In order to validate the Førsund-rules using hourly data from automatic weather stations, field trials were carried out in the period 1994-1996.

Materials and methods

The experiments presented in this paper were located at Roverud, Rygge, Særheim and Kvithamar. Information on the four locations is given in Table 1.

The field experiments were randomized complete block designs with four replicates. Each treatment plot measured approx. 7m x 2.8m (4 rows).
Each morning hourly weatherdata provided by the automatic stations were collected and late blight warnings according to Førsund-rules automatically prepared.

Table 1. Characterisation of the locations for the experimental fields.

	Roverud	Rygge	Særheim	Kvithamar
Geographical location	Eastern N.	South-eastern N.	South-western N.	Mid-N.
Distance to automatic weatherstation	50 m	200 m	300 m	3000 m
Experimental plot	in cereal field	in growers field	in exp. field	in exp. field
Cultivar	'Saturna'	'Beate'(94,95) 'Saturna' (96)	'Pimpernel'	'Pimpernel'

The experimental treatments were as follow:

1. Non-treated.
2. Routine sprays, that is start of spraying at «row-closure» and spray-intervals according to local practice, usually 10-14 days. Last spray about one week before haulm-killing.

3. Førsund-rules, that is spraying according to late blight warnings based on historical weather data distributed by TELEVIS. In 1994 the «1965-rules» were used, in 1995 and 96 the warnings were prepared using the adjusted «1995-rules». The first spray was carried out when the first warning was given after the time of «row-closure». The minimum spray interval was not shorter than 7 - 14 days.

Fluazinam (Shirlan) 0.3 l/haa was used in all the presented experiments. No other fungicides were applied. Approx. two weeks before harvest haulm-killing (diquat, 2 l/haa) was carried out.

Registration of late blight attack on the potato haulm was usually carried out close to haulm-killing, that is during the first half of September. The B.M.S. key for late blight infection was used (Anonymous 1947). After harvest tubers were stored 2-3 weeks at 15° C and then assessed for late blight.

Results and discussion

Some of the data from these experiments are presented in Table 2. The level of late blight infection varied through the different years at each location. Tuber infection was low in all locations and years except at Særheim in 1995. The conclusion so far is that treatments according to warnings based on Førsund-rules are reliable in most areas and years, but not in all. The warnings are not reliable every year at locations with relatively low temperature and high humidity (e.g. Roverud). The quality of the warnings was however improved after the adjustment of the rules in 1995.

One important weakness in the Førsund-rules is that precipitation is necessary for a positive warning. The last two years we have experienced that late blight has developed in periods with high humidity and heavy dew, although without precipitation (data not shown). Duration of leaf wetness, which is also measured by the automatic weather stations, should probably taken into consideration when preparing the warnings.

Table 2. Results from validation trials in 1994-96 in which fungicide treatments (fluazinam 0.3 l/ha) scheme designated by Førsund-rules was compared with untreated and routine treatments at four locations in Norway.

			Late blight %	
Location:	**Roverud**	No of sprays	Haulm	Tubers [1)]
1994	Non treated	-	49.3	0
	Routine sprays	4	0.03	0
	Førsund-rules (TELEVIS)	0	33.8	0
1995	Non treated	-	6.0	0
	Routine sprays	4	0.03	0
	Førsund-rules (TELEVIS)	3	0.1	0
1996	Non treated	-	17.5	
	Routine sprays	4	0.1	
	Førsund-rules (TELEVIS)	1	1.8	
Location:	**Rygge**			
1994	Non treated	-	96	1.7
	Routine sprays	7	5.8	0.4
	Førsund-rules (TELEVIS)	4	7.3	0.4
1995	Non treated	-	0.3	0.5
	Routine sprays	7	0	0
	Førsund-rules (TELEVIS)	5	0	0
1996	Non treated	-	45	
	Routine sprays	5	0.2	
	Førsund-rules (TELEVIS)	3	0.3	
Location:	**Særheim**			
1994	Non treated	-	79.5	2.7
	Routine sprays	5	0.5	0.5
	Førsund-rules (TELEVIS)	5	2.4	0
1995	Non treated	-	78.8	15.1
	Routine sprays	6	0.2	0
	Førsund-rules (TELEVIS)	5	0.2	6.3
1996	Non treated	-	1.7	
	Routine sprays	6	0	
	Førsund-rules (TELEVIS)	4	0.05	
Location:	**Kvithamar**			
1994	Non treated	-	8.8	0
	Routine sprays	3	6.3	0
	Førsund-rules (TELEVIS)	3	10.0	0
1995	Non treated	-	28.3	0.9
	Routine sprays	6	0.05	0
	Førsund-rules (TELEVIS)	4	0.1	0
1996	Non treated	-	1.0	
	Routine sprays	4	0	
	Førsund-rules (TELEVIS)	3	0.03	

[1)] Data from 1996 not available when preparing this paper.

NEGFRY has also been tested in Norway (Hansen et al 1995). This model is functioning about at the same level as Førsund rules regarding number of sprays and effect on the epidemic.

In the experiments a spraying scheme following the TELEVIS warnings reduced the number of sprays by 0 to 3 compared to the routine sprays, without increasing the late blight infection significantly. This reflects the potential of reducing the fungicide use in late blight control. More work is however needed to improve the models for late blight warnings.

References

Anonymous 1947. The measurement of potato blight. Trans. of the British Mycological Society 31: 140-141.

Førsund, E. 1958. Varslingsteneste mot tørråte på poteter. Samanstelling av varslingstenesta sommaren 1957. Norsk Landbruk 16 og 22.1958: 16 pp.

Førsund, E. 1983. Late blight Forecasting in Norway 1957-1980. EPPO Bulletin 13: 255-258.

Hansen, J.G., Andersson, B. & A. Hermansen 1995. NEGFRY - A system for scheduling chemical control of late blight in potatoes. In: L.J. Dowley, Bannon, E., Cooke, L.R., Keane, T. & E.O` Sullivan (eds), Phytophthora infestans 150, Proceeding of Conference of EAPR-Pathology Section, Dublin, Ireland, 1995: 201-208.

Magnus, H. & Å. Ligaarden 1991. Voice response database in plant protection warning systems. Danish Journal of Plant and Soil Science (1991), 85 (S2161): 233-234.

Sæthre, M.G. & T. Hofsvang 1995. Forbruk av plantevernmidler i enkeltkulturer. En spørreunderøkelse blant gartnere og bønder i Sør-Norge i 1994. Et dokumentasjonsoppdrag for Konkurransestrategier for norskmat, Landbruksdepartementet fra Planteforsk, Plantevernet 1995: 115 pp.

First Workshop of an European Network for Development of an
Integrated Control Strategy of potato late blight
Lelystad, The Netherlands, 30 September - 3 October 1996

CRUCIAL WEATHER CONDITIONS FOR *PHYTOPHTHORA INFESTANS:* A RELIABLE TOOL FOR IMPROVED CONTROL OF POTATO LATE BLIGHT ?

K.Q. CAO[2], M. RUCKSTUHL[1†], H.R. FORRER[1]

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

[2] Hebei Agricultural University, Department of Plant Protection
Baoding, Hebei 071001, People's Republic of China

† corresponding author for publication11

Abstract

Studies on the in-field late blight epidemics in 1995/96 with the highly susceptible varieties Charlotte and Bintje, revealed a description of crucial weather conditions (CWC) for infection periods of *Phytophthora infestans.* CWC were defined as periods of 24 hours with I) at least 6 hours of precipitation with air temperatures of ≥10°C and II) a minimum of 6 successive hours with a relative humidity of ≥90%. CWC were met on 7 days in 1995 and on 4 days in 1996.In field trials, potato late blight was successfully controlled with a CWC based spraying schedule that required only 3 fungicide applications. The CWC model performed considerably better than PhytoPRE in terms of fungicide inputs, but also better than NegFry in terms of disease control.

Keywords: DSS, epidemiology.

Introduction

Recent progress in meteorological data processing and farmers' interest to invest in modern communication technology, open new ways for plant protection models such as PhytoPRE,

Special PAGV-report 1. (1996), 85-90

the DSS used in Switzerland for the control of potato late blight (Forrer *et al.*, 1993). The employment of forecasted and observed weather data relevant to the development of late blight epidemics, combined with monitoring information on the onset of the epidemics, is expected to optimise plant protection measures in a future version PhytoPRE+2000.

The project is aimed at identifying days with weather conditions crucial for both sporulation and infection of *Phytophthora infestans.* Crucial weather conditions (CWC) were described and tested in a fungicide application schedule.

Materials and Methods

In 1995, crucial weather conditions (CWC) were formulated based on observations in a field experiment with naturally infected plots planted with the highly susceptible variety Charlotte, near Zürich. Significant increases in disease severity were registered by daily counts of leaflets with newly expressed symptoms. The lengths of the latency periods (LP) were determined with periodical artificial inoculations, and allowed the identification of days with heavy infections. Comparisons of meteorological parameters on these days revealed the crucial weather conditions.

Field experiments in 1996 with variety Bintje were carried out to validate the relevance of the CWC-model. The apparent disease infection rate r was calculated according to Vanderplank (1963) and visually compared to field meteo data. Daily r_x values were based on disease incidence ratings at day d_x and day $d_{(x+LP)}$. The intervals between the two ratings were determined by the varying lengths of the latency period.

In 1996, the CWC-model was compared with spraying schedules based on PhytoPRE and NegFry (Hansen, 1993) in small plot fungicide trials with variety Bintje, using mean values of AUDPC. Daconil combi DF ®, containing both a protectant (chlorothalonil) and a locally systemic (cymoxanil) component, was applied at a rate of 2 kg ha^{-1}, one day after thresholds were met.

Results

Six days with heavy late blight infection were identified in June and July 1995. Figure 1 integrates disease readings and weather parameters as registered in the Charlotte field trial.

CWC, as derived from the comparison of meteorological data on days with heavy infections, were defined as:

<u>Periods of 24 hours with</u>

1. at least 6 hours of precipitation with air temperatures of ≥10°C

and

2. a minimum of 6 successive hours with a relative humidity of ≥90%.

In 1996, the late blight epidemic in Switzerland was unusually delayed. In our experimental plots, CWC were met on only four days after the first national observation of late blight on May 23, 1996. However, these days also revealed the highest daily r values (Figure 2).

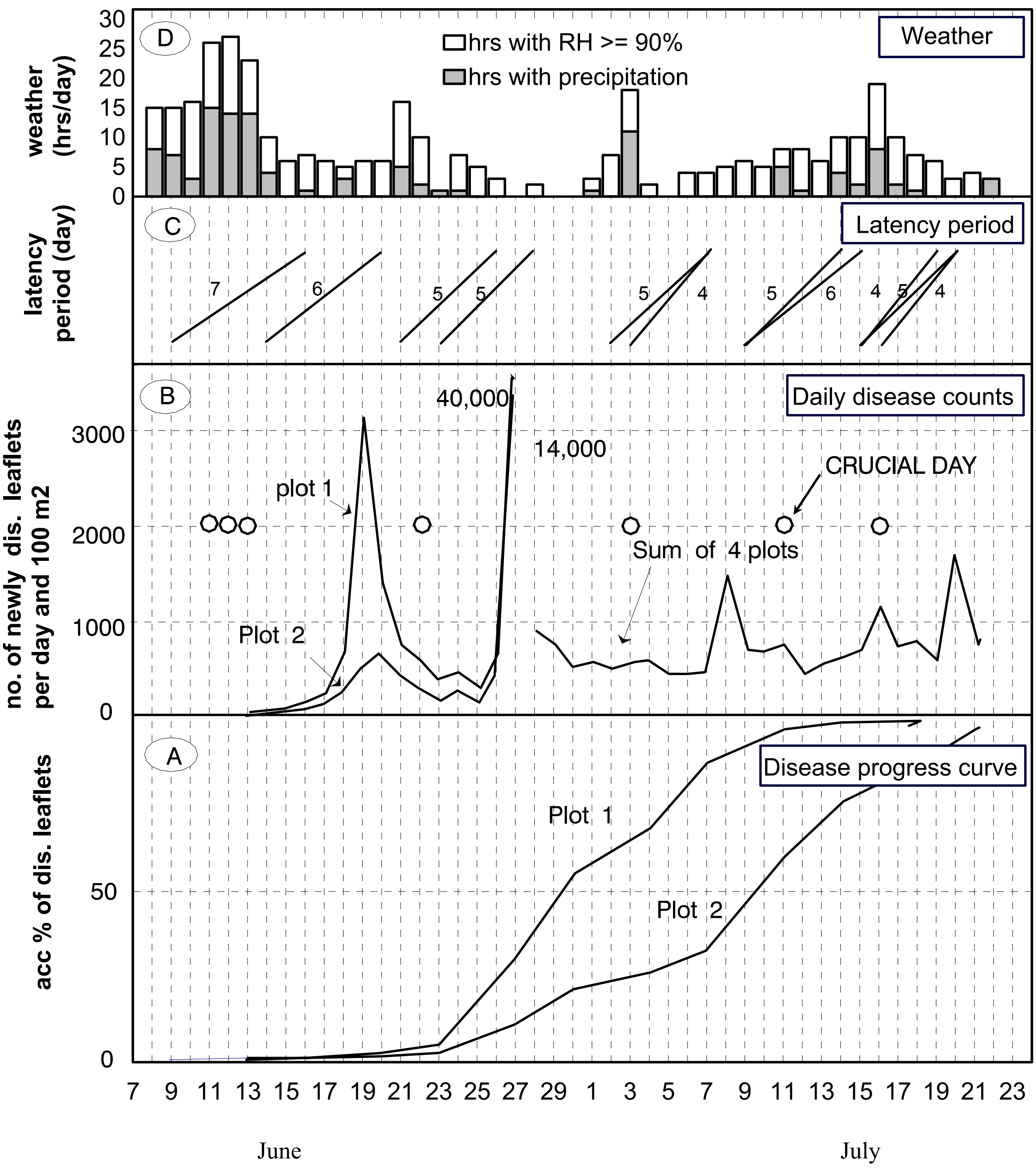


Figure 1. Comparison of daily weather records and disease progress of potato late blight on variety Charlotte. Crucial days for infections with *P. infestans* were defined based on daily disease increase rates, considering the varying length of latency periods. (dis.=diseased, acc.=accumulated)

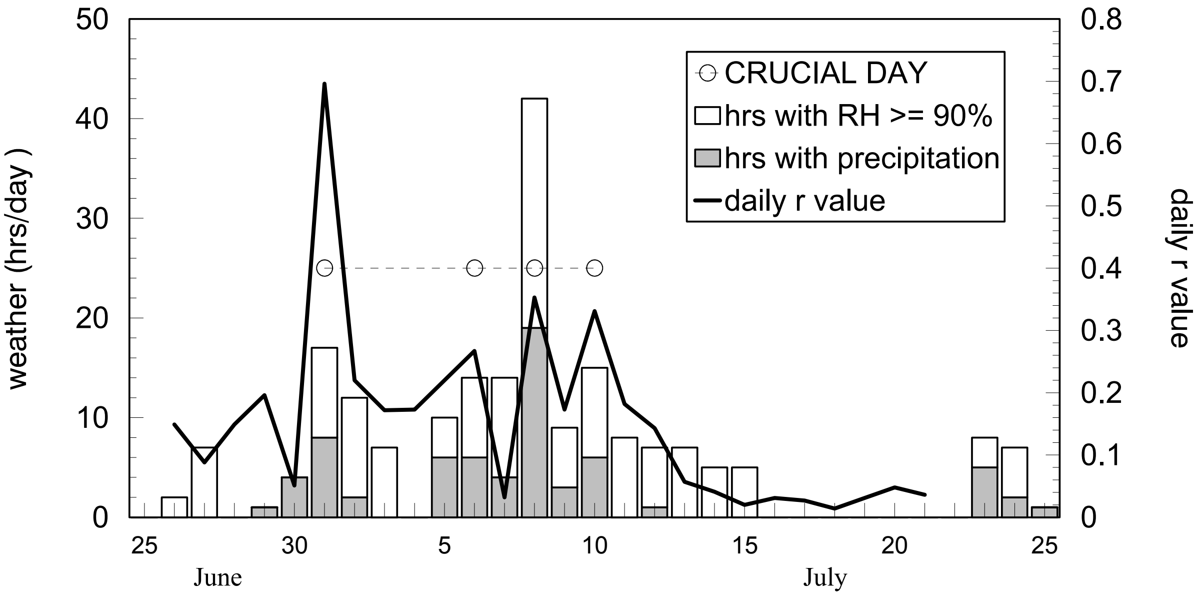


Figure 2. Relationship between daily apparent infection rates r and weather conditions as observed in a field trial with the variety Bintje in 1996.

In a field validation trial, the performance of three DSS for the control of potato late blight was compared. The number of fungicide treatments recommended by the CWC-model was considerably reduced with equal control of potato late blight when compared to PhytoPRE. NegFry required only two treatments, but gave insufficient protection as indicated by the relative values of AUDPC (Table 1.).

Table 1. Control of potato late blight in Bintje (1996), using three different DSS.

Decision Support System	No. of Fungicide Treatments	rel. AUDPC[a] (in % of the check)
CWC-model[b]	3	2
PhytoPRE[b]	6	2
NEGFRY[b]	2	30
untreated check	0	100

[a] AUDPC values were calculated from June 26 to July 29, 1996, for all plots.

[b] In all 3 DSS an initial treatment was applied on May 29, 1996, according to the Swiss recommendations for the control of potato late blight.

Conclusions

A simple set of meteorological parameters was found that described a weather event favourable for infection of potato leaf material, with the late blight causing organism *P. infestans.* CWC were employed in a model for fungicide schedules and proved to be a promising tool for optimised disease management. *P. infestans* was successfully controlled with only three fungicide applications in the 1996 season when there was a particularly late disease outbreak. Multilocational trials are needed to check on the robustness of CWC in different environments and under varying disease pressure.

References

Forrer, H.R, H.U. Gujer, and P.M. Fried, 1993. PhytoPRE - A comprehensive information and decision support system for late blight in potatoes. SP-Report, Danish Inst. Plant and Soil Sci. 7:173-81.

Hansen, J.G., 1993. The use of meteorological data for potato late blight forecasting in Denmark. SP-Report, Danish Inst. Plant and Soil Sci. 7:183-93.

Van der Plank, J.E., 1963. Plant Diseases: Epidemics and Control. Academic Press, INC. NewYork, 349.

12First Workshop of an European Network for Development of an
Integrated Control Strategy of potato late blight
Lelystad, The Netherlands, 30 September - 3 October 1996

RAINFASTNESS AND RESIDUAL ACTIVITY OF SOME *PHYTOPHTHORA* FUNGICIDES

S. K. MATHIASSEN[1], P. KUDSK[1], E. KIRKNEL[1] and H. SCHULTZ[2]
Danish Institute of Plant and Soil Science
[1] Department of Weed Control and Pesticide Ecology
Flakkebjerg, DK-4200 Slagelse, Denmark
[2] Department of Plant Pathology and Pest Management
Lottenborgvej 2, DK-2800 Lyngby, Denmark

Abstract

The rainfastness and residual activity of different late blight fungicides were examined on potted potato plants grown outdoors. The biological efficacy of treatments was assessed by the number of lesions following incubation of detached leaflets with small drops of a spore suspension of *Phytophtora in-festans*. The efficacy of fluazinam was maintained through a 13 days period whereas the efficacy of propamocarb+mancozeb and maneb was significantly reduced 3 and 13 days after application, respectively. However, 13 days after application the activity of maneb was higher compared to the other fungicides due to a high initial activity of this fungicide. Chemical analyses showed that rain reduced the maneb deposits, but significant influence on the biological activity was only observed in very low doses. The results with rainfastness of fluazinam were inconsistent.

Keywords: Late blight, fungicide, rainfastness, residual activity, decomposition.

Introduction

NEGFRY is a potato late blight model which can recommend farmers on the date of the first application and consecutive spraying intervals based on the influence of climatic conditions on the epidemology of *Phytophthora infestans*. Weather conditions also influence the duration of protection following fungicide applications as leaf deposits are subject to losses

Special PAGV-report 1. (1996), 91-97

by volatilization, photolysis and wash-off. Therefore, knowledge to the residual activity of the different fungicides is an important factor which makes it possible to improve the timing of fungicide applications recommended by NEGFRY.

The objective of the present experiments was to examine the rainfastness and residual activity of different potato fungicides.

Material and methods

Potato plants were established by planting pregerminated sections of tubes in 2 l pots in a soil/sand/peat mixture (2:1:1) containing all necessary macro and micro nutrients. The pots were placed on outdoor tables. When plants were 25-30 cm high the plants were thinned so all leaves were freely exposed to the application. Fungicides were applied in ca. 300 l water per ha using a laboratory pot sprayer equipped with two Hardi 4110-24 flat fan nozzles.

The following commercial formulations were used: Trimangol DG (750 g maneb/kg, Atochem), Dithane DG (750 g mancozeb/kg, KVK Agro), Tatoo (248 g propamocarb/l + 301 g mancozeb/l, AgrEvo) and Shirlan SC (500 g fluazinam/l, Zeneca). Normal doses (n) of the fungicides were 1500 g a.i./ha maneb/mancozeb, 200 g a.i./ha fluazinam and (992+1204) g a.i./ha propamocarb+mancozeb.

In the experiments concerning residual activity different exposure times were obtained by spraying the plants at different days. The pots were placed outdoors during the whole experiment.

The rain treatments were carried out in a rain simulator 24 hours after application. The rain volume varied between 2 and 27 mm while the rain intensity was kept constant at 27 mm/h.

Biological assessment

From each treatment 10 single leaves were detached and placed individually in petri dishes on a plastic net. A piece of wet filter paper was placed in the bottom of the petri dishes in order to maintain 100% relative humidity.

The day after detaching each leaf was inoculated with 10 small drops of a spore suspension containing 10^5 zoospores/ml of *P. infestans*. The leaves were incubated at 18^oC and the number of lessions on the leaflets was assessed the following 10 days.

Chemical analysis

In some of the experiments the deposits of maneb and mancozeb on the leaves were determined by a chemical analysis. The principle of the analytical method is based on the release of carbon disulphide by addition of a hydrochloric acid solution of tin(II)chloride. The carbon disulphide is determined by head-space analysis using gas chromatography (GC) with flame-photometric-detector (FPD) (Kudsk *et al.*, 1991).

Results and discussion

The results of the biological assessments and the chemical analyses are presented as the relative efficacy and relative deposits, respectively.

Figure 1 shows the biological responses and the corresponding fungicide deposits following treatment of potato plants with different doses of mancozeb. We are not able to explain the reduced activity at high doses but a similar trend was observed with maneb (results not shown).

The results of the fungicide treatments over time after exposure to natural climate are shown in figure 2. The residual activity is the combined result of decomposition and dilution due to plant growth. The initial efficacy of maneb was high and although the activity was significantly reduced after 13 days the residual activity was still much higher than the activity of the other fungicides. The chemical analyses showed a significant reduction in amount of deposit over time (figure 3).

With propamocarb+mancozeb the initial activity was similar to maneb but a significant decline in efficacy was found already 3 days after application and on subsequent dates.

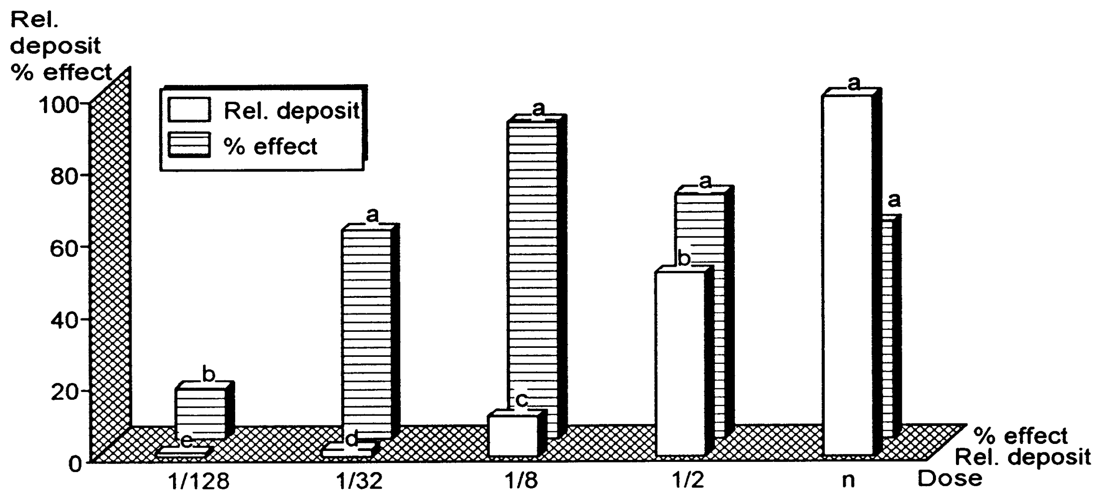


Figure 1. Deposits on leaves and biological response after treatment with different doses of mancozeb. Bars with different letters are significantly different (Duncans test).

The initial efficacy of the applied doses of fluazinam was low compared to the other fungicides. However, in contrast to maneb and propamocarb+mancozeb no significant reduction of the residual activity was found after exposure to natural climate for 13 days (figure 2).

In a glasshouse experiment with tomato plants Lindner *et al.*, (1995) found a higher residual activity of mancozeb compared to propamocarb+mancozeb and fluazinam 14 days after application. In their experiment the activity of fluazinam declined through the first day and the activity of propamocarb+mancozeb was drastically reduced between 4 and 7 days after application.

Rainfall shortly after application is known to reduce the activity of many fungicides applied to foliage. The rainfastness of the fungicides included in this trial is mainly dependent on retention to the leaf surface as all of them are residual fungicides. Retention can be affected of the environmental condition before application because temperature, humidity and wind affect the structure and chemical composition of the leaf wax (Stevens *et al.*, 1988). It therefore seems very important to us to use outdoors grown plants to rainfastness experiments.

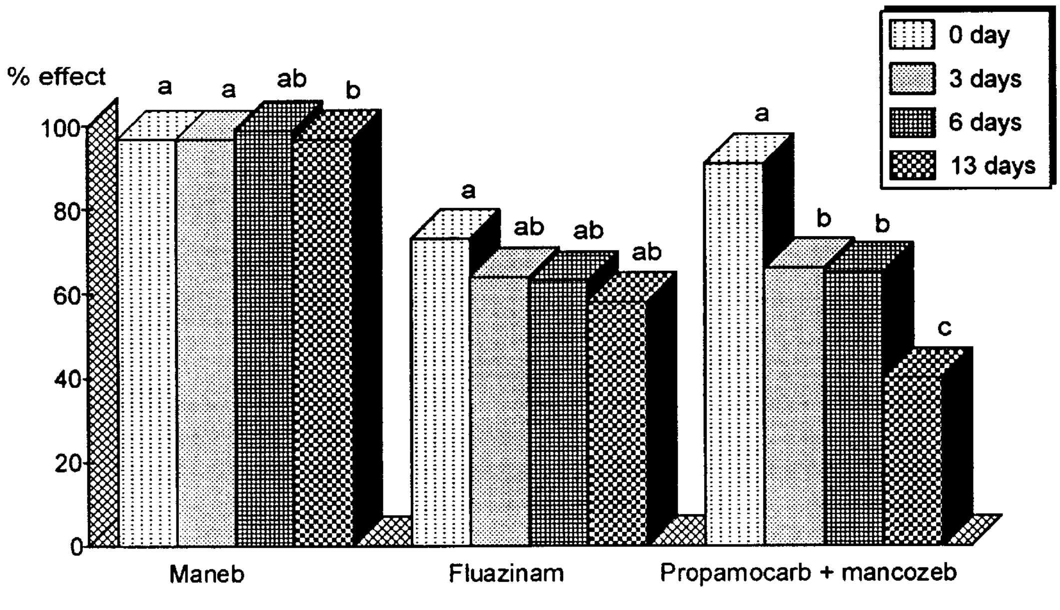


Figure 2. Biological efficacy of 1/2 n of the fungicides after exposure to natural climate a different number of days. Within each fungicide treatments with different letters are significantly different (Duncans test)

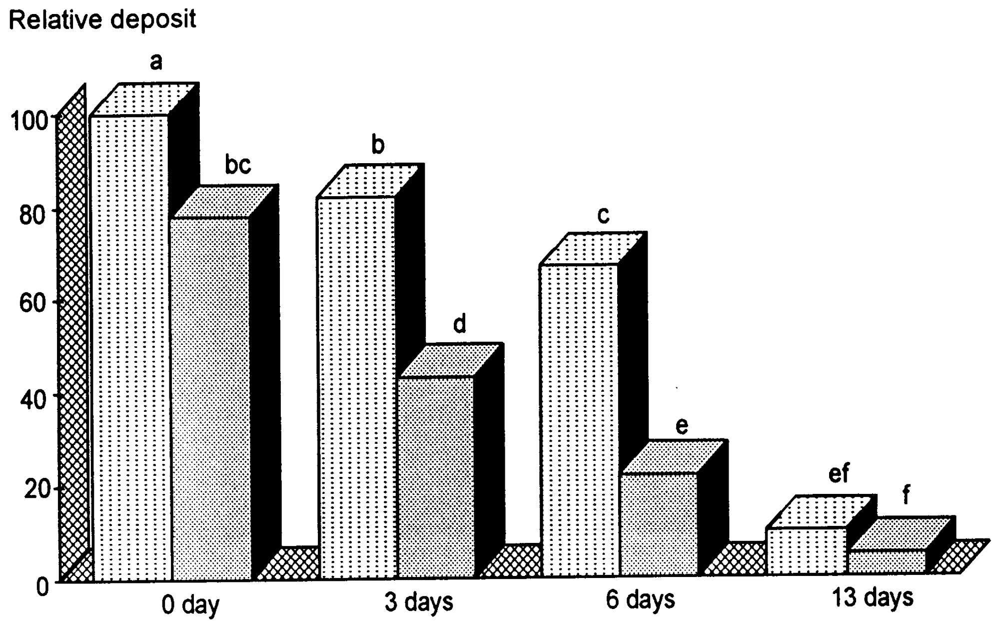


Figure 3. Deposits on leaves of potato plants treated with ½ n: [legend box] and 1 n: [legend box] maneb and exposed to natural climate a different number of days. Treatments with different letters are significantly different (Duncans test).

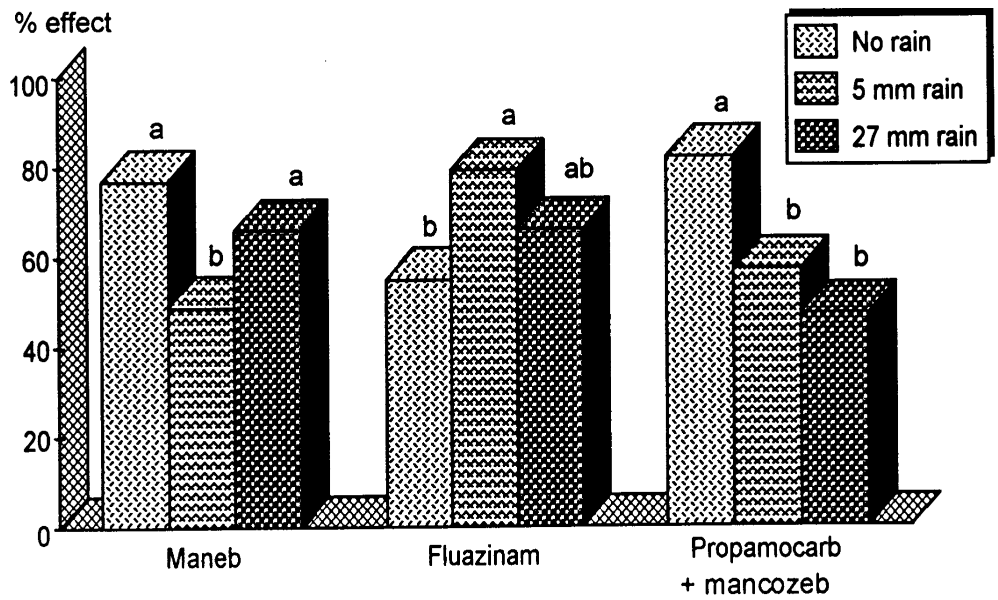


Figure 4. Rainfastness of fungicides (1/40 n) assessed by biological response. Within each fungicide treatments with different letters are significantly different (Duncans test).

For herbicides it has been found that the water soluble herbicides generally are more vulnerable to rain than the lipophilic herbicides and that the detrimental effect of rain is mainly determined of the rain volume whereas droplet size and intensity are only of minor importance (Kudsk and Kristensen, 1992). However, earlier studies have indicated that for maneb and mancozeb high-intensity rain seems to wash off more fungicide than low-intensity rain and products with smaller particles tended to be more rainfast than products with larger ones. It looks like other factors related to the interaction between the particles and leaf surface might play a more significant role in the resistance to rain of these fungicides.

The efficacy of 1/2 and 1/8 n of maneb and propamocarb+mancozeb was not significantly influenced by 2, 5, 9 and 27 mm rain. However, the chemical analyses showed that all rain treatments reduced the maneb deposits (result not shown). The biological efficacy of 1/40 n of maneb and propamocarb+mancozeb was reduced by rain but with maneb the result was only significant after 5 mm rain (figure 4). In other experiments Bardsley and Thompson (1995) found no significant influence on the biological activity of propamocarb of rain applied 30 minutes after spraying whereas Lindner *et al.* (1995) reported that rain significantly reduced the activity of this fungicide. With fluazinam applied at 1/2 and 1/8 n no significant influence of 2 and 9 mm rain was observed but the efficacy of 1/8 n was significantly reduced after treatment with 5 and 27 mm rain. The activity of 1/40 n fluazinam was significantly improved by 5 mm rain (figure 4). Enhanced protective effect of fluazinam after rain has also been reported by Scheppers (1996) and could be due to redistribution of the deposits.

Conclusion

Deposits of maneb and mancozeb can be determined with high accuracy using chemical analyses but knowledge of the biological response of the detected deposits is necessary for practical implementation. In general, the biological responses to the treatments have been low possibly due to use of to high fungicide doses. The variability in our biological assessments has been high and consequently, the bioassay method has to be improved. More results are required before information on rainfastness and residual activity can be incorporated in NEGFRY.

References

Bardsley R. & Thompson N. 1995. Rainfastness of propamocarb based products (Tattoo and Tattoo C) used in the control of potato late blight (*Phytophthora infestans*).In *Phytophthora infestans* Proceedings from the European Association for Potato Research - Pathology Section Conference p.358.

Kudsk P. & Kristensen J.L. 1992. Effect of environmental factors on herbicide performance. Proceedings 1.International Weed Control Congress, 1, pp 173-186.

Kudsk P., Mathiassen S.K. & Kirknel E. 1991: Influence of formulations and adjuvants on the

rainfastness of maneb and mancozeb on pea and potato. Pesticide Science, 33, 57-71.

Lindner K., Burth U., Stachewick H. & Gutsche V. 1995. Beurteilung von Wirkungs komponenten neuer Phytophthora-fungizide auf der Basis von Modelluntersuchungen. Nachrichtenblatt Deutsche Pflanzenschutzd. 47 (11), pp 297-303.

Schepers H.T.A.M. 1996. Rainfastness of fungicides used to control *Phytophthora infestans.* Abstracts of the 13. European Association of Potato Research Conference, p 374-375.

Stevens P.J.G., Baker E.A. & Anderson N.H. 1988. Factors affecting the foliar absorbtion and redistribution of pesticides 2. Physicochemical properties of the active ingredients and the role of surfactant. Pesticide Science, 24, pp 55-62.

First Workshop of an European Network for Development of an
Integrated Control Strategy of potato late blight
Lelystad, The Netherlands, 30 September - 3 October 1996

THE ROLE OF *P. INFESTANS* INOCULUM FROM STEM LESIONS IN THE INFECTION OF TUBERS

Bain, R A, Fairclough, R W[1], Holmes, S J[2] & Ligertwood, G L
Plant Science Department, SAC, Auchincruive, Ayr KA6 5HW, UK.
[1] Present address: Wood MacKenzie, 74-77 Queen Street, Edinburgh EH2 4NS, UK.
[2] Present address: ADGEN Diagnostic Systems, Auchincruive, Ayr KA6 5HW, UK.**13**

Abstract

Several field experiments confirmed the importance of stem lesions as a source of inoculum for progeny tuber infection. The incidence of tuber blight was more closely related to the incidence of stem infection, especially of the stem base, than the severity of foliar blight. Although sporangia were produced early on in the development of stem lesions on pot-grown plants, their number was limited until the lesions were well developed and the plants began to senesce. When sporangia production was at its greatest, sporangiophores were produced along the whole length of the lesion and, unlike leaf lesions, were not largely restricted to the advancing margin of the lesion. The effect of fungicide treatment on stem blight was complex and depended on whether stem lesions developed from direct infection of the stems or as a result of *P. infestans* growing down the leaf petiole into the stem after an initial leaf infection.

Keywords: *Phytophthora infestans*, late blight, stem blight, tuber blight

Introduction

One of the key parameters in late blight forecasting or decision support systems should be the amount of *P. infestans* inoculum. It is a prerequisite to quantifying *P. infestans* to understand the relative importance of sporangia originating from different sources to the infection of tubers or the further development of the foliar epidemic. Until now little distinction has been made between inoculum produced on leaves and stems. Evidence that there are important dif-

Special PAGV-report 1. (1996), 98-105

ferences between leaf and stem lesions and that the latter are an important source of inoculum for tuber infection is presented in this paper.

Materials & Methods

Experiment 1 The relationship between stem lesion development and sporangia production

Potato plants, cv. Home Guard, were grown in the glasshouse. Selected stems were inoculated c. 5 cm above the surface of the growing medium with c. 5000 sporangia of *P. infestans*. After inoculation the plants were kept at 10 ^{O}C and a relative humidity of 70% in a growth cabinet. The length of stem lesion was measured on nine randomly selected plants 7, 14, 22, 28 and 34 days after inoculation. The assessed plants were then incubated at 10 ^{O}C with a humidity close to 100% for 48 hours to encourage sporangia production. Following incubation the length of stem on which sporulation was visible was measured along with the number of sporangia released from the lesions after the application of 4 mm of simulated rainfall.

Experiment 2 Stem base lesions as a source of inoculum for tuber infection

Field plots of King Edward were established using seed that was blight-free. Plots were separated by a minimum distance of 6 m of bare earth. In half of the number of plots (three per treatment) stems were inoculated as described in experiment 1. The trial was inoculated when the foliage was meeting along the rows. Plots of non-inoculated plants served as controls. Overhead irrigation was applied to simulate the rainfall at Auchincruive during July, August and September 1988. In some of the Scottish crops grown in 1988 the incidence of tuber blight was substantially higher than usual and this coincided with prolonged rainfall during July, August and September. The plots were sprayed with mancozeb (Dithane 945, 1.7 kg/ha) every 10 days from shortly after emergence in order to minimise the development of foliar blight. Suspect lesions on the foliage were incubated and examined for the presence of *P. infestans*. Plants were harvested 39 days after inoculation and the incidence of tuber blight and the length of stem lesions were recorded.

Experiment 3 The effect of foliar and stem blight on the incidence of tuber blight

Plots of King Edward, separated by a minimum of 5 m of bare soil, were established in the field. There were three replicate plots of six treatments, i.e. plots with inoculated stems, inoculated leaves or non-inoculated control plants treated with either mancozeb (Dithane 945, 1.7 kg/ha) or fentin hydroxide (Duter 50, 0.56 kg/ha). The trial was inoculated as the foliage was meeting along the rows. Either the stem base or the terminal leaflet of a leaf midway up the stem was challenged with c. 5000 *P. infestans* sporangia. The fungicides were applied from shortly after emergence at 10 to 14 day intervals. Overhead irrigation was applied to simulate the rainfall of 1988. Fifty-nine days after inoculation plants were harvested and stem lesion length and the number of blighted tubers were recorded. The severity of foliar blight in the plots was recorded throughout the growing season.

Experiment 4 The incidence of tuber blight in relation to the number of blighted stem bases

A dropleg sprayer system to improve the deposition of blight fungicides throughout the full depth of the potato crop canopy has been developed by Benest Engineering Ltd. In addition to having a conventional overhead boom, the dropleg sprayer applies fungicide from within the canopy using nozzles attached to droplegs. In a misted trial at SAC Auchincruive in 1994 (cv. King Edward) the control of foliar, stem and tuber blight achieved with fungicides was compared with the Benest and a conventional sprayer. The fungicide programme applied was three sprays of cymoxanil + mancozeb + oxadixyl (Trustan, 2.5 kg/ha) followed by cymoxanil + mancozeb (Curzate M, 2.0 kg/ha) and completed with two applications of fentin acetate + maneb (Brestan, 0.5 kg/ha). The fungicides were applied at both 10 and 14 day intervals (four and two applications of Curzate M, respectively). There were four replicate plots per treatment. Foliar blight was recorded weekly. The incidence of stem blight was assessed on 50 randomly selected stems per plot shortly before desiccation. Those lesions on the lower third of the stem were recorded as lower stem blight. Tuber blight was assessed for 60 randomly selected tubers per plot.

Results

Experiment 1 The relationship between stem lesion development and sporangia production

The number of sporangia produced was not directly related to the length of the stem lesions. Sporangia were produced 9 days after inoculation but necrotic stem lesions were first recorded 16 days after inoculation (Fig. 1). Lesion length increased significantly between each of the dates of assessment. However, the number of sporangia produced after the incubation of stems at c. 100% relative humidity for 48 hours did not increase significantly until 30 days after inoculation. The increase in sporangia production coincided with a switch from sporangia being produced only at the advancing margins of the lesion to most of the lesion length, a reduction in the rate of lesion growth and the start of senescence of the plants. No lesions were observed on the stems of control plants that had not been inoculated.

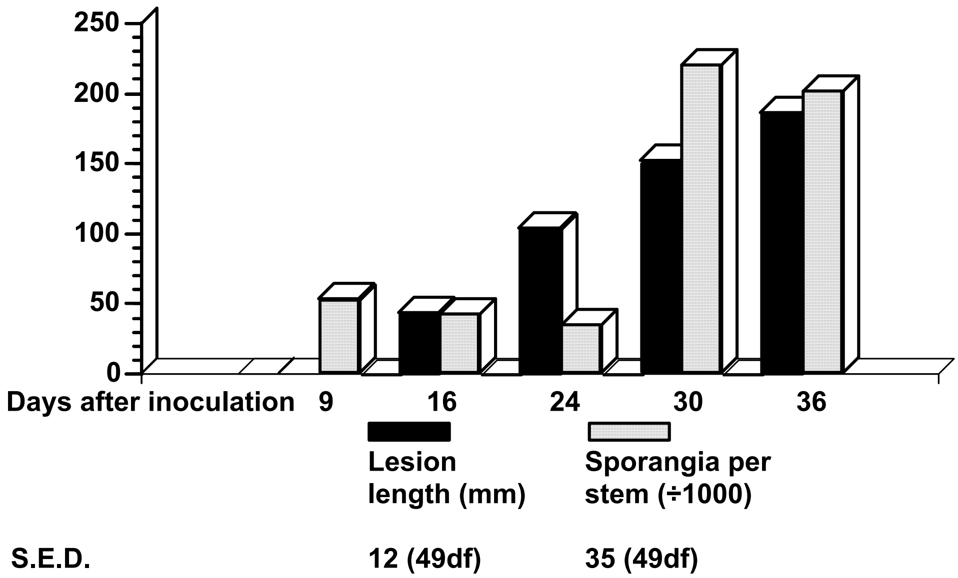


Fig. 1 Sporangia production in relation to stem lesion development

Experiment 2 Stem base lesions as a source of inoculum for tuber infection

Although mancozeb was applied to the plots at 10 day intervals, the length of the stem lesions had increased significantly 39 days after inoculation (Table 1). A high incidence of tuber blight occurred in plots in which stems had been inoculated. None of the daughter tubers sampled from the control plots were blighted. No *P. infestans* sporangia were observed on incubated, suspect leaf lesions.

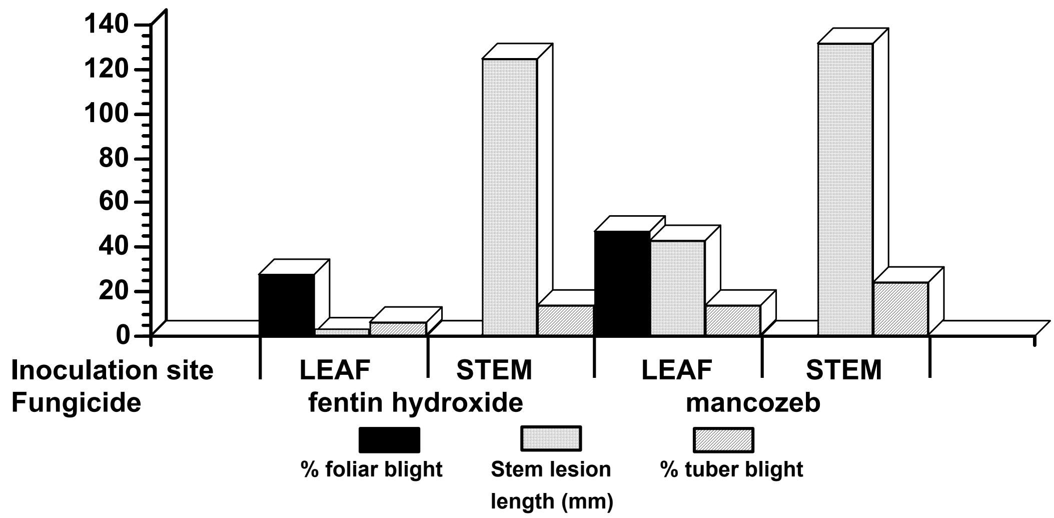
Table 1. Blight lesions on the stem base as a source of inoculum for the infection of progeny tubers.

	Inoculated	Control	S.E.D. (23 df)
Stem lesion length (mm)	180	0	26.9
Incidence (%) of tuber blight[1]	20	0	8.1

[1] angular transformation

Experiment 3 The effect of foliar and stem blight on the incidence of tuber blight

The incidence of tuber blight was more closely related to the length of stem lesions than the severity of foliar infection for the four treatments in which plants were inoculated (Fig 2).



S.E.D. (71 df) **4.7** **17.4** **3.3**

Fig. 2 The relationship between tuber blight incidence and the relative severities of foliar and stem blight

Where the terminal leaflet of plants was inoculated, fungicide type had a profound effect on the development of stem lesions. Treatment with fentin hydroxide, compared with mancozeb, significantly reduced the growth rate of lesions in inoculated leaflets and this resulted in a significantly reduced stem lesion length at the junction of the petiole and stem. In contrast, where the stems had been inoculated directly, fungicide type had little effect on stem lesion length.

Experiment 4 The incidence of tuber blight in relation to the number of blighted stem bases

The incidence of tuber blight was more closely related to the number of blighted stem bases than the severity of foliar disease or the overall incidence of stem blight (Table 2). There were no significant differences between treatments in the severity of foliar blight or in the overall incidence of stem blight. For both spray intervals the incidences of lower stem blight and tuber blight were significantly greater with the conventional sprayer compared with the dropleg.

Table 2. The relationship between the number of blighted stem bases and the incidence of tuber blight

Spray interval (days)	10	10	14	14	
Sprayer	Dropleg	Conventional	Dropleg	Conventional	S.E.D.
Severity (%) of foliar blight	0.9	0.8	1.8	1.3	0.66 (28 df)
Incidence (%) of lower stem blight	7.5	67.5	2.5	27.5	4.18 (28 df)
Incidence (%) of tuber blight	1.4	6.6	1.0	6.2	2.00 (20 df)

Discussion

The results presented in this paper show that in the absence of foliar lesions *P. infestans* inoculum produced on lesions located at the base of potato stems can infect daughter tubers when washed into the soil by rain or irrigation water. The regular application of fungicide to the plots did not prevent tuber infection. In another experiment, the incidence of tuber blight was more closely related to the incidence of lower stem blight than the severity of foliar disease. The most likely explanation is that sporangia on stem lesions can be transferred more easily to the progeny tubers than inoculum produced on foliar lesions. It was suggested in the 1960s that stem lesions could be an important source of inoculum for tuber infection. 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 (1967b) also observed a high incidence of tuber infection close to the stems in pot-grown potato plants. There is evidence that the sporangia on stem lesions can be readily transported in water channelled down the stems to infect the tubers. Rain water was preferentially channelled down the stems of the three cultivars tested by Lacey (1967a). In addition, catches in spore traps attached to the stems of potato plants in the field demonstrated that *P. infestans* sporangia were washed down from stem lesions on all rainy days (Lapwood, 1966). It was found that while potato stems remained upright, any water that was channelled down them went into the gap around their base that was formed as a result of wind rocking (Lacey, 1967a). 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 considerably limit infection.

There are important differences between stem and foliar blight lesions. For example, the temporal and spatial distributions of sporulation differ. In experiment 1 most of the sporulation on stem lesions did not take place until the plants began to senesce and sporulation was evident along the whole lesion, not simply at the advancing margins. It is generally accepted that for foliar lesions sporulation is largely restricted to an annulus at the advancing margin of the lesion. In addition, stem lesions can continue to develop when weather conditions are too hot and dry for foliar blight development. There are reports that under these circumstances many infected leaves abscise prematurely and therefore no longer act as a source of inoculum for disease spread when conditions favourable for blight return (Weihing & O'Keefe, 1962). In contrast, Clayson & Robertson (1956) reported that stem lesions continued to enlarge during a hot, dry period of 40 days and sporangiophores were produced when the weather became favourable for *P. infestans*. Finally, recent experiments have shown that stem lesions produce more sporangia per unit area than foliar lesions and that the difference is very substantial on some cultivars (data not presented).

Acknowledgements

The financial support of the Scottish Office Agriculture, Environment and Fisheries Department, Sandoz Agro Ltd. and Benest Engineering Ltd. is gratefully acknowledged as is the technical assistance of Lynda Raynor.

References

Clayson A M & Robertson N F (1956) Survival of *Phytophthora infestans* in potato stem lesions. Plant Pathology **5**, 30-31.

Lacey J (1967a) The role of water in the spread of *Phytophthora infestans* in the potato crop. Annals of Applied Biology **59**, 245-255.

Lacey J (1967b) Susceptibility of potato tubers to infection by *Phytophthora infestans*. Annals of Applied Biology **59**, 257-264.

Lapwood D H (1964) Haulm and tuber resistance to blight (*Phytophthora infestans*). In: Rot-

hamsted Experimental Station Report for 1963, 111-112.
Lapwood D H (1966) Tuber susceptibility to potato blight. In: Rothamsted Experimental Station Report for 1965, 129-130.
Weihing J L & O'Keefe R B (1962) Epidemiological potentials of potato varieties in relation to
late blight. Phytopathology **52**, 1268-1273.

First Workshop of an European Network for Development of an
Integrated Control Strategy of potato late blight
Lelystad, The Netherlands, 30 September - 3 October 1996

PROPHY. A COMPLETE ADVICE SYSTEM FOR POTATO BLIGHT CONTROL FOR ON-FARM USE. OBJECTIVES, WORKING AND RESULTS IN THE NETHERLANDS AND GERMANY.

W. NUGTEREN
Prolion Development
P.O. Box 34, 2140 AA Vijfhuizen
The Netherlands**14**

Abstract

Development of the ProPhy advice system was started in 1988 from the objective to offer the farmers a dedicated tool to help them in effective and safe control of potato blight (*Phytophthora infestans*). The system is strongly built on empirical and practical knowledge. Country-specific versions have been made for a number of Western European countries, in order to accomodate differences in varieties, chemicals, application laws etc.
Both research and practical use in The Netherlands and Germany have shown that ProPhy results in good blight control with less chemical input. The article explains the objectives of the advice system and outlines the working. Some examples of field trials are included.

Keywords:Potato blight, *Phytophthora infestans*, decision support system, advice system, weather station, microclimate.

Introduction

Prolion Development is a commercial company specialised in development and market introduction of process control systems in agriculture. Research and development on Crop Management Systems started around 1986. An automatic weatherstation was introduced in the European market in 1988. After investigating the management issues in the most important crops in The Netherlands, all attention was focussed towards an advice system for potato blight. The resulting ProPhy system is now being used by over 200 farmers in Holland and on over 30 locations in Germany.

Based on success of the ProPhy system, Prolion has introduced similar systems for other fungus diseases in other crops (onions, flowerbulbs, celery, Brassica's).

Objectives

Potato is one of the most important (cash) crops on many Western European farms, especially in The Netherlands. Control of potato blight is responsible for most of the fungicide input. Besides being an important cost factor, this involves frequent and difficult management decisions of the potato grower. The best strategy in blight control can depend on national circumstances: climate, intensity of potato growing, disease pressure, production purpose etc.

ProPhy is designed to meet the following objectives:

1. Good and safe control of potato blight.
2. Support the potato grower by offering assistance, expertise and insight.
3. Decrease chemical input.

In the bigger part of The Netherlands, potatoes are grown on approximately 25% of the arable land for seed potatoes and long storage consumption potatoes. Keeping free of potato blight is priority no. 1. This results on average in weekly sprayings with preventive chemicals.

Working of ProPhy

Essential basis of the ProPhy system is the continuous and accurate measurement of the micro-climate. Hourly data of temperature, humidity and rainfall is necessary to compute risk of infection/sporulation and disease pressure. Based on practical experience, choices were made to have the following daily output:

* Conclusion "dangerous" or "not dangerous"
* Relative index (0 to 100) as a measure for the risk of infection on that day
* Relative index (0 to 100) as a measure for the disease pressure of the moment

Both measured and forecasted weather (if available) are processed in this way. The weather-criteria in this submodel are mostly based on theoretic research and scientific publications. Adaptions and finetuning have been done by years of use in practical circumstances.

Besides the weather status, the system needs the crop and protection status for giving the final advices. Relevant data is recorded on field level in a dedicated submodule.

The scheme underneath gives an outline of the calculation of the protection status, including the *influencing parameters*:

Standard protection period
last application
type of chemical

+ Dosage factor
relative dosage

+ Wash-off factor
rainfall (amount, intensity, time after spraying)
irrigation

+ Variety factor
leaf susceptibility
tuber susceptibility
production type

+ Crop factor
leaf growth since last spraying
development (heavy-light crops)

+ Risk factor
blight infection in the field
blight sources in the area
disease pressure

All items are expressed in days. For example: the effect of the "crop factor" can range between -2 days and +2 days. The sum of the standard protection period plus all influencing factors gives the actual or calculated protection period (in days). This can be regarded as the period that the crop is sufficiently protected, giving all present circumstances.

An important advantage of the model above is that it gives the farmer a very clear insight in how all parameters are influencing the protection level. It is quite easy to see what the effect is if one of the inputs is changed.

Roughly said, the overall advice depends on the Weather status, the Protection status, and the Crop stage (development stage, presence of blight). The advice consists of a recommendation whether or not to spray and what chemical type to use. With the explanation facilities, the farmer can see how and why the advice is given (text and figures).

Use of ProPhy

In The Netherlands there is a network of around 45 automatic Prolion weatherstations located at farms. About 30 of these are being used for the ProPhy system. Besides a few farmers who own a weatherstation individually, most of the stations are exploited by groups of 5 to 25 farmers. The weatherstations are at a farm centrally located in the group. All participating farmers have the ProPhy software on their own PC, and contact the weatherstation by modem. In total there were over 200 farmers using ProPhy this way in 1996. ProPhy includes different submodels to be activated whether the station is located in the crop (measuring temperature and humidity in the crop) or not. Placement in the crop is an obvious advantage, both technically and psychologically.

In Germany, the ProPhy system is marketed in cooperation with AgrEvo GmbH. Ending in 1996, there has been 3 years of testing and field trials on over 30 locations. Broad market introduction is planned for 1997.

Already in 1989, dedicated versions of ProPhy were developed for France and the U.K. also, followed by two years of field trials in each country. Until now, the focuss in marketing was mainly limited to The Netherlands and Germany.

Though ProPhy is designed as a PC application to be used on-farm, it is a very suitable system also for extension people of gouvernmental organisations and commercial companies. Customized applications have been made ranging from advice by telephone to videotex services to automatic distribution by telefax.

Results

Summarized results of official field trials done by the PAGV on 3 research farms over 1994 and 1995 are in Table 1. Results of some German field trials in 1995 are given in Table 2. Artificial infections were applied to create high disease pressure.

Discussion

Both field trials and practical use by farmers show that the ProPhy system performs very well. From the field trials with high disease pressure it is clear that ProPhy gives a good and safe blight control; equal or better than the standard (weekly) spraying regime. The opinion of the farmers using the system, shows that they experience ProPhy as a good support in their management decisions. Though not in every year at every location, ProPhy is also capable of reaching the third objective, i.e. reduced chemical input. Sufficient blight protection has been realised with reduced dosages, and/or 1 up to 6 sprayings less than a standard treatment.

The general conclusion is that ProPhy is a good help towards effective and efficient blight control. Also it has acted as a good example for other developments of Crop Management Systems. Future improvement and finetuning is possible, but requires basic research on the relationships between fungus, weather and crop. Detailed research on the weather criteria can help to reduce the chemical input even further, without increasing the risk level.

Table 1. Field trial results PROPHY in The Netherlands

Field trial	Standard protection rate	ProPhy protection rate	Standard number of sprayings	ProPhy number of sprayings
* KW 219 (1994)				
Bintje	6.4	6.5	14	14
Agria	6.7	6.7	14	13
Texla	8.0	8.5	14	11
* KW 260 (1995)				
Bintje	8.9	9.4	15	15
Agria	9.0	9.1	15	14
Texla	10.0	10.0	15	11
* KP 336 (1994)				
Elkana	6.0	6.0	15	13
Astarte	4.7	5.7	15	12
Kartel	8.0	8.0	15	11
* KP 352 (1995)				
Elkana	8.7	8.8	16	12
Astarte	9.1	9.3	16	11
Kartel	9.8	9.9	16	11
* RH (1994)				
Bintje	10.0	10.0	14	13
Agria	10.0	10.0	14	11
Texla	10.0	10.0	14	8
* RH (1995)				
Bintje	10.0	10.0	14	10
Agria	10.0	10.0	14	9
Texla	10.0	10.0	14	8

Explanation:

- Protection rate on (logarithmic) PD scale (10 = 0% blight)
- Standard: weekly preventive spraying in 100% dosages
- Observation dates: KW 219 26/09/94 , KW 260 25/09/95

KP 336 03/10/94 , KP 352 25/09/95

RH No significant blight in 1994 and 1995

Table 2. Field trial results PROPHY in Germany 1995

	Number of sprayings s - l - c	Yield (rel.)	Costs (DM/ha)	Yield - costs (DM/ha)
* **Burghorn 1995**				
Untreated	0 - 0 - 0	100	0	5253
Standard A	0 - 0 - 10	120	395	+663
Standard B	0 - 2 - 6	111	403	+194
Standard C	0 - 2 - 6	114	410	+342
Standard D	0 - 0 - 8	104	367	-173
Standard E	0 - 1 - 7	117	477	+387
Simphyt	0 - 2 - 2	109	253	+198
ProPhy	0 - 2 - 4	119	335	+644
* **Puch 1995**				
Untreated	0 - 0 - 0	100		6086
"Gesundvar."	4 - 8 - 0	130		+923
Simphyt	0 - 2 - 8	103		-76
ProPhy	0 - 1 - 7	122		+1014
Adcon I	0 - 4 - 0	111		+349
Adcon II	0 - 4 - 0	108		+209
* **Straßmoos 1995**				
Untreated	0 - 0 - 0	100		6302
"Gesundvar."	2 - 6 - 3	129		+1090
Simphyt	0 - 7 - 1	124		+941
ProPhy	0 - 2 - 6	133		+1713

Explanation:

- Sprayings: s = systemic, l = local-systemic, c = contact

- Yield (DM 19.50/100 kg) minus chemical costs

References

Ridder, J.K., Bus, C.B. & H.T.A.M. Sche4pers. (1995) Experimenting with a decision support system against late blight in potatoes (PROPHY) in the Netherlands. Proc. Phytophthora 150 Sesquicentennial Scientific Conf., Dublin, Ireland ,214-219

Zellner, M. (1996) Kartoffelbau 47 (5) 1996 p. 156-158

First Workshop of an European Network for Development of an
Integrated Control Strategy of potato late blight
Lelystad, The Netherlands, 30 September - 3 October 1996

INTEGRATION OF NEGFRY WITH PC-PLANT PROTECTION: PERSPECTIVES

N.S. MURALI[1] and J. G. HANSEN[2]
Danish Institute of Plant and Soil Science (DIPS)
[1]Department Plant Pathology and Pest Management
Lottenborgvej 2, 2800 Lyngby, Denmark
[2]Department of Land Use, Research Centre Foulum
P.O. Box 23, 8830 Tjele, Denmark.**15**

Abstract

NegFry, a computer program for predicting the optimal times for control of potato late blight, is in the process of being integrated with PC-Plant Protection (PCPP), an on-farm, need-based decision support system for control of pests, diseases and weeds. Both programs use hourly weather data from on-farm climate station in estimating the disease risk indices. PCPP been in commercial use since 1992 and more than 1700 farmers and all of the advisory centres and agriculture schools in Denmark have purchased the system.

Key words: late blight, weather, decision support system, disease risk indices

Introduction

PC-Plant Protection (PCPP) is an on-farm, need-based decision support system for control of pests, diseases and weeds (Murali et al., 1996). It has been in commercial use since 1992 and more than 1700 farmers and all of the advisory centres and agriculture schools have purchased the system. The control recommendation model for pest and disease is based on the incidence level, weather data and agronomic factors. The recommendation includes a list of approved pesticides with its normal dosage, recommended reduced dosage, price and toxicity classification.

Special PAGV-report 1. (1996), 114-116

During the last two years, a pest and disease risk indices model has been field tested to improve the control recommendation and dosage. The model is based on the hourly weather data obtained from an on-farm weather station and the results are presented as a daily risk index and as an accumulated index over a latent period. In the upcoming Windows 95 version of PCPP, the risk indices model is planned to be integrated with the recommendation model.

NegFry is a computer program for predicting the optimal times for control of potato late blight based on the hourly weather data obtained from on-farm or national met stations (Hansen et al., 1995). The system, however, does not recommend optimal control measure in terms of pesticide selection and dosage. Risk indices in NegFry are presented as daily and accumulated indices.

The risk indices model and NegFry use similar weather data and presentation mode for risk indices. Thus, the data and presentation modules can be developed on a common standard and integrated with PCPP. Furthermore, a project on the control measures in terms of fungicide choice and dosage has been initiated along with the integration, which is planned during the 1997.

Database structure

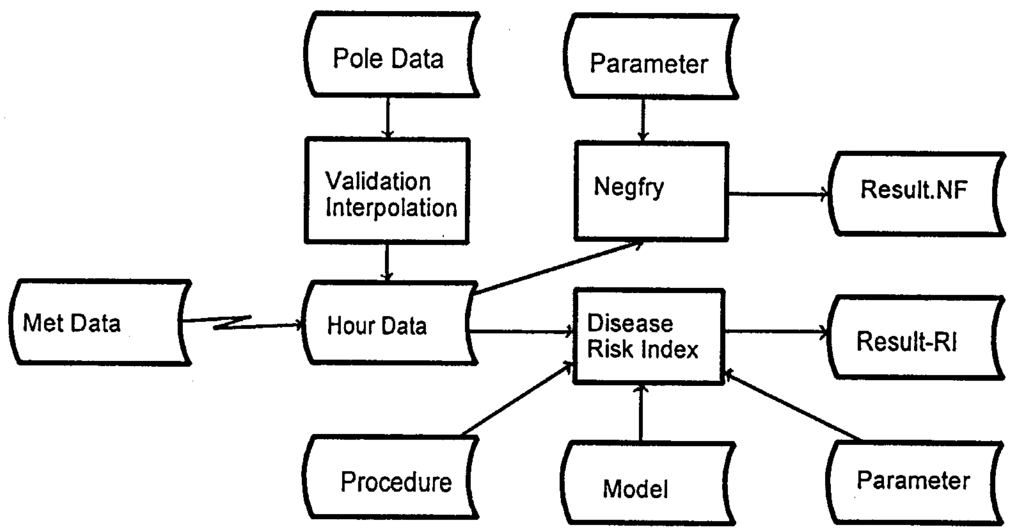


Fig. 1. Data flow structure for Negfry and Disease Risk Indices.

In Fig. 1 is shown the data flow structure common to Negfry and the disease risk indices. Weather data can be accessed from the Danish Meteorological Institute or from the on-farm climate pole. Hourly DMI Met data can be available through the internet and the data interpolation is for a ground resolution of 10x10 km grid nearest to the farm. Pole data are stored as a

Paradox database and are validated for the range and the missing data are interpolated. The updated data are stored as hourly data in table Hour Data and serve as a common weather data for both Negfry and the disease risk indices. The hourly risk indices are calculated and stored in table Results. In both the models the parameter values for the model procedures are separated from the source code and stored in the Parameter table. In addition, the type of procedure and model to be used for each of the disease and pest in the risk indices are defined in tables Procedure and Model, respectively. By separating parameters, procedures and models from the program source code, it is possible to modify or add new pest or diseases through database manipulation rather than program codes. Database manipulation is much easier and more convenient than program code modifications.

Program procedure

The program is being developed using Borland's Delphi and Paradox DBMS. The program include basic and routine procedures which are activated once at the beginning of the season and routinely during the season, respectively.

The basic procedure include defining the field data such as the potato cultivar, sprouting date, soil type, the expected end of season and the source of weather data.

During the season, the user updates the last field operations such as fungicide spraying or irrigation and the model calculates risk indices. If the model recommends a control measure, DIPS recognised fungicides are listed together with the dosage and price in the same format that of PCPP. The risk indices can be viewed as a graph or a table.

References

Hansen, J.G., B. Andersson & A. Hermansen. 1995. NEGFRY - A system for scheduling chemical control of late blight in potatoes. Proc. Phytophthora 150 Sesquicentennial Scientific Conf., Dublin, Ireland, 201-208. Boole Press Ltd. (See also article in this proceedings).

Murali, N.S., B.J.M. Secher, P. Rydahl & F.M. Andreasen. 1996. Application of information technology in plant protection in Denmark: from vision to reality. Proc. 6th Int. Cong. for Computer Tech. in Agri. (ICCTA'96), June 16-19, 1996, Wageningen, The Nether-lands. Agro-Informaticareeks nr. 10, 146-150.

First Workshop of an European Network for Development of an
Integrated Control Strategy of potato late blight
Lelystad, The Netherlands, 30 September - 3 October 1996

EXPERIENCE WITH A LATE BLIGHT DSS (PLANT-Plus) IN STARCH POTATO AREA OF THE NETHERLANDS IN 1995 AND 1996

JAN HADDERS
Dacom Automatisering b.v.
P.O. Box 2243
7801 CE Emmen, The Netherlands**16**

Abstract

In 1994 Dacom Automatisering introduced a Decision Support System for *Phytophthora infestans* named PLANT-Plus. Within the context of a broad project for sustainable agriculture, the Star-project, in 1996 over 100 farmers used PLANT-Plus as a DSS for controlling *Phytophthora*. Also a trial on the research farm 't Kompas was executed. The main elements of coming to a succesful usage of the system are the close guidance of the participants and the use of an integrated computer system. As part of this system, the model used in PLANT-Plus for the warning module is a combination of empirical and fundamental submodels. The amount of spores above a field, the unprotected part of the crop, the possibility of an infection and the micro climate are taken into account. In the practical situation of the Star-project, about the number of sprayings were was reduced with approximately 50%.

Keywords: DSS, Phytophthora infestans, Plant-Plus, starch potatoes

General information project

In the three northern provinces of the Netherlands a project (Star-project) was started to stimulate sustainable agricultural methods. About 120 farmers with over 3000 ha of potatoes, mainly for the starch industry, participated in the project with the Plant-Plus system. In the region a network of automatic weather stations was set up. Contacted by phone every two hours, the measured weather data is processed and stored in the central databank. Also the regional weather forecast is stored in this databank.

The location of potato fields, of weather station and of observed infection sources is recorded with their coördinates. This geographic information is used to calculate spore dispersal.

During the season an employee of Dacom observes a field of each farmer every week. Furthermore this person supports the farmer in the use of the computer. Two or three times per season groups of farmers are invited at the Dacom office to discuss the actual Phytophthora situation and to learn more about the use of the system.

In order to get an overview of the sources of infestation of an area, fieldworkers of different suppliers and institutions relay data about these sources to the central databank.

At the end of the season, all data from one field of each participant of the Star-project is gathered and analysed.

Basic system Plant-Plus

The basic system consists of a computer program on the farm and a central databank. A communication module takes care of data interchange. The local program is supplied with data directly from the farmer and by electronic means from the central databank. The farmer enters basic crop data, crop treatments and if possible, crop observations. On the databank information from local weatherstations, regional weather forecast, crop observation from scouts, basic data about fungicides, actual information from extension services etc. is available. Data exchange is fully automatic. All data needed for e.g. variety choice or the calculation of a possible infection period in a field are on the computer of the farmer.

The Dacom model for calculating treatment dates

General

The model used by Dacom consists of a combination of empirical and fundamental submodels. Where possible, data from different publications is used [1]). Additional information is provided by ir. L. Turkensteen form IPO-DLO. The results are compared with practical experience and discussed with ir. Turkensteen.

Submodels

The submodels can be divided into 3 groups:

- climatic calculations

- value of crop protection
- the fungus *Phytophthora infestans*

Climatic calculations

The calculation of the micro climate in the crop is based on (standarised) measurements of the weatherstation and the density of the crop. In separate models the temperature and the humidity (= leaf wetness situation) are calculated. The climatic elements are: temperature, relative humidity, radiation and windspeed. The crop density is based on a scale from 0 - 10. For each crop Dacom made a list with a description of the crop for each index number. One of the results is an extension of the leaf wetness period if the crop density number is increased.
The Dacom model calculates all data per hour. If the weather forecast is not supplied with this interval, hourly data is calculated by the system. Rainfall is mostly forecasted as a chance of rain with a certain amount. Together with the forecasted relative humidity, the system recalculates forecasting intervals of three hours to a rainfall of one, two or three hours.

Value of crop protection

The Dacom model calculates the unprotected part of the crop. The calculation is based on two elements; crop growth and wear off of the applied fungicide. Crop growth starts at the emergence of the potato plants, before that the unprotected part is zero.
Crop growth is determined by a list based on the number of new leaves each week. This growth is observed either by paint spraying some plants or by recalculating stem growth measuring each week. Instructing the farmers and the examples set by the scouts are very important.
The calculation of wear off of the fungicide is based on the fungicide itself and the amount used in relation to the advised dose. The weather elements used are the radiation and the precipitation. Although each fungicide can have its own characteristics, data of some fungicides is copied to comparable fungicides because information is not available.
During the time after emerging or after a spraying in most cases the crop will become more unprotected. This value of crop protection, together with the probability of an infection by *P. infestans*, is used to calculate a recommendation for an application.

Phytophthora infestans

The Dacom model divides the life circle of *P. infestans* into sporulation, release (and sur-

vival) of spores and penetration of spores into a leaf.
The calculation of sporulation, eg. the possibility of forming spores on a lesion, is based on the calculated relative humidity.
The release of spores is based on three elements; time, rainfall and a decrease of RH in two successive hours. It is known that after a period of formation of spores, some spores are released into the air.
The release of spores triggers another submodel. Sources of infestation are recorded by fieldworkers of supply companies and different institutions. Time and date, the coördinates, the type of source and the expected danger are recorded. The different type of sources are: normal fields, biological fields, cull piles, volunteer potatoes and private gardens. Recordings are checked every day by the project managers to warn for longer existing and not changing sources. The expected danger is bases on a list provided by Dacom. This quality list, from 0 - 10, describes the estimated number of infected leaves. Cull piles and spot infections have different descriptions. If spores are ejected, the amount of spores coming above a specific field is calculated with the wind direction and for each source within a certain distance and the angle to the wind direction, the distance and the quality of the source. The sum of these spores can be described as the infection pressure on a field. If the situation continues, new spores will be released and dispersed and will be added to the existing spores. If conditions are not favourable for forming or releasing spores, the amount of spores will be decreased depending on temperature and radiation.
The presence of spores will trigger the submodel for calculating the possible penetration (including the time for germination) of spores on an unprotected leaf. The elements used by the model are: formerly calculated leafwetness, calculated temperature and the resistance of the potato variety.

An infection chance does not necessary trigger a treatment. In this case the Dacom model assumes that infection has taken place. Depending on the quality of the start of this infection and the calculated micro climate, the possibility of forming new spores (latent period) is calculated. In this case, the source is looked upon as a "normal" source with a distance to the field of zero.
The total danger of an infection is determined by the amount of spores in an specific hour multiplied by the length of the period in which penetration is possible. This figure, combined with the unprotected situation of the crop can trigger Plant-Plus in advising a spraying. With

an infection based on the forecast, a preventive spraying is advised. When an infection is calculated within the last 48 hours, a curative spraying is advised. If an infection took place more than 48 hours ago it is considered too late for a spraying and the farmer has to wait for the effect. The incubation period (Hartill en Young, 1985) of such an infection will be calculated and can have an effect on following infection periods and spraying advice.

Results

Developing the Plant-Plus system Dacom had two objectives in mind: preventing *P. infestans* and saving on the amount of chemicals used. Saving on chemicals is dependent on the weather in general and also on sources of infestation (and their activity) in the area. The basic idea of Plant-Plus is: if a heavy infection is expected, the crop has to be protected!

The general experiences with Plant-Plus are: 1. Farmers have to learn to trust the advice and 2. compared to a weekly schedule, in 1995 and 1996 considerable savings could be made. (see appendix "Practical research Late Blight management RC 't Kompas 1996."

Learning farmers to use the system is done by an employee of Dacom. Working with the system will make farmers far more conscious of the occurence of *P. infestans*. In order to have confidence in the system, the farmer has to understand the advice as calculated by Plant-Plus.

Discussion

The Dacom model used in the Plant-Plus system is a combination of fundamental and empirical submodels. On some specific subjects more research data is needed. Differences between varieties in time of penetration at different temperatures is not recorded at all or not in an uniform manner. Also the dispersal of spores and the calculation of the micro climate has to be modeled more precisely. This scientific data has to be evaluated for the impact when used in systems that operate on farm level.

By carefully monitoring actions and results of a relative large group of farmers and by experimenting on trial farms, it seems that a further reduction of the number of sprayings will be very difficult.

A point of concern is the possibility for a normal spraying machine to fully protect a crop with a preventive fungicide. Therefore Dacom will investigate whether an improvement of the deposition of fungicides can be achieved with the Benest Dropleg spraying machine (Rund, 1996).

Conclusion

Spraying by advice from Plant-Plus saved a group of farmers in the starch potato area a considerable number of sprayings. Also the way of thinking about Phytophthora has changed. In 1997, more farmers, in the project area as well as in other parts of the Netherlands and in other countries will use the system. With Plant-Plus researchers have a tool to calibrate their data and to add new knowledge to fight *Phytophthora infestans*.

References

Harrison, J.G. 1992. Effect on aerial environment on late blight of potato foliage - a review.
Plant Pathology 41:384-416

Rund, T. 1996 Dropleg provides superior blight control. Arable farming, May: 62-63

Frinking H.D. Zadoks, J.C., '72, '75 Epidemiologie, KB-college (2s.u.) 614-05

Zaag, D.E. van der. Overwintering en epidemiologie van P. Infestans

First Workshop of an European Network for Development of an
Integrated Control Strategy of potato late blight
Lelystad, The Netherlands, 30 September - 3 October 1996

DECISION SUPPORT SYSTEMS FOR *PHYTOPHTHORA INFESTANS*: THE IRISH EXPERIENCE

LESLIE. J. DOWLEY
Plant Pathology & Entomology Department,
Oak Park Research Centre,
Carlow, Ireland.**17**

Abstract

Potato production in Ireland has fallen steadily since the beginning of the twentieth century. In recent years this decline has been halted and the current area planted is 18,000 ha. The cost of pesticide inputs in potatoes is £IR 4.00m per annum of which over 50% is spent on fungicides for the control of late blight. This emphasises the continued importance of late blight as a major disease of potatoes under Irish conditions. It is estimated that the annual loss from the disease is 8% (Copleland *et al*, 1993).

Introduction

The control of *Phytophthora* is effected by the routine application of fungicides from ground sprayers. The fungicides used include the dithiocarbamates, phenylamides, fluazinam, dimethomorph, propamocarb and the organo-tins. The main problems encountered include phenylamide resistance, increased virulence and aggressiveness together with the A2 mating-type.

Phenylamide resistance can be confirmed in about 60% of crops monitored, while crops with resistance present normally contain about 50% of resistant inoculum (Dowley & O'Sullivan, 1991). Over the years the virulence of isolates has increased from race 1,4 to race 1,3,4,7,10,11 with race 2 tending to make its appearance only later in the season. An increase in the aggressiveness of a number of isolates has also been observed but the frequency of these isolates within the population has not been confirmed. The A2 mating-type was first

Special PAGV-report 1. (1996), 123-126

confirmed in 1989 when it made up one third of the population (O'Sullivan & Dowley, 1991). Since then, the frequency of A2 has reduced annually up to 1995 when the presence of A2 could not be confirmed.

The forecasting of late blight has been practised in Ireland for many years (Bourke, 1953). This system has failed to give consistent results when compared to routine spraying (Frost, 1974) and has subsequently been used only to identify future periods of high blight pressure. More recently, the in-crop weather stations have provided precise local weather data which have been combined with computer based forecasting programmes which identify the most suitable dates for spraying. This report compares the preliminary results from routine spraying with the Lufft/Agricast and Hardi Metpole/Negfry systems.

Material & Methods

Trials were conducted at Oak Park Research Centre, Carlow, on the foliage blight susceptible maincrop cultivar `Rooster` during 1994 and 1996. The design for each trial was a randomised complete block with four replications per treatment. Each replicate consisted of 6 drills 8.2 m long. The drill width was 0.76 m and the distance between tuber centres was 0.33 m. The total replicate size was 37.5 m^2 from which 25 m^2 were harvested across the centre 4 drills. A 3 m unplanted divider strip was left between replicates to facilitate mechanical harvesting and no artificial inoculum was used in the experiments. Weed control consisted of paraquat (600 g a.i./ha) and simazine (600 g a.i./ha) applied pre-emergence.

Fungicide application commenced in mid-June when the plants were beginning to meet along the drill and was repeated at 7-14 day intervals throughout the season or as indicated by the division support systems. The spray volume was equivalent to 250 l/ha and the spray pressure was 3 bars. Machinery access was by means of rotovated spray paths to prevent crop damage.

Fungicide Programmes

In 1994 the Irish Meteorological Service (IMS) warnings and the Lufft/Agricast system based on mancozeb (1,800 gr a.i./ha) was compared with routine applications of mancozeb and a PAM programme (metalaxyl/mancozeb mixture (2.25 kg product/ha) for the first three sprays followed by mancozeb to the end of the season) at 10-day intervals. In 1996 the Irish Meteorological Service warnings based on mancozeb and the Hardi Metpole/Negfry system based on mancozeb and fluazinam (0.2 l a.i./ha) was compared with routine applications of mancozeb and a PAM programme. During each season, disease levels were assessed at weekly intervals up to desiccation using the British Mycological Society foliage blight assessment key (Cox & Large, 1960).

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 & Discussion

During 1994 the IMS system resulted in a saving of 70% in spray numbers while the Lufft/Agricast system resulted in a saving of 30%. The level of foliage blight at the end of the season was lowest for the two routine spray programmes and these were significantly lower than the Lufft/Agricast system or the IMS system (Table 1). This would indicate that while savings in fungicide were achieved in 1994, the level of disease control was inadequate.

During 1996 when disease pressure was high, the IMS system resulted in a saving of 60% in spray numbers while the Hardi Metpole/Negfry system resulted in a saving of 50%. The level of foliage blight at the end of the season was lowest for the routine PAM programme but this was not significantly lower than either the fluazinam or the mancozeb treatments applied as per the Hardi Metpole/Negfry system (Table 2). These treatments were also significantly better than the routine application of mancozeb. This would suggest that savings in fungicide can be made in a severe blight year without the loss of disease control. This effect may be due to the more accurate timing of the fungicide applications.

Table 1. % foliage blight 1994

Treatment	% Foliage Blight
Mancozeb (R)	6.25
PAM (R)	4.00
Mancozeb (IMS)	56.25
Mancozeb (L/A)	22.5
L.S.D. (0.05)	6.32

R = routine application
IMS = Irish Meteorological Society Warnings
L/A = Lufft/Agricast System

Table 2. % foliage blight 1996

Treatment	% Foliage Blight
Mancozeb (R)	14.00
PAM (R)	0.78
Mancozeb (IMS)	15.00
Mancozeb (L/A)	3.00
Fluazinam (L/A)	0.78
L.S.D. (0.05)	11.00

R = routine application
IMS = Irish Meteorological Society Warnings
L/A = Lufft/Agricast System

References

Bourke, P. M. A. 1953. The potato blight weather warning service in Ireland in 1952. IMS Technical Note, No. 13, Dublin, pp 1-45.

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

Copeland, R. B., L. J. Dowley and J. F. Moore. 1990. The vulnerability of the Irish potato industry to harmful organisms. **In:** Plant Health and 1992. (Eds J. A. Kavanagh & P. Brennan) Royal Irish Acadamy, Dublin, pages 95-106.

*Dowley, L. J. and E. O`Sullivan.* 1991. Changes in the distribution of phenylamide-resistant strains of *Phytophthora infestans* (Mont.) de Bary in Ireland 1985-`89. Potato Research **34**:67-69.

Frost, M. C. 1974. *Phytophthora infestans* on potatoes in Ireland - its incidence, control by fungicides and predictability in relation to weather. Ph. D. Thesis, National University of Ireland.

O`Sullivan, E and L. J. Dowley. 1990. A note on the occurrence of the A2 mating type and self fertile isolates of *Phytophthora infestans* in the Republic of Ireland. Ir. J. Agr. Res. **30**:67-69.

First Workshop of an European Network for Development of an
Integrated Control Strategy of potato late blight
Lelystad, The Netherlands, 30 September - 3 October 1996

FIELD SPECIFIC AND REGIONAL WARNING FOR DEVELOPMENT OF POTATO LATE BLIGHT

Jens Grønbech Hansen
Danish Institute of Plant and Soil Science
Department of Land Use
Research Group for Agrometeorology and Crop Physiology
Research Centre Foulum, 8830 Tjele, Denmark**18**

Abstract

In Denmark decision support for late blight control is available via NEGFRY and Pl@nteinfo. NEGFRY is a PC- based decision support system and Pl@nteinfo is World Wide Web based information system, which includes prognosis and risk analysis for late blight development on a regional scale. The two systems and their practical implementation are presented and discussed.

Keywords: late blight, chemical control, weather, www, NEGFRY, Pl@nteinfo

Introduction

Potato late blight caused by *Phytophthora infestans* (Mont.) de Bary is a serious problem for potato growers in Northern Europe, and large amounts of pesticides are used to control the disease.

In 1987 the Danish Institute of Plant and Soil Science initiated investigations into the influence of the weather on the development of potato late blight (Hansen & Holm, 1991; Hansen, 1992). Based on results and experiences from this work, NEGFRY, a PC-based decision support system for chemical control of late blight, was developed (Hansen, 1993; Hansen, 1995a; Hansen, Andersson & Hermansen, 1995).

Through a Nordic collaboration on the development and test of warning systems for late blight, NEGFRY has been tested in about 30 field trials and field experiments. The results show that the number of treatments can be reduced considerably and with the same effect as routine treatment (Andersson, 1994; Andersson, 1995; Hansen & Simonsen, 1994; Hansen, Andersson & Hermansen, 1995).

The calculations with NEGFRY on the need for fungicide treatments are based on knowledge of the weather's influence on the biology of the fungus and the mode of operation of fungicides.

In 1996 a Danish information system for agriculture called Pl@nteinfo was introduced via World Wide Web (Jensen, A.L. et al, 1996; Jensen, T. et al., 1996). In this system a regional warning for potato late blight was available and updated every day during the growing season. The method used was based on the German negative prognosis. In this paper the NEGFRY system and Pl@nteinfo are introduced and the advantages of both systems are discussed.

The Negfry decision support system

The NEGFRY system is based on two existing models, the "negative prognosis", for forecasting the risk of primary attacks (Ullrich & Schrödter, 1966), and a model for the timing of subsequent fungicide applications during the season (Fry *et al.*, 1983). The parameterization of the NEGFRY model was based on biological and meteorological data obtained from Foulum, DK during the period 1987-1992. The NEGFRY input and output variables are shown in Figure 1.

According to the "negative prognosis" there is no risk of primary attacks until the accumulated risk value has exceeded a threshold value of 150 (Ullrich & Schrödter, 1966). In the NEGFRY model the initial fungicide application is recommended once the accumulated risk value has exceeded 160 and the daily risk value, calculated according to the "negative prognosis" is above 8 (Hansen, 1992; Hansen, 1995a). In hot and dry weather this can be one or two weeks after exceeding the risk value of 160 (Hansen, Andersson & Hermansen, 1995). After the initial spray, favourable weather for disease development is expressed as blight units according to the method of Fry *et al.* (1983). All parameters in the model are saved in a setup file and can be changed by the user.

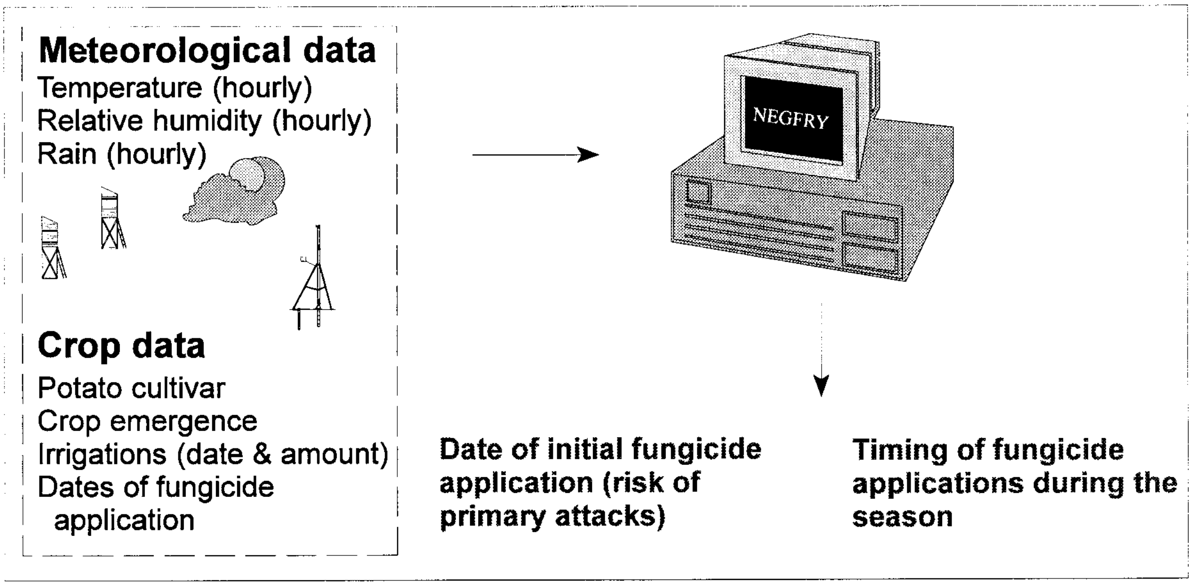


Figure 1. Input and output from NEGFRY. The source of weather data may be the Hardi metpole or ordinary meteorological stations.

Sporulation happens during nights, and sporangies containing 5-7 spores are released into the air during morning hours when the relative humidity is rapidly decreasing. To optimize the timing of fungicide treatment, it is important to keep NEGFRY updated with the most recent meteorological data. The development of NEGFRY was therefore correlated with the development of the Hardi metpole, a weather station for on farm use (Høstgaard, 1993; Hansen; 1995b).

Pl@nteinfo

Pl@nteinfo is a World Wide Web based information system for Danish agriculture (*http://www.sp.dk/planteinfo/*). The project was initiated in 1996 with the objective of investigating the potentials and demonstrate the advantages of using WWW for dissemination of information for crop management. The project is a collaboration between the Danish Institute of Plant and Soil Science (DIPS), the Danish Agricultural Advisory Centre (DAAC) and the Royal Veterinary and Agricultural University (RVAU).

In Pl@nteinfo different kinds of information are available:

* General weather information
* Warnings for pest and diseases

* Recordings of pest and diseases
* General information

Formerly pest and disease warnings in the form of maps and tables were sent from DIPS to the Central Extension Service by mail or fax once a week. With Pl@nteinfo the weather based pest and disease warnings are updated every day in the form of coloured maps and tables including comments from the DAAC. Via a link to DAAC it is possible to have updated information on disease development based on data from a network of field recordings of pest and diseases. In the 1996 version of Pl@nteinfo, warnings were available for the following pest and diseases:

* Septoria spp in winter wheat (risk of dispersal)
* Leaf blotch and net blotch in barley (risk of dispersal)
* Brassica pod midge
* Frit fly
* Potato late blight

In Pl@nteinfo late blight warning is based on the German negative prognosis as used in NEGFRY (figure 2). The user choose " late blight" on the Pl@nteinfo main menu using a "mouse", and a new page with two maps appears. Map 1 shows the accumulated risk value at 21 ordinary meteorological stations in Denmark. Map 2 shows the daily risk value at the same stations. A click on a station on map 1, will show the accumulated risk value curve with start at three different crop emergence dates. A click on a station on map 2 will show the daily risk values from crop emergence to current date. The Pl@nteinfo warning method based on map 1 and 2 is given in figure 2.

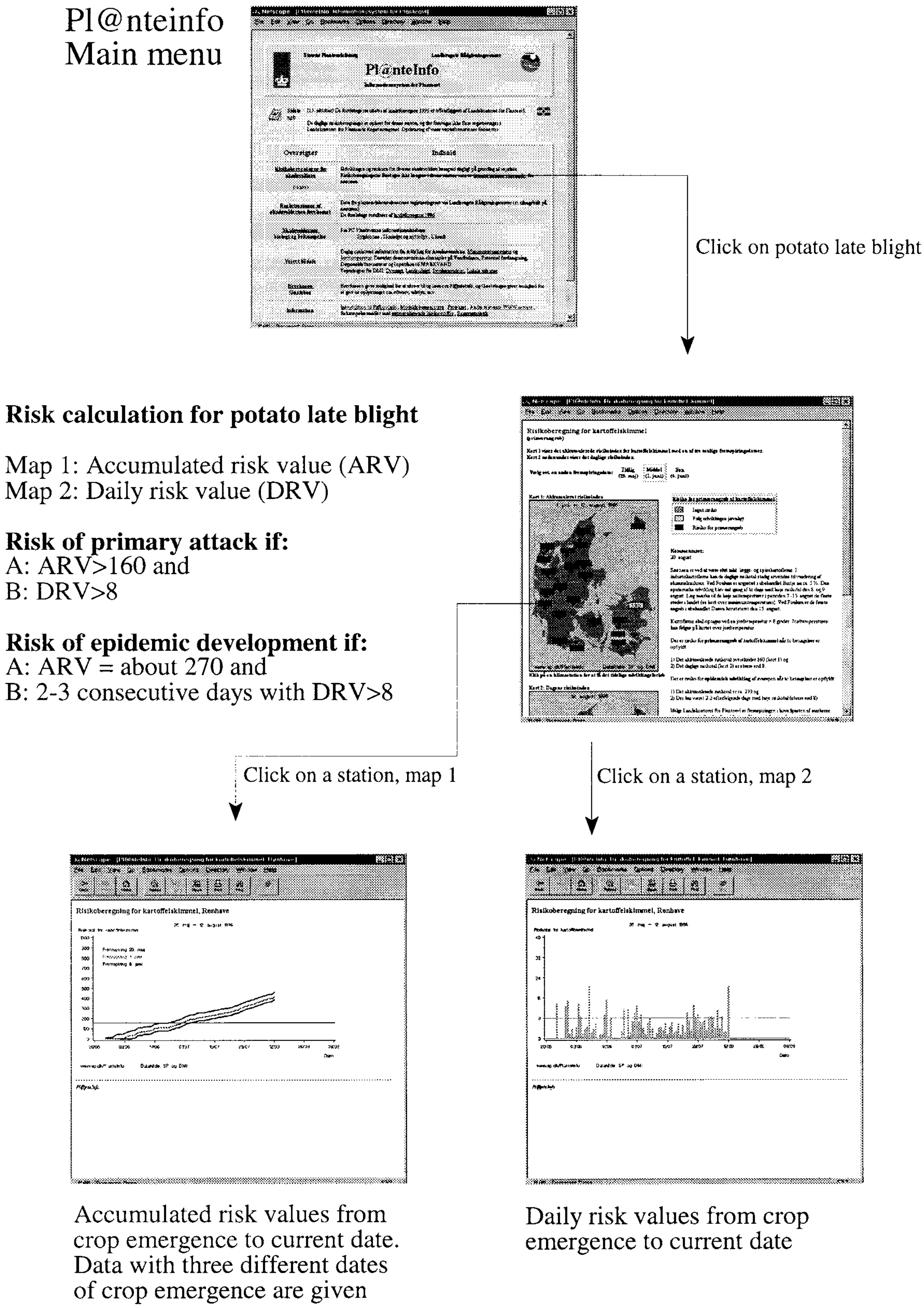


Figure 2. Late blight warning information available in Pl@nteinfo

Interpretation of the results and information from other sources are given in text on the page with map 1 and 2. The text physically located at the web-server in Foulum is updated automatically via Internet connection by a responsible person situated at the central extension service in Århus. There is a link to documentation of the method used and a link to a description of the biology of potato late blight.

Discussion and conclusion

The NEGFRY system is used by the extension service and by farmers for field specific control of potato late blight. Based on local meteorological and field specific crop data (figure 1), the farmer can get advice about when to start the spraying season and about spraying intervals. As calculations in Pl@nteinfo are based only on meteorological data, Pl@nteinfo can only give advice on the risk of primary attack and not on spraying intervals. On the other hand the regional presentation of risk values is valuable to the extension service for general advice.

Farmers that use NEGFRY and meteorological data from a local meteorological station like the Hardi metpole may use the risk values calculated in Pl@nteinfo as a quality control of their meteorological data.

Local weather stations may cost between 35.000-75.000 Dkr. At the moment information via Pl@nteinfo is free of charge, but an annual charge may be applied case in future. Via the Danish Meteorological Institute primary meteorological data interpolated in 10*10 km GRID will be available via the Internet from 1997. The charge for this service is not known at the moment. For the local use of NEGFRY, GRID data will be an alternative to a private local weather station, but we still need to test the quality of interpolated data compared to local measurements.

To keep the price low for the use of the Hardi Metpole, the Hardi company in 1996 offered a modem solution for transfer of data over greater distances. An automated system collect data from several metpole "PC-servers" in an area to be stored centrally at the local extension service centre. This solution was tested by the extension service in 1996 to enable more farmers via modem to share data from a few metpoles in order to run NEGFRY.

Only few of the Danish potato growers were connected to the Internet in 1996, but it is expected that this will change dramatically during the next years. The next step in the Pl@nteinfo project will be to investigate how to integrate Pl@nteinfo and the PC-based DSS systems like NEGFRY. Via the Web system it is possible to coordinate informations from databases with information of fungicides, their use and activity, information of varieties, their susceptibility to late blight and other diseases etc. Pictures of potato diseases, guidelines for use of meteorological equipment etc. may be stored on a CD-ROM and specific pictures may be activated via links in text in Pl@nteinfo.

References

Andersson, B. 1994. Bekämpning av potatisbladmögel enligt prognos. 35:e Svenska Växtskyddskonferensen Uppsala 26-27 januari 1994*,* 369-376.(in Swedish).

Andersson, B. 1995. Prognos av potatisbladmögel med hjälp av väderdata. 36:e Svenska Växtskyddskonferensen Uppsala 25-26 januari 1995*,* 335-342.(in Swedish).

Fry, W.E., A.E.Apple and J.A.Bruhn 1983. Evaluation of Potato Late Blight Forecasts Modified to Incorporate Host Resistance and Fungicide Weathering. Phytopathology **73**, 1054-1059.

Hansen, J.G. og Holm, S. 1991. Validering af Negativ-prognosen til varsling for kartoffelskimmel. 8. Danske Planteværnskonference*,* 253-259. (in Danish).

Hansen, J.G. 1992. Mikroklima i kartofler i relation til kartoffelskimmel (*Phytophthora infestans*). Tidsskrift for Planteavls Specialserie **nr. S 2178,** 45 pp. (in Danish).

Hansen, J.G. 1993. The use of meteorological data 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. & Simonsen, J. 1994. Behovsbestemt fungicidbehandling mod kartoffelskimmel (*Phytophthora infestans*) - erfaringer fra Danmark 1993. 35:e Svenska Växtskyddskonferensen Uppsala 26-27 januari 1994, 377-385. (in Danish).

Hansen, J.G. (1995a). 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.

Hansen, J.G. (1995b). Klimaspyd - Konklusioner og erfaringer fra et femårigt projekt. 12. Danske Planteværnskonference, sygdomme og skadedyr, SP-rapport nr 4*,* 129-138.

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.

Jensen, A.L., I.Thysen & Bo J.M. Secher (1996). Decision support in crop production via the *internet.In:* Proceedings from the workshop on decision support systems in crop protection, Münster, Germany, 4-8 November 1996, Report series from DIPS, SP-Report 1996, **no. 15**, 37-39.

Jensen, T., Hansen, J.G., Thysen, I., A.L. Jensen & P. Boll. (1996). Regional agrometeorology on World Wide Web. In: International symposium on applied agrometeorology and agroclimatology, Volos, Greece, 24-26 April 1996, 5 pp *(in press).*

Høstgaard, M. 1993. A climatic station with wireless transmission. EPPO Bulletin, **23 No 4**, 681-683.

Ullrich J. & H. Schrödter 1966. Das Problem der Vorhersage des Auftretens der Kartoffelkrautfäule (*Phytophthora infestans*) und die Möglichkeit seiner Lösung durch eine "Negativprognose". Nachrichtenblatt Deutsch. Pflanzenschutzdienst (Braunschweig) **18**, 33-40.

First Workshop of an European Network for Development of an
Integrated Control Strategy of potato late blight
Lelystad, The Netherlands, 30 September - 3 October 1996

MODELS USED IN FRANCE
IN THE WARNING SYSTEMS

S. DUVAUCHELLE[1] & L. DUBOIS[2]
[1]Service Régional de la Protection des Végétaux
BP 47,62750 Loos-En-Gohelle- France
[2]Station d'Etudes sur Ie Lutte Biologique
(FREDEC),21, ruc Becquerel
62750 Loos-En-Gohelle- France **19**

Abstract

In the model Guntz Divoux, three levels risks of contamination are calculated with meteorological (RH > 90 %) of the last days. The length of incubation, calculated with average temperature permits to decide the of treatment.

In Ifilsol, each compartent : contamination, incubation and sporulation, is quantified.

Keywords : Phytophthora infestans, late blight, warning system, model, meteorological data.

Special PAGV-report 1. (1996), 135-147

Phytophthora infestans control in France

	Slight epidemic ex : 1996	High epidemic Ex : 93, 94, 95
Number of sprays		
Ware production	11	17
Starch and processing production	16	20
If irrigation	+ 5	+ 5
Fungicides		
dithiocarbamates	≈ 75 % (80 %)	≈ 60 %
cymoxanil	≈ 8 %	≥ 15 (20 %)
phenylamide	< 5 %	≈ 5 %
fluazinam	≈ 5 - 8 % (last treatt)	≤ 10 %
propamocarbe	≈ 5 % (irrigation)	≤ 8
sel d'étain	≈ 3 %	≥ 5
dimethomorph		
Kg ai per year ware production	14 kg	20 kg

Estimations of Mister DUVAUCHELLE

"Warning systems"

Models: Guntz Divoux

MILSOL

Fields observations

"Institutes working on subjects relevant for control of Phytophthora infestans"

* Research station of biological control (FREDEC Loos-en-Gohelle)
* Plant Protection Service Paris (SDPV) and others areas (Bretagne, Picardie, Haute Normandie, Champagne Ardenne, lle de France, Centre)
* INRA Le Rheu : Resistances, types of strains
* Fongicides compagnies : effectiveness of fungicides stratégy
* Breeding research: R~ Ploudaniel, Germicopa, FNPPPT
* ITPT (ITCF since 1996) : effectiveness of fungicides
* Processing firmes : Stragegy
* ConcertationwithinBelgium: M.Ampe(Flandres)

  M. Ducatillon (Hainaut)
* Concertation with institut in Québec : M. Tartier

What is integrated control?

Only reduce pesticide load ?

= easy but dangerous for ex: only 1 or 2 Al (fluazinam)

or reduce pesticide load

+ choice less ecotoxic ingredients

+decrease number of treatments

+alternate treatments

Opportunities :

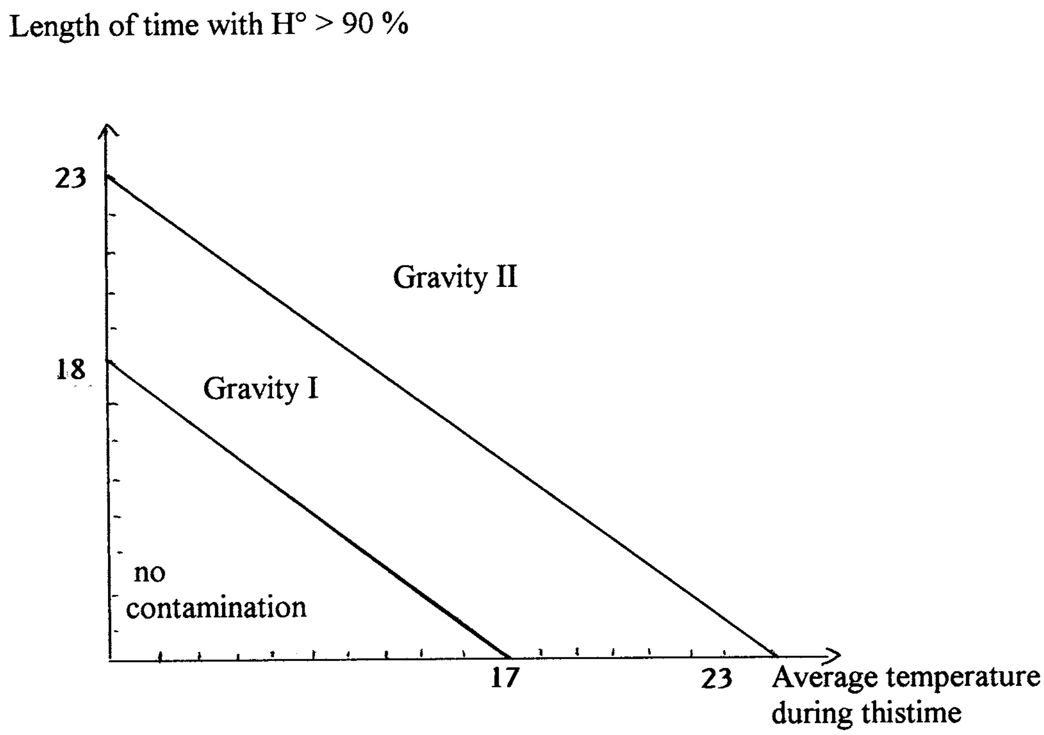
- choice of pesticides - cultivars - production - technics (irrigation, plantation)
- warning systems

Goal of harvest: -highest yield ?

-zero desease on tubers ?

<u>GUNTZ DIVOUX MODEL</u>

<u>Evaluation of the risk of contamination</u>

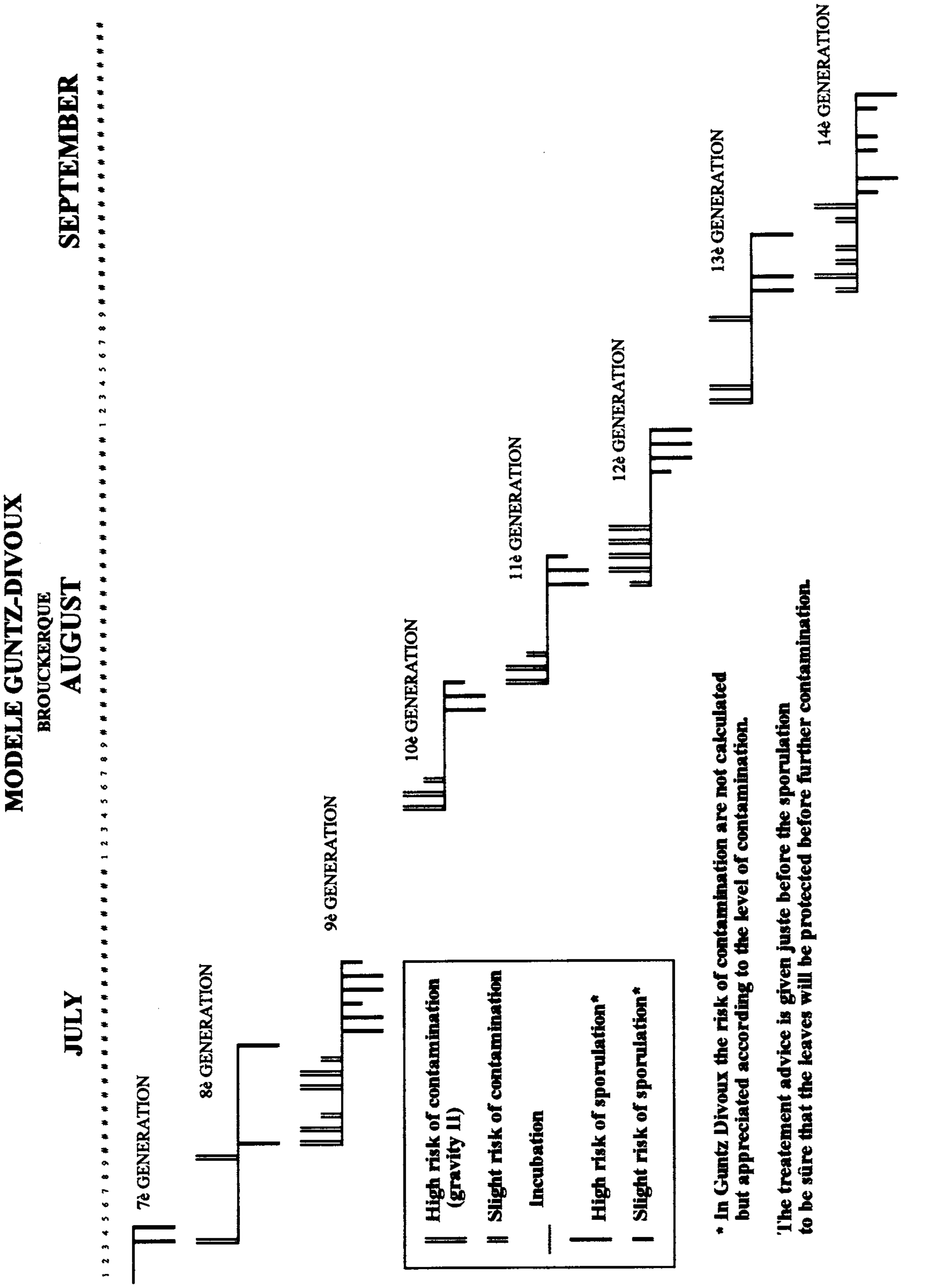


When the metheorological data are in area II, this is a risk of contamination

Evaluation of the incubation time of *phytophthora infestans*

The sporulation is systemic when the sum of day units insce the infection reaches 7.

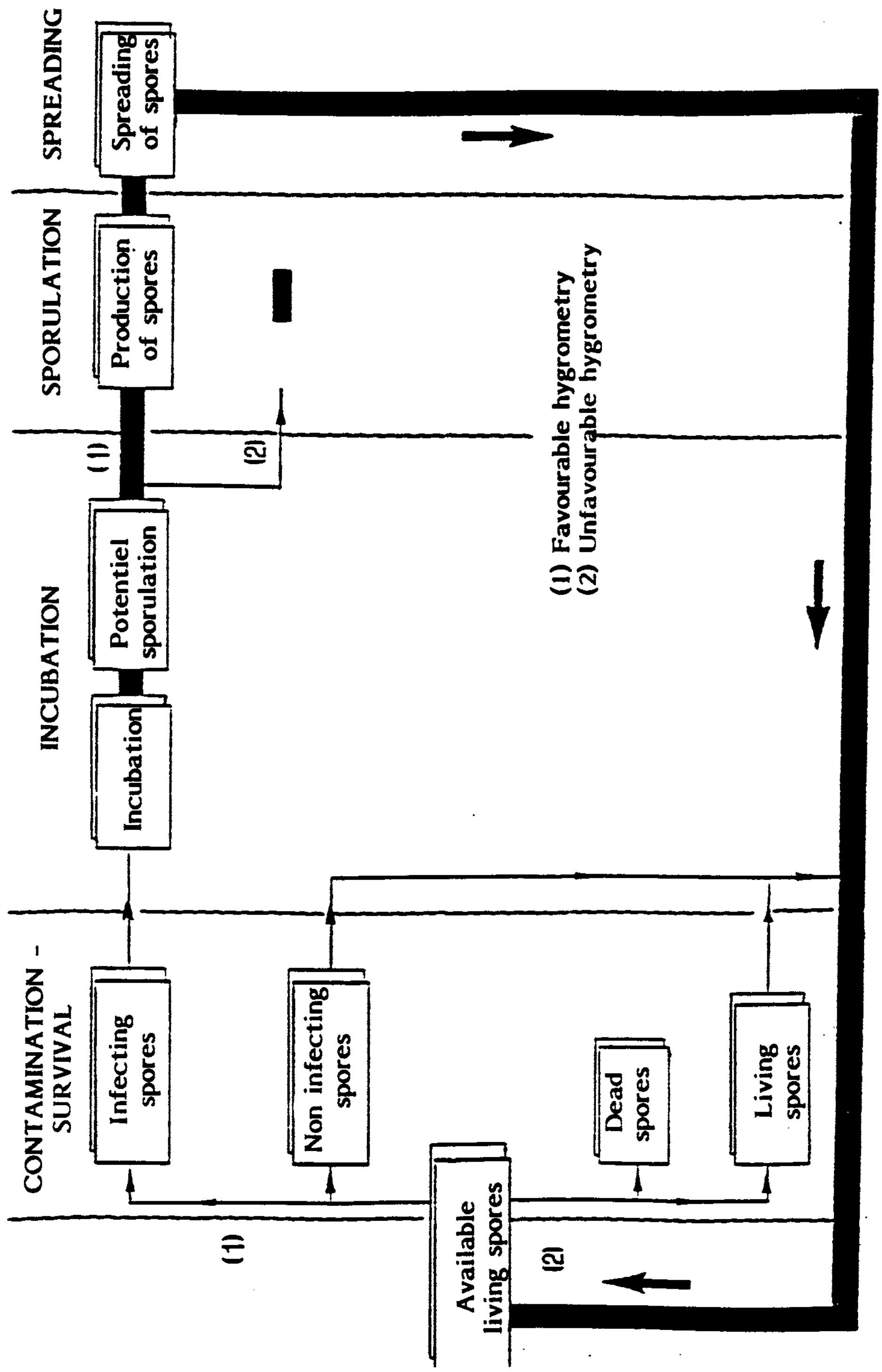
Average daily T°	**Units**
	0
< 8	0,75
8-12	1
12,1 - 16,5	1,5
16 - 6 - 2	1
> 20	
T max > 30	0



The model milsol

Mister Lechapt, according to models Gunz Divoux, Blitecast (Wallu); Blight (Sporks) wanted to quantify each compartment of the biological cycle of the fungus.

Compartments of milsol



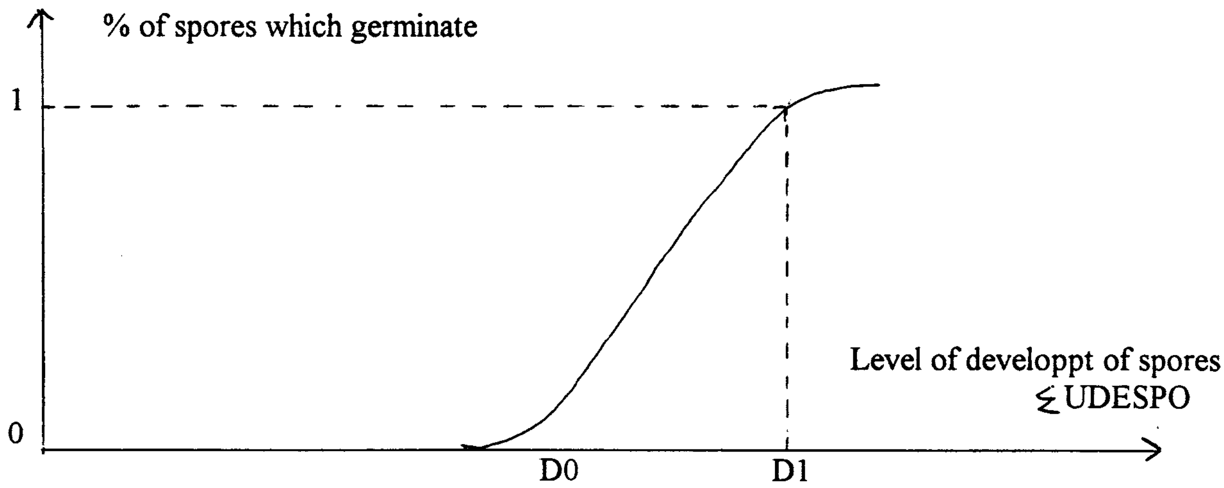
Contamination

Measure of grivity of contamination

Percentage of precent spores which contaminate

RH<90%   Gr=0

RH>90%   G2



D0 and D1=parameters

Real weight of the cycle

Gravity X number of spores on the culture

Survival of spores

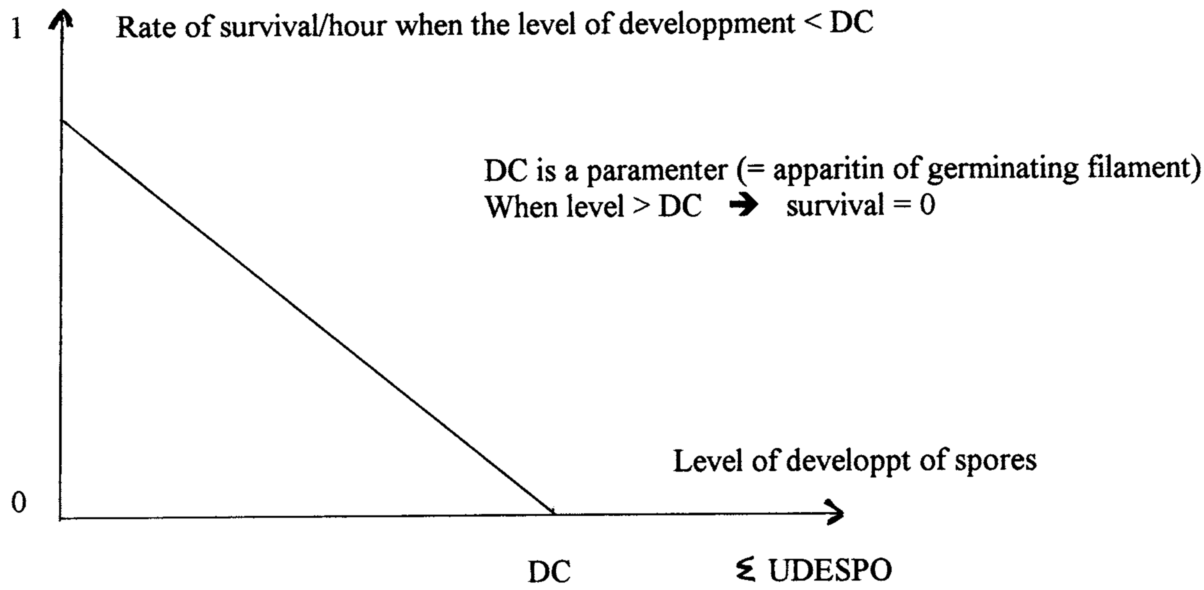
Non germinated spore → complete vitality

Survival =100%

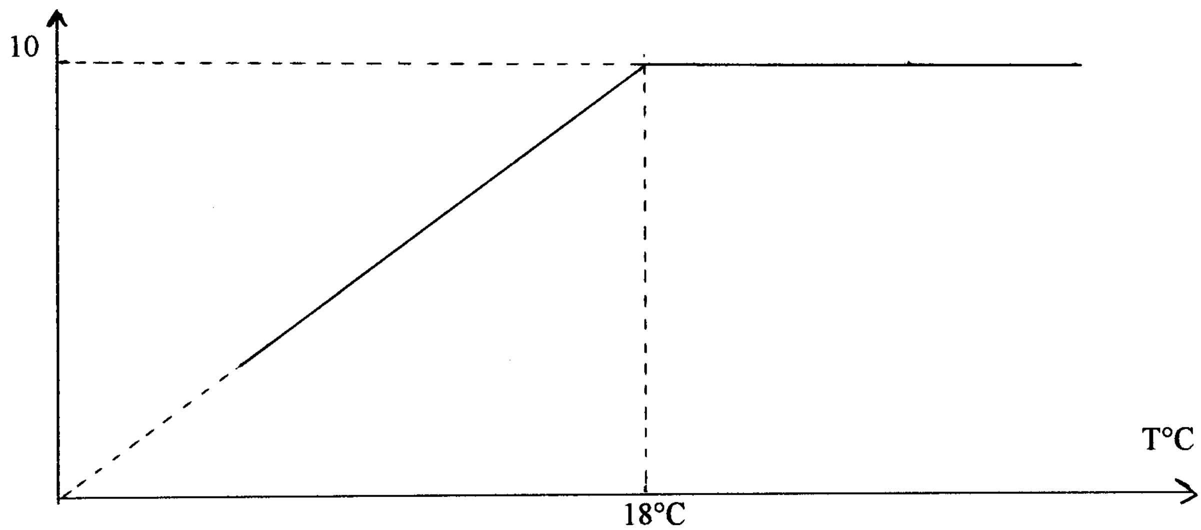
Spore which is germinating:

RH>100%-→ Survival =100%

RH<100%



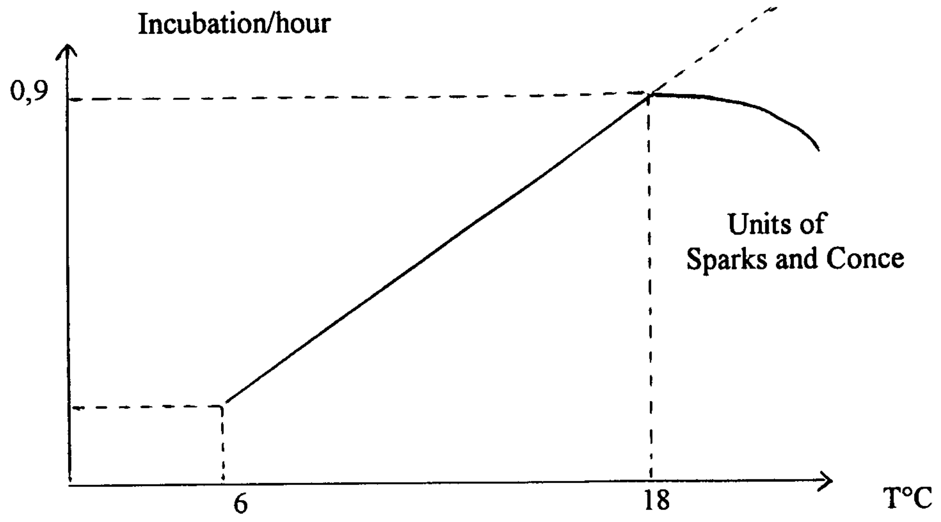
Development unit/hour (the optimum of development is this in 1 hour at 21°C)



Incubation and sporulation

Incubation

Incubation

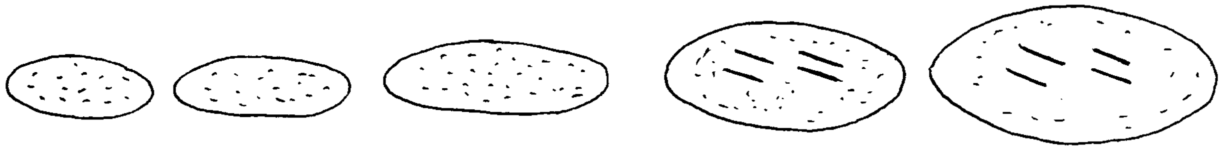


Potentiel of sporulation

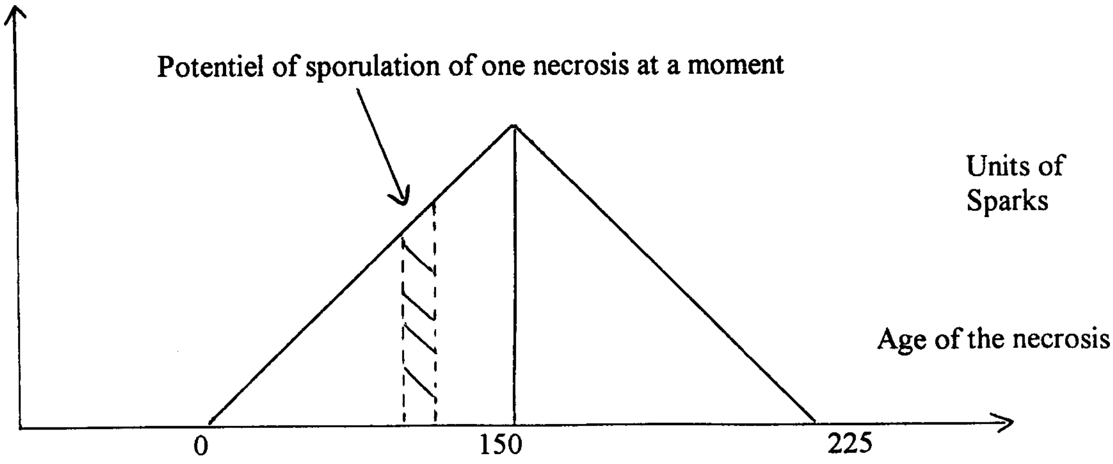
Potentiel of sporulation

Potentiel of sporulation

necrosed area



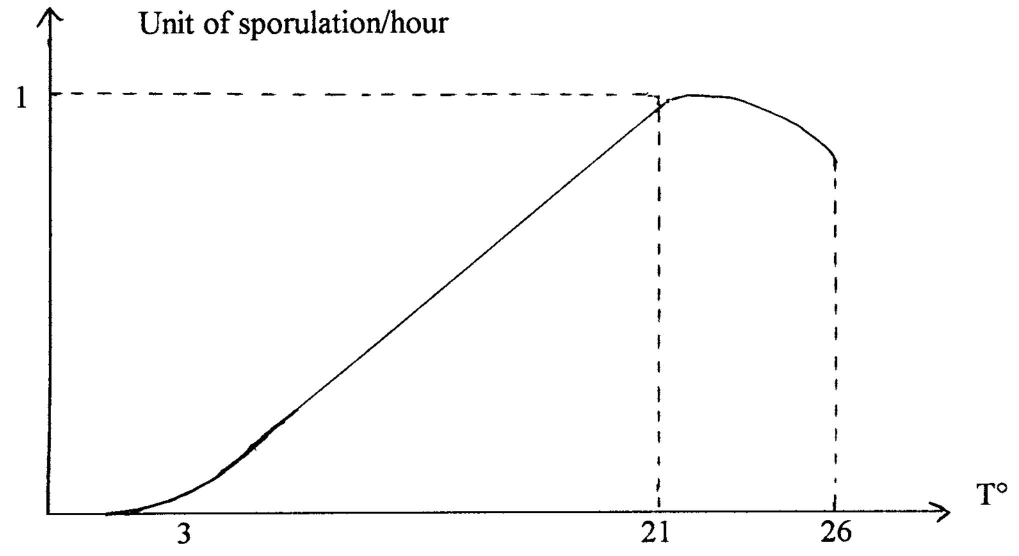
Potentiel of sporulation

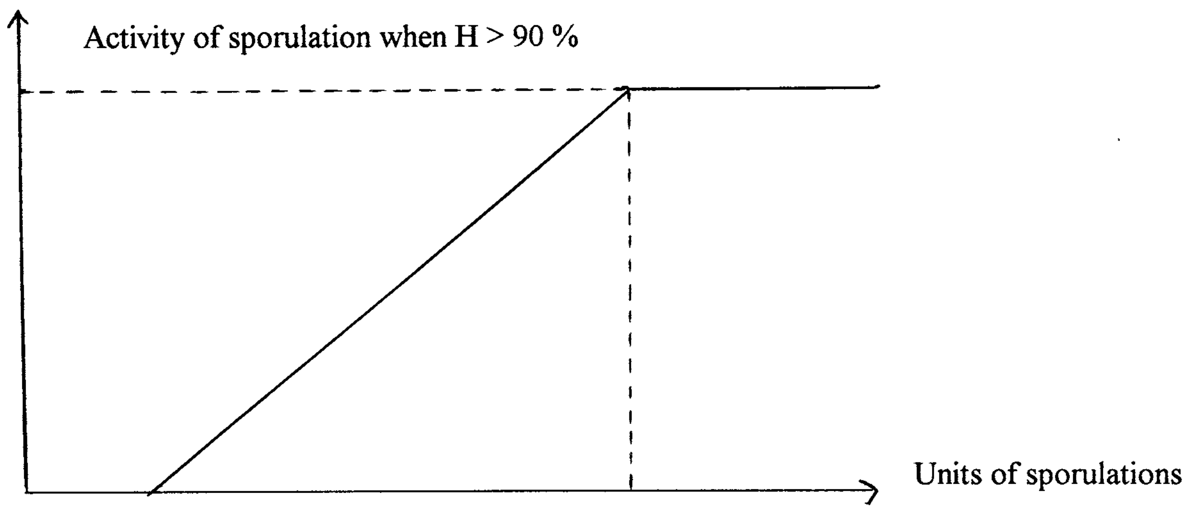


Sporulation

Activity of sporulation

Sparks-sporulation is RH>100% from 3 to 26°C, optimum 21°C



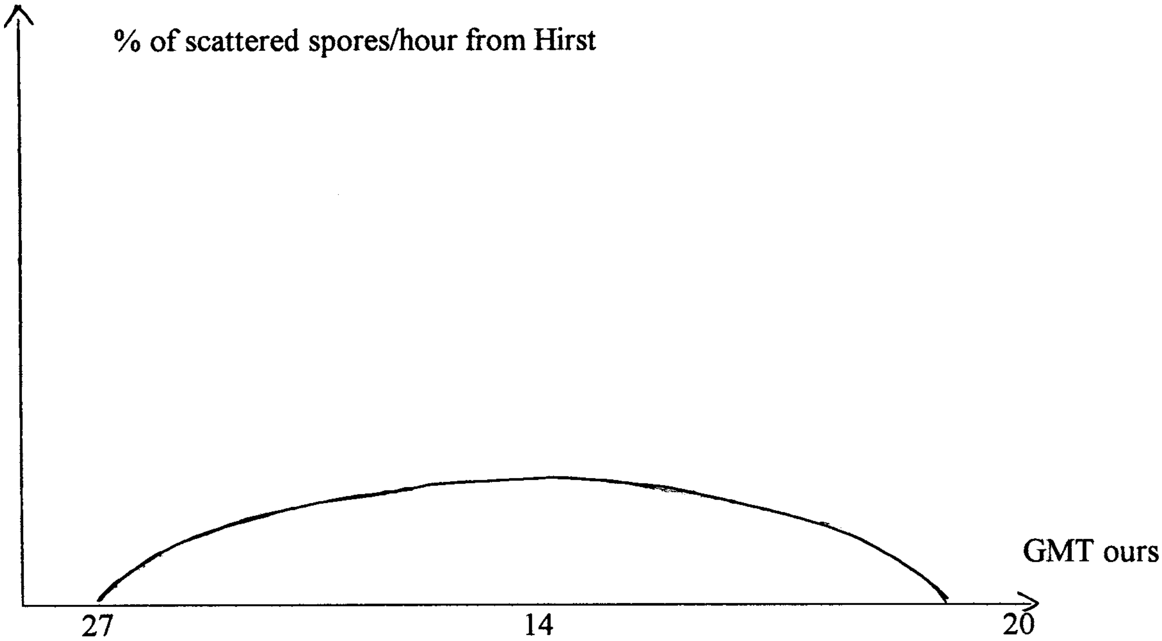


RH<90% - Activity of sporulation =0

Sporulation

Sporulation + potential of sporulation x activity of sporulation

Dispersion



DATE	PERIODE (1)	POIDS (2)	CUMPOID	SPOSPO (3)	SPORUL (4)	PACPS (5)	PRCPS (6)
	154		5.21	7.54		136	144
22/07/96	155		5.21	6.96		138	146
	156		5.21	6.62		138	148
23/07/96	157		5.21	5.35		140	148
	158		5.21	4.87		140	150
24/07/96	159		5.21	1.15		144	150
	→ 160	0.42	5.21	1.04	0.99	144	150
25/07/96	161	0.26	5.21	0.87	0.59	144	150
	162	0.47	5.21	0.62	0.58	144	150
26/07/96	163		5.21	0.00		146	150
	164		5.21	0.00		146	150
27/07/96	165		5.21	0.00		148	150
	166	0.00	5.21	0.00		150	150
28/07/96	167		5.21	0.00		150	150
	168	0.00	5.21	1.93		160	160
29/07/96	169		5.21	2.82		160	161
	170	0.47	5.21	3.20	3.19	160	162
30/07/96	171		5.21	3.46		160	162
	172		5.21	3.59		160	162
31/07/96	173		5.21	3.72		160	162
	174	0.00	5.21	3.80	3.37	160	166
01/08/96	175		5.21	3.82		160	166
	176	0.00	5.21	3.81	2.77	160	168
02/08/96	177		5.21	3.69		160	168
	178		5.21	3.61		160	170
03/08/96	179		5.21	3.48		160	170
	180	0.00	5.21	3.40		160	170
04/08/96	181		5.21	3.28		162	170
	182		5.21	3.33		166	174

(1) Period of 12 hours

(2) Level of risk of contamination in each period

(3) Potential sporulation

(4) Sporulation

(5) End of the period of sporulation

(6) Start of the period of sporulation

For excample: The contamination of the 24/07 can give spores from 29/07 to 03/08

Validation

Some differents methods have been used:

-Comparrison of the risk with the global evolution of the epidemic

-Observation in a controlled field of the number of symptoms, number of spores on each leaf
-Survey in farmers fields

Conclusion

Milsol gives a good figure of the evolution of the epidemic
It’s necessary to precise the creteria of treatment and no treatment