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

Munich, Germany, 6-10 September 2000

C.E. Westerdijk and HT.A.M. Schepers (editors)

Applied Plant Research, Wageningen-UR
Applied Research for Arable Farming and
Field Production of Vegetables

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Preface

Integrated control of potato late blight

In March 2000 the Concerted Action entitled "European network for development of an integrated control strategy of potato late blight (EU.NET.ICP)" came to an end. In the framework of this Concerted Action, four Workshops were organised, resulting in four PAV-Special Reports (1, 3, 5 and 6) comprising the Proceedings. However, all participants agreed that in order to keep the network intact a yearly workshop should be organised. The Agrochemical companies Aventis, BASF, DuPont and Syngenta were prepared to sponsor a part of the organisation of the workshop in 2000. The Technische Universität Weihenstephan, Lehrstuhl für Phytopathologie organised the workshop in Munich (München, Germany) from 6-10 September 2000. The workshop was attended by 52 persons from 13 European countries. Representatives from all countries presented the late blight epidemic in 2000 and recent research results regarding integrated control and decision support systems of late blight in potatoes. The papers and posters presented at the Workshop and discussions in the subgroups are published in this Proceedings, PAV-Special Report no. 7.

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

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Contents

The development and control of *Phytophthora infestans* in Europe in 2000

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Introduction

From 6-10 September 2000 a Workshop was held on control of *Phytophthora infestans*. Representatives from 16 European countries presented the development and control of late blight in their country in 2000. In this paper these presentations are summarised. The weather conditions of 2000, the disease progress and the input of fungicides are presented.

Weather conditions

In the northern region of **Italy** it was extremely wet at the end of April and also in May, especially when temperatures increased during the last week of April and conditions became very favourable for blight development. Similar “risky” weather conditions also occurred in May. In the Emilia-Romagna region the IPI model correctly warned for the first spray at the end of April which coincided with the first recorded high risk period (MISP) of the season. By the end of the season 6-7 infection events were recorded. The first occurrence of blight was recorded 11 May following the second MISP of 6 May. In the Basque Country in **Spain** the weather conditions were very favourable for the development of blight. Blight was first observed on 15 June. Blight did not spread at that time but was restricted to some sporadic lesions. Starting from 26 July blight became epidemic especially in those fields where fungicide treatments were applied late. In other regions where early potatoes are grown, almost no blight foci were found. In three regions in **Portugal**, blight warnings were given using the Guntz-Divoux system. During March and April the weather conditions were extremely wet, resulting in serious infections with blight. In Entre-Douro e Minho the first blight lesions were observed on 21 March on small patches of potatoes planted in early January. In potato crops planted late February or early March, which represent the majority of crops in this region, the first risk period began 23 March. Severe rainfall (363 mm) in April and May led to the appearance of infections and to the recommendations to protect the crop with 5 preventive sprays. Early June the weather improved but late blight remained present. In **Switzerland** the first late blight attack was observed very early on 3 May in a polythene covered crop. As weather conditions were rather dry in May and June, blight did not develop as fast as in 1999. Weather conditions were very favourable for the development of blight in July and August, thus allowing the fungus to spread over the whole country. At the beginning of the season, blight was mainly restricted to the western and central part of Switzerland. The first blight in the eastern part was observed much later (mid-July). In the intensive production areas in the north and north-east of **Austria** late blight occurred later because of very hot and dry weather conditions in May and June. In the north (Waldviertel) the first outbreak was on 20 July, a few weeks later than average. In the north-east (Weinviertel) the first outbreak was on 9 August, many weeks later than average. In the west (Petzenkirchen) blight was first seen on 14 July, this is more or less the average over the last 20 years. During the rather dry growing season only two periods with a high infection pressure were recorded. The first period was around 14 July, the second period was from 30 July to 8 August. In the region of Styria potatoes developed very early. Blight occured late in relation to the crop stage but on average in relation to the date of appearance. The first blight in **Germany** was recorded in polythene covered crops (11 May). In field crops blight was observed early in Bavaria (early June) and in the western regions (end May & beginning June). The blight epidemics were severe in the region where a lot of polythene covered crops are grown (Rheinland Pfalz) and in the western regions. In the early crops in Brittany (**France**) the pressure was very high in May and some serious blight outbreaks were observed in polythene covered crops. The first sprays were applied at 50% emergence. In southern France (Marmande) the blight pressure was also high which is very unusual for this region. In the north-west the weather conditions were very bad (frequent rainfall) resulting in blight developing from the end of April up to the beginning of June. Blight developed on dumps in early May. When crops emerged in late May, the disease pressure was very high and the first sprays were applied at 30% emergence. Some unsprayed crops had 40% foliage destroyed by late May and stem lesions were very common. The drier weather in June stabilised the epidemic, but the pressure remained very high. Rain in early July together with vigorous foliage growth resulted in a rapidly developing epidemic from 21 July onwards. The disease pressure remained high during July and August. Flanders (**Belgium**) experienced the worst late blight epidemic of the last 10 years. Especially the province of West-Flanders (close to France) was hit hard; control was very difficult if not impossible, and fields were destroyed completely. An extremely high level of primary inoculum- mostly from waste piles and unharvested fields from 1999- was perceived as the principal cause. Fields with emerging potato plants showed serious infections evenly spread over the whole field, varying from 1 lesion/m^2 up to several lesions per plant. The first blight was observed 30 April on a waste pile. Towards the end of May, the numerous attacks and inoculum sources led to the advice to treat fields immediately after emergence. The critical weather conditions of 4-5 June however caused a general and serious outbreak of blight throughout the entire region. On early crops in Hainaut/Wallonia (Belgium) the first blight was observed in the second half of May. In the other parts of Wallonia blight was observed from 11 June onwards. This early disease pressure also came from inoculum on waste piles and from volunteers in sugar beet and maize. The daily rainfall in July and August washed off contact fungicides and prevented farmers from spraying. Late blight was present in most fields by the end of July and stem lesions were more common compared with previous years. Seriously infected crops had to be desiccated early. In the south of Wallonia the disease pressure was low and first symptoms were observed 10 July. In **The Netherlands** a very mild winter was followed by a planting period in April-May with difficult soil conditions. Most crops made a good and early start. Volunteers were abundant in other crops. Blight was first observed on waste piles in April. In early crops in the south-west blight was observed between 10-15 May. Critical weather in the last days of May and the first days of June led blight becoming widespread by mid June. Stem lesions were frequently observed. Except for one week in mid-June there was no long period of dry safe weather. The weather in July was almost continously critical. Several varieties proved less resistant then the official list suggested. Some new problems arose in the beginning of August in fields that were not sprayed every 5-6 days until the end of July. Following a mild winter in **England & Wales** which allowed infected tubers to survive, blight was found early on dumps (10 May). Smith Periods were widespread during mid-May and blight moved from dumps to crops in SE England where the disease became established and was severe in many fields. Outbreaks in early polythene covered crops in East Anglia were thought to have originated from infected seed. Smith Periods were recorded from 31 May-3 June and by early June, blight was present in crops and on dumps in East Anglia. Wet weather in May delayed some plantings and these crops were exposed to blight inoculum as they emerged. Very early spraying was recommended for these crops. Although the weather became generally hot and dry in mid-June, further outbreaks were reported on dumps as a result of the earlier blight favourable weather. Stem lesions were very common and allowed the disease to survive the hot dry conditions. Further Smith Periods were recorded in early-July by most met stations, some continuously for up to 7 days. Dry conditions occurred in the latter half of July returning to Smith Periods on 28/29 July and in early August. By the end of July, blight was reported to be present in 75% of the crops in some parts of East Anglia although mostly at low levels. In **Northern Ireland** the first outbreak of blight was recorded on 22 June which was slightly later than usual. Weather conditions during late June, July and August were drier than normal and whilst blight risk was high during August low levels of rainfall occurred. The number of reported field outbreaks was also less than previous years. In **Scotland** the first outbreaks recorded were in crops under polythene in the west of Scotland (22 June). The first outbreak in a crop not under polythene was in the north-east on 6 July. The season was generally not very favourable for late blight until August and September. The number of blight outbreaks was limited compared with previous years. In **Jersey** the first observation of blight out in the field was on 20 March. The number of infected fields was 479 compared to 390 in 1999 and 667 in 1998. In **Ireland** the first blight was observed in the south in late May. Blight developed further in June and was first seen at Oak Park, Carlow on 4 July. Although blight developed very fast in unprotected crops, no serious problems occurred during the season in fields that were sprayed every 7-10 days. In **Poland**, the first blight symptoms were observed very late (23 June) on dumps but once blight became established it developed much faster compared to other years. In **Sweden** the development of the crop was 2 weeks earlier than normal due to early planting and a warm May. The weather during the season was very conducive for the development of blight. Blight was first observed in the south-west around 5 June in polythene covered potatoes. The attacks in that area were always early and probably originated from oospores in the soil. Blight was observed in all potato growing areas of Sweden, the disease reached as far as Boden (6550’N, 2145’E) in mid July. In **Finland** the first observations of blight were relatively late, but from then on the epidemic developed rapidly in unprotected crops. In some fields the foliage was destroyed within one week. The infection pressure remained high during the whole growing season. At the end of the growing season infected foliage was found in almost every field. In **Denmark** crop emergence was 10-14 days earlier than normal. Based on the national forecasting system a general warning for risk of primary attacks was issued on 20 June when the first blight outbreak was observed in the field. The infection pressure was relatively low in June and the first part of July. In many crops the epidemic developed following blight favourable weather during mid July. The infection pressure in **Norway** was higher than normal due to infected seed potatoes and frequent rainfall in June. This resulted in more blight than normal although control was good in fungicide treated fields.

Fungicide input

In **Italy** fluazinam was registered and introduced for control of late blight. The use of famoxate and azoxystrobin increased, both on potato and tomato. In **Spain**, metalaxyl was used in the early stages of crop growth. After the appearance of the first blight outbreaks, cymoxanil and dimethomorph were applied followed at the end of the growing season by copper. In **Portugal** 8 treatments were recommended; 3 systemic fungicides, 3 translaminar fungicides and 2 contact fungicides. In **Switzerland** the fungicide use by 85 PhytoPRE participants was recorded. On average they used 3 sprays with a contact fungicide, 4 sprays with a translaminar fungicide and 0.4 sprays with a systemic fungicide. In **Austria**, on average 2-3 sprays are applied with a (local)systemic fungicide (propamocarb, cymoxanil, dimethomorph) and 2-4 sprays with a contact fungicide (maneb, mancozeb). In **Germany** fungicide input varied considerably from region to region. In some eastern regions connected to Poland, 2- 5 sprays (of which 1-2 systemic fungicides) gave sufficient control, whereas in western and north-western regions connected to Belgium and The Netherlands, 10-14 sprays (of which 5-6 systemic fungicides) were necessary to control blight. The other regions in Germany were between these ranges. In the north of **France** the warning system recommended 16-17 sprays on ware potatoes. Some starch potatoes were treated with up to 23 dithiocarbamate sprays. When the spray interval of systemic fungicides does not exceed 10 days a protection of new growth is obtained. Cymoxanil was also used frequently. The use of contact fungicides with a good rainfastness resulted in an efficient control with fewer sprays. In Flanders (**Belgium**) tin fungicides were used in tank mixtures, while translaminar materials were used during June and July in 2 out of 3 treatments. Phenylamides were used on average 1.5 times despite the high levels of resistance determined on isolates in 1999. In Wallonia (Belgium) translaminar and systemic fungicides were recommended during the rainy periods. Alternatively where contact fungicides were being used recommendations were to spray in short intervals because of wash-off and very rapid haulm growth. Where blight was present, growers sprayed in weekly intervals with mixtures including tin fungicides. In **The Netherlands** farmers started spraying very early and kept short intervals. Spraying conditions were not extremely difficult. Spraying tracks were used in a number of fields. Disease control demanded full attention from the beginning to end. The main fungicides used were fluazinam, cymoxanil and propamocarb. Metalaxyl and dimethomorph were not registered in 2000. In **England & Wales** growers maintained an intensive spray programme throughout the season in the high risk areas using translaminar materials often in mixture with tin fungicides to 'dry up' foliar infection and protect tubers. Fluazinam was also commonly used and also in mixture with other fungicides. The main fungicides used in **Northern Ireland** were phenylamide based in early season, followed in mid season by translaminars (cymoxanil, dimethomorph) and protectants such as mancozeb and fluazinam. In **Jersey** weather conditions were very difficult for applying fungicide protection (systemic, translaminar, contact), therefore in the early new potato production only 4-5 applications were being made at the shortest possible interval. In **Poland** the average number of sprays per season was two. A wide range of different fungicides was used, including the new active famoxate. There was also a remarkable increase in the use of fluazinam. Due to severe blight epidemics in 1998 and 1999, farmers in **Sweden** started spraying early and maintained short spray intervals. In some areas there were difficulties to keep intervals short due to frequent rainfall resulting in difficult spraying conditions. In **Finland** a common strategy started with 1-2 sprays of dimethomorph or propamocarb followed by mancozeb or fluazinam. Epok (metalaxyl/fluazinam) was not widely used. Where spray programmes started early serious outbreaks were prevented although maintaining close intervals was sometimes difficult due to frequent rainfall. In **Denmark** the most commonly used fungicides were: mancozeb, fluazinam, propamocarb and dimethomorph. Metalaxyl is no longer registered in Denmark. In **Norway** a common strategy started with one spray of dimethomorph or propamocarb followed by fluazinam. Mancozeb is still used as a contact fungicide, but fluazinam is the standard late in the season. Epok (metalaxyl/fluazinam) was not recommended in areas with high levels of metalaxyl resistance.

Tuber blight

Due to the early timing of the workshop, hardly any information regarding the occurrence of tuber blight was available. At the end of August a significant proportion of crops in most areas in **England & Wales** were carrying low levels of foliar infection. Tuber infection was first reported mid August. In late August blighted tubers were also observed in **France** and **The Netherlands** where fluazinam is recommended for tuber blight control.

Organic crops

In **Switzerland**, the late blight situation for organic farmers was much better than in 1999. May and June were rather dry followed by higher risk conditions in July and August. Although outbreaks occurred, farmers were able to control blight with regular copper sprays. The new varieties Appell and Naturella were tested and showed a very low susceptibility for blight. Appell will be on the official variety list in 2001. Many organic crops in **France** were completely destroyed by the end of July. In **The Netherlands** however, the situation varied from region to region. In some regions late blight entered the crop very early and forced growers to kill their crop prematurely. In other regions blight was also present but not to such an extent that the yield was dramatically reduced. Organic crops are becoming increasingly important in **Northern Ireland**, although the area is still small. Some blight occurrence was reported. The most widely grown cultivars were Navan, Santé, Pentland Squire and Cultra. In **Jersey**, organic production has made conventional production very difficult, even though copper sprays were being applied. A hand-held flame gun was made available to organic growers so that small outbreaks of infection could be destroyed. In **Sweden** the blight appeared early in organic crops and developed very rapidly. Therefore, many fields had to be destroyed and could not be harvested. In **Finland** the early varieties reached reasonable yields, but later varieties were destroyed by blight before tubers were formed. In organic potatoes in **Denmark** blight developed relatively late (end July). In **Norway**, yields in organic crops and home gardens was lower due to late blight.

Oospores

In **Sweden** oospores were observed in commercial potato crops, both in fields where infection from oospores was suspected and in fields infected by air borne inoculum. A remarkable observation in **Finland** was the occurrence in many fields of the first lesions in the lower leaves that touched the soil. This might indicate infection from oospores. In **Denmark** the first observed late blight attacks were 20 June in three fields in Northern Jutland and infection from oospores was suspected. Oospores were observed in leaf samples from commercial crops in Southern **Norway**. A survey in **The Netherlands** showed that in all potato growing regions, leaves were infected with both A1 and A2 strains and this demonstrated a high potential for the formation of oospores.

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Table 1. Weather conditions favourable for the development of late blight and dates of first recorded outbreaks of blight in potato in 2000 in relation to other years.

	May	June	July	August	September	First outbreak				
						2000	1999	1998	1997	1996
Austria	*	*	**	**		14 July	15 May	25 June	17 July	
Belgium										
* Flanders	***	**	***	***		30 April[2]	29 April[1,2]	28 April[1]	15 May[1]	September
* Wallonia	*(*)	*(*)	***	***	**	19 May	5 July	12 July		
Denmark	*	*	**	**	*	20 June	18 June	16 June	end June	begin July
Finland		*	***	***	**	4 July[1]	2 June[1]	20 June	1 July	17 July
France	***	**	***	***		End April[1,2]	Early April[2]	20 April[2]	23 May[2]	13 June[2]
Germany	**	**	**	**		11 May[1]	28 April[1]	5 June	30 May	12 June
Italy	***	**	**	*		11 May	10 May	No blight	No blight	19 May
Ireland						4 July	20 July	1 July	25 July	28 July
Netherlands	**	**	***	**		April[2]	26 April[2]	Beginning May	2 June	
Norway	**	***	***	***	**	16 June[1]	15 June[1]	20 June[1]	6 August	29 July
Poland						23 June[2]	27 May	Beginning June	end June	
Portugal	***	***	**	**		21 March				
Spain (Basque country)						15 June	21 June	15 June	1-7 June	
Sweden	***	***	**	**	**	5 June[1]	20 May[1]	15 May[1]	24 May[1]	
Switzerland	**	**	***	**		3 May[1]	8 May[1]	15 May[1]	16 May	23 May
United Kingdom										
*Northern Ireland	*	*	**	***		22 June	16 June	8 June	30 May	27 June
*England/Wales	***	**	***	**	**	10 May[2]	mid-May[1]	31 May[1]	29 May	
* Jersey	***	***	*	*	*	20 March	10 March	31 March	7 March	22 April
*Scotland	*	*	***	***		22 June[1]	12 May[3]	25 June	3 July	

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

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

Table 2. The estimated use[1] of fungicides to control *P. infestans* on potato in 1996, 1997, 1998, 1999 and 2000.

	Average number sprays/season				
	1996	1997	1998	1999	2000
Austria	4-6	5-6	4-6	4-12	4
Belgium	8-12	14-15	12-14	10	12-20
Denmark	5.5	5.5	8	7.5	7-8
Finland	3-4	4-5	3-8	2-6	5-9
France	9-11	11-14	?	15	16-17
Germany	5-6	7-9	3-10	4-5	2-14
Italy	6-8	6-8	4-5	8-10	6-8
Ireland	?	?	?	?	?
Netherlands	5-12	7-15	7-15	7-16	15-20
Norway	2.9	4	5	5-6	6-7
Poland	1.6	1.7	1.7	2	2
Portugal					8
Spain	3	5-6	3	4-5	2-6
Sweden	4-7	4-7	4-12	4-11	?
Switzerland	6-7	7-9	5-7	6-10	7
United Kingdom					
*Northern Ireland	2-10	3-15	4-16	4-14	3-12
*England/Wales	2-10	4-18	8-15	4-16	?
*Scotland	5	?	12	?	?
* Jersey	4-5	4-5	4-5	4-5	4-5

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

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

N.J. BRADSHAW

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Objective

The objective of the sub-group meeting was to review the ratings given to the various fungicide characteristics at the last Concerted Action meeting in Oostende, Belgium (PAV-Special Report No 6, pp 23-26).

Whilst there remained a general agreement for the majority of the ratings previously given in relation to the effectiveness and mode of action of late blight fungicides, following discussions with the company representatives present it was clear that the table required some minor revision. Changes were therefore agreed for the ratings for cymoxanil (protectant activity) and dimethomorph (curative activity). The ratings are intended as a guide for use in the development of Decision Support Systems or the improvement of existing ones. A revised table of ratings is given below.

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

Definitions

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

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

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

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

Tuber blight control - activity against tuber infection as a result of mid/late season post infection fungicide application and has a direct effect on the tuber infection process.

The effect of phenylamide fungicides on tuber blight control was therefore not considered relevant in the context of the table as these materials should not be applied

The effect of the most important fungicide active ingredients used for the control of P infestans in Europe. Opinion of the fungicides sub-group at the Munich workshop, 2000

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

* = See text for comment on phenylamide resistance.

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

to potato crops post tuber initiation according to FRAC guidelines. Only the direct (biological) effect of a particular fungicide on the tuber infection process was considered relevant and NOT the indirect effect as a result of manipulation of the foliar epidemic.

N.B. The information in the Table is based on the consensus of experience of scientists in countries present during the Workshop. The ratings refer to all products currently available on the market in the EU which contain the above active ingredients whether as a single or in a co-formulated mixture. They are therefore an average rating for all products.

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

The application intervals indicated in the Table are not intended as a guide as to how frequently a particular fungicide should be used. Where disease pressure is low, intervals between applications may be extended and, in some countries, fungicide applications are made in response to nationally issued spray warnings and/or Decision Support Systems. It is essential therefore to follow the instructions given on the approved label of a particular blight fungicide appropriate to the country of use before handling, storing or using any blight fungicide or other crop protection product.

Further Updating

The sub group discussed the need to continually update the table and in particular to include details on new blight fungicides currently under development but not yet registered in the EU. It was agreed that the manufacurers would be asked to provide such information on the properties of new active substances once a commercial formulation had been registered and becomes available on the market in an EU member State. An updated table would be published in the proceedings of the next workshop to be held in 2001.

Fifth Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Munich, Germany, 6-10 September 2000

Results of validation trials of Phytophthora DSS in Europe in 2000

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Abstract

In 2000 the DSS validation trials with four Late Blight DSS's, started in 1999, had been continued. Seven trials were laid out in five European countries. In general *P. infestans* epidemics in the trials were severe. Prediction of the date of first occurrence was more precise than in 1999. Compared to a "routine strategy" of weekly contact fungicide sprays all DSS's tested reduced the number of applications considerably in most of the trials. Highest reductions were obtained with NegFry, followed by SIMPHYT and Plant Plus. ProPhy recommended the most conservative strategy. In contradiction to 1999 NegFry and SIMPHYT gave the about same control efficacy as the other DSS's. Plant Plus did not perform as good as in 1999. A more thorough analysis based on the investigation of the behaviour of more sensible epidemiological parameters is needed to identify the fields of DSS improvement.

Key words: DSS, decision support systems, validation, *P. infestans*, control efficacy, fungicides.

Introduction and Status

In 1998 during the third workshop of the European Network for Development of an Integrated Control Strategy of Potato Late Blight at Uppsala, Sweden from 9th to 13th of September 1998 it was decided to lay out validation trials for the *Phytophthora* - DSS available to the participants of the DSS – Subgroup. A protocol was developed and in 1999 9 trials were laid out in six European countries (Kleinhenz and Jörg, 2000). DSS's compared in the trials were: SIMPHYT1/2, Plant Plus, NegFry and ProPhy. In addition two models (Guntz-Divoux and MISP) had been tested in two of the trials. The concept of the trials proved to be suitable and most of the technical problems could be solved in the preparation phase in 1999. The results revealed some differences between the fungicide strategies of the DSS tested. They may be summarised as follows (Kleinhenz and Jörg, 2000):

- By using DSS numbers of spray applications could be reduced.
- SIMPHYT I/II and NegFry recommended less sprayings compared to Plant Plus and ProPhy.
- Plant Plus advised more contact fungicides than the other DSS.
- Plant Plus and SIMPHYT I/II recommended systemic compounds.
- SIMPHYT I/II and NegFry tolerated higher Late Blight disease severities than Plant Plus and ProPhy.
- Due to some constraints and mistakes made during the conduction of the trials results need careful interpretation.
- The validation efforts should be continued.

Validation in 2000

According to the protocol from 1998 and taking into the consideration the constraints from the 1999-trials 7 trials were laid out in 2000 in Belgium, The Netherlands, Ireland, Austria and Germany. For the DSS tested see Table 1.

Table 1. Participants and DSS included in the validation trials 2000.

Country	Institution	No. trials	DSS						
			SIM-PHYT	NegFry	Plant Plus	Pro-Phy	Guntz-Divoux	Routine	Un-treated
B	CRA,Gembloux	1	X	X			X	X	X
NL	PAV, Lelystad	3	X	X	X	X		X	X
IRL	Oak Park,Res. Cent.	1	X	X	X	X		X	X
A	BFL, Wien	1	X	X				X	X
D	LPP, Mainz	1	X	X	X	X			X

For details concerning the conduction of the trials, as e.g. assessment methods or fungicide applications see Kleinhenz and Jörg (2000) and Jörg and Kleinhenz (1999). The "routine treatment" consisted of weekly sprayings of a contact fungicide (fluazinam).

Results

First Appearance of Late Blight

Late Blight occurred in all the trials. Dates of first occurrence varied from Mid June til the last decade of July (Fig. 1). Dates of first occurrence predicted by the DSSs considerably varied in the trials (Fig. 2). But the differences between the predicted dates and the ones observed in the trials were not as big as in 1999. Unsatisfactory were the results in Ireland and also Belgium where the models predicted the outbreak of the *P. infestans* epidemic 30 to 50 days earlier than observed (Fig. 2). Acceptable results (ca. 20 days earlier) were obtained in the Austrian trials and by some DSSs (ProPhy) in the trials in The Netherlands. Optimal forecasts by all the models were given in the German trial (8-11 days in advance). In the Dutch trials some of the DSSs predicted the date of first occurrence very close to the real outbreak which must be considered to be too late for practical crop protection. In one case SIMPHYT was a day too late.

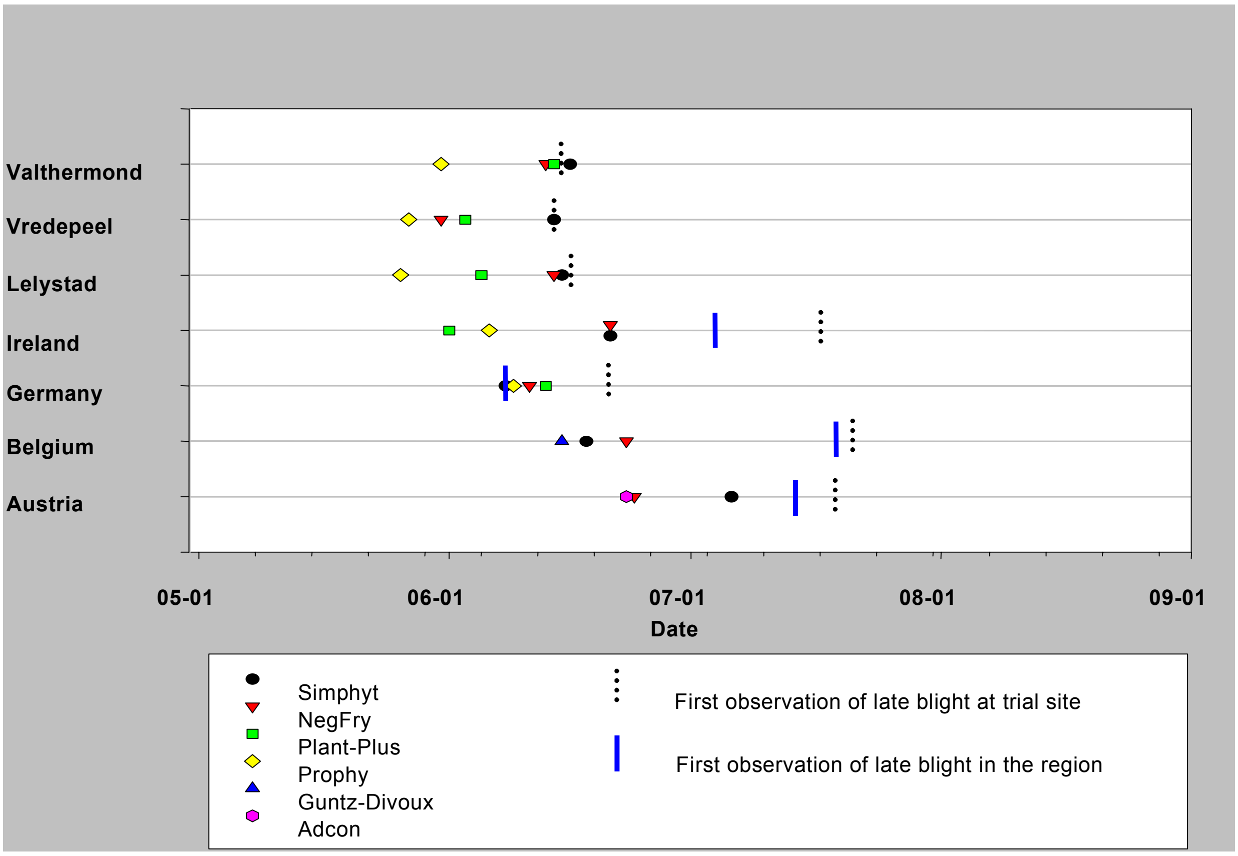

Figure 1. Recommendation of first spray compared to date of first of late blight at trial site and in the region.

In general the results of 1999 could be confirmed: SIMPHYT1 predicts closest to the observed first appearance date, followed by NegFry. Plant Plus and especially ProPhy tended to give too early forecasts. (It must be clearly stated that SIMPHYT1 predicts the day of first occurrence eight days in advance, and fungicide applications should be started within this eight days time span.).

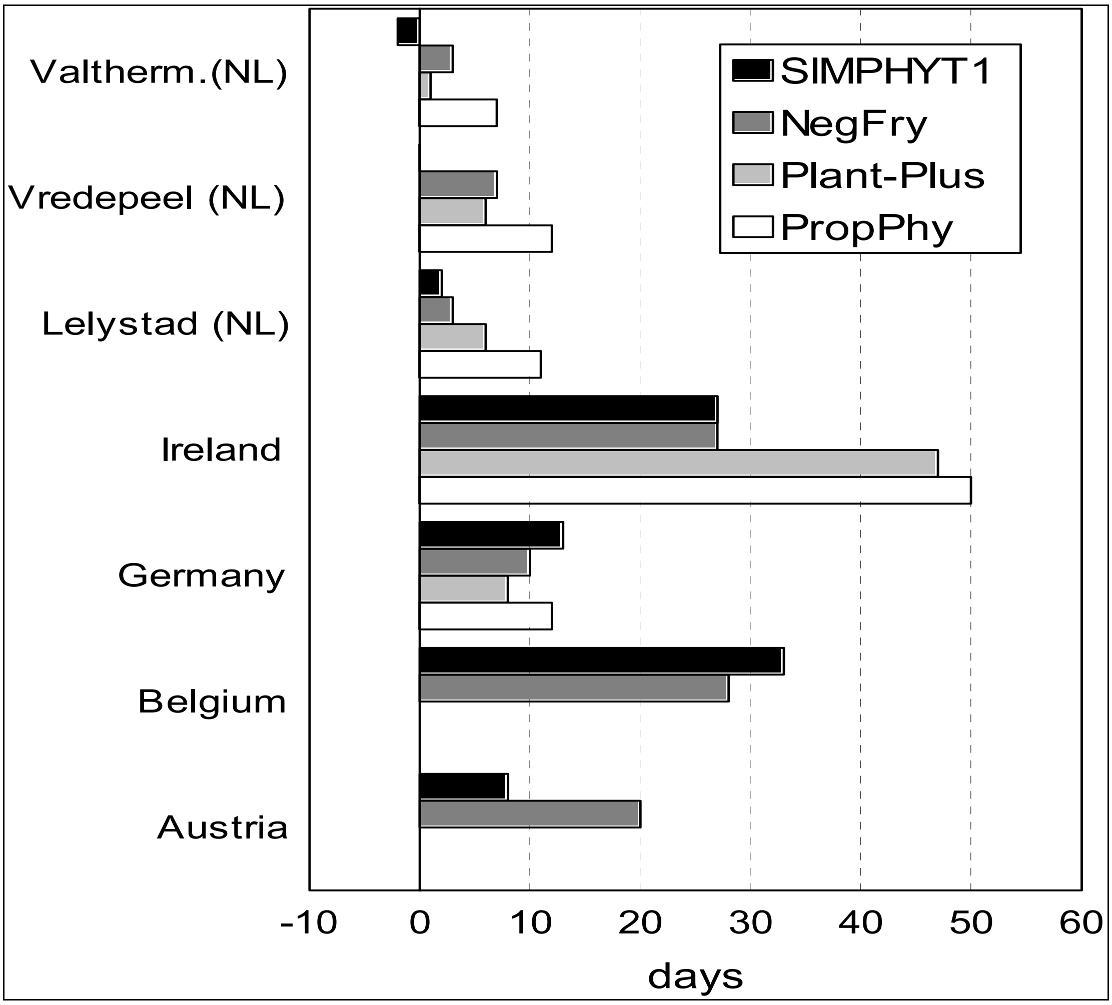

Figure 2. Difference between the date of first spray recommended by DSS's and the observed date of first *P. infestance* occurrence.

Fungicide Strategy

Compared to 1999 in general the fungicide input was higher. In 1999 the average number of fungicide applications varied from less than 7 to less than 10 whereas in 2000 the minimum was 7 treatments and the maximum average was 12 (Fig. 3). NegFry recommended the least number of fungicide applications (about 7). In the average SIMPHYT and Plant Plus advised 10 sprays. ProPhy had an average of 12 fungicide treatments (Fig. 3).

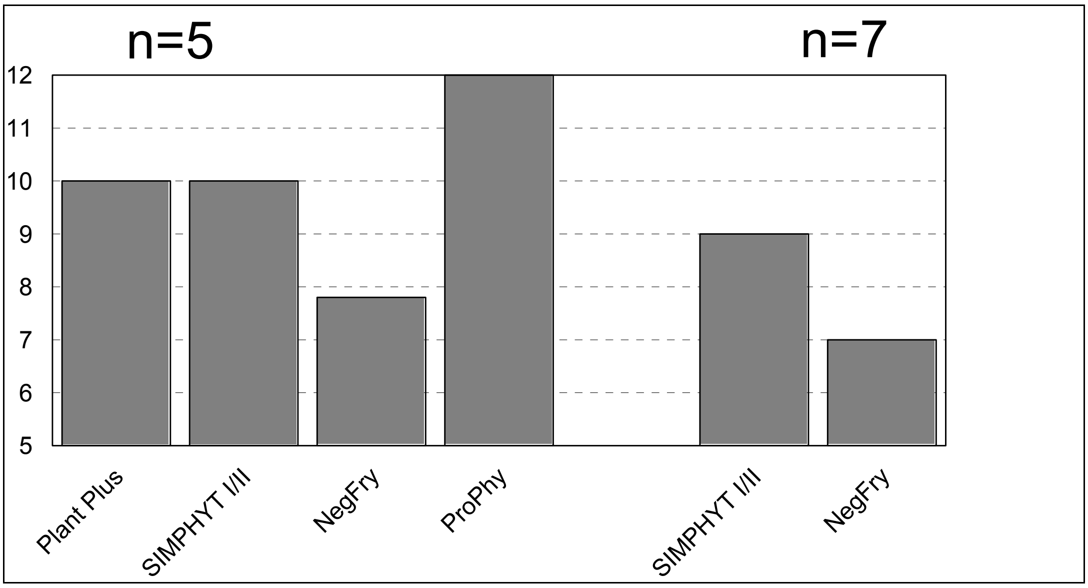

Figure 3. Average number of fungicide treatments recommended by the DSS's.

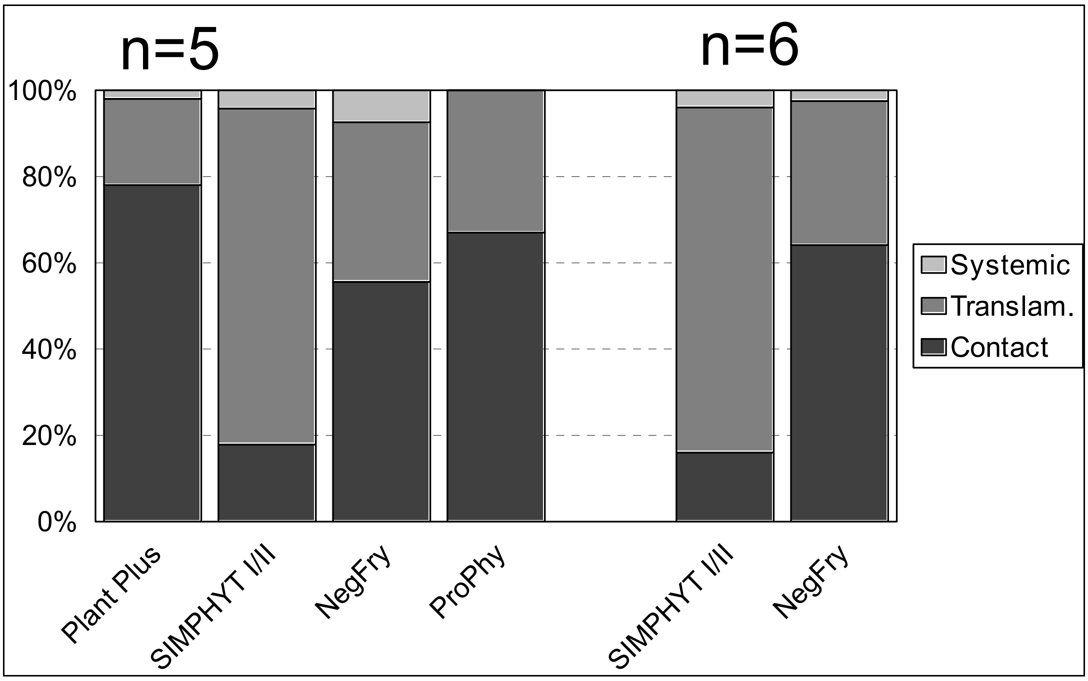

Figure 4. Share of recommended fungicide groups.

The results of the single trials are shown in Fig. 5 to 11.

In the average of the five trials in which all DSS's were compared NegFry reduced the number of applications by 43%. SIMPHYT and Plant Plus followed with a reduction of 23 – 28% and ProPhy recommended the most conservative strategy with a reduction of 14%. In all the trials where NegFry and SIMPHYT were tested, and in the average NegFry recommended much less fungicide treatments than SIMPHYT (-46% versus –28%).

Concerning the choice of products NegFry, Plant Plus and ProPhy mainly relied on contact fungicides with a share of 60 – 80% of the treatments (Fig. 4). SIMPHYT had a share of 80% translaminar products. This is due to the fact that SIMPHYT strategy in the Dutch trials was entirely (!) based on this group of fungicides. In all the other trials SIMPHYT advised 33 to 60% of translaminar products only. Systemic compounds were recommended to a share of less than 10% by all models except ProPhy which did not recommend systemic fungicides at all.

Disease Severities

With the exception of one Dutch trial (Lelystad) *P. infestans* epidemics almost completely destroyed the leaves by the end of the vegetation period (disease severities >90%).
In comparison with the „routine strategy“ in most of the cases the DSS's showed the same efficacy in the control of Late Blight. In 6 resp. 5 of seven trials SIMPHYT and NegFry gave satisfactory results (Fig. 5-11). In the Valthermond trial all the DSS's except ProPhy failed to control *P. infestans* sufficiently. But ProPhy strategy resulted in higher disease severity in 2 of 5 trials (Germany and Vredepeel). Plant Plus gave worse control than the „routine strategy“ in 3 of 5 trials, in 2 of them the DSS failed (Fig. 7-11).
In contradiction to the 1999-results NegFry and SIMPHYT in the average did not tolerate more disease severity than ProPhy. In 2000 Plant Plus strategy in average resulted in higher disease severities compared to 1999.

Restraints and Problems

In accordance with last years validation efforts the results must not be overestimated. Several problems occurred and it was not always possible to solve them before decisions had to be taken. In general the mistakes already described (Kleinhenz and Jörg, 2000) were made again. Two problems shall be highlighted because they are relevant for the interpretation of the results obtained. Inappropriate weather data formats resulted either in wrong model output or in a lack of information on decision-making in crucial situations. In some cases model recommendations were not properly converted into the conduction of the treatments. This holds for both, choice of products and dates of fungicide application.
Also a lack of complete data sets must be stated for 2000. Data on disease severities, products applied and yields are still missing.

Conclusion

Also in 2000 no congruent application dates nor similar lengths of spraying intervals nor similarly directed fungicide choice could be observed in the comparison of the DSS strategies. The inconsistent results from 1999 and 2000 indicate that more knowledge is needed to fully understand the DSS strategies and that there is potential for optimising the DSS's. Thus the validation trials should be continued and more detailed analyses, with recordings on sensitive epidemiological parameters, which permit the interpretation of the decisions taken by the DSS's, should be applied.

Acknowledgements

We wish to thank cordially the colleagues who participated in the validation trials (R. Leonard, D. Michelante, E. Rauscher, J. Wander).

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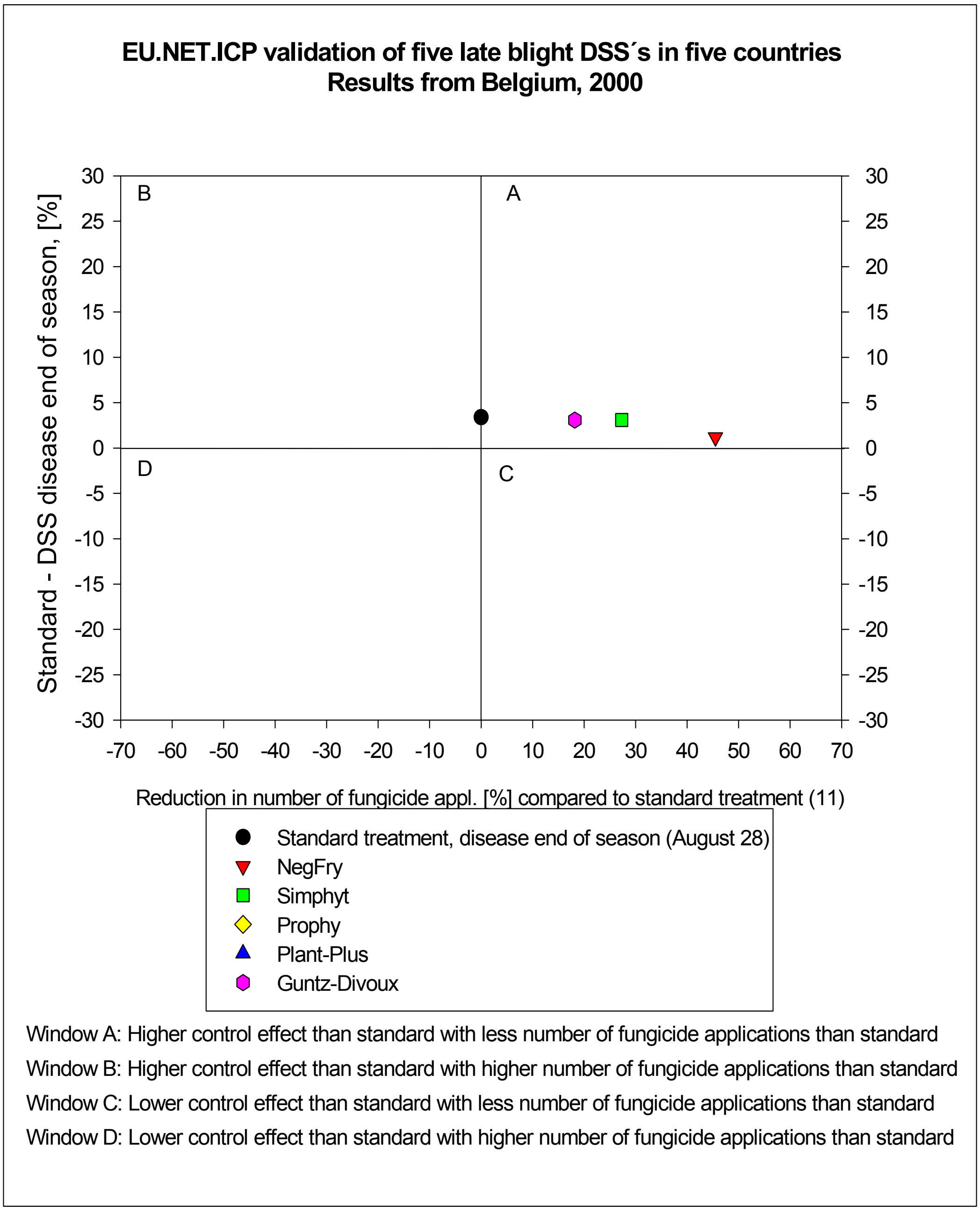
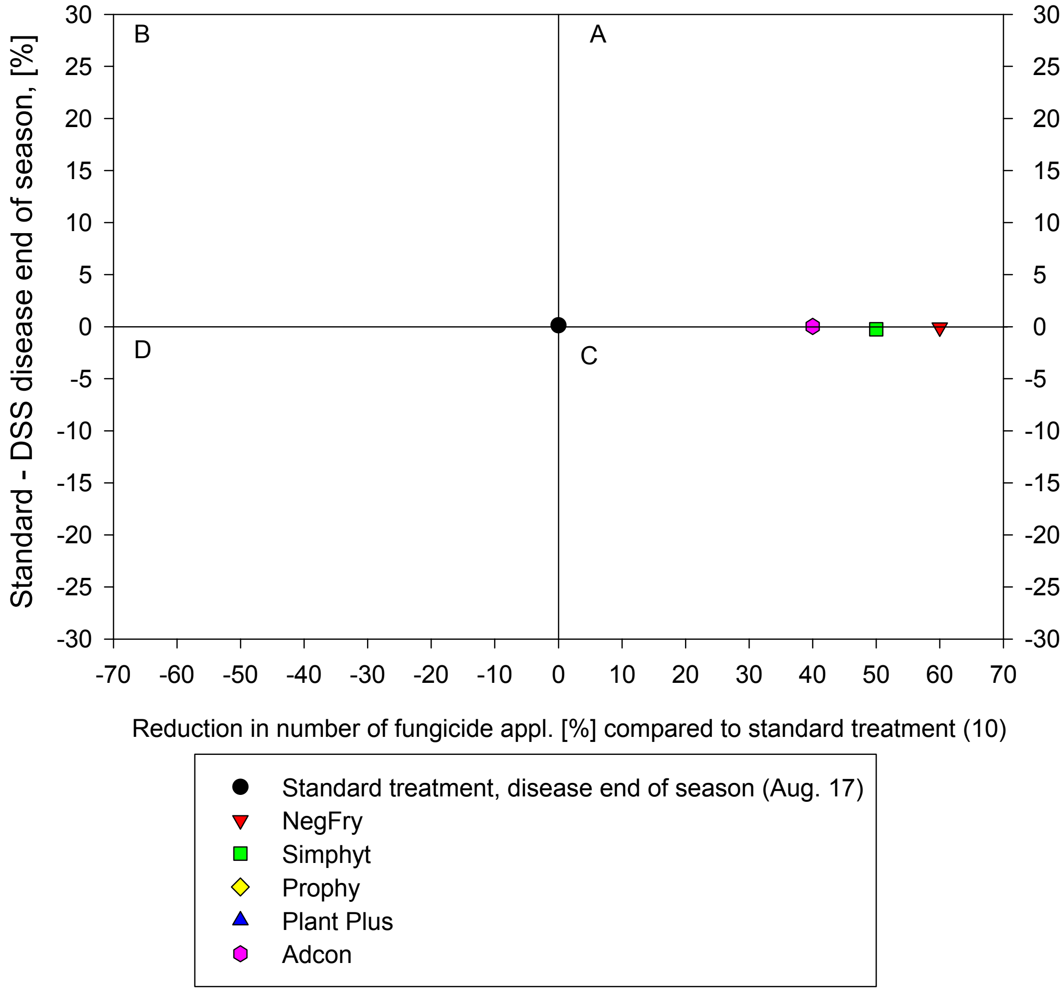


Figures 5 –11. DSS validation trials 2000 in Europe.

EU.NET.ICP validation of four late blight DSS´s in five countries.
Results from Austria, 2000



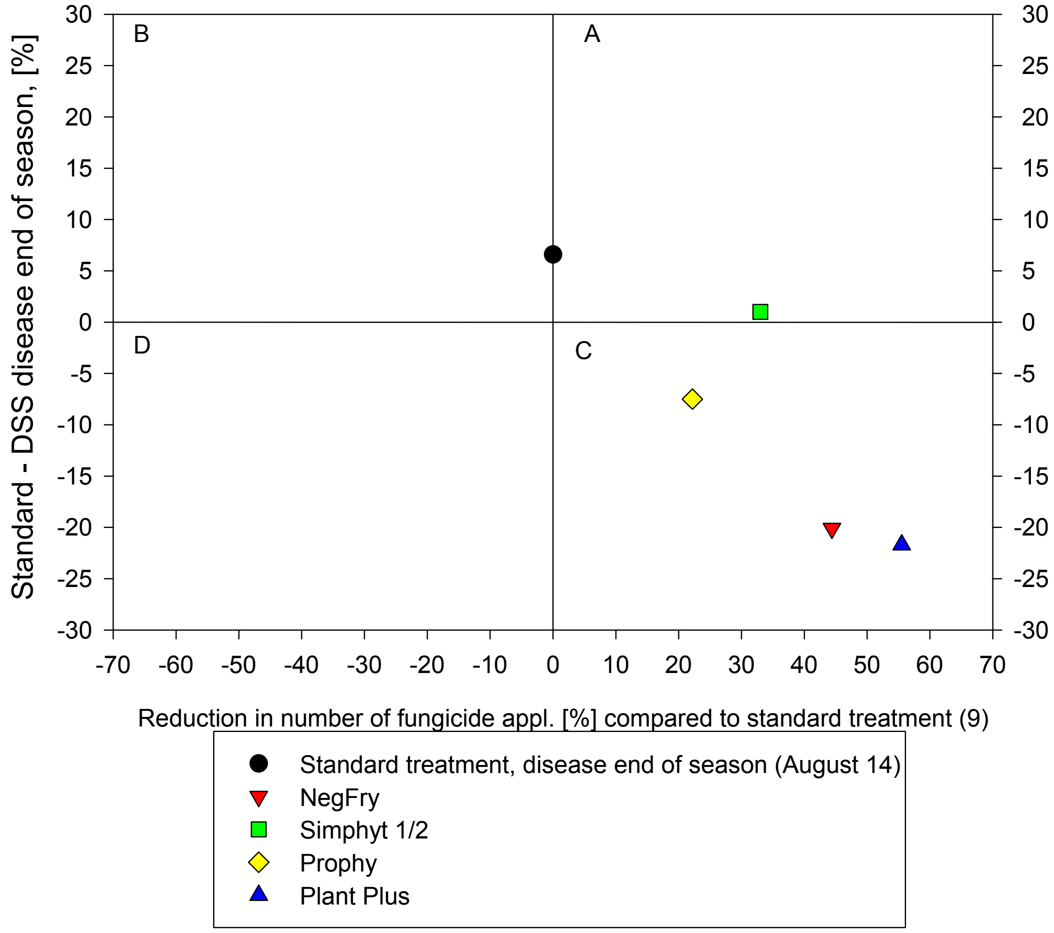
Window A: Higher control effect than standard with less number of fungicide applications than standard

Window B: Higher control effect than standard with higher number of fungicide applications than standard

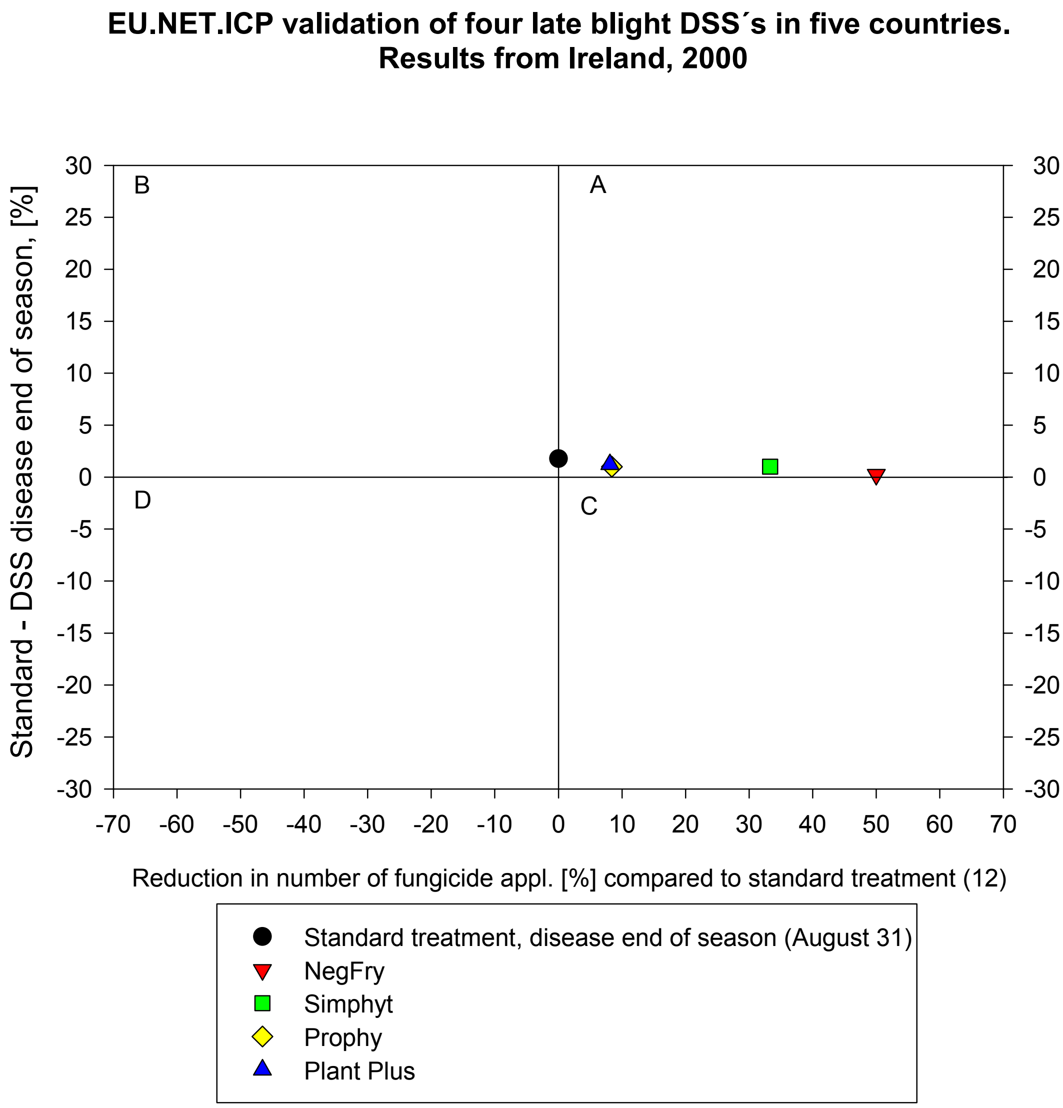
Window C: Lower control effect than standard with less number of fungicide applications than standard

Window D: Lower control effect than standard with higher number of fungicide applications than standard

EU.NET.ICP validation of four late blight DSS´s in five countries.
Results from Germany, 2000



Window A: Higher control effect than standard with less number of fungicide applications than standard
Window B: Higher control effect than standard with higher number of fungicide applications than standard
Window C: Lower control effect than standard with less number of fungicide applications than standard
Window D: Lower control effect than standard with higher number of fungicide applications than standard



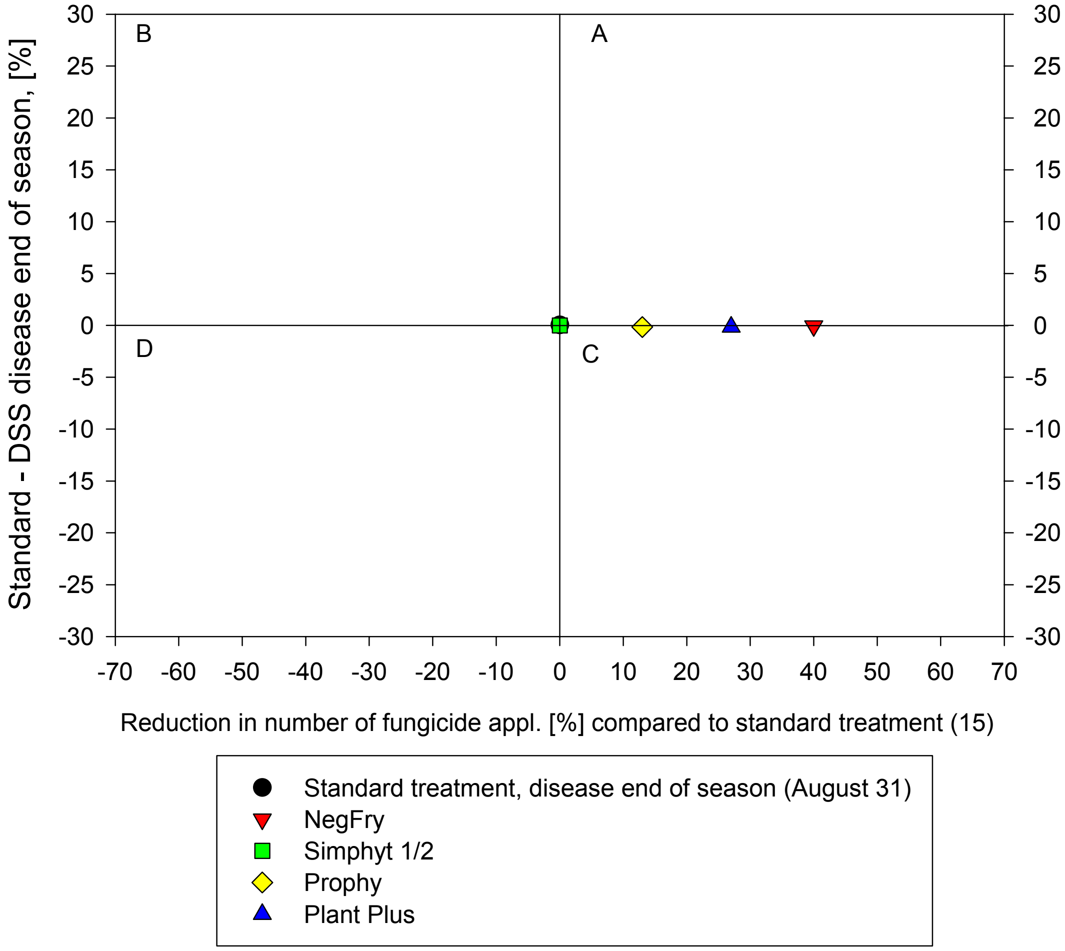
Window A: Higher control effect than standard with less number of fungicide applications than standard

Window B: Higher control effect than standard with higher number of fungicide applications than standard

Window C: Lower control effect than standard with less number of fungicide applications than standard

Window D: Lower control effect than standard with higher number of fungicide applications than standard

EU.NET.ICP validation of four late blight DSS´s in five countries.
Results from Lelystad, 2000



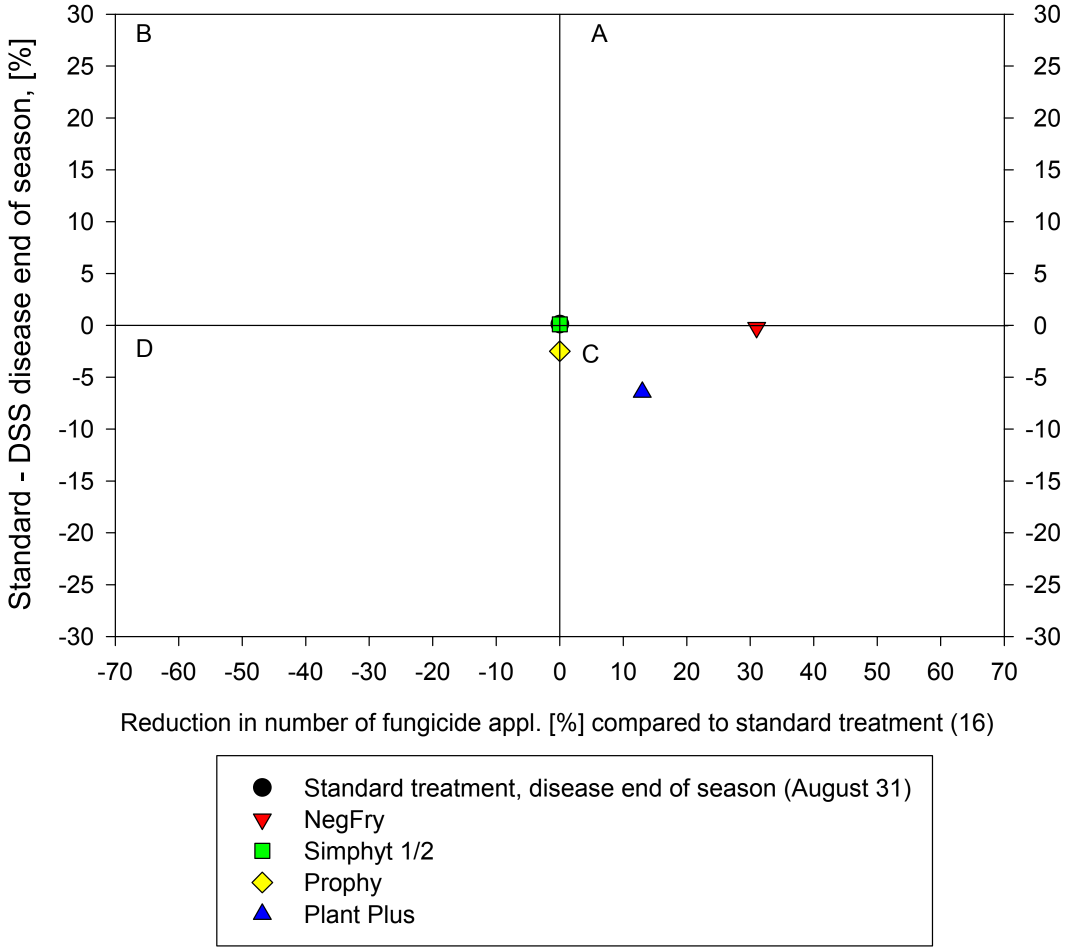
Window A: Higher control effect than standard with less number of fungicide applications than standard

Window B: Higher control effect than standard with higher number of fungicide applications than standard

Window C: Lower control effect than standard with less number of fungicide applications than standard

Window D: Lower control effect than standard with higher number of fungicide applications than standard

EU.NET.ICP validation of four late blight DSS´s in five countries.
Results from Vredepeel, 2000

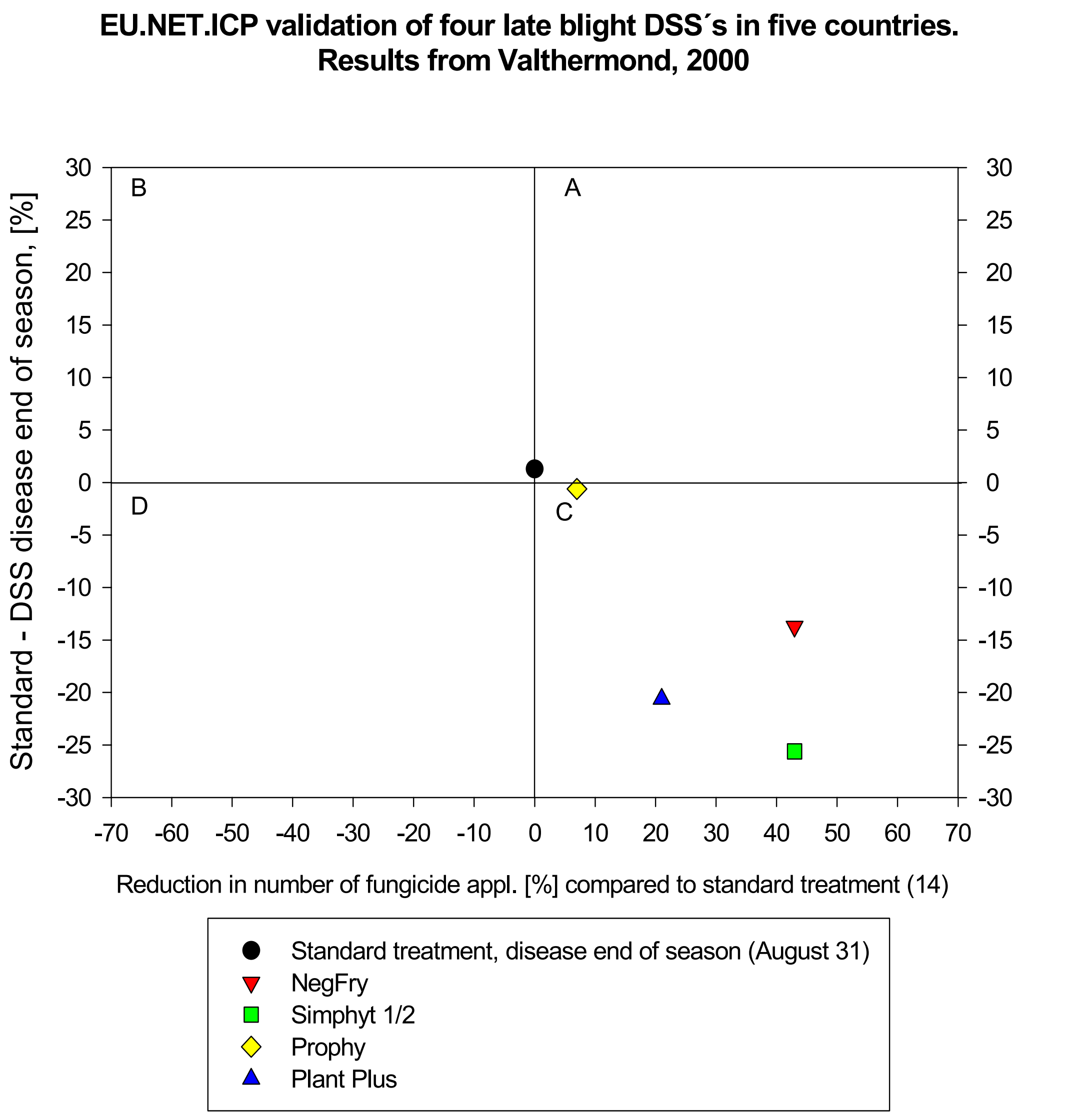


Window A: Higher control effect than standard with less number of fungicide applications than standard

Window B: Higher control effect than standard with higher number of fungicide applications than standard

Window C: Lower control effect than standard with less number of fungicide applications than standard

Window D: Lower control effect than standard with higher number of fungicide applications than standard



Window A: Higher control effect than standard with less number of fungicide applications than standard

Window B: Higher control effect than standard with higher number of fungicide applications than standard

Window C: Lower control effect than standard with less number of fungicide applications than standard

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Fifth Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Munich, Germany, 6-10 September 2000

Monitoring of potato late blight based on collaborative PC- and Internet applications

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Summary
A late blight monitoring system based on collaborative PC- and Internet applications was developed as a part of a new international Internet service called Web-Blight (http://www.web-blight.net). During the growing season, 2000, Denmark, Norway, Sweden, Finland and Lithuania used this system as a part of their Internet based warning service. Early attacks of late blight were found in the late part of June in Denmark, Norway and Lithuania and in early July in Sweden and Finland. Up to 88 % of the attacks found were recorded as primary attacks (in Denmark 87 % and in Lithuania 88 %). A regional forecast based on the NegFry system was used in Denmark, Finland and Lithuania. Early attacks of late blight in commercial fields was well predicted by the forecasting system. No late blight was found on plants at growth stage lower than 30 according to the BBCH scale. The change in the epidemiological behaviour of *P. infestans* is a threat for the control of late blight in general, but also for the use of existing warning and forecasting systems. Therefore it is expected that monitoring via Internet will be a component in future decision support systems in many countries. The experiences using the Web-Blight monitoring application is very promising and the system will be further improved in the future.

Keywords: Late blight, monitoring, Internet, Nordic countries, Web-Blight.

Introduction

During the last 10-15 years a new *Phytophthora infestans* population has been established in Europe (Fry and Goodwin, 1997). There are indications that the sexual recombination by *P. infestans* has caused a change in the behaviour of the fungus e.g. more aggressive genotypes and infections from oospores in the soil (Flier and Turkensteen, 1999; Andersson *et al*., 1998; Hermansen *et al*., 2000). The A2 mating type is widespread in all the Nordic countries and the proportion of A2 seems to be higher in the Nordic countries than in many other European countries (Bødker *et al*., 1998; Sandström and Andersson, 1999; Hermansen *et al*., 2000).

Other alternative inoculum sources than oospores in the soil have now been identified as important for early attacks of late blight. In Holland it was found that 87 % of collected leaflets with two or more lesions on volunteer plants contained oospores (Flier and Turkensteen, 2000). This indicates that volunteer plants not only cause a direct threat to neighbouring fields (asexual spore production), but they can also serve as an important source of oospore inoculum. Recently, also in Holland, it was found that 74 % of the commercial potato fields with early infections were clearly associated with nearby infested refuse piles (Zwankhuizen *et al*, 1998). In the Nordic countries, early attacks associated with waste potatoes, refuse piles and volunteers formerly were not considered as a problem, because of very cold winters. Many periods with frost were expected to kill left tubers in soils and dumps. Now, it seems that winters has become more mild than in the past, and early attacks associated with waste potatoes and volunteers might be a problem in the future in some regions as found in Holland.

The NegFry warning system is based on data collected before the new population was established. Secondly, the oospore biology and the biology of *P. infestans* on volunteers is not well known and therefore not taken into account in this system (Hansen *et al*., 1995; Hansen, 1998; Hansen *et al*., 1999). The change in the epidemiological behaviour of *P. infestans* is a threat for the control of late blight in general, but also for the use of existing warning and forecasting systems (Hansen *et al*., 1999). As a consequence of the situation described above, an “Internet based monitoring system for potato late blight" was prepared with the following objectives:

- General warning about early attacks of late blight.
- Analyse the consequences of a possible change in late blight epidemiology.
- Analyse the cause of very early establishments of primary attacks e.g. local climate, crop rotation, crop resistance, seed physiology, infections by oospores etc.
- Validate and improve existing forecasting systems.

A prototype system was developed in 1998 in the frame of the Danish Internet based information and decision support system called Pl@nteInfo (Hansen *et al.*, 1999; Jensen et al., 2000). In 1999, all the four Nordic countries and Lithuania used this system. As a part of collaborative projects with the Baltic countries the system was improved and reconstructed. This paper introduces the methods and data flow in the monitoring system that now has become a part of a new International Internet based service called Web-Blight. Monitoring results from the Nordic countries and Lithuania are presented and discussed.

Materials and methods

Web-Blight - Collaborative Internet applications

The Web-Blight service was developed to manage and operate networks for collaborative Internet based late blight decision support applications. The system behind this service is build up by a package of Pi-programmes for entering, storage and transfer of primary data to one central server in Denmark. "Pi" refers to *Phytophthora infestans* and all Pi-programmes are PC-programmes written in the Borland, C++ programming language. When data are received by the Web-Blight database, programmes written in the SAS programming language do the processing of the data (SAS Institute Inc., 1996). Finally, a combination of SAS programmes (SAS Institute Inc., 1998) and Active Server Pages (ASP) present the data on the Internet. The advantage of using integrated PC-and Internet applications was discussed earlier (Hansen *et al*, 1999). "Collaborative" in the context of "Collaborative Internet applications" refers to the fact that several countries use the same Internet (and PC) based system. This has the advantage, that programmes only have to be updated and improved on one server. In this way several countries "share" the same applications and thereby avoid duplicate of work. As all countries use the same methods, the results can be compared and analysed together. This is very important for making clear conclusions fast, and it facilitates international scientific collaboration.

In a first version of Web-Blight, applications were developed for international collaboration in the areas of late blight monitoring, evaluation of crop resistance in variety observation trials and evaluation of results from field trials for validation of late blight decision support systems. The corresponding Pi-programmes are called Pi-Monitoring, Pi-OBSTrial and Pi-DSSTrial respectively. The general idea about collaborative Internet applications and the background for all three Pi-programmes is described in more detail at the Web-Blight home page (Hansen *et al*., 2000).

In 2000 the Web-Blight monitoring systems was used in the Nordic countries and in Lithuania. A much more comprehensive system was developed for Germany including forecasting, monitoring, recommendation of control strategies and more. Even the German system is not a "true" Web-Blight application, the maps and monitoring results on the Internet were produced with exactly the same SAS programmes as for the Nordic countries and Lithuania. A description and results obtained in the German system can be found via Web-Blight or at http://www.phytophthora.de.

Organising a monitoring network

To use the Web-Blight monitoring network, each country is responsible for organising a late blight disease survey network and for describing what kind of fields that are surveyed, by whom and how intensive, quality control of assessed data etc. A description of the organisation of monitoring in the different countries is available via the Web-Blight homepage.

Organising a late blight disease survey network can be done in many ways, and there are advantages and constraints in each way to do it. In Denmark, the monitoring network is organised by the Danish Agricultural Advisory Service (DAAC). In 2000, about 50 advisors participated in a formal survey network, and they were paid 3-500 DKr for doing the work. It was discussed to do the observations in fields pre-selected before the season and in field trials, but this would cause a problem: "When the monitoring map contain no recordings of late blight in selected fields we cannot be sure that late blight is not established in farmers fields somewhere around." Therefore all conventional and organic fields, field trials and experimental trials were appointed as the target for monitoring, and the scouts were all the farmers and the appointed advisors in the network. When the farmer (or somebody else) found potato late blight, he contacted his local advisor. If the advisor recognised symptoms as late blight, he sent a plant sample to the Danish Agricultural Advisory Centre in Århus including background information. This was what he was paid for. A specialist in the lab verified the sample, if needed under microscope, and the result was then entered into the system at this point.

The Danish forecasting system based on NegFry was used to identify the time when scouting should be intensified. This can differ up to three weeks (mid June - early July) for Danish conditions. In the Danish Pl@nteInfo system, the map with forecasting data and the map with monitoring data were put side by side on one page. In that way the regional forecast was evaluated directly and the monitoring system was used as a "security system" if the forecast for any reason should fail in being too late. Monitoring in Denmark was ended at July 14, when late blight was found in the most important potato growing regions.

Monitoring - dataflow

When late blight is found in a certain field, a description of the recording including geographical position was transferred via the Internet to the Web-Blight server using the PC-programme called Pi-Monitoring (Figure 1, **b** and **c**). A detailed description of Pi-Monitoring can be found in the user manual (Hansen and Lassen, 2000). This manual can be downloaded from the Web-Blight home page.

Reporters using the Pi-Monitoring programme are called Country Reporters (CR). In each country a Country Administrator (CA) is responsible for the appointment of Country Reporters. Via a programme called Pi-CountryAdministrator, a unique configuration file was sent via the e-mail system to CR´s and in the same step via FTP to the Web-Blight server in

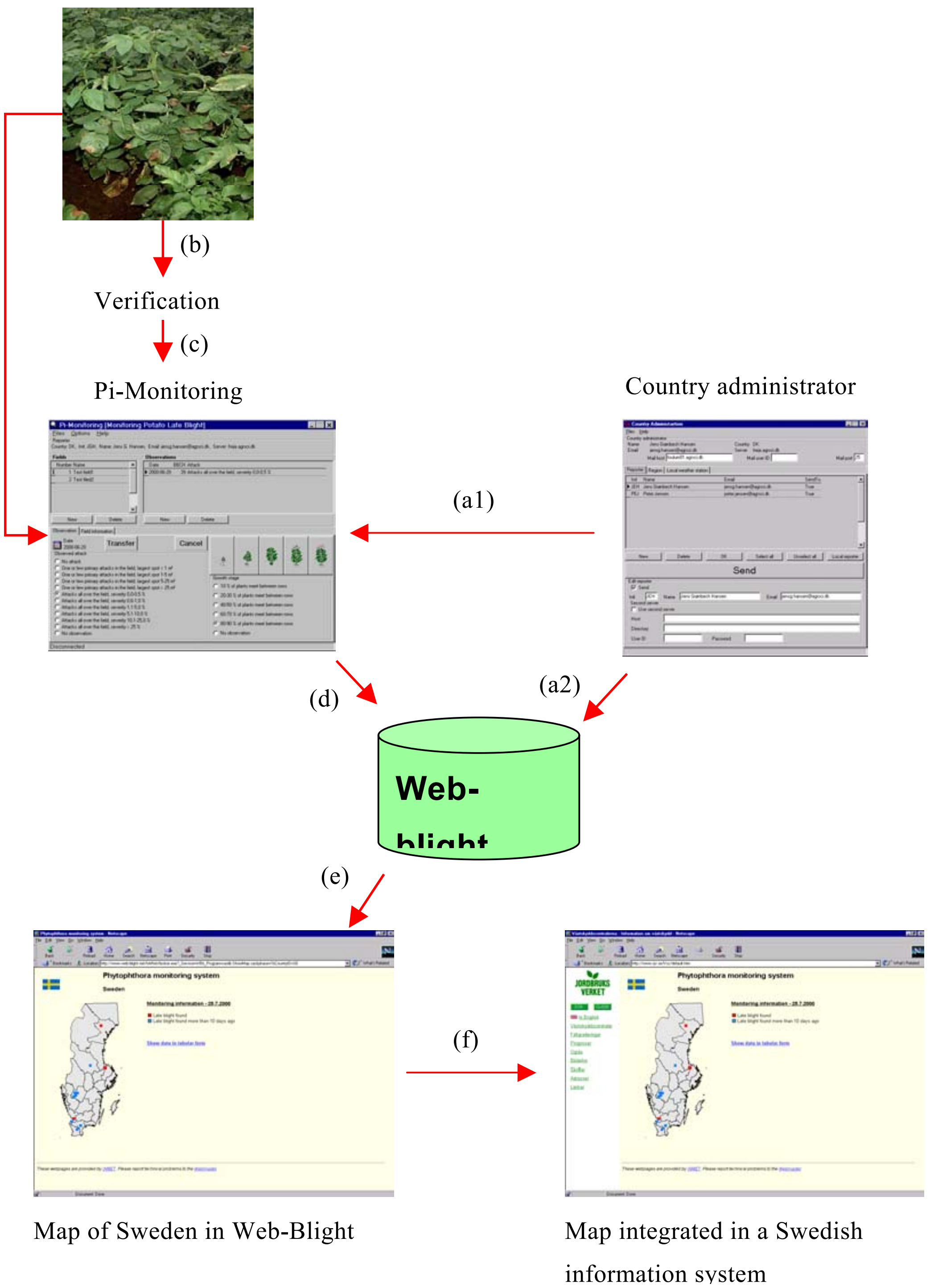

Figure 1. Monitoring of potato late blight using the Web-Blight monitoring system. Dataflow and presentation on Internet: See text for explanation.

Denmark (Figure 1, **a** and **a1**). The configuration file identified the users of Pi-Programmes and this identification was integrated with the monitoring data sent from Pi-monitoring to Web-Blight. The same identifications of country reporters sent to Web-

Blight from a country administrator was used to check, if incoming data were allowed to be stored in the Web-Blight database.

In Web-Blight, maps and tables were produced automatically with tools like Active Server Pages (ASP) and SAS programmes each time the database was updated (Figure 1, **e**). Results were available via the Web-Blight homepage, but the web pages were easily integrated in national information systems via simple hyperlinks (Figure 1, **f**). All texts in figures and tables were translated into national languages including English (default language).

The appointment of country reporters and the flow of data to Web-Blight were 100 % controlled by one Country Administrator per country and one to several Country Reporters in each country. Data sent to Web-Blight were processed and presented on the Internet in a few seconds with the same Internet applications for all countries in the network. Only the production of maps and language differed between countries.

Monitoring - presentation of results on the Internet

The results are shown as dots on a specific map for each country. A click with the mouse on a dot on the map link to a small table with background information of the recording such as location name, variety name, date of crop emergence, field type and date and type of the last recording at this site. All data are available in another table that can be sorted ascending or descending for each variable in the table. In that way the results can be analysed and presented in different ways (Figure 2).

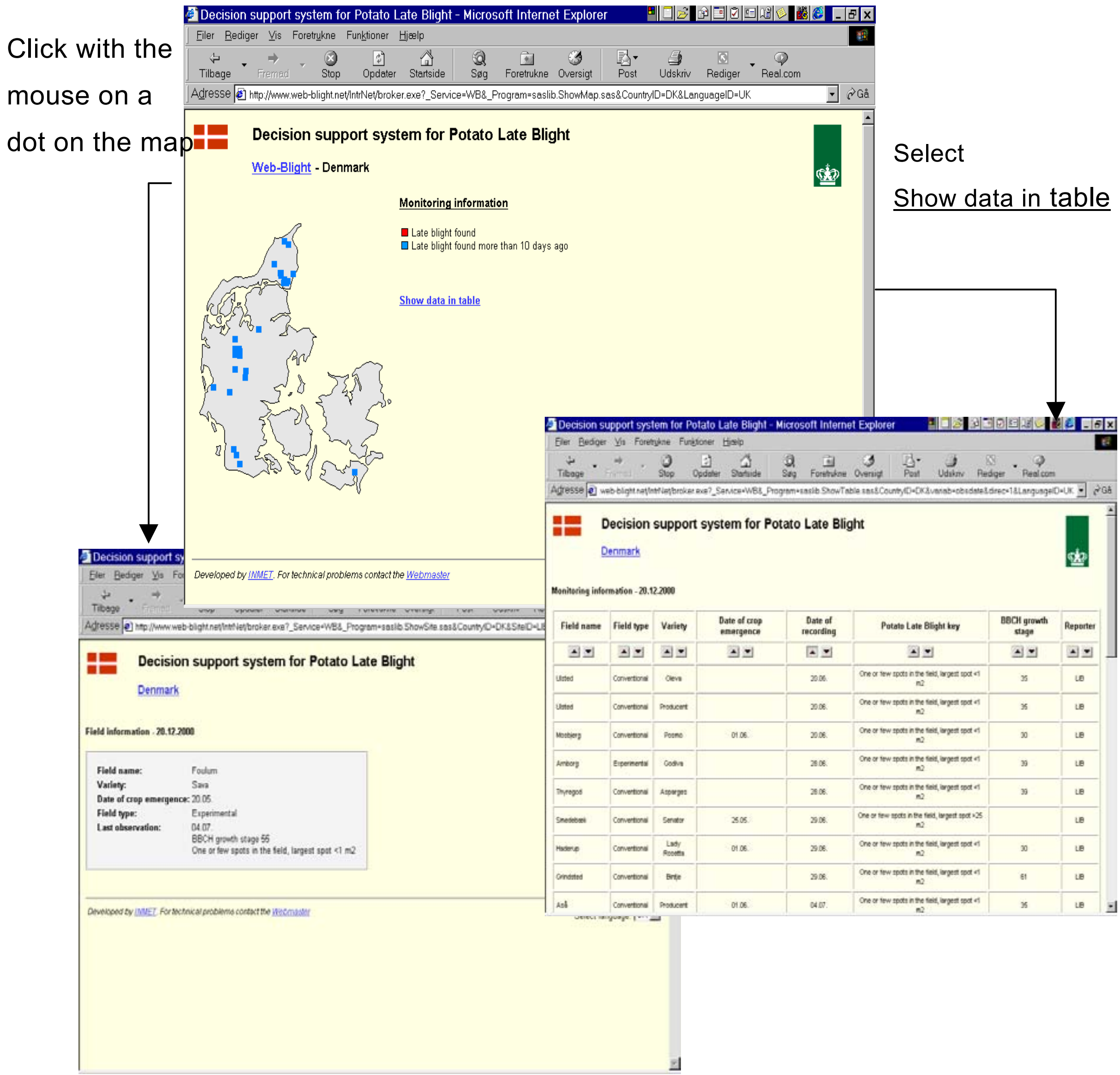

Figure 2. Results of late blight monitoring available in Web-Blight.

Results

In 2000, Denmark, Norway, Sweden, Finland and Lithuania participated in the Web-Blight monitoring network. In all countries except Lithuania recordings of late blight were verified centrally by "experts" before publication on the Internet. Only Lithuania made several recordings in the same fields during the season. Other countries stopped the monitoring when late blight was found widespread in the important potato growing areas. In Denmark, the monitoring was stopped on July 14. At that time no fields were recorded at severity levels more than 0.5 %, attack all over the field.

It has often been questioned if it is possible to find the very early attacks of late blight. That is at the level of primary attack defined as spots in the field from less than 1 m² up to more than 25 m². To answer that question the data were divided into different classes according to attack level (Table 1). In Denmark, 87 % (71%+16%) of the first recordings were recognised as primary attacks. The same number was a little bit lower for Norway, Sweden and Finland, and the reason may be that these monitoring networks were less intensive than in Denmark and in Lithuania. In Denmark, 50 advisors participated in an official monitoring network and the advisors were paid for the extra work needed. In Lithuania 88 % of the first observations were recorded as primary attacks. This high number may be explained by the facts that an official monitoring network was established, and pre-selected fields were monitored at least once a week from early in the season when late blight was not found yet.

Table 1. Level of first attacks of potato late blight divided into four classes and given as percentage of the total amount of fields assessed. Fields assessed more than one time only counts as one.

Country	Percentage of fields recorded as ”primary attack” (spots in the field)		Percentage of fields recorded as ”late blight found all over the field”		Number of fields
	Spots 1-5 m²	Spots 5-25 m²	Severity 0-1%	Severity >1 %	
Denmark	71 %	16 %	13 %	0 %	31
Norway	34 %	16 %	37 %	13 %	38
Sweden	33 %	27 %	20 %	20 %	15
Finland	49 %	6 %	26 %	20 %	35
Lithuania	88 %	0 %	8 %	4 %	25

The daily updated forecast from the NegFry system in Denmark, Lithuania and Finland additionally made it possible to intensify the monitoring when attacks were expected based on the forecast.

A more detailed description of the first recorded attacks is given in Table 2. Recordings in potatoes under plastic were excluded in the presentation of the results. In Denmark, the first attacks of potato late blight were found on June 20 in the northern part of Jutland in three conventional fields with starch potatoes. In the same area in 1999 there were indications of infections from oospores in the soil and relatively aggressive behaviour of the disease (Martin Andersen, personal communication). Again this year a lot of stem attacks were found, several plants close to each other were attacked with symptoms like primary infected mother plants and lower leaves touching the ridges were found with numerous new symptoms on the same leaves. On exactly the same day, June 20, a regional forecast of risk of primary attacks was issued for the northern part of Jutland. Only five new attacks were recorded in Denmark during the period June 21 to July 3. This supports the theory, that special conditions were the case in these three fields. In addition to the special disease symptoms on the plants, it was not expected to find very early attacks in the variety Producent that is characterised as a moderate resistant variety (MR) in the Danish list of varieties (see the potato variety information system in Pl@nteInfo: http://www.Pl@nteInfo.dk).

In Norway, early primary attacks were found on June 26-27 in susceptible varieties at Råde and at Rygge. In Sweden, primary attacks were found on July 3-7 in susceptible varieties at Eldsberga, Kvänum and Landsbrunn. The large size of the spots found in the Swedish fields (Table 2) indicates, that primary infections took place during the late part of June. In Finland, one field at Kälviä was recorded as primary attack and two at Hammarland and Tampere respectively were recorded as secondary attacks on July 4-7. Similar to Sweden this indicates that primary infections took place during the late part of June. In Lithuania, early primary attacks were found on June 26 in susceptible varieties at Prie Tvenkinio and Maisiagala.

As a general trend for all countries no attacks in the monitoring network in 2000 were recorded at growth stages earlier than row closing (BBCH 30-39). Early attacks probably were established in all countries in late June. Epidemic development recorded as "late blight found all over the field" started in many fields mid July and epidemics were recorded from mid to late July in many regions.

As a consequence of the early crop emergence in combination with a relatively late epidemic development in Denmark, yield amount in ecological potato production have been extremely high (Schepers, 2001. This proceedings).

Table 2. Descriptions of first recordings of late blight in Denmark, Norway, Sweden, Finland and Lithuania in 2000. Susceptibility indices are: Susceptible (S), Moderate susceptible (MS) and Moderate susceptible (MR). The potato late blight key and the BBCH growth stage key used, is defined in the user manual for Pi-Monitoring.

Country	**Field name**	**Field type**	**Variety and susceptibility**	**Date of crop emergence**	**Date of recording**	**Potato Late Blight key**	**Growth stage (BBCH)**
Denmark	Ulsted	Conventional	Oleva (MS)	Not recorded	20.06	One or few spots in the field, largest spot <1 m^2	35
	Ulsted	Conventional	Producent (MR)	Not recorded	20.06	One or few spots in the field, largest spot <1 m^2	35
	Mosbjerg	Conventional	Posmo (MS)	01.06	20.06	One or few spots in the field, largest spot <1 m^2	30
Norway	Råde	Conventional	Rutt (S)	15.05	26.06	One or few spots in the field, largest spot <1 m^2	59
	Rygge	Home garden	Snøgg (S)	15.05	27.06	One or few spots in the field, largest spot <1 m^2	39
Sweden	Eldsberga	Organic	Asterix (S)	Not recorded	03.07	One or few spots in the field, largest spot 5-25 m^2	61
	Kvänum	Conventional	King Edward VII (S)	Not recorded	06.07	One or few spots in the field, largest spot >25 m^2	59
	Lundsbrunn	Conventional	King Edward VII (S)	Not recorded	07.07	One or few spots in the field, largest spot >25 m^2	59
Finland	Hammarland	Conventional	Asterix (S)	26.05	04.07	Attacks all over the field, severity 0.6-1.0 %	35
	Kälviä	Home garden	Rosamunda (MS)	21.05	07.07	One or few spots in the field, largest spot 1-5 m^2	67
	Tampere	Home garden	Van Gogh (MS)	Not recorded	07.07	Attacks all over the field, severity >25 %	67
Lithuania	Prie tvenkinio	Home garden	Dietskoselskij (S)	04.05	26.06	One or few spots in the field, largest spot <1 m^2	69
	Maisiagala	Conventional	Sante (MS)	Not recorded	26.06	One or few spots in the field, largest spot <1 m^2	63

Discussion and conclusions

In many western European countries, Internet has now become **the** media for exchange of information and data in the agricultural community. In Denmark, now more than 50 percent of farmers have access to Internet and this number is increasing rapidly. Introducing the Web-Blight monitoring system emphasises the advantages of sharing the same Internet based applications in a network-collaboration. Including a new country in this system is more or less only a question of making the application for drawing the country map and translating the written texts in web outputs and in the Pi-Programmes. Together with Lithuanian partners a total Lithuanian information and decision support system was implemented using the existing Pl@nteInfo shell. The monitoring system was only one of several components in this system (http://www.planteinfio.dk/lt). For Norway, Sweden and Finland, the maps and tables with monitoring information were available from their own information systems on the Internet via simple hyperlinks to the Web-Blight server. The user doesn't care on which server applications are running if only the information is local and relevant and texts are in own language.

Fungicides to control late blight are only effective, if they are applied before or very close to the time of infection (Bødker and Nielsen, 2001, this proceedings). Therefore it is vital for the potato growers, that recordings of early attacks of late blight is published and available as soon as possible after primary attacks have been found. The Web-Blight monitoring system fulfil this requirement, as new data can be uploaded to the system any time of the day and without any manual work on the server side. On the other hand most of the countries participating in 2000 decided to verify all attacks found before publication on the Internet. This procedure delayed the time from recording to publication. The advantage of the verification is that all information on the Internet is certainly late blight. We know that even experienced potato advisors can be wrong in the interpretation of "late blight symptoms”. In 1998, four out of fifty samples received by the Danish Agricultural Advisory Service turned out not to be late blight after verification. In earlier years, rumours about early attacks of late blight got many Danish farmers to start preventive spraying programmes. Later, it showed up not to be late blight or it was found in only one home garden. Farmers in Denmark are very satisfied about the verification method and more and more farmers support the monitoring system by looking carefully in own fields and by making contact to the local advisors when symptoms are found.

One major question has been if it was possible to find the early attacks at a stage when secondary spread from mother foci still was insignificant. It is to some extent surprising that 87% in Denmark and 88 % in Lithuania of the late blight attacks were found as foci in the fields. No early attacks were found associated with volunteers, dumps or refuse piles. Often “you find what you look for” and maybe we have not looked carefully enough on the right places. Based on the experiences from Holland and other countries, we should pay more attention in the future on these alternative inoculum sources.

Another question was if data from the monitoring system could be used to document an association between oospores in the soil and early attacks of late blight. From Sweden and Denmark we have indications of infections from oospores in the soil in areas with potatoes under plastic and at the same time with narrow crop rotation. Still in conventional fields we have only a few indications and still no proof, that oospores play a significant role in practical potato growing. The three early attacks in Denmark in 2000 expressed symptoms that probably were initiated by oospores in the soil (numerous infections on leaves touching the ridges). None of the early attacks in the Nordic countries and Lithuania in 2000 was recorded at growth stages earlier than row closing (BBCH 30-39). That is the time when late blight normally is found in susceptible varieties and at the time when farmers start spraying programmes according to a routine schedule. In 2000, the NegFry forecasting system was used in Denmark, Finland and Lithuania. In most cases attacks of late blight was found at the time when it was predicted. This does not mean that oospores do not play a role in the *P. infestans* epidemiology later in the season. We do not know if this situation will change in the future, maybe caused by a build-up of oospores in the soil.

Late blight will usually, but not always, appear in susceptible cultivars before it appears in moderately resistant ones. This was concluded after an experiment when seed tubers of susceptible and moderate resistant cultivars were inoculated with *Phytophthora infestans* and planted in a field in four trials over three years in the United States (Doster *et al*., 1989). For the thirteen very first recordings of late blight in the present survey (Table 2) seven cultivars were susceptible, five were moderate susceptible and only one moderate resistant. This is in correspondence with the conclusion by Doster *et al*, 1989, but more results are needed before clear conclusions can be made.

In Europe we have to reduce the use of fungicides because of national and EU political action plans. Exploitation of crop resistance in control strategies will be very important to reach the goals. Probably monitoring systems will be used in the future to monitor the practical (and a potential change) in different resistance components expressed under field conditions. This may lead to a delay of first applications or lower fungicide dosage in moderate resistant cultivars during the first part of the season.

Diseases don't stop at borders. Therefore the Web-Blight monitoring maps will be combined into one map covering larger regions of Europe to forecast the spread *of Phytophthora infestans* over longer distances. By experience, early attacks of late blight in a neighbouring country or region can warn other regions that late blight will be relatively early or late often depending on current weather conditions. In that way monitoring information may act as an important component in a warning system

Collaborative Internet applications like the Web-Blight monitoring system must be a part of future warning system for the control of late blight in Europe. We cannot afford to duplicate work, and network collaboration and harmonisation of methods facilitate that conclusions and quantitative knowledge are obtained faster and more reliable.

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Fifth Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Munich, Germany, 6-10 September 2000

An Internet-based DSS for the control of potato late blight PhytophthoraModell Weihenstephan

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Abstract

For several years some efforts have been made to improve a warning service of potato late blight. The Institute of Phytopathology in Munich-Weihenstephan in cooperation with the Bavarian State Institute of Agronomy and Crop Protection developed a Phytophthora information system: PhytophthoraModell Weihenstephan. The model is based on two components: monitoring and prognosis.

Since 2000 the PhytophthoraModell Weihenstephan, a DSS for the integrated control of late blight is established in Germany. The weather-based prognosis calculates the epidemic pressure on the basis of the weather data from more than 70 local weather stations. The monitoring is based on the actual disease observations in more than 250 monitoring fields.

The basics of the model and the results of the year 2000 are presented and discussed here.

Key words: DSS, warning system, *Phytophthora infestans,* late blight, plant protection, monitoring, internet

Introduction

Since several years we are working with different DSS based on PC-programs. The results of the years indicate that for a functional warning service it is useful to have also a monitoring system. The integration of these two components – prognosis and monitoring – is given in the concept PhytophthoraModell Weihenstephan. According to the results we derived basic tools for the integration of these information and for the use in the advisory service and in practice.

In 1997, the warning service of potato late blight was introduced in Bavaria in cooperation with the Bavarian State Institute of Agronomy and Crop Protection and the Bavarian State Advisory Service, providing advice thoughout the growing season on the optimal fungicide application.

In 2000 the model was established in Germany.

Materials & Methods

The main idea of the **PhytophthoraModell Weihenstephan** is the integration of two components (Fig. 1):

- Weather-based prognosis
- Monitoring

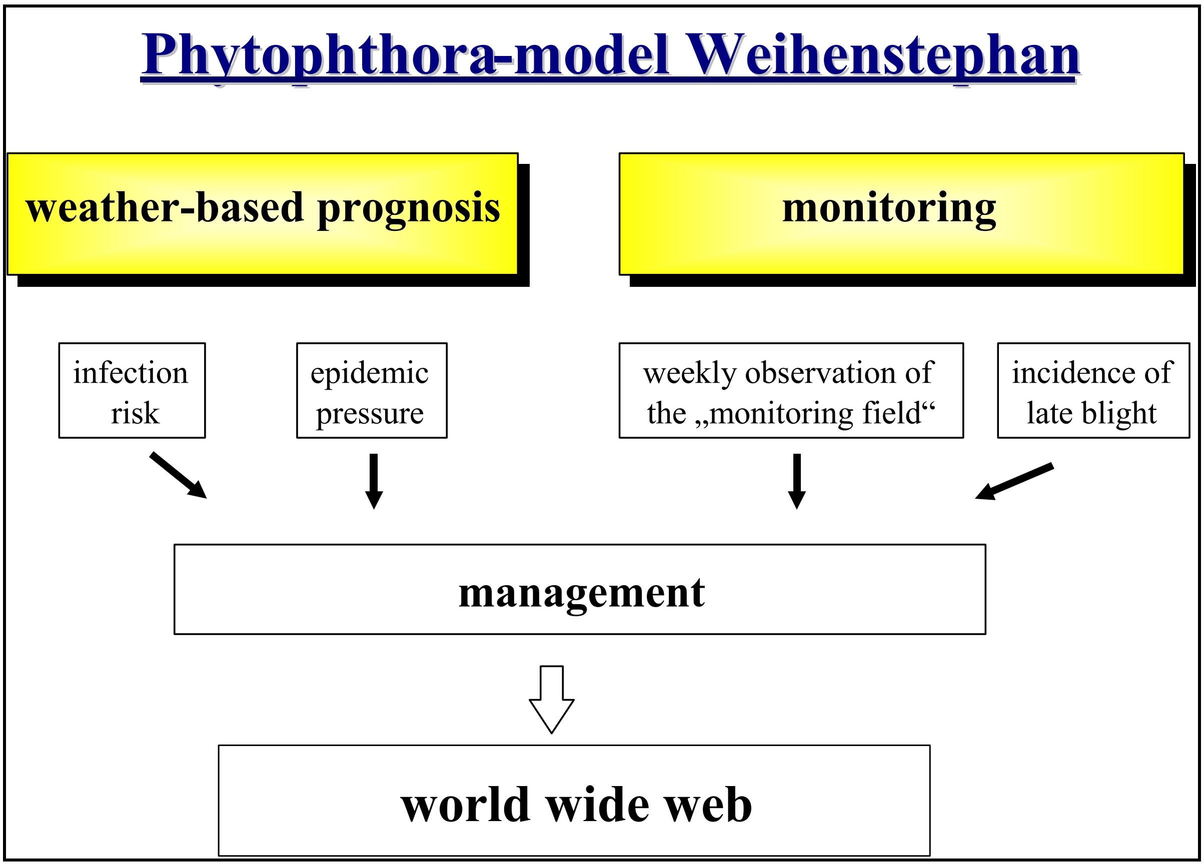

Figure 1. Scheme of the PhytophthoraModell Weihenstephan.

Prognosis

Hourly meteorological data on temperature, relative humidity and rainfall were provided automatically by weather stations. The local weather data were transferred online to a server.

The model provided information on epidemic pressure and information about the efficiency of the development of *Phytophthora infestans* on a single day were given (Gutsche, 1999). The idea is to reduce the spraying interval during periods of high epidemic pressure and to extend the interval during low infection periods. The model itself does not recommend a fungicide strategy, but from the calculated epidemic pressure under consideration of the factors:

- foliage growth,
- cultivar resistance,
- blight situation in the field,
- irrigation,
- fungicide usage,

a spraying interval could be derived (Hausladen & Habermeyer, 2000)

Monitoring

The monitoring is divided in two parts:

- information about early outbreaks of *Phytophthora infestans*
- weekly information from monitoring field during the growing season

Information about the appearance of late blight in a region (monitoring fields, practice fields, dumps, etc) is very important for the first fungicide application. On the other hand we got detailed information from fields during the growing season. The observed fields called “monitoring fields” were sown with cultivars most frequently grown in the region. These fields, which belong to farmers, also contained an untreated control plot of about 150 m^2. No fungicide applications were carried out on this plot until the occurrence of the first symptoms of *Phytophthora infestans*. The fungicide treated fields were monitored weekly by counting leaf and stem symptoms. There were two or three monitoring-fields in the vicinity of each weather station.

Monitoring -field

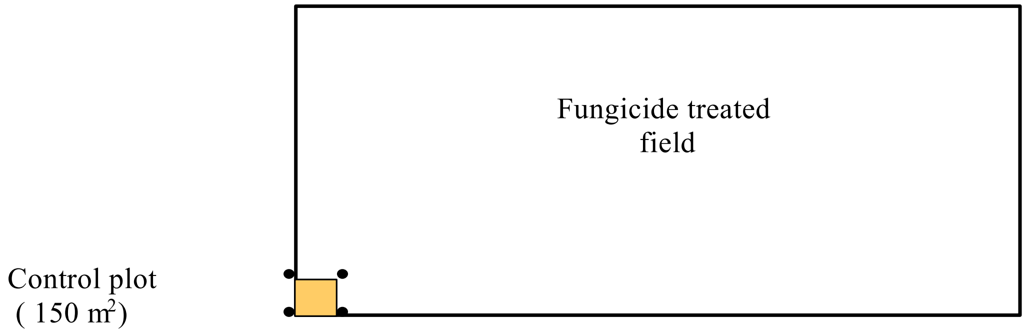

Figure 2. Structure of the monitoring field

The following information was available from the monitoring fields:

- General information: cultivar, crop emergence, fungicide treatment
- Outbreak in the unsprayed control plot
- Information about the disease level in the fungicide treated field
- Information about the occurrence of further disease

Data processing

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

For a successful control of the fungus *Phytophthora infestans*, it is necessary to inform the farmer with the latest data. Using the latest technology for efficient dissemination of information the Phytophthora warning system has been available via World Wide Web. The information from the PhytophthoraModell Weihenstephan is daily updated.

Results and Discussion

In 2000 the model was introduced in Germany supported by Zeneca Agro.

The weather-based prognosis calculated the epidemic pressure on the basis of the weather data from more than 70 local weather stations. The hourly data were checked by the German Weather Service. Further a three day weather forecast was available and therefore the epidemic pressure could be forecasted. The weather data were transferred via FTP to a main WWW-server. The calculation of the weather-based prognosis were updated daily.

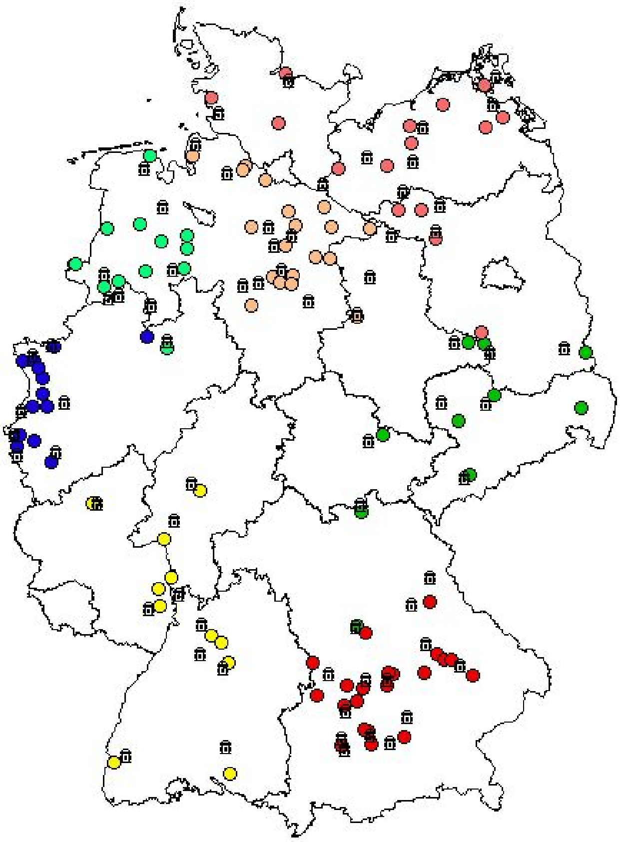

Figure 3. Network of the weather stations and monitoring fields used in the PhytophthoraModell Weihenstephan

The monitoring was based on the actual disease observations in more than 250 monitoring fields. The disease observations were done by the potato grower. Every trained expert monitored weekly two or three fields.

The disease level was established according to the following rules:

0 no disease

1 blight in the field (one attack)

2 several blight attacks in the field

3 disease frequency up to 10%

4 disease frequency from 11 to 50%

5 disease frequency higher than 50%

Furthermore the potato growers gave also information about the occurrence of potato late blight in the region.

All the monitoring data were checked and evaluated. The results were entered into the web system via a web-data Interface.

The user of the internet (www.zeneca.de) find maps about the occurrence of late blight and about the regional epidemic pressure (Fig. 4). A click to a region gave very detailed information about the actual Phytophthora situation.

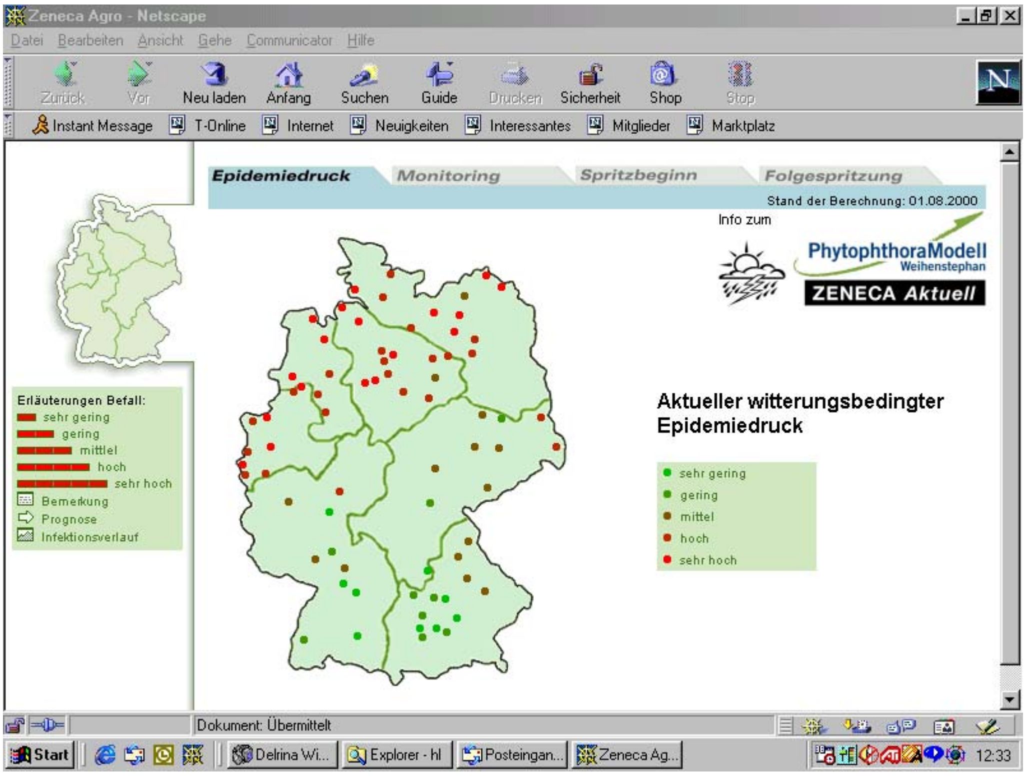

Figure 4. Overview about the actually epidemic pressure

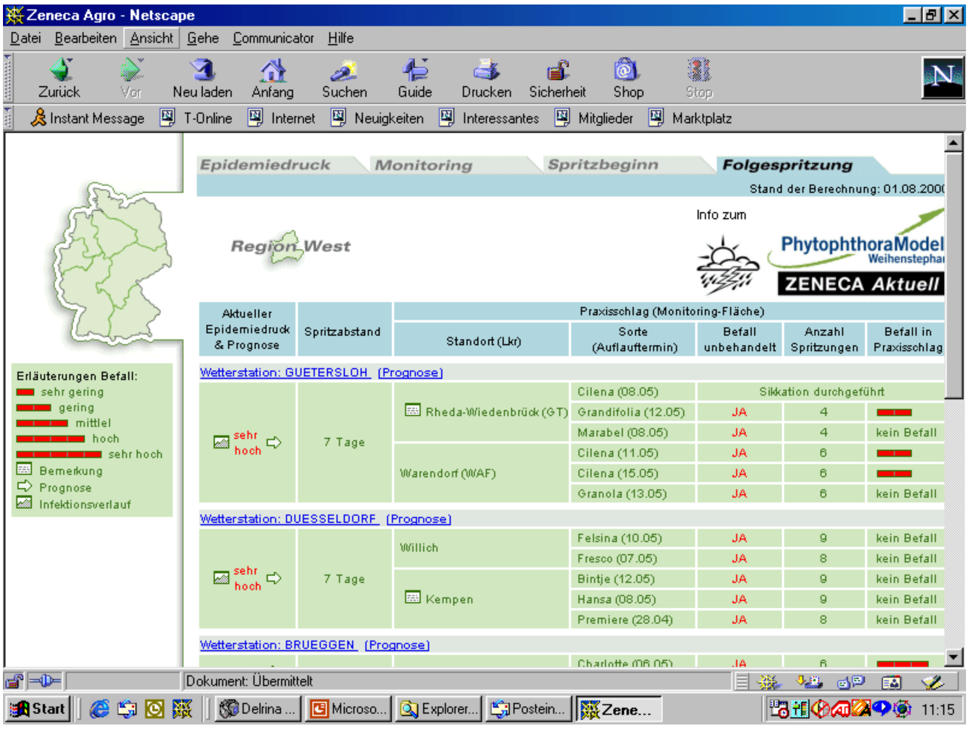

Figure 5. Detailed information about Phytophthora in the region

Further development

Results from the study of the fungus *Phytophthora infestans* showed that the population has changed. The occurrence of the "new populations" in combination with increased levels of aggressiveness showed the necessity of the adaptation of the weather-based prognosis. It also indicates that it is very useful to have two components in a functional integrated Phytophthora-concept.

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Fifth Workshop of an European Network for development of an
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WWW.PHYTOPHTHORA.DE – An Internet – Based warning service for potato late blight provided by the governmental crop protection services

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Abstract

In 2000 the governmental crop protection services installed an Internet-based warning service for Late Blight (www.phytophthora.de) throughout the whole Federal Republic of Germany. All relevant potato growing regions were included. The system combined results of predictive models and decision support systems, data from comprehensive monitorings in farmers` fields and specific local advice given by extension officers. Information on the first occurrence, the epidemic development and fungicide strategy were provided to the growers. The system comprises an interactive part in which the growers can use their own data to aid decision-making for *P. infestans* control. The acceptance of www.phytophthora.de was unexpectedly high. The system will be improved and integrated in a more complex information system on integrated crop production (ISIP).

Key words: *Phytophthora infestans*, decision support systems, DSS, SIMPHYT, monitoring, Internet, warning service, ISIP.

Introduction

In 1997 the governmental crop protection services (GCPS) decided to install and finance a central unit (ZEPP) to develop and elaborate predictive models and decision support systems (DSS). During the last three years ZEPP developed several DSS's and successfully introduced them into agricultural practices (an overview is given by Kleinhenz and Jörg, 1998). With respect to Late Blight of potatoes the SIMPHYT – models (Gutsche and Kluge, 1996), after several years of intensive validation efforts (Gutsche, 1998; Kleinhenz and Jörg, 1999, 2000; Zellner, 1998), meanwhile have been widely accepted in practice and have become essential tools in decision-making in *P. infestans* – control.

Due to reductions in staff and shortages in finances more tasks of the GCPS have been centralised and transferred to ZEPP. In January 2000 the GCPS decided to install an Internet-based warning service on Late Blight control (www.phytophthora.de) on the federal scale in Germany. All relevant potato growing regions should be included.

Organisation

Work on www.phytophthora.de started in February 2000. It must be clearly stated that without the valuable help and know-how of our Danish colleagues from DIAS (Department of Agricultural Systems, Danish Institute for Agricultural Science, Foulum) it would not have been possible to elaborate the Internet service within an extremely short period. From the beginning on it was intended to include the German Internet – based warning service into the European network installed by DIAS (Hansen *et al.*, 1999; Jensen *et al.*, 2000). After Denmark, Norway, Sweden, Finland and Lithuania, Germany became the fifth participant in www.web-blight.net (Fig. 1).

From February to May 2000 the structure of, and the infrastructure to run the system (Fig. 2) was elaborated by ZEPP in close co-operation with DIAS and the GCPS.

1) Weather data: From 110 meteorological stations located within the potato growing regions and either owned by the GCPS or the German Meteorological Service (DWD) data required to run the SIMPHYT – models were centrally collected by ZEPP*. Daily model runs were conducted automatically.
2) All results from GCPS-monitoring activities in a total of 55 growing areas and 190 surveyed potato fields as well as the advices given by the extension officers were recorded at the regional institutions of the GCPS with a specific computer program

- In Bavaria an Internet-based warning system had been elaborated prior to the federal one. It works according to the same principles and the same information are provided to the growers. The Bavarian system is linked to www.phytophthora.de.

(Fig. 3). Afterwards the informations were sent to ZEPP* where they were analysed, summarised and prepared for the creation of the Internet pages.

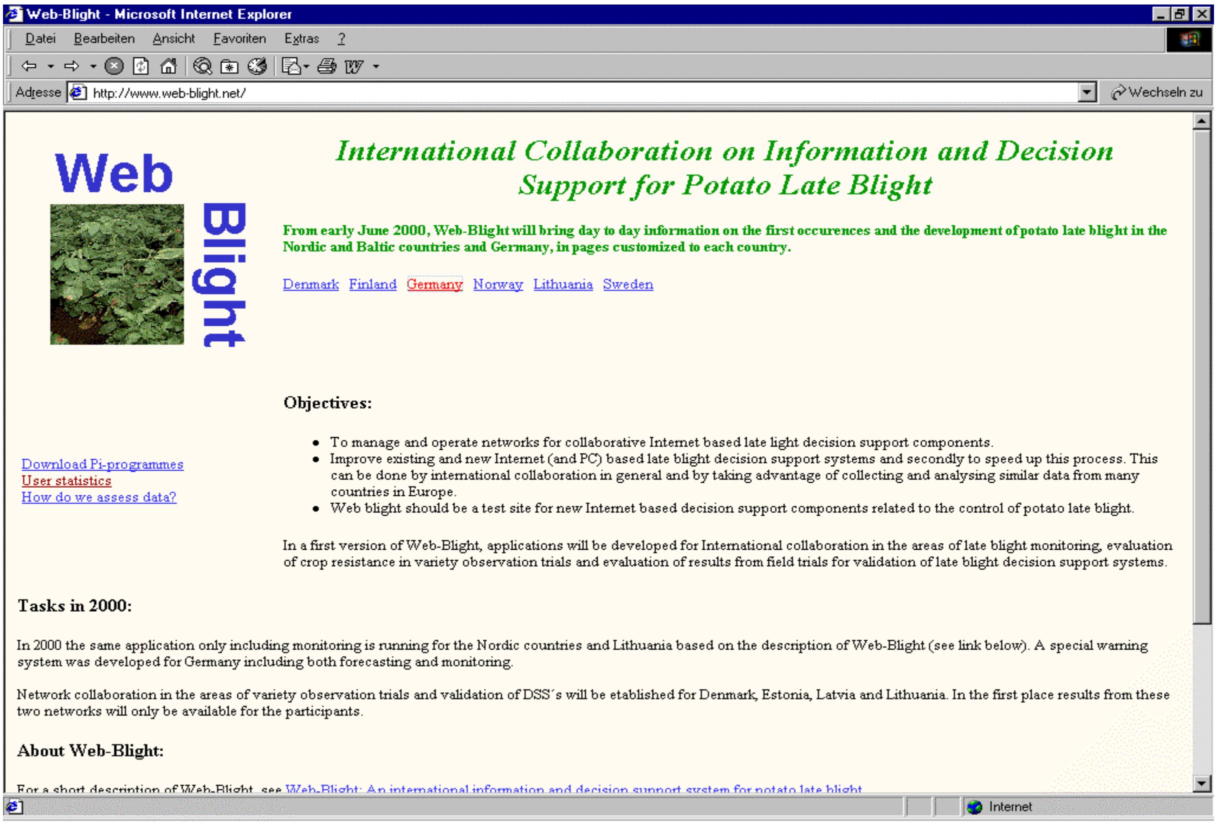


Figure 1. Internet page site of www.web-blight.net.

3) Via ftp-transfer (Hansen *et al*., 1999) the data were transferred to DIAS where the Internet-server is located. DIAS provided the interactive Internet – pages to the user.

In 2000 a total of 3200 records were processed and more than 15000 simulation runs resp. forecasts were performed and their results have been published in the Internet.

Structure

There are three ways to get access to www.phytophthora.de. In the www.web-blight.net you may chose „Germany“ and you will be led to the overview map of Germany (Fig. 4).

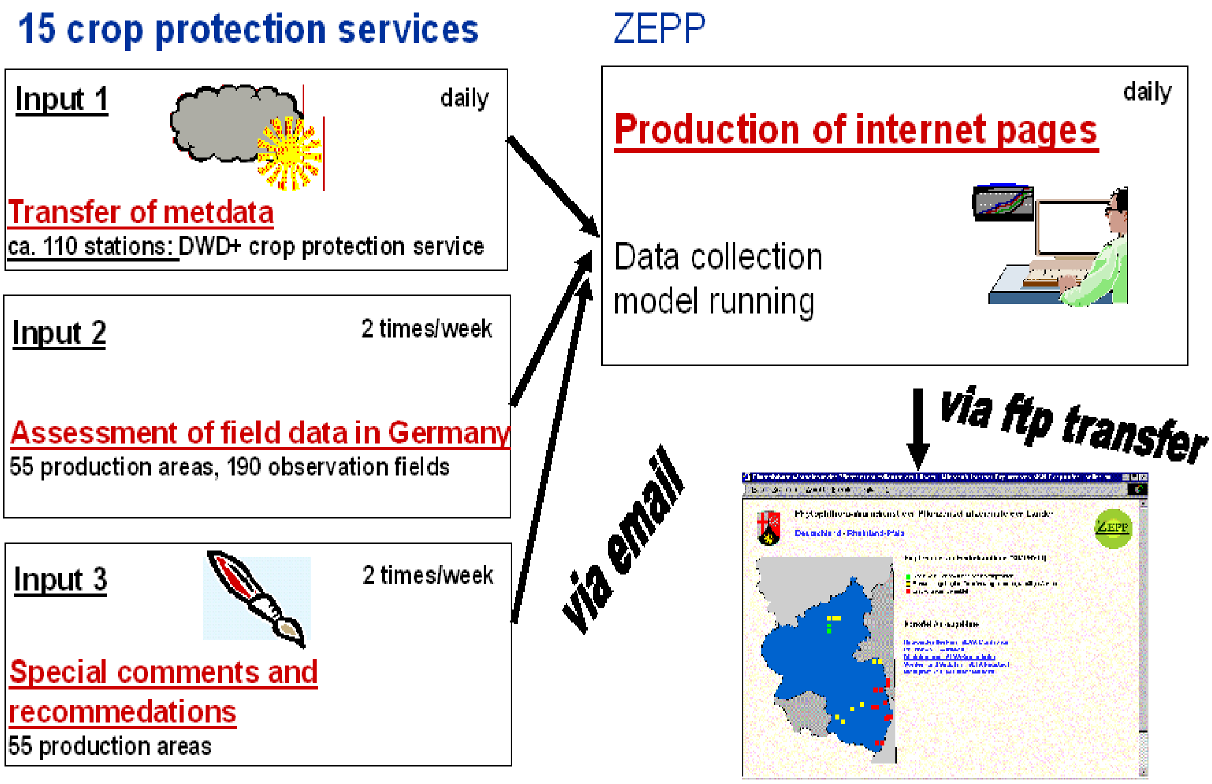


Figure 2. Data flow of Phytophthora-warning-service in Germany.

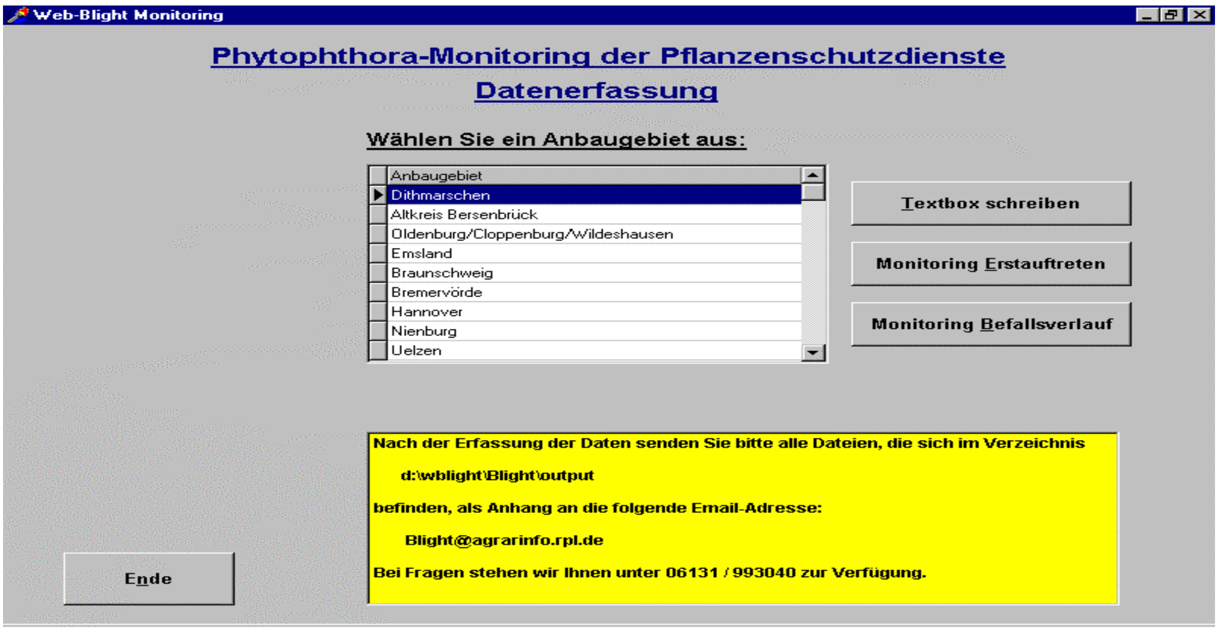


Figure 3. Blight-exe: a software-form for registration of monitoring data and recommendations.

Second possibility is to directly go to this Internet – page. And thirdly all regional Internet – services of the GCPS link to this page when you ask for specific information on Late Blight control.

The information provided in www.phytophthora.de may be divided into four groups:

1) Results of SIMPHYT – models on a regional scale (first occurrence and infection pressure).
2) Results of a comprehensive monitoring which is done by the extension officers of the GCPS in regular intervals and includes a proper diagnosis.
3) Regional advice and recommendations concerning start of the spraying schedule, spraying intervals and choice of the products.
4) (Interactive) calculations of appropriate plot-specific spraying intervals on the basis of a few, simple data inserted into the system by the grower himself.

All these information combined and simplified enable the grower to optimise his strategy of *P. infestans* – control.

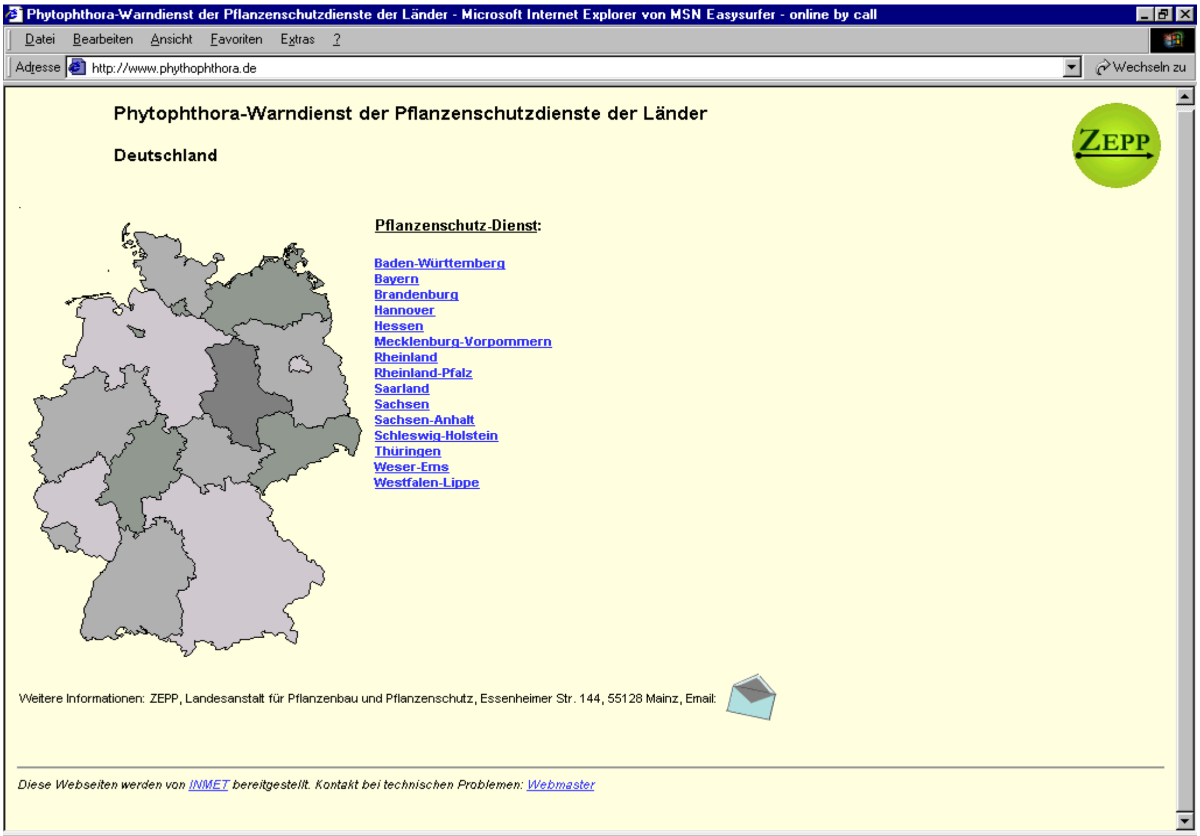


Figure 4. Homepage of www.phytophthora.de.

Content of www.phytophthora.de

The Internet – based warning service provides the growers with advice on the first occurrence of *P. infestans*, on the epidemic progress and actual infection pressure and on spraying intervals.

- ***First Occurrence***

If the user decided to get information on the start of the Late Blight epidemic he is led to a map of the country he has chosen. An overview on the growing areas in this country is given and monitored fields (characterised by a representative weather station) are identified by spots of different colours (Fig. 5).

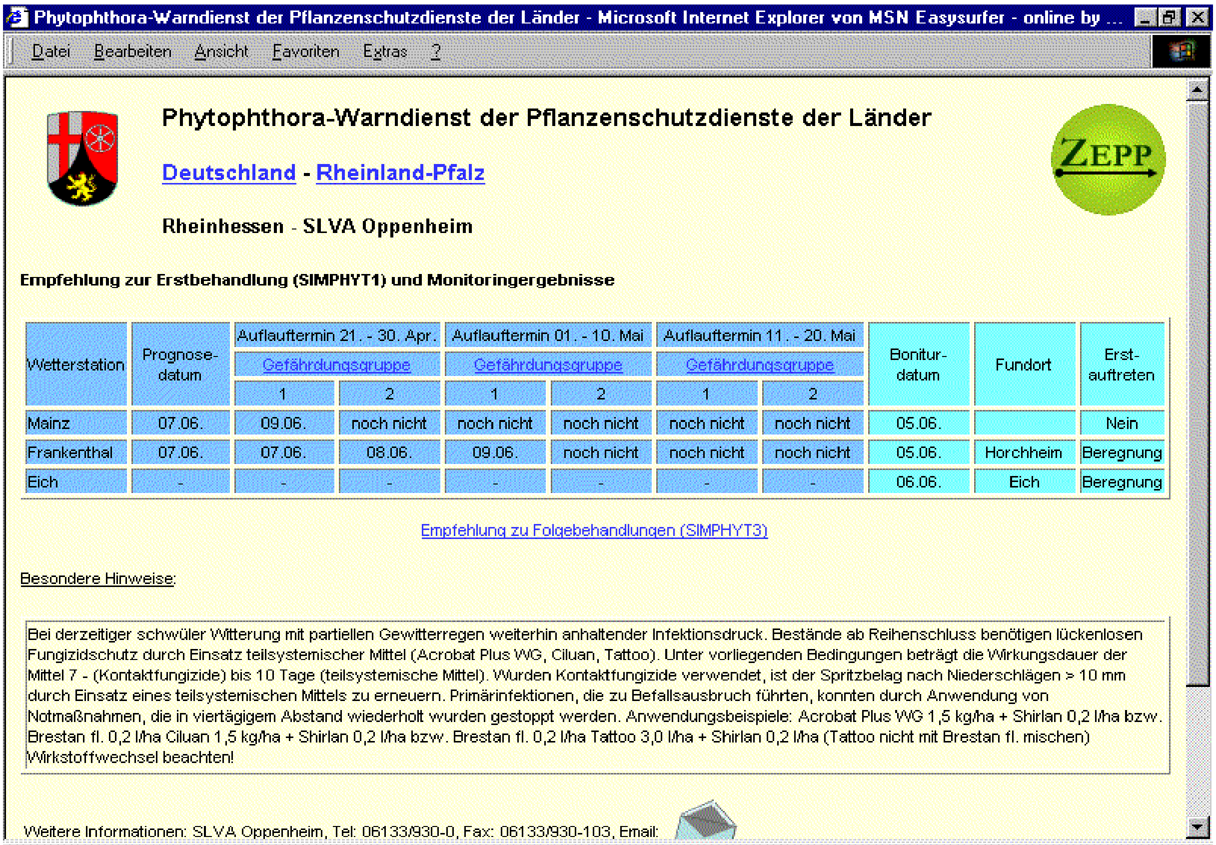
The colours inform on the status of Late Blight in the fields as follows:

- „green“ = *P. infestans* – occurrence is neither predicted by SIMPHYT1 nor has it been recorded during the GCPS monitoring.
- „yellow“ = *P. infestans* – occurrence has been predicted by SIMPHYT1 but has not been recorded yet in the region.
- „red“ = *P. infestans* – occurrence has been recorded by the monitoring.

Thus a rough overview is given on the start of the epidemic in a region and the surrounding growing areas. More specific results are presented in a table if the user clicks on a certain coloured spot (Fig. 6).

1) In the left part of the table SIMPHYT1 forecasts for the three main emergence date classes in the region are shown, specified according to a high or an average „risk“ (see Kleinhenz and Jörg, 1998). Help is available on the definition of „risk“.
2) Results of the GCPS monitoring are presented in the right part of the table. Municipality and date of the first record of *P. infestans* in the region is shown and in addition the circumstances are described (occurrence in a housegarden, irrigated field, a field under plastic cover, normal field).
3) In a text-box below the table specific advice is given to the farmers of the region. Normally the text contains information on distribution of *P. infestans* in the region, decision – making (cultivars to be treated or products to be used) but also on further pests and diseases that occur.

Local institutions and extension officers in charge of crop protection are named and quick contact via email is possible to obtain more information if necessary.



Phytophthora-Warndienst der Pflanzenschutzdienste der Länder - Microsoft Internet Explorer von MSN Easysurfer - online by ...

Datei Bearbeiten Ansicht Favoriten Extras ?

Phytophthora-Warndienst der Pflanzenschutzdienste der Länder

Deutschland - Rheinland-Pfalz

Rheinhessen - SLVA Oppenheim

ZEPP

Empfehlung zur Erstbehandlung (SIMPHYT1) und Monitoringergebnisse

Wetterstation	Prognose-datum	Auflauftermin 21. - 30. Apr. Gefährdungsgruppe		Auflauftermin 01. - 10. Mai Gefährdungsgruppe		Auflauftermin 11. - 20. Mai Gefährdungsgruppe		Bonitur-datum	Fundort	Erst-auftreten
		1	2	1	2	1	2			
Mainz	07.06.	09.06.	noch nicht	noch nicht	noch nicht	noch nicht	noch nicht	05.06.		Nein
Frankenthal	07.06.	07.06.	08.06.	09.06.	noch nicht	noch nicht	noch nicht	05.06.	Horchheim	Beregnung
Eich	-	-	-	-	-	-	-	06.06.	Eich	Beregnung

Empfehlung zu Folgebehandlungen (SIMPHYT3)

Besondere Hinweise:

Bei derzeitiger schwüler Witterung mit partiellen Gewitterregen weiterhin anhaltender Infektionsdruck. Bestände ab Reihenschluss benötigen lückenlosen Fungizidschutz durch Einsatz teilsystemischer Mittel (Acrobat Plus WG, Ciluan, Tattoo). Unter vorliegenden Bedingungen beträgt die Wirkungsdauer der Mittel 7 - (Kontaktfungizide) bis 10 Tage (teilsystemische Mittel). Wurden Kontaktfungizide verwendet, ist der Spritzbelag nach Niederschlägen > 10 mm durch Einsatz eines teilsystemischen Mittels zu erneuern. Primärinfektionen, die zu Befallsausbruch führten, konnten durch Anwendung von Notmaßnahmen, die in viertägigem Abstand wiederholt wurden gestoppt werden. Anwendungsbeispiele: Acrobat Plus WG 1,5 kg/ha + Shirlan 0,2 l/ha bzw. Brestan fl. 0,2 l/ha Ciluan 1,5 kg/ha + Shirlan 0,2 l/ha bzw. Brestan fl. 0,2 l/ha Tattoo 3,0 l/ha + Shirlan 0,2 l/ha (Tattoo nicht mit Brestan fl. mischen) Wirkstoffwechsel beachten!

Weitere Informationen: SLVA Oppenheim, Tel: 06133/930-0, Fax: 06133/930-103, Email:

Figure 5. Overview of first appearance of *P. infestans* and first fungicide treatment.

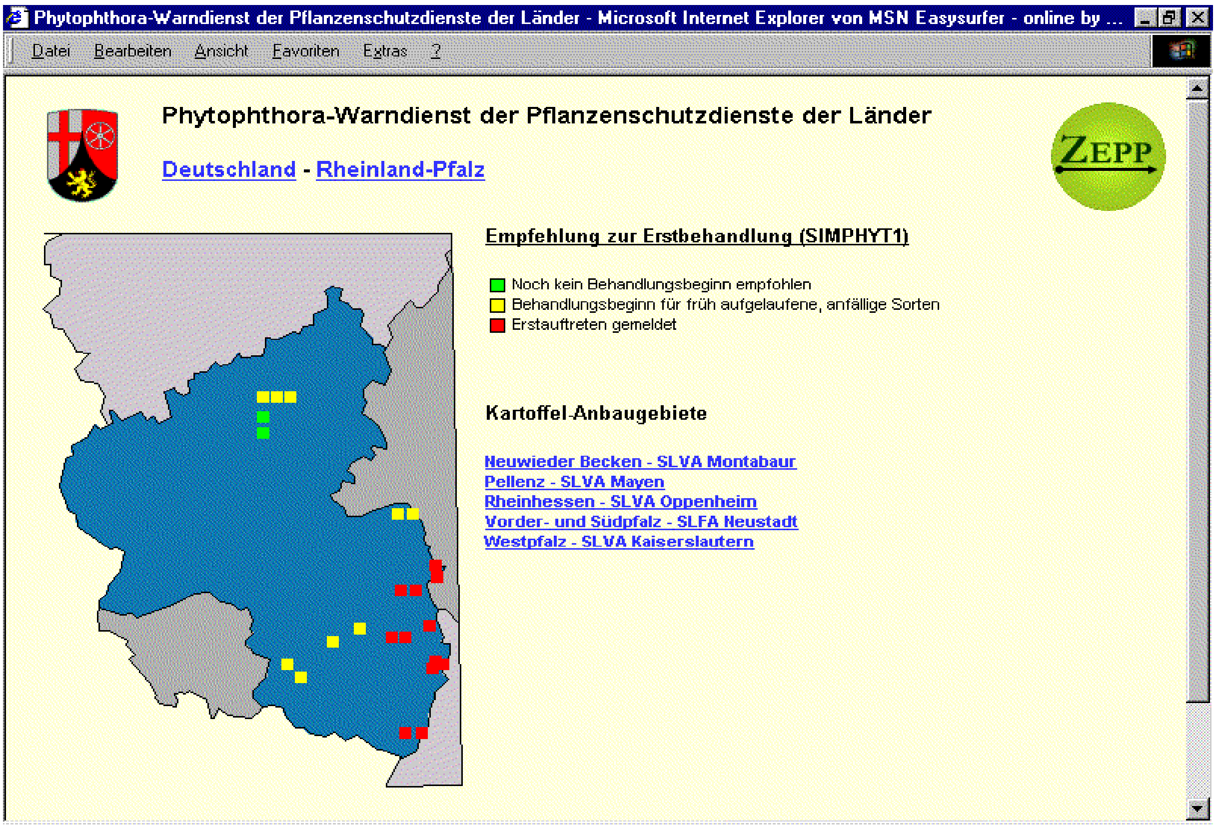


Figure 6. Detailed informations of Late Blight first appearance and recommendations given by the advisory service.

- Further Epidemic Progress

Once the epidemic has started information is needed on the epidemic progress to plan the fungicide schedule properly. www.phytophthora.de presents SIMPHYT3 (Gutsche *et al.*, 1999) results and assessments in farmers` fields to aid decision-making. Information is presented analogous to those on the first occurrence.

A map again gives an overview on *P. infestans* infection pressure in a country (Fig. 7). Again spots indicate the fields which are monitored. From the colours the infection pressure and Late Blight risk can be seen. In five categories from green (=low pressure) via yellow and orange to red (=very high pressure) the SIMPHYT3 results are presented.

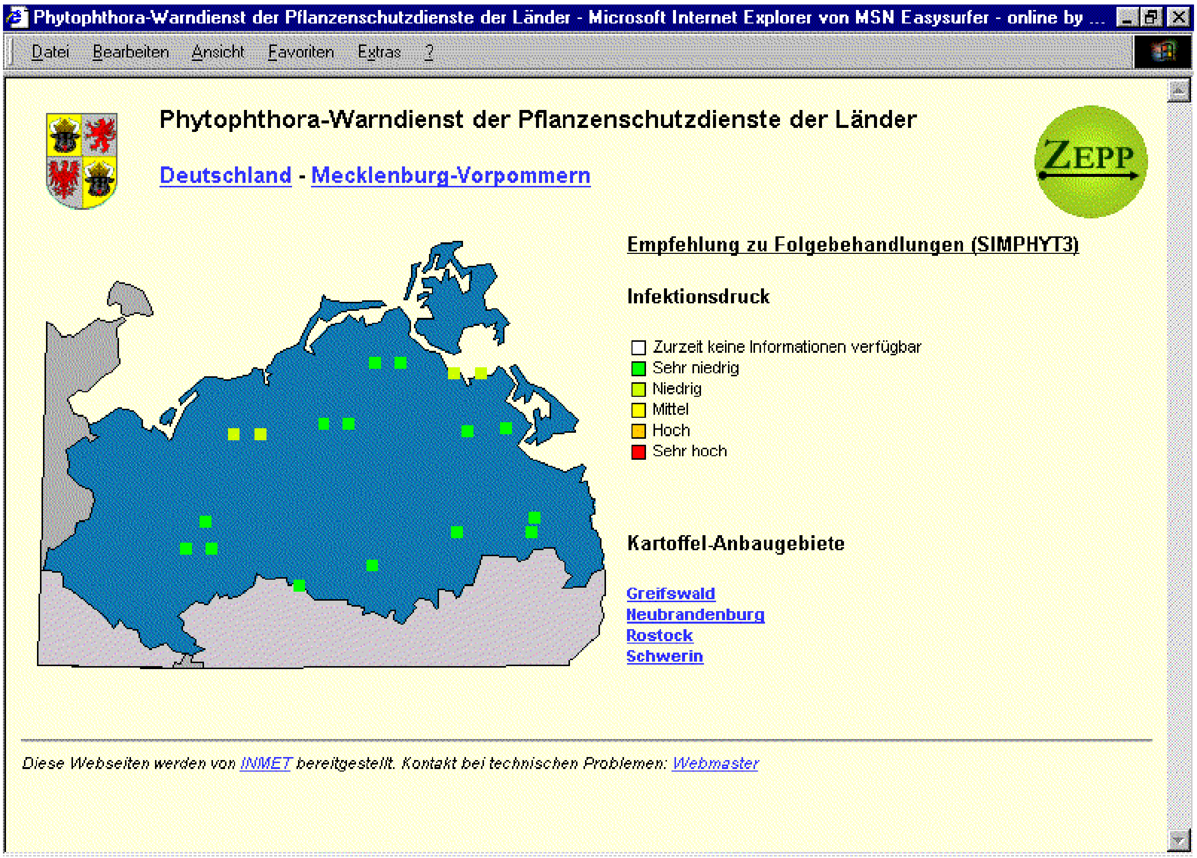


Figure 7. Graphic indication of infection pressure given by SIMPHYT3.

For more detailed information a table (Fig. 8) and a special graphical presentation of SIMPHYT3 results (Fig. 9) are available.

1) The right part of the table (Fig. 8) informs on the monitoring results in farmers` fields. In most of the cases two or three fields per region around a weather station are monitored. The table shows the municipality, the cultivars grown, date of last assessment, and the number of treatments which have been applied up to the actual

day. In addition *P. infestans* occurrence in an untreated plot within the field is registered and the disease incidence in the treated part of the field is assessed and roughly categorized. Help is available on the definition of „disease incidence“.

2) In the left part of the table SIMPHYT3 infection pressure calculated for all the weather stations in the region is shown and from it a mean length of spraying interval is derived.
3) Again below the table extension officers give specific advice on spraying schedules and local information.

All SIMPHYT3 results (Gutsche, 1999) can be seen if in the left part of the table the small graphic beside the name of the weather station is clicked on (Fig. 9). Infection pressure over time and pew-values which classify the days according to their „*P. infestans* – efficiency“ are presented.

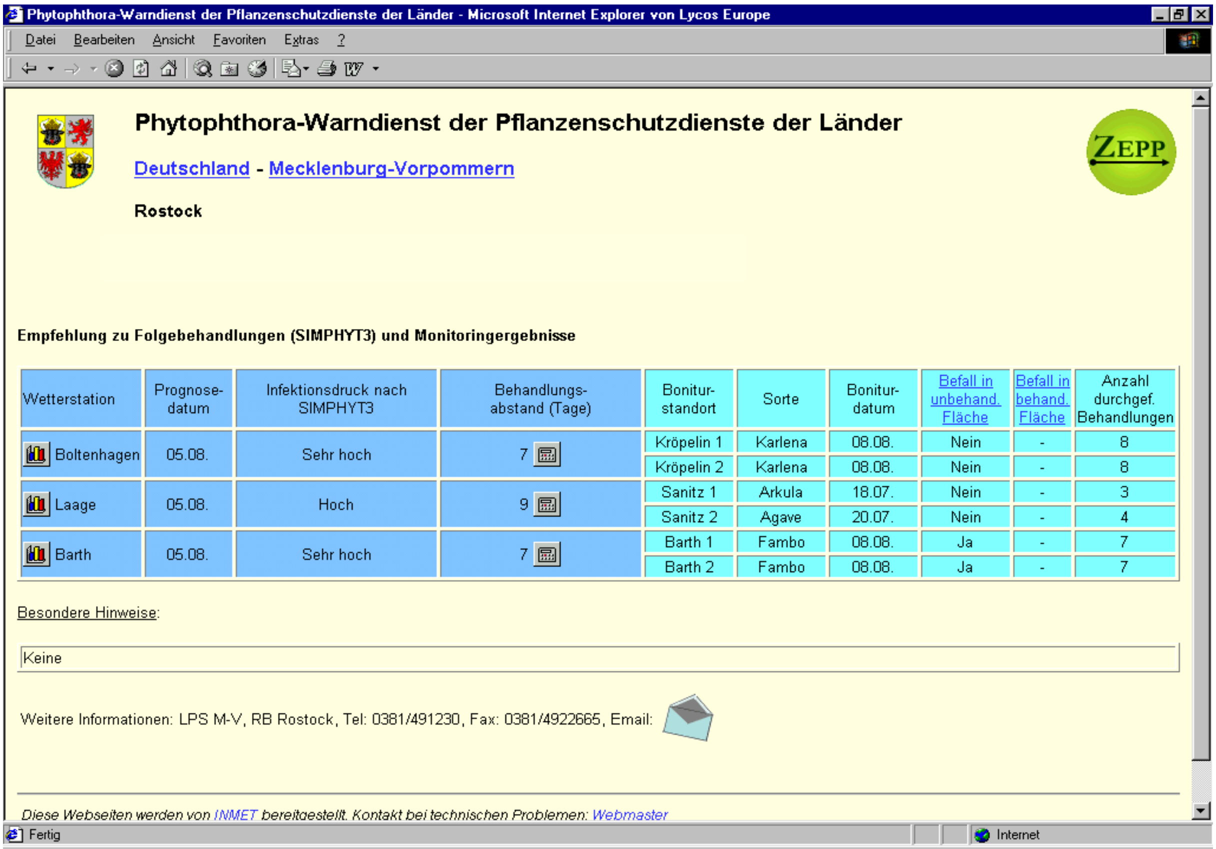


Figure 8. Detailed information of infection pressure and monitoring results.

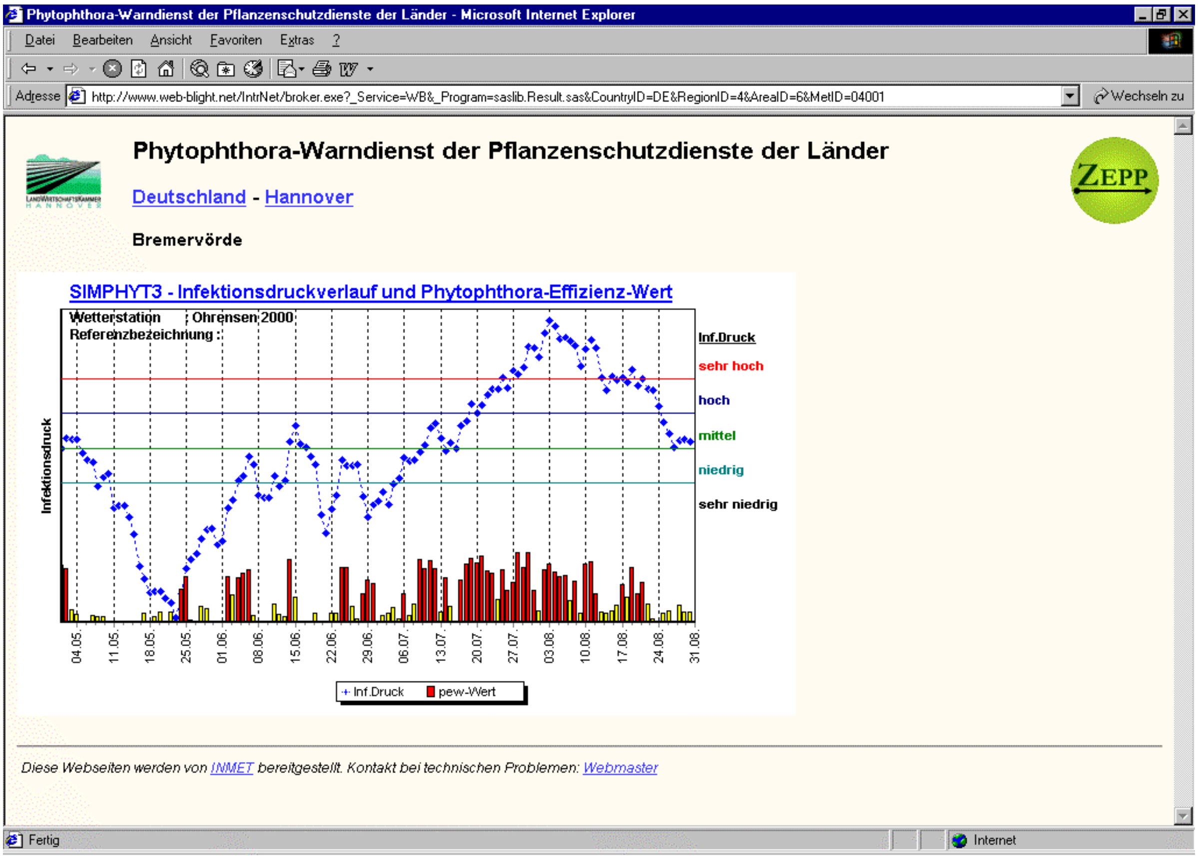


Figure 9. Results of SIMPHYT 3 model calculations.

- *Interactive Part*

Beside the mean length of spraying interval in a region given in the table a calculator symbol is shown. A mouse-click on this symbol leads to an interactive page (Fig. 10). By inserting simple but specific data the farmer can modify the mean spraying interval according to his field conditions. The system needs information on crop growth, cultivar susceptibility, the last fungicide application and local precipitation. Depending on the constellation the length of the spraying interval may be reduced or increased up to three days. In case of sporulating lesions in the field the system reduces the spraying interval to zero days and recommends a quick contact to the local extension officer to get information on emergency treatments.

Acceptance

Although almost no advertising for www.phytophthora.de was done the interest in the Internet-based warning service was very high. A total of about 3000 different users have been identified. From June to September a user statistic was available and it is known how often the warning service has been requested. Farmers and advisors showed greatest interest in June when ca. 25000 accesses to the Internet-pages were registered. In July 14000 visits happened.

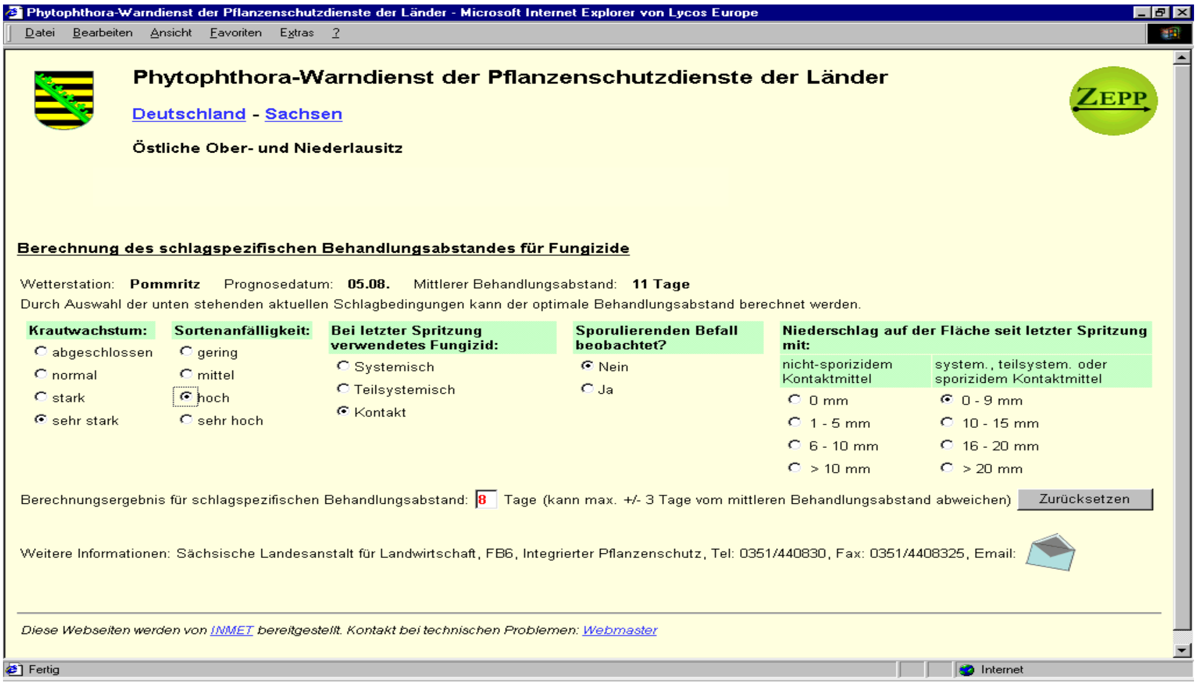


Figure 10. Site specific recommendation of spraying interval.

After the end of the vegetation period for very early, medium early and early cultivars had ended the interest decreased (August and September: 6300 and 600 accesses resp.). In total about 45000 requests were registered in 2000.

Outlook

After a successful introductory phase www.phytophthora.de will be offered to the potato growers also in the future. The assessments have to be rationalized and improved. Data transmission (meteorological data and field data) has to be optimised. Careful changes in the Internet - presentations have to be made and more aid to the interpretation of the results has to be given to the user (farmer).

In 2001 a validation method for SIMPHYT3 – output will be elaborated because the potential of the model`s results yet is not fully exploited. In addition we aim at a validation of the field – specific spraying strategy of the farmers to identify „hot spots“ where an improvement is necessary.

In 2001 a project will be started on the elaboration of a comprehensive Internet – based information system on integrated crop production (ISIP) in which data and information of many external sources can be linked and processed. The intention is to provide the farmers with modules for each crop. As a study revealed the users of such a system mainly are interested in information on crop protection, especially on pest and disease occurrence and decision support. www.phytophthora.de will be one of the essential parts of the potato – module of ISIP.

Acknowledgements

We wish to thank our Danish colleagues from DIAS Jens G. Hansen, Iver Thysen and especially Manfred Röhrig for their valuable help and in addition the colleagues from the governmental crop protection services in Germany for their work and support.

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Fifth Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Munich, Germany, 6-10 September 2000

Field evaluation of four decision support systems for potato late blight in the Netherlands in 2000

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Summary

In 2000, three field trials were carried out in The Netherlands to evaluate weather-based decision support systems for potato late blight control: Plant-Plus, Prophy, NegFry and Simphyt. The four models were compared with a practice spraying schedule. The models succeeded in decreasing the number of sprays. The recommended number of curative sprays varied both between models and trials.

In all three trials, the models did control late blight sufficiently under Dutch potato growing conditions. Simphyt started spraying too late in all trials, resulting in an infection before the first spraying was carried out. Plant-Plus, Prophy and NegFry managed to control the disease to an acceptable level in all trials.

Percentage blighted tubers in trials varied between models and trails. In all trials percentage blighted tubers remained under 4 percent.

Introduction

In the Netherlands, two weather based decision support systems (DSS) for late blight control in potatoes are commercially available, Plant-Plus and Prophy. A DSS is considered as an important tool to optimise fungicide sprays and thus restrict the amount of chemicals to a minimum. In 1999 a research project was started to compare Dutch and foreign DSS's with each other and with a weekly/practice spraying schedule. This comparison is expected to produce information that can be used to further improve the systems. The foreign DSS's are NegFry from Denmark and Simphyt from Germany. This report describes the results of three trials carried out in the Netherlands in 2000.

Materials and Methods

Trial sites, experimental set-up and weather data

Trials were set up on three locations in The Netherlands. Trial site information is given in Table 1. All trials included Prophy, Plant-Plus, NegFry and Simphyt and plots sprayed as "good agricultural practice". Untreated plots were incorporated in the experimental set-up. In Lelystad and Valthermond there were three untreated plots incorporated per replication and in Vredepeel two. When the development of Phytophthora in untreated became unacceptably high, the crops in these plots were killed with diquat and untreated two (treated as practice schedule until that time) were left untreated. All experiments were set up as randomised block treatments with four replications. Statistical analyses were carried out using GENSTAT 5, release 4.1.

Fertilisation, apply of insecticides and weed control were carried out as good agricultural practice.

Table 1. Trial site information of three locations in 2000.

Location	Lelystad	Vredepeel	Valthermond
Soil texture	Loamy soil	Sandy soil	Sandy soil
Plot size (gross)	10.5 * 13 m	8.25 * 11 m	10.5 * 14 m
Plot size (net)	4.5 * 11 m	4.5 * 8 m	4.5 * 8 m
Cultivar	Bintje	Oscar	Karida
Susceptibility	susceptible	medium susceptible	medium susceptible
Distance between ridges	75 cm	75 cm	75 cm
Planting space	33 cm	32 cm	25 cm
Planting date	May 4	April 18	May 1
Emerging date	May 26	May 14	May 22

On all three locations automatic weather stations were situated within 1 km from the trial site, measuring hourly values of air temperature, rain, relative humidity, wind direction and wind speed at 150 cm height. Hourly data on crop temperature and relative humidity were measured in Lelystad on the trial site and in Valthermond in a crop within 2 km distance of the trial site. These data were used by Opticrop. Crop data were not available in Vredepeel. Prophy and Plant-Plus both used 3-hourly regional weather forecasts for five consecutive days.

Irrigation was only applied in Vredepeel on June 17, July 6, August 9 and 18 with 30 mm each time.

Observations

Disease observations on the crops in all three experiments were carried out weekly. The first disease observation was carried out on June 14 (Vredepeel), June 15 (Valthermond) and June 16 (Lelystad). The last observations were on August 30, September 6 and September 11 respectively. The number of diseased leaflets, petioles and stems on six ridges of net length of the plots were counted. At the end of the growing season yield was assessed of the net plots. A tuber sample out of the yield was stored for some weeks in a barn. At Lelystad the tuber sample was stored at a temperature of 18 °C for three weeks. In this sample the number of potatoes with one or more lesions of Phytophthora were counted.

Use of the DSS's

The systems were asked for advice daily (before 9.30 am) except on Sundays. Practice schedule is on basis of weekly sprays with Shirlan (fluazinam). However, lower interval between sprays and application of curative sprays were carried out when necessary. The farm manager decided how to interpret the advises of Prophy and Plant-Plus and decided on the sprays of the practice schedule.

Prophy

The 2000 version of Prophy (CROP 2000) was used. Preferentially, Prophy uses crop weather data on temperature and RH. In Lelystad and Valthermond, these data were available. In Vredepeel, Prophy had to use climate data at standard height (1.50 m). The program can account for this change in weather data origin. Crop and disease observations acknowledged to the Prophy program are summarised in Table 2. Between July 20 and August 7 the weather-station in Lelystad was measuring in a crop that was sprayed to kill (untreated one).

On August 30 a spray with cymoxanil/mancozeb was applied two days later than advice.

Table 2. Observations acknowledged to the Prophy program.

Crop growth stage	Lelystad	26/5: 100% emergence; 9/6: crop height 15 cm; 26/6, 30/6, 7/7, 14/7, 21/7, 3/8, 11/8, 18/8, 25/8, 31/8 and 11/9: crop canopy 100%
	Vredepeel	14/5: 100% emergence; 17/5: crop height 15 cm; 5/6, 28/6, 12/7, 26/7, 2/8, 10/8, 17/8, 24/8 and 30/8: crop canopy 100%
	Valthermond	24/5: 100% emergence; 30/5: crop height 15 cm; 15/7, 27/7, 10/8 and 23/8: crop canopy 100%
Crop growth rate	Lelystad	9/6, 14/7 and 28/7: moderate; 26/6 and 30/6: strong; 7/7, 21/7 and 28/7: average; 3/8, 11/8, 18/8, 25/8, 31/8 and 11/9: low
	Vredepeel	25/5, 28/6 and 12/7: average; 29/5 and 14/6: strong; 26/7: moderate; 2/8, 9/8, 17/8, 24/8 and 30/8: low
	Valthermond	24/5 and 27/7: moderate; 30/7 and 15/8: average; 7/6: strong; 10/8 and 23/8: low
Phytophthora infections	Lelystad	25/6: slight infections near plots; 26/6, 30/6 and 7/7 no infections in or near plots; 10/7,14/7, 28/7, 11/8, 18/8 and 25/8 slight infection within 500 m; 21/7 and 31/8: heavy infection within 500 m; 3/8: old infection in plots; 11/9: few plants with infection in plots
	Vredepeel	14/6, 28/6 and 17/8: few plants with infection in plots; 12/7, 26/7 and 2/8: old infection in plots; 9/8 and 24/8: 5-10% of plants with infections; 30/8: 10-20% of plants with infections
	Valthermond	13/6: heavy infections within 500 m; 15/7: old infections near plots; 27/7: 10-20% of plants with infections; 10/8: 5-10% of plants with infections; 23/8: few plants with infections in plots

Plant-Plus

Windows version 1 of the Plant-Plus model was used in the trials. During the growing season the program was several times up-grated until version 1.11. Regarding Phytophthora observations it should be stressed that, in the Netherlands, the Plant-Plus system makes use of a Phytophthora monitoring network. Data from these activities were incorporated in advises given by the program which is supplied with the geographical trial site co-ordinates. Sprayings in Lelystad and Vredepeel were carried out whenever calculated infections passed a threshold value of 200. In Valthermond a threshold of 250 was used. Erroneously, in Lelystad a spray with cymoxanil/mancozeb was carried out on August 28.

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

Crop growth stage	Lelystad	26/5: 100% emergence; 9/6: development leaves + stems; 26/6 and 30/6: crop canopy 100%; 7/7: heavy canopy, stems still upright; 14/7, 21/7 and 28/7: heavy canopy, starting to flatten; 3/8, 11/8, 18/8, 25/8, 31/8 and 11/9: heavy canopy, flattened
	Vredepeel	14/5: 100% emergence; 25/5: crop canopy 50%; 6/6 and 14/6: crop canopy 100%; 21/6 and 28/6: heavy canopy, stems still upright; 4/7, 12/7 and 19/7: heavy canopy, starting to flatten; 26/7, 2/8, 9/8, 17/8, 24/8 and 30/8: heavy canopy, flattened
	Valthermond	24/5: 65% emergence; 7/6: crop canopy 50%; 13/6, 23/6 and 30/6: crop canopy 100%; 14/7 and 21/7: heavy canopy, stems still upright; 27/7 and 10/8: heavy canopy, starting to flatten; 23/8 and 6/9: heavy canopy, flattened
Crop growth rate	Lelystad	9/6, 26/6, 30/6 and 7/7: 2.5 leaves a week; 16/6: 2 leaves a week; 21/7: 1.5 leaves a week; 14/7 and 28/7: 1 leaf a week; 3/8: less than 0.5 leaf a week; 11/8,18/8,25/8 and 11/9: no growth
	Vredepeel	21/6 and 4/7: 2.5 leaves a week; 29/5, 14/6 and 28/6: 2 leaves a week; 25/5 and 12/7: 1 leaf a week; 26/7and 2/8: 0.5 leaf a week; 19/7: less than 0.5 leaf a week; 9/8, 17/8, 24/8 and 30/8: no growth
	Valthermond	7/6: 3.5 leaves a week; 23/6 and 30/6: 3 leaves a week; 2/6: 2.5 leaves a week; 14/7: 2 leaves a week; 24/5and 21/7: 1.5 leaves a week; 27/7: 1 leaf a week; 10/8 and 23/8: less than 0.5 leaf a week; 6/9: no growth
Phytophthora infections	Lelystad	14/6, 10/7, 21/7, 3/8, 11/8, 18/8, 25/8 and 11/9: slight infections near plots; 16/6, 26/6 and 7/7: no infections in or near plots; 31/8: heavy infection near plots
	Vredepeel	14/5 and 14/6: no infections in or near plots; 21/6, 28/6, 4/7, and 19/7: slight infections in plots; 12/7: slight infection near plots; 26/7 and 2/8: infections in plots; 9/8 and 30/8: 10-20% of plants with infections; 17/8 and 24/8: 5-10% of plants with infections
	Valthermond	13/6 and 21/7: slight infections in plots; 30/6and 14/7: slight infection near plots; 27/7, 10/8 and 6/9: 5-10% of plants with infections; 23/8: few plants with infections in plots

NegFry

NegFry 2000 version 5.2 was used in the trials. The model parameter threshold for negative prognosis (first application) was set from 130 in 1999 to 100 in 2000. The weather data to be used by NegFry were copied from Plant-Plus. Sprayings were carried out when the blight units had reached a level of 37 (Lelystad) or 40 (Valthermond and Vredepeel) or when the user expected that the blight units would pass that level that day. Sprayings were carried out with fluazinam (500 g l^{-1}) 0.3 or 0.4 l ha^{-1} when an application was carried out on the day of advice and with cymoxanil/mancozeb (4.5/68%) 2.5 kg ha^{-1} or chlorothalonil/propamocarb-HCl (375/375 g l^{-1}) 2.7 l ha^{-1} when the application had to be postponed by 1-2 and 3-5 days respectively. For Vredepeel an advice was given on August 23. Afterwards it seemed that irrigation on August 18 was not incorporated in the program. After incorporation the advice of August 23 should have been on August 20.

Simphyt

The model version PASO for windows was used in the trials. The weather data to be used by Simphyt were copied from Plant-Plus. First sprays should be carried out as soon as the model forecasted a date for Risk Level I in Simphyt 1. In all trials the first lesions of Phytophthora were found in the Simphyt plots before the first advise was given. In this case Simphyt 1 can not be used anymore, so we switched to Simphyt 2, which advised in this situation to spray twice a combination of chlorothalonil/propamocarb-HCl and fluazinam. Model parameter metalaxyl-resistance in region was changed in "yes" because metalaxyl may not be used anymore in The Netherlands. Appearance of first Phytophthora in the plots was in Lelystad on June 13 and in Vredepeel and Valthermond on June 14.
Until June 19 a wrong format for the weather data was used. Because of that the program gave the recommendation for the first spray at Lelystad for June 20 instead of June 18. However, this had no effect on the application of the first spray because on June 15 and 19 emergency sprays were carried out because of a late blight infection. On the other two locations emergency sprays were also carried out.
Erroneously, in Valthermond a spray with fluazinam instead of cymoxanil/mancozeb was carried out on August 5.

Results

Sprays and advises

According to Table 4, using a DSS decreased the number of applications, except Simphyt in Lelystad and Vredepeel and Prophy in Vredepeel. However, it should be noted that in Vredepeel on Prophy a spray had to be repeated because of rain after application.
In the plots of Practice hardly any curative sprays were used. The number of curative treatments in the DSS plots varied between trial site and DSS. The number of curative sprays varied between 2 and 17. The high number of sprays with chlorothalonil/-propamocarb-HCl by Prophy, compared to other DSS's, were partly caused by the fact that disease severity of the fields was incorporated to the program after asking the program for an advice (once for Lelystad) and not consulting the systems on Sundays (twice for Vredepeel). Once (for Vredepeel) an application with chlorothalonil/-propamocarb-HCl had to be repeated because of rain right after the application.

The amount of active ingredients applied was low for the plots that were sprayed as practice due to the usage of fluazinam, which is sprayed at a low rate. A higher number of curative sprays inevitably results in a higher amount of active ingredients. The importance of a good timing of the first spray was this year illustrated by Simphyt plots on all trial sites, which suffered from an attack before/or on the same day as the first application.

In general, the plots that were sprayed as practice were sprayed first compared to DSS's. On all trial sites Prophy gave advice for the first spray earlier (average 10 days) than Plant-Plus.

Table 4. Date of first spray, number of applications, amount of active ingredients, cost of all applications, longest interval, shortest interval and average interval depending on DSS and trial site.

Trial site		Practice	Prophy	Plant-Plus	NegFry	Simphyt
Lelystad	Date of first spray	June 5	May 26	June 5	June 16	June 15
	Total number of sprays	16	15	13	10	17
	- preventive (fluazinam)	16	12	11	6	0
	- curative (cymoxanil/mancozeb)	0	1	2	4	15
	- curative (chlorothalonil/propamocarb-HCl)	0	2	0	0	2[1]
	kg a.i. ha^{-1}	3.2	8.3	5.8	8.4	29.9
	cost ha^{-1} (€)	340	350	272	199	358
	1ongest interval	8	12	17	18	9
	shortest interval	4	4	5	6	4
	average	6.1	7.8	7.8	9.7	5.5
Vredepeel	Date of first spray	May 22	May 27	June 3	May 31	June14
	Total number of sprays	16	18	14	11	17
	- preventive (fluazinam)	14	10	12	7	0
	- curative (cymoxanil)	1	1	2	3	15
	- curative (chlorothalonil/propamocarb-HCl)	1	7	0	1	2[1]
	kg a.i. ha^{-1}	5.9	17.5	5.4	8.5	29.9
	cost ha^{-1} (€)	280	444	230	207	358
	1ongest interval	12	10	13	13	8
	shortest interval	3	1/5[2]	2	7	2
	average	7.0	5.9/6.2[2]	6.7	9.2	5.1
Valthermond	Date of first spray	June 14	May 31	June 14	June 13	June 16
	Total number of sprays	15	14	12	9	9
	- preventive (fluazinam)	12	10	10	3	2
	- curative (cymoxanil)	2	0	2	5	5
	- curative (chlorothalonil/propamocarb-HCl)	1	4	0	1	2[1]
	kg a.i. ha^{-1}	7.1	9.7	5.2	11.5	12.6
	cost ha^{-1} (€)	264	322	203	182	206
	1ongest interval	10	11	11	21	14
	shortest interval	2	5	2	8	3
	average	6.0	7.8	7.6	11.0	10.0

[1] in combination with fluazinam.

[2] if no rainfall after spray on July 11 had occurred

Disease severity

Lelystad

In Lelystad the natural disease pressure during growing season was considered as low compared to other years. In figure 1 the development of the disease severity during the season for all trial treatments is shown.

In the beginning of the growing season an infection was observed in one plot of the practice schedule. This infection did not develop to a large infection in this plot.

Because of the fact that there was an infection of Phytophthora before the first fungicide application was carried out, Simphyt advised an emergency treatment with chlorothalonil/propamocarb-HCl in combination with fluazinam for June 15 and June 19. During the growing season the infection pressure slightly increased but did not result in large infections in any plots of the DSS's or the practice schedule. Nevertheless Simphyt only recommended to spray with cymoxanil/mancozeb.

Only on August 31 on the Plant-Plus plots significantly more attacked leaflets were observed than on the other DSS's and the practice schedule.

Vredepeel

Natural disease pressure at Vredepeel during the growing season was higher than at Lelystad. Already on June 21 untreated 1 had a high disease severity (figure 2). In spite of a spray with cymoxanil/mancozeb on June 14, Simphyt still advised an emergency treatment with chlorothalonil/propamocarb-HCl in combination with fluazinam on June 16 and June 19.

Until July 12 significant differences in disease severity between the DSS's and the practice spray schedule were not observed. On July 19 Plant-Plus and NegFry resulted in significantly higher disease severity than the practice spray schedule. Other significant differences in disease severity were not observed in this trial.

From August 9 until the end of the season on one out of four plots of Prophy and one plot of Plant-Plus a high disease severity was observed. The untreated plots near those two plots were desiccated on July 26. Other surrounding plots of the same DSS's did not show such a high disease severity. An explanation for this phenomenon is hard to find. The high disease severity in those two plots was the major cause of the high disease severity of Plant-Plus and Prophy in August.

Valthermond

The first attack of Phytophthora was visible on June 14. Infection of the crop took place before the first fungicide application was applied (except Prophy). Despite of the two fungicide applications a low disease severity was also observed in the plots of Prophy. Because of the fact that there was an attack by Phytophthora before the first fungicide application was carried out, Simphyt advised an emergency treatment with chlorotalonil/-propamocarb-HCl in combination with fluazinam on June 16 and June 19.

Natural disease pressure in Valthermond was high. On July 17 untreated one was killed and on August 11 untreated 2. Until July 21 all DSS's and the practice schedule kept the disease severity on a relatively low level. After this date the disease severity increased in all plots. On August 3 the disease severity in the plots that were sprayed according to practice spraying schedule was significantly higher than the plots of the different DSS's. On August 10 the disease severity in the Simphyt plots was significantly higher than the plots of the different DSS's and practice spraying schedule. The disease severity in one plot of Prophy and of Simphyt was unacceptable high, so they were prematurely killed on August 11 successively on August 17. From August 10 until the end of the growing season no significant difference in disease severity between the DSS's were observed.

Tuber blight and Yield

At the end of the growing season a tuber sample was taken from the net plots to determine yield and percentage blighted tubers. Results are listed in Table 5.

Table 5. Yield and percentage blighted tubers per DSS and trial location.

	Yield (ton/ha)			% blighted tubers		
object	Lelystad	Vredepeel	Valthermond	Lelystad	Vredepeel	Valthermond
Practice	75.6	81.1	70.0	0.89	1.61	1.89
Prophy	69.7	74.2	68.0	1.04	0.58	2.22
Plant-Plus	77.2	82.4	67.6	0.83	0.57	1.56
Negfry	75.7	76.4	68.5	1.05	1.17	2.38
Simphyt	74.6	84.7	65.2	3.55	1.13	2.56
F-prob	0.713	0.009	0.813	0.151	0.898	0.674
LSD ($\alpha = 0.05$)	12.1	5.6	8.7	2.51	2.66	1.60

In Vredepeel yield of the Prophy and NegFry plots were significant lower than Simphyt and Plant-Plus plots. There is no explanation for this effect. Difference in crop vegetation between plots of the DSS's was not observed during growing season. Significant differences in percentage blighted tubers were not observed on the three trail locations. At Lelystad the Simphyt plots resulted in more blighted tubers. This can be explained by the fact that on these plots almost only sprays with cymoxanil/mancozeb were applied. It is well known that cymoxanil/mancozeb has less or no action mode on reducing sporulation, killing spores or decreasing spore motility.

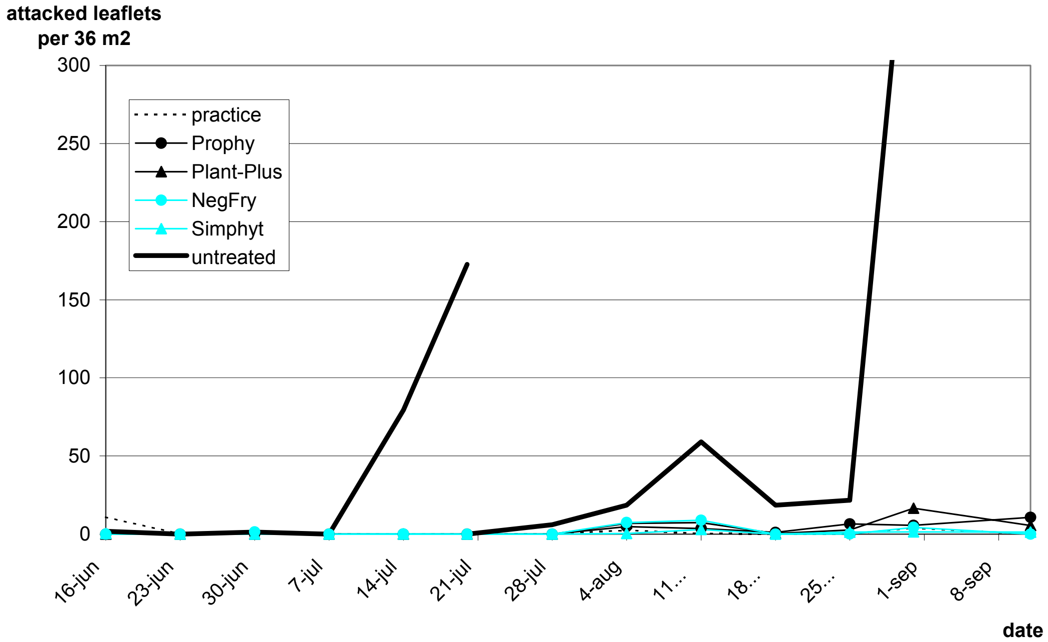

Figure 1. Disease severity per DSS in Lelystad.

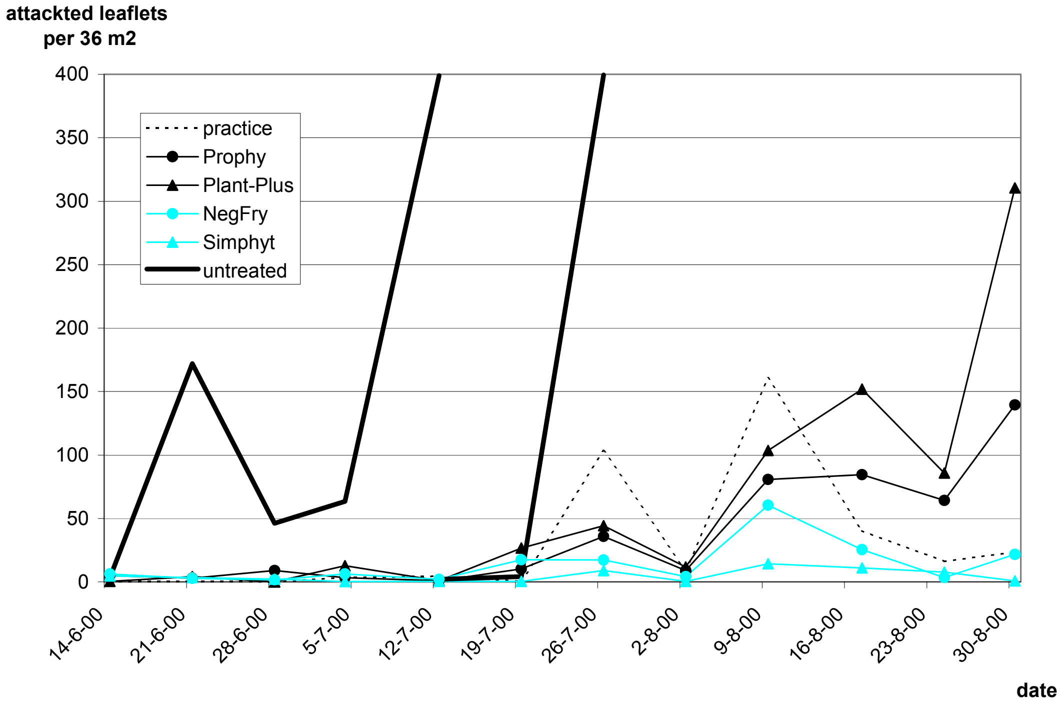

Figure 2. Disease severity per DSS in Vredepeel.

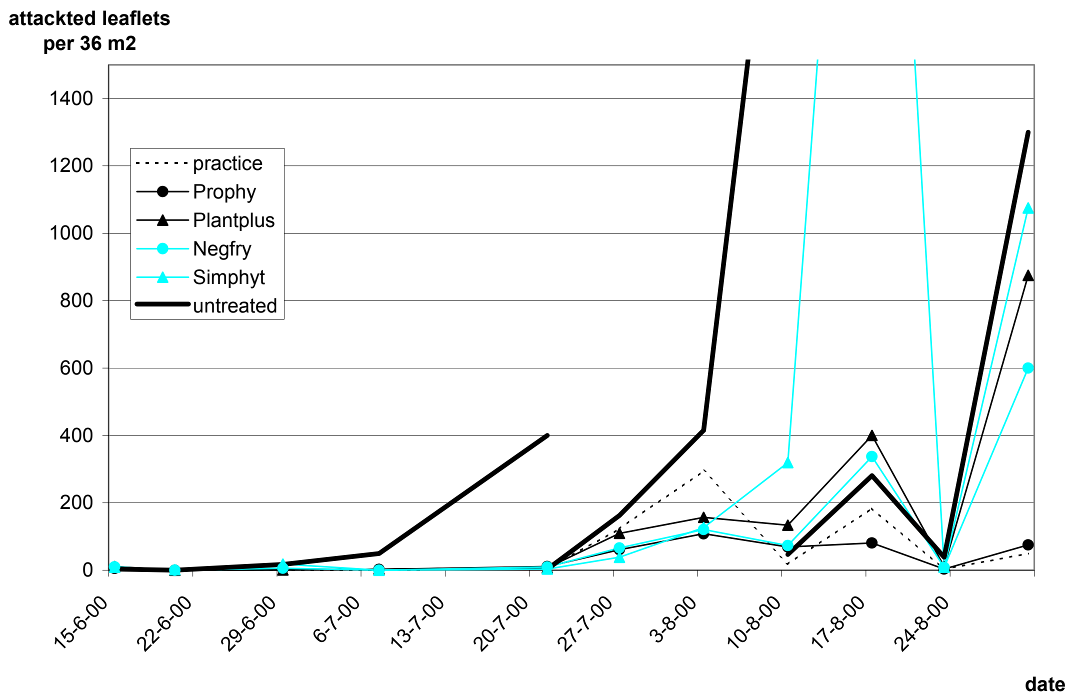

Figure 3. Disease severity per DSS in Valthermond.

Discussion

By using the models more curative sprays were carried out in comparison to the plots sprayed according to practice schedule. On the plots of the practice schedule mainly the preventive, low rate fungicide fluazinam was applied, resulting in a low total amount of active ingredients. Curative sprays on the DSS plots were applied either following the fungicide strategy of the model, following unfavourable weather conditions on days when a preventive treatment was recommended or following the non-consulting of the models during the weekend (Sundays). Consequently, the amount of active ingredients applied while using the models was sometimes considerably higher. Additionally, some remarks can be made regarding the different decision support systems.

Prophy

In Lelystad Prophy managed to control disease to a level of PD 9 (5 to 10 plants per 100 with 1- 5 attacked leaflets). It has to be mentioned that the disease pressure in Lelystad was low. In Vredepeel disease control in three plots was to a level of PD 8 (10-20 plants per 100 with ± 5 attacked leaflets). The overall disease control (four plots) until August 2 was PD 8. After August 2 one plot showed a high disease severity until the end of the growing season. This has resulted in a (too) high overall disease severity (more than 20 plants per 100 with 10 attacked leaflets), according to practical standards. However, a higher disease severity did not result in a higher level of blighted tubers compared to other DSS's. As mentioned earlier two of the seven chlorothalonil/propamocarb-HCl sprays in Vredepeel were recommended because on Sundays the systems were not consulted. On one occasion the spray with chlorothalonil/propamocarb-HCl had to be repeated because of rain within 3 hours after spraying. In Lelystad the two chlorothalonil/propamocarb-HCl were recommended when disease severity of the fields were adapted to the program after consulting the system. If advice would have been asked after adapting the disease severity, the program would have advised more cymoxanil instead of chlorothalonil/-propamocarb-HCl. If Prophy will be used more practically, the number of (curative) sprays can be reduced.

Plant-Plus

Plant-Plus controlled the disease sufficiently in Lelystad, while saving 3 sprays. In Vredepeel until August 2 disease severity was comparable to the other DSS's. After August 2 one plot showed a high (increase of the) disease severity until the end of the growing season. This has resulted in a (too) high overall disease severity (more than 20 plants per 100 with 10 attacked leaflets), according to practical standards. However, a higher disease severity did not result in a higher level of blighted tubers compared to other DSS's. An explanation for the high disease severity in one of the four plots at the end of the growing season is hard to find. In Valthermond the disease severity was (too) high at the end of the growing season, according to practical standards. However, the disease severity and blighted tubers (%) in Plant-Plus plots were not significantly higher than plots of other DSS's. On all locations Plant-Plus used no more than 2 curative sprays. All preventive sprays were carried out with fluazinam known as an active ingredient with a strong action mode on spores. This could be contributing to the fact that high disease severity did not result in a high level of blighted tubers.

NegFry

On all three locations NegFry kept the disease severity on a level of the other DSS's, while saving 5 (Vredepeel) or 6 (Lelystad and Valthermond) sprays compared to practical spraying schedule. The recommendation for the first spray in 2000 was considerably earlier than in 1999. Lowering program parameter threshold for negative prognosis from 130 to 100 contributed to an earlier advice. However, in Lelystad the first recommendation was in our point of view to late. The first attack by late blight was already found in other plots. The late crop emergence of the trial site, compared to the surrounding potato fields, might have contributed to the late recommendation. A program parameter that would ask for the development stage of surrounding potato fields could contribute to a better (earlier) recommendation of the first application.

The many sprays with cymoxanil/mancozeb were caused by the fact that the consultation of the system was not right. When consulting NegFry (8.30-9.00 AM) not all weather data from the same day was used. On a few occasions a recommendation was given for the previous day. In that case we sprayed with cymoxanil/mancozeb. Sprays with cymoxanil/mancozeb could probably be reduced when NegFry was asked for advice later on the day.

Simphyt

Problems with the right format of weather data for Simphyt resulted in a late advice (two days) in Lelystad.

However, this late advice had no effect on the first application. Before the first recommendation there was an attack by late blight in the Simphyt plots. Therefore, two emergence treatments were carried out. Since that day in Lelystad and Vredepeel Simphyt recommended cymoxanil sprays within a short (5-6 days) interval.

In Valthermond Simphyt did not recommend to spray in a short interval with cymoxanil contained fungicide like in Lelystad and Vredepeel in spite of the infection before the first spray (emergence treatments). Most likely the production aim (starch) caused this other recommendation strategy in Valthermond. Spraying advice during growing season in Valthermond was not sufficient for a good control of late blight. At the end of the growing season the Simphyt plots had the highest disease severity and blighted tubers, but this was not significantly higher than plots of the other DSS's. Results from the Valthermond trial have shown that some intervals were to long.

In Lelystad and Vredepeel disease control was good. The disease severity in the plots of Simphyt on both locations was the lowest of all DSS's. However, only curative sprays (17) were carried out in a short interval. In spite of the low disease severity in Lelystad, plots of Simphyt resulted in a high number of blighted tubers. This can be explained by the frequent use of cymoxanil/mancozeb, known as a fungicide with a limited action mode against spores.

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The use of decision support systems in Ireland for the control of late blight

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Abstract

Routine fungicide application for the control of late blight was compared with the NegFry decision support system in field trials from 1996 to 2000. 1996 was a normal blight year while 1997, 1998, 1999 and 2000 were severe blight years. There was no significant difference in disease control or yield between routine fungicide application and the NegFry blight system in any of the years. The reduction in fungicide use obtained by the NegFry compared with a 10-day routine spray program was 27% on average over the five years. Within the Negfry system, fluazinam tended to give better disease control than mancozeb. Fungicide applications following the NegFry system also strongly tended to give better control than the fungicide applications following the Irish Meteorological Service Blight warnings.

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

Introduction

The area of potatoes in the Republic of Ireland remained relatively stable over the last seven years having been at 15,885 ha in 1993 and in 1999 was at 15,662 ha. During this period the potato area peaked at 18,152 ha in 1996 and reached a low of 15,502 ha in 1997 (National potato census 1999, 1999).

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

The use of decision support systems to determine when fungicide treatments should be applied for the control of *Phytophthora infestans* (Mont.) de Barry are becoming more acceptable across Europe. This has been helped by legislation which is aimed at reducing pesticide inputs. Ireland has no legislation in place and there is none envisaged in the immediate future. As a result, decision support systems used in Ireland must produce a direct benefit to the farmer. However, during 1999 some of the large supermarket chains in Ireland have begun to show an interest in the use of decision support systems.

This paper examines the results of replicated field trials carried out at Teagasc's Crops Research Centre, OakPark, Carlow, Ireland, to examine the effects of the use of decision support systems in the production of potatoes over the years 1996 to 2000.

Decision support systems

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

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

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

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

Materials and Methods

Trials were conducted at Oak Park Research Centre, Carlow, on the maincrop cultivar \`Rooster\` in the years 1996 to 2000. This cultivar is moderately susceptible to late blight having ratings of 4 and 6 for foliage and tuber blight resistance respectively (Dowley, 1995). The design for each trial was a randomised complete block with four replications per treatment. Each replicate consisted of 6 drills 7.69 m long. The drill width was 81.28 cm and the distance between tuber centres was 31.75 cm. The total replicate size was 37.5 m^2 from which 25 m^2 were harvested across the centre 4 drills. Weed control consisted of paraquat (600 g a.i./ha) and simazine (600 g a.i./ha) applied pre-emergence. This trail procedure follows the EPPO (European and Mediterranean Plant Protection Organisation) guidelines for the biological evaluation of fungicides.

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

The treatments compared in each year were as follows:

1) Unsprayed,
2) Mancozeb at 2.25 kg/ha at 10 day intervals,
3) Mancozeb at 2.25 kg/ha according to the NegFry,
4) Fluazinzm at 0.4 l/ha according to the NegFry,
5) Mancozeb at 2.25 kg/ha according to the Irish Met. Service Warnings.

Crop assessment

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

Data analysis

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

Results

Table 1 shows the accumulated risk values, as calculated by the decision support system NegFry based on weather data collected at Oak Park Research Centre, Carlow, Ireland, for the years 1996 to 2000. As can be seen from the accumulated risk values, 1996 was the least severe blight year of the five years tested, while 2000 was the worst year for blight based on the weather patterns during each growing season.

Table 1. ARV for the different growing seasons at Oak Park Research Centre.

Year	1996	1997	1998	1999	2000
Accumulated Risk Value	427.2	542.4	525.9	506.2	565.1

Table 2. Delay in disease onset for the different treatments.

		DELAY (days)					
	Year	1996	1997	1998	1999	2000	Average
Treatment	Interval						
Unsprayed		0.00	0.00	0.00	0.00	0.00	0.00
Mancozeb	10 days	12.75	24.50	59.75	14.00	21.50	26.50
Mancozeb	Met. Warnings	15.50	3.50	26.25	14.00	18.00	15.45
Mancozeb	NegFry	17.00	15.75	44.75	17.50	21.50	23.30
Fluazinam	NegFry	25.50	12.25	59.75	17.75	30.25	29.10
L.S.D (α = 0.05)		9.10	14.20	12.90	14.20	13.20	

However the severity of the blight attacks did not follow the same pattern as the accumulated risk values. This can be seen from tables 2 and 3, which show the delay in disease onset and the area under the disease progress curve (AUDPC) for each treatment in each season. All the sprayed treatments significantly delayed the onset of late blight in comparison with the unsprayed control in most cases. Overall the NegFry treatments were not different to the 10-day routine application of mancozeb, but tended to be better than the Irish Met. Service warnings treatment.

When looking at the AUDPC's (Table 3) for the different treatments it can be seen that all the sprayed treatments gave significantly better control than the unsprayed control in every year. Within the sprayed treatments it can be seen that the Irish Met. Warnings gave the lowest level of foliage blight control on average over each season. In 4 out of the five years the NegFry treatments and the 10-day routine treatment were significantly better than the Irish Met. Service warnings, while there were no significant differences between the two NegFry treatments and the 10-day routine treatment.

Table 3. Area Under the Disease Progress Curve for the different treatments.

		AUDPC					
		1996	1997	1998	1999	2000	Average
Treatment	Interval						
Unsprayed		1782.3	2980.8	1522.0	1114.1	3100.2	2099.9
Mancozeb	10 days	214.7	363.7	0.0	18.5	18.5	123.0
Mancozeb	Met. Warnings	198.2	1505.1	18.7	171.7	896.8	558.1
Mancozeb	NegFry	33.0	777.5	1.5	13.1	84.9	182.0
Fluazinam	NegFry	10.9	596.1	0.0	5.1	11.1	124.6
L.S.D.(α = 0.05)		386.7	484.5	1124.1	360.3	292.7	
L.S.D.(α = 0.05)	(excluding unsprayed)	225.2	462.1	16.69	142	292	

The tuber yield results are similar to the results of the foliar blight. In the case of marketable yield, table 4, the unsprayed control gave significantly the lowest yield of marketable tubers in each season, while on average the yield of marketable tubers produced following the Irish met. Service warnings was the next lowest. There was little difference between the 10-day routine treatment and the NegFry treatments. There were no significant differences between any of the sprayed treatments.

Table 4. Yield of marketable tubers in the years 1996 to 2000.

		MARKETABLE YIELD (t/ha)					
	Year	1996	1997	1998	1999	2000	Average
Treatment	Interval						
Unsprayed		39.16	29.70	24.53	34.81	28.84	31.41
Mancozeb	10 days	47.78	47.91	34.24	52.07	48.68	46.14
Mancozeb	Met. Warnings	51.86	39.54	38.39	43.72	40.24	42.75
Mancozeb	NegFry	49.02	41.94	31.69	46.09	53.32	44.41
Fluazinam	NegFry	49.64	44.77	37.95	48.64	50.68	46.34
L.S.D.(α = 0.05)		5.72	6.08	12.68	10.6	7.6	
L.S.D.(α = 0.05)	(excluding unsprayed)	5.72	5.16	12.28	10.2	8.48	

Table 5 gives details of the levels of tuber blight following each treatment for all the years the trials were performed. It can be seen that on average the Irish Met. Service warnings allowed for the overall highest level of tuber blight to be present at the end of the season. The two NegFry treatments were similar to the 10-day routine treatment in relation to the level of tuber blight present at the end of the season. However, there were few significant differences between any of the treatments.

Table 5. Mass of blighted tubers produced following the different treatments.

		TUBER BLIGHT (t/ha)					
	Year	1996	1997	1998	1999	2000	Average
Treatment	Interval						
Unsprayed		0.01	0.19	0.10	0.50	0.04	0.17
Mancozeb	10 days	0.05	0.29	0.04	0.17	0.04	0.12
Mancozeb	Met. Warnings	0.02	0.34	0.01	0.63	0.08	0.22
Mancozeb	NegFry	0.18	0.36	0.01	0.14	0.16	0.17
Fluazinam	NegFry	0.00	0.22	0.22	0.08	0.00	0.10
L.S.D.(α = 0.05)		0.124	0.284	0.076	0.34	0.144	
L.S.D.(α = 0.05)	(excluding unsprayed)	0.14	0.316	0.044	0.34	0.16	

Spray savings

Table 6 shows the number of sprays applied following the different spray routines at Oak Park Research Centre over the five years. It can be seen that the routine treatments always applied the greatest number of sprays, while the Irish Meteorological Service warnings always applied the lowest number of sprays.

Table 6. No. of sprays applied in each year following each routine.

Treatment	1996	1997	1998	1999	2000
Routine	9	9	10	10	10
NegFry	4	7	8	8	8
ME Warnings	3	5	4	5	5

The reduction in spray no.s achieved by the NegFry equates to an average spray saving of 27% over the five years. This is achieved with no loss in disease control.

Discussion

The results show that the NegFry decision support system can control late blight as effectively as a 10-day routine spray program while saving on average 27% of the fungicide applied following the routine program. These savings have been achieved in what were considered to be severe blight years based on the weather during the potato growing season. These results compare favourable with the Irish Meteorological Service Blight warnings which, while achieving a 54% reduction in sprays applied did not maintain as good a level of disease control as the routine application of fungicide.

The poor results of the NegFry in 1997 were due to hardware and software problems with the Hardi Metpole which was used for collection of the required weather data. The issues with the Metpole were only fully resolved after the first spray had been due to be applied, and as a result of the first application of fungicide was applied late, and subsequent to the appearance of late blight in the crop.

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Can blight forecasting work on large potato farms?

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Summary

The practicalities of operating a Plant-Plus blight forecasting service was assessed with a large potato farm, Strawson Farming Limited. An area of 250 ha of processing potatoes in the East Midlands was allocated to the service carried out by DMA Crop Consultants. Fields were grouped into blocks, depending on location to nearest weather station, variety and planting date. In total 10 blocks were formed, averaging 25ha each.

Blight pressure was high throughout the season, however no infection was observed in any of the blocks. Fungicide input was high, averaging 13 applications/block, but cost was kept relatively low at £167/ha (average), by the predominant use of contact and translaminar products. During the spraying period 55 spray days were required, the frequency of spraying was every 2.3 days. On 80% of spray days 3 blocks or less were treated.

Reaction to spray recommendations was mostly within the target period of 2 days. The main causes of delays were the hindrance caused by irrigation pipes and spray demands from the carrot crop. The conclusion was that, yes blight forecasting can work on large farms, providing the operation has adequate sprayer capacity, frequent communication between the adviser and farm agronomist, accurate crop records, sufficient spray stocks and good management of the spraying teams.

Key Words: Blocks, Reaction, Sprayer Capacity, Communication, Good Management

Introduction

The trend in UK potato growing is for fewer producers growing larger areas of potatoes. In 1991 there were a total of 17,141 registered producers with 136 farms growing more than 100ha of potatoes (*Potato Marketing Board,* 1996), by 1999 the total number of registered producers had decreased to 7331 with 375 farms growing more than 100ha of potatoes (*British Potato Council,* 2000). This equates to 5% of producers growing 36% of the UK crop.

Traditionally large farms have sprayed their potato area routinely, on a fixed interval and with a predetermined fungicide programme. However, pressure from suppliers to justify inputs, and the need to reduce costs, is causing growers to consider a more flexible approach to blight spraying. In the past regional blight forecasts have highlighted periods of risk, but they have not given sufficient warning for growers to react to the advice. Recently the development of blight models such as Plant-Plus, which include forecasts ahead of time, provide a more proactive decision support system. Despite the availability of new forecasting systems, there is still a degree of scepticism among farmers and advisers, on the practicality of them working on a large potato operation.

In 1998 DMA Crop Consultants introduced the PLANT-Plus system into the UK, providing a forecasting service for growers on 20ha of potatoes per farm (*Hinds,* 1998). In 1999 the service expanded with several existing users increasing the service to 40ha. This year, for the first time, a significant number of previous users allocated all their potato area to the service. Among these were a few large farms with over 200ha of potatoes on the service. The challenge was therefore to prove that it was possible to run blight forecasting on large potato farms.

This report details a case study of one such farm, Strawson Farming, and their experience in operating a blight forecasting service on 250ha of potatoes in Nottinghamshire.

Strawson Farming Forecasting System and Operation

Weather Data

Weather data for the decision support system was collected remotely from 6 Adcon stations within a 30km radius of the farm base. Data was also collected from three regional synoptic stations to give a five day weather forecast. All weather data was sent automatically on a daily basis to Dacom NL for processing.

Field Blocks

The 250ha of potatoes grown by Strawson Farming in Nottinghamshire was split into 10 blocks, of 25ha each, in order to simplify model advice. Fields were allocated to a block on the basis of three principles;

- Location to nearest weather station
- Variety
- Dating Date

Fields of the same variety (or similar disease rating) close to a weather station were thus run as one block if planting date was also similar. The target area for each block was planned to be higher than 25ha, however a wet April caused planting to be interrupted by a month in some blocks, therefore early and late plantings had to be run separately, even though they were sometimes in the same field. The varieties grown were Saturna, Hermes and Lady Rosetta. All were processing varieties for farm storage on contract to Pepsico Foods International. Saturna and Lady Rosetta are classified with a foliar blight resistance rating 4 on the NIAB list, Hermes is classified with a 3 rating.

Crop Recording and Data Input

In addition to weather data the Plant-plus system requires weekly recordings of crop growth measurements from each block and local infection sources. The farm agronomist was responsible for providing this data and sending it to the nearby DMA Consultants office. It was then the consultants duty to input crop recording data into the model.

Such is the importance of the crop recording data for the accuracy of model output that DMA Crop Consultants give training to users of Plant-Plus. It is intended that this training will lead to a recognised award for those crop recorders who show an acceptable level of competence in this activity.

System Advice

All model blocks were monitored daily by a DMA consultant on the Plant-Plus software programme. Advice from the model was interpreted by the consultant and communicated to the farm agronomist, initially over the telephone. If the advice was to spray, a recommendation was made stating the block/s to be treated, the category of fungicide and the latest date of application (see recommendation sheet below). The category of fungicide relates to contact products (cat. A), translaminar products (cat. B) and systemic products (cat. C). The aim was to give at least two days warning for the spray to be applied. Recommendations were sent to the agronomist by email.

Crop Spraying and Spray Updates

Once a spray recommendation was made, the agronomist was responsible for managing a spraying team to implement the recommendation within the given time period. The team consisted of two full time spray operators running two self-propelled, 24 metre sprayers. Once applied, the application date was then sent via email, by the agronomist, to the consultant to update the system. If spray updates were not received within the recommended application time, the consultant would check for delays, which could lead to the fungicide category being revised.

Recommendation Sheet

DMA Plant-Plus Service **Potato Late Blight Treatment Recommendations**

Adviser Howard Hinds
Contact numbers 01623 836457 0370 541355
Farm Strawson Farming Ltd.
Contact name Keith Mawer

Crop Reference	Recommendation Details			Application Details			
	Treatment Category	Latest Date	Comments	Date Applied	Time applied	Product	Rate/ha
Cuckney	B	07/08/00	Invader	05-Aug	1.30pm	Invader	2.0kg
Oxton Later	B	07/08/00	Curzate	05/08/00	2.30pm	Curzate	2.0kg
Tolney Lane	A	08/08/00	Shirlan	07-Aug	1pm	Shirlan	0.3lt
Bilsthorpe Early	A	08/08/00	Shirlan	08/08/00	9.30am	Shirlan	0.3lt

Product Category Reference

A Mancozeb Products (eg Dithane), Fluazinam Products (eg Shirlan), Chorothalonil Products (eg Bravo), Tin Products (eg Brestan)
B Curzate/Fytospore, Invader
C Merlin, Tattoo C, Trustan/Repost*, Fubol*, Patafol*, Recoil*, Tairel*, Folio* - * contai phenylamide

Results Of the Service

Infection Pressure and Crop Protection

Blight pressure was high for most of the season, with severe periods in July and August. Prior to emergence of crops blight was found in dumps around the farm. Locally blight infection in crops was first reported in late June. By mid August there were numerous field infections in the region, some causing significant defoliation. The weather pattern this year left no room for error, and many infections established because of poor application technique.

No foliar blight was observed on any of Strawson Farming blocks, during, or at the end of the season.

Spray Application Details

The average number of sprays/block for the season was 13 (Table 1). Spray intervals for blocks ranged from 4 to 15 days, and averaged 8.4 days. Translaminar products (Curzate/Invader) accounted for 58% of fungicide use, contact products (Shirlan/Tin) 33% and Systemics (Trustan) 8% (Table 2). During the spraying period 55 spray days were required, the frequency of spraying was every 2.3 days (Table 3). On most occasions one block/day was sprayed, however there were 11 days when more than 4 blocks in a day were treated (Table 4). On 80% of spray days 3 or less blocks were treated.

Table 1. Timing of sprays used in the Plant-Plus programmes.

Block	Variety	May	June	July	Aug	Sept	Total
Bilsthorpe Early	L.Rosetta	2	3	5	3		13
Hexgeave Early	Hermes	2	4	4	4	1	15
Cuckney	Hermes	2	4	4	4		14
Tolney Lane	L. Rosetta	2	4	4	3		13
Oxton Early	Hermes		4	4	4	1	13
Bilsthorpe Late	L.Rosetta		3	4	4	3	14
Hexgreave Late Trials	Hermes		2	4	4	1	11
Hexgreave Late	Saturna		2	4	4	2	12
Bathley	L. Rosetta		4	4	4	1	13
Oxton Late	Hermes		3	4	4	1	12

Table 2. Spray product selection and program costs.

Block	Curzate	Invader	Shirlan	Trustan	Tin	Cost £/ha
Bilsthorpe Early	4	4	4		1	156
Hexgeave Early	5	3	6	1		190
Cuckney	4	5	4		1	161
Tolney Lane	3	3	4	2	1	179
Oxton Early	5	2	4	1	1	168
Bilsthorpe Late	5	4	2	2	1	198
Hexgreave Late Trials	3	1	5	2		151
Hexgreave Late	4	4	3	1		163
Bathley	4	2.6	5	1		162
Oxton Late	6	4	1	1		150

*Costs based on Curzate £12 / 2.0kg, Invader £15 / 2.0kg, Shirlan £10 / 0.3lts, Trustan £25/2.5 lts and Tin £8/ 0.5lts.

Table 3. Spraying days/month used.

	May	June	July	Aug	Sept	Total
Number of spray days used	4	15	15	15	6	55
Number of blocks sprayed	8	33	41	38	10	130

Table 4. Number of blocks treated per spraying day.

	Number of blocks sprayed /day					
	1	2	3	4	5	6
Frequency of days	21	12	9	5	5	1

Reaction to Spray Recommendations

Application was mostly made within the recommended latest date, which was usually within 2 days. This was made possible by treating blocks sequentially to reduce the spray burden at any one time. Therefore when a risk period occurred there was generally only two or three blocks to treat. A consequence of spreading the blocks out in time was that communication between consultant and agronomist had to be very frequent. In a high pressure year such as this season communication was sometimes made daily (6 days a week), with either the consultant advising a spray and checking spray dates, or with the agronomist passing information back. Without this level of communication it would have been easy to miss a risk period or spray window.

Occasionally there were delays beyond latest date. The most common reasons for delays were;

- Irrigation pipes
- Demands from other crops
- The weather
- Weekends

Irrigation itself was not usually a problem as spray timings could be planned around one field, however the pipes from one field would sometimes stretch across other nearby potatoes blocks which acted as a barrier to the sprayer reaching fields.

The Strawson farm also grows over 250 ha of carrots. Like potatoes, carrots are a high value crop and although the spraying demands on the carrot crop are not as great as on potatoes, there are periods when there is a conflict for sprayer resources. This occurs in late July and most of August when carrots require regular protection against carrot fly and foliar diseases such as alternaria. It was these situations, which highlighted the need to spread spraying over as many days as possible. Avoiding spraying too many blocks in one day meant other crops could be brought into the workload.

The weather did not pose a serious problem in physically applying sprays, as the records show applications were made one in every two days. Probably the main concern was when the very large infection periods occurred. This had the effect of bunching blocks up over a one or two days, which as already mentioned was not a desirable situation.

Weekend working for this farm is not a problem, however sometimes plans made on the Friday can change by the Saturday if the forecast changes. This can result in staff shortages, if they have been promised the weekend off.

Conclusion – Can Blight Forecasting Work on Large Potato Farms?

From this case study the answer to the above question is, yes. Other farms should also be able to achieve the same result, providing they meet the following practical conditions;

- Fields need to be grouped into practical blocks for convenience of spraying.
- Treatment of blocks should occur on sequential days to avoid unrealistic workloads.
- Sprayer capacity should be sufficient to spray 100ha of the potato area (or 4 blocks) in one day.
- Reaction to spray recommendations must be within 2 days on most occasions, weather permitting.
- Crop recording must be the responsibility of a member of staff who is trained and is allowed the time to perform this duty on a set day.
- Communication between adviser and farm agronomist/manager must be regular, daily if necessary. Following a recommendation there must be a communication once the latest date of application is reached.
- Agronomist/manager must have overall responsibility for pesticide ordering and management of the spray team.
- A sufficient stock of fungicides must be kept in store to treat the whole potato area with a category A, B or C product. Preferably there should be enough A and B product for 2 rounds.

Acknowledgements

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Effect of temperature on the curative and Anti-sporulant action of cymoxanil for control of *Phytophthora infestans*

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Summary

The curative activity of cymoxanil on potato late blight was investigated in a leaf disc assay, on detached leaves and on whole plants. Curative activity ranged from 3 days at 15ºC in a detached leaf assay to 24 hours at 20ºC in a leaf disc assay. Good 24-hour curative efficacy was also observed on whole plants using the more aggressive US-8 isolate incubated at 16ºC or 24ºC. Disease control was significantly reduced when the fungicide was applied 2 days post-infection, particularly at the highest temperature. Cymoxanil was always more active than the mixtures dimethomorph + mancozeb and propamocarb + chlorothalonil. When applied on visible symptoms of late blight cymoxanil reduced significantly the production of sporangia. The effects of cymoxanil on lesion development and spore production are likely to contribute to its ability to stop or slow down late blight epidemics.

Key words: cymoxanil, late blight, *Phytophthora infestans*, curative activity, anti-sporulant

Introduction

Cymoxanil (Curzate®) is a fungicide used for the control of several oomycete fungi on a variety of crops. It is particularly effective on the potato late blight pathogen *Phytophthora infestans* (Douchet *et al.,* 1977). Cymoxanil exhibits curative activity on late blight but relatively short residual properties due to rapid metabolism in the plant tissue (Klopping and Delp, 1980). The post-infection activity of cymoxanil on *P. infestans* has been found to decrease as temperature increases (Forbes *et al,.* 1996). Although cymoxanil has been shown to reduce sporulation of existing blight lesions (Genet *et al.*, 1996), curative activity is usually assessed in terms of lesion development only. Lesion development is an important component of disease development. However, the number of sporangia produced on infected leaves is also likely to have great influence on the progression of a blight epidemic. The objective of this study was to examine the curative activity of cymoxanil on *P. infestans* both in terms of lesion development and sporangia production. The effect of temperature was also investigated using different blight isolates including the more aggressive US-8 genotype. Other blight fungicides known for having curative activity were also evaluated in comparison.

Materials and methods

Fungal isolates

The *P. infestans* isolates used in these experiments were maintained on agar plates and regularly re-isolated from infected potato tissue. Studies conducted in Nambsheim used a field isolate originating from the Alsace region of France. In the USA an isolate of the more aggressive US-8 strain was used. Experiments conducted at SAC used a mixture of phenylamide-sensitive and -resistant UK field isolates.

Fungicides

The following fungicides were used in these experiments at their respective use rates:

Curzate 60DF (cymoxanil, 60%WG) 0.18 kg/ha

Curzate M68 (cymoxanil + mancozeb, 4.5 + 68%, WP)2.0 kg/ha

Acrobat M (dimethomorph + mancozeb, 9 + 60% WP)2.0 kg/ha

Invader (dimethomorph + mancozeb, 7.5 + 66.7 WP)2.0 kg/ha

Tattoo C (propamocarb + chlorothalonil, 375 + 375 g/l SC) 2.7 l/ha

Experiment 1 (Leaf disc assay, DuPont, Nambsheim, 1995)

Potato leaf discs (18 mm in diameter, var. Bintje) were spray-inoculated with a freshly harvested suspension of *P. infestans* sporangia (20,000 sporangia per ml) and kept inside a moist chamber. After 6, 24, 36 or 48 hours the leaf discs were transferred to Petri dishes with their lower surface in contact with a filter paper impregnated with a solution of cymoxanil at 300 mg/l. The discs were incubated at 17ºC or 20ºC with a 18/6 hour photoperiod. Disease development was scored visually both in terms of sporulation and lesion development.

Experiment 2 (Whole plant assay, Dupont, Stine, 1999)

Five week-old potato plants (var. Bintje) were spray-inoculated with a suspension of *P. infestans* sporangia (20,000 sporangia per ml) and kept in a dew room for infection. The plants were sprayed with the fungicides at various intervals following inoculation. The fungicides were applied at their field dosage in a water volume equivalent to 300 l/ha. The plants were then transferred to controlled environmental chambers at the appropriate test temperature. Disease level was assessed either by the lesion area, overall percentage of infected leaf surface or the number of sporangia produced per cm^2 lesion.

Experiment 3 (Detached leaf assay, SAC, Auchincruive, 1996)

Glasshouse-grown potato plants of the very susceptible cultivar King Edward were point-inoculated with a suspension of *P. infestans* sporangia (1000 sporangia per site) and incubated in the glasshouse at a mean temperature of 14.4ºC. Three, 5 or 7 days after inoculation, leaves were detached and sprayed with the fungicides and placed inside a Petri dish containing damp tissue paper and incubated at 15ºC with a day length of 16 hours. The petioles were protected during spraying to prevent fungicide landing on the cut surface. There were 18 leaflets per combination of spray timing and fungicide treatment. Five or 6 days after treatment, the leaves were assessed for the presence or absence of sporulating *P. infestans* lesions. The effect of fungicide treatment on sporulation was assessed by washing the sporangia from 6 inoculated leaflets with 3 ml of sterile distilled water.

Results

Effect of temperature on disease development

Disease development was affected by the temperature of incubation both in the leaf disc assay (Table 1) and in the whole plant tests (Figure 1). Disease progress was faster at higher temperature with significant disease occurring after 3 days of incubation. For the US 8 isolate, disease failed to develop at constant 30°C whereas at 30/18°C day/night the rate of development was equal to that at 24°C.

Table 1. Effect of temperature on disease progression on potato leaf discs infected with *P. infestans*. (Experiment 1, DuPont Nambsheim, 1995).

Days Post infection	Disease severity (%)	
	17°C	20°C
1	0.0	0.0
2	0.0	0.03
3	17.2	50.0
4	92.3	100.0
5	100.0	100.0

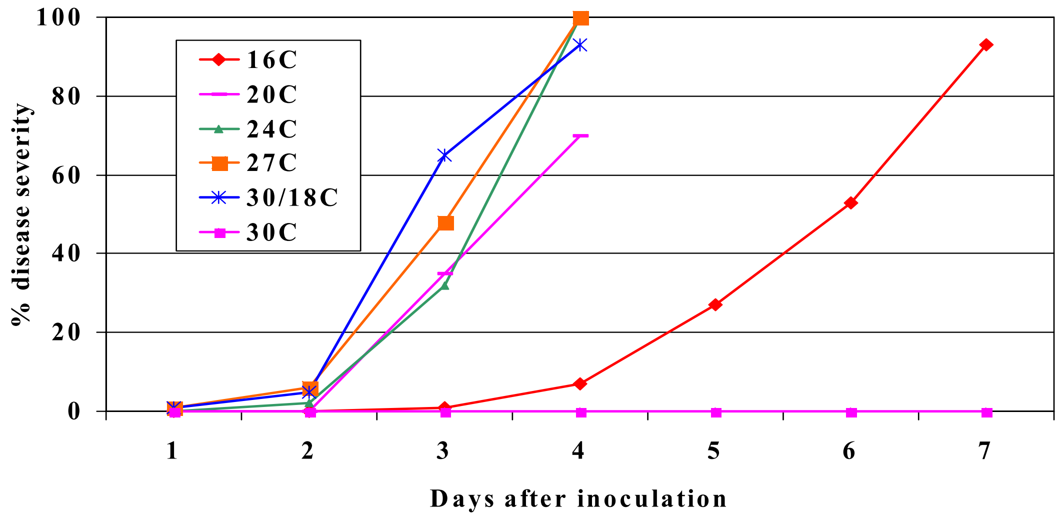

Figure 1. Effect of temperature on rate of disease progress from infection with a US-8 genotype of *P.infestans* in untreated potato plants (Experiment 2, DuPont Stine, 1999).

Effect of temperature on the curative activity of cymoxanil

At 17ºC, cymoxanil exhibited excellent curative activity when applied within 36 hours after inoculation in the leaf disc assay (Figure 2). Curative activity however was shorter at 20ºC.

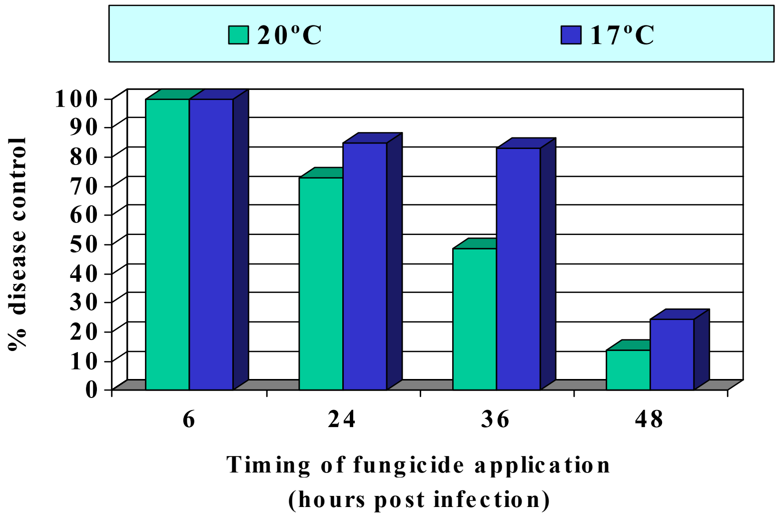

Figure 2. Effect of temperature on the curative activity of cymoxanil on potato late blight in a leaf-disc assay (Experiment 1, DuPont Nambsheim, 1995).

At 15ºC, the mixture cymoxanil + mancozeb showed significant 3-day curative action when applied to detached leaves which had been point-inoculated (Figure 3). Little activity was seen at longer intervals.

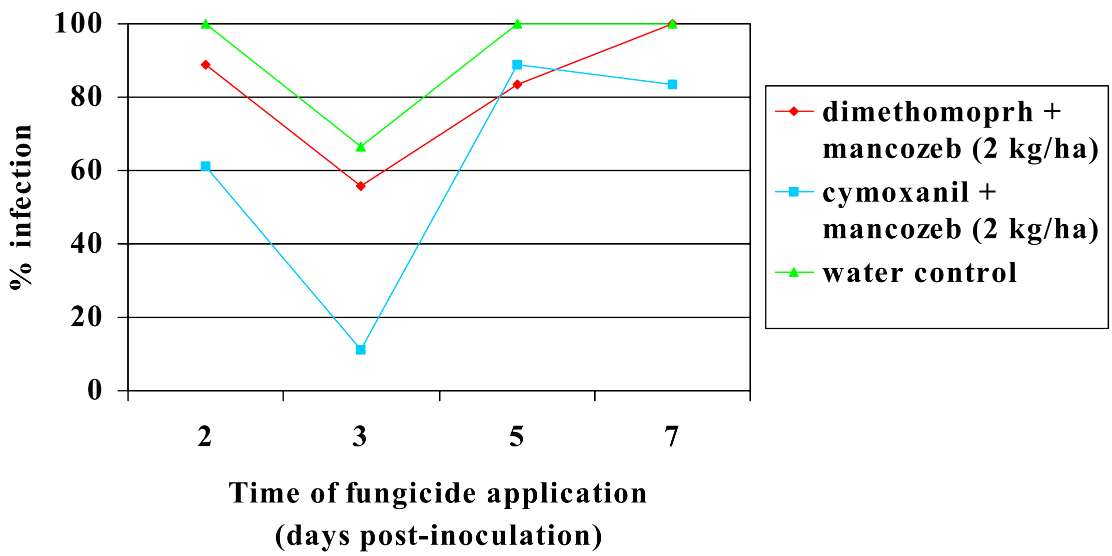

Figure 3. Effect of post-infection fungicide applications on late blight lesion development on detached potato leaves at 15ºC; SED = 14.57, 62 df (Experiment 3, SAC, 1996).

Good 24-hour curative efficacy was observed also in the whole plant assay using the more aggressive US-8 isolate incubated at 16ºC or 24ºC (Figure 4). Disease control was however significantly reduced when the fungicide was applied 2 days post-infection, particularly at the highest temperature. Cymoxanil had no significant effect on the disease when applied 3 days after infection, regardless of the temperature during incubation (Figure 4).

Comparison with other fungicides

In the whole plant assay, the mixture propamocarb + chlorothalonil exhibited 1-day curative action against blight at 16ºC only (Figure 4). No activity was seen at longer intervals. The mixture dimethomorph + mancozeb showed little activity at 15ºC in the detached leaf assay (Figure 3) and also at 16ºC and 24ºC in the whole plant assay (Figure 4).

16ºC **24ºC**

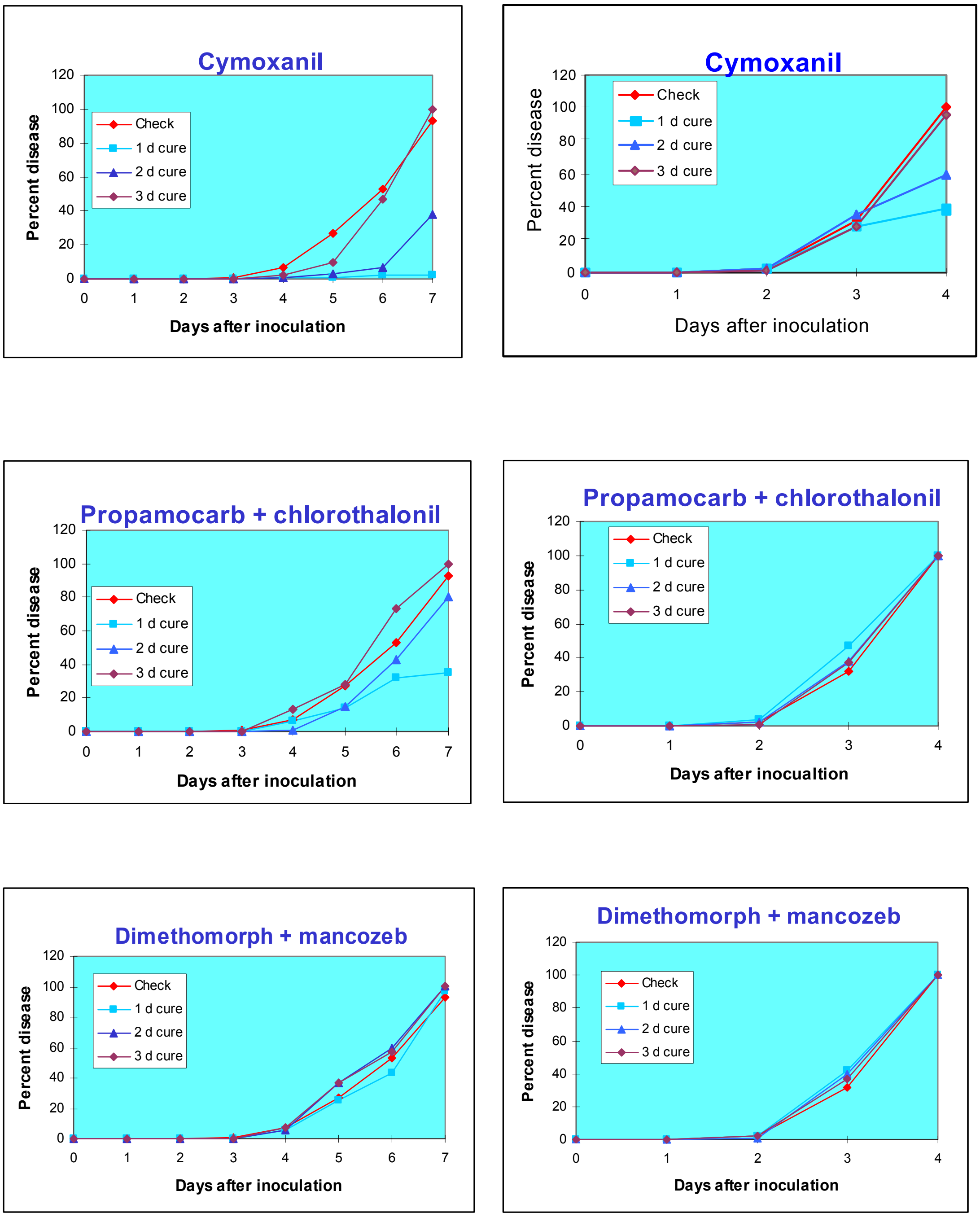

Figure 4. Curative action of cymoxanil against *P. infestans* genotype US-8 compared to the mixtures dimethomorph + mancozeb and propamocarb + chlorothalonil. Disease severity assessed on whole plants after incubation at 16ºC (left) and 24ºC (right) (Experiment 2, DuPont Stine, 1999).

Effect on sporulation

Cymoxanil had a greater effect on reducing sporulation than lesion development in the leaf disc assay (Figure 5). In experiment 2, plants treated with cymoxanil 1 or 2 days after inoculation exhibited lesions which were smaller in size and also produced fewer sporangia than untreated lesions (Table 2). Similar observations were made at SAC where the mixture cymoxanil + mancozeb substantially reduced sporangia production from point-inoculated lesions when fungicide application was made up to 7 days after inoculation (Figure 6). In comparison, the mixture dimethomorph + mancozeb had a smaller effect on sporulation.

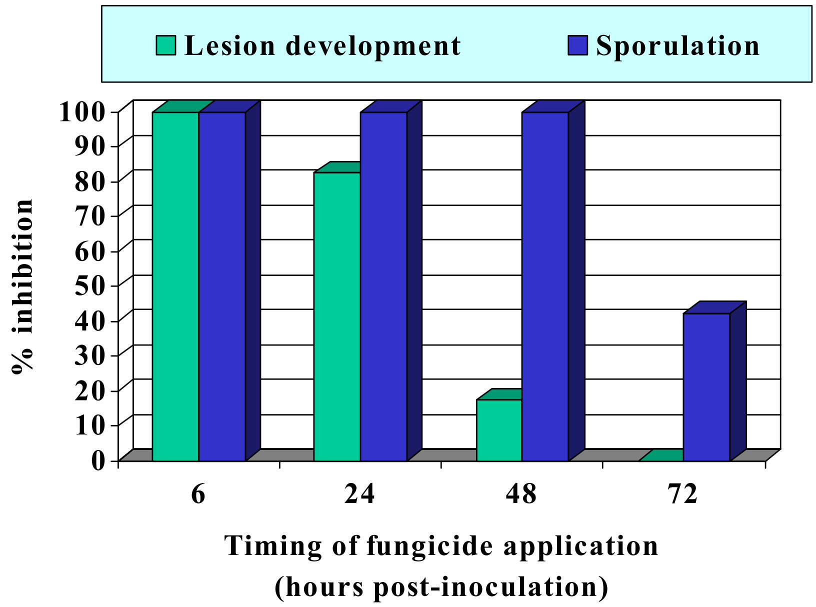

Figure 5. Curative and antisporulant effect of cymoxanil applied to potato leaf discs inoculated with *P. infestans* (20ºC) (Experiment 1, DuPont Nambsheim, 1995).

Table 2. Antisporulant action of cymoxanil against P. *infestans* genotype US-8 in a 1-day and 2-day curative whole-plant study at 20ºC (Experiment 2, DuPont Stine, 1999).

Treatment	1-day curative		2-day curative	
	Lesion area (cm^2)	Sporangia per cm^2 lesion	Lesion area (cm^2)	Sporangia per cm^2 lesion
Untreated	10	1.8	10.3	2.5
Cymoxanil	2.1	0.6	4	1.2
SED	1.61	4.13	1.65	6.63

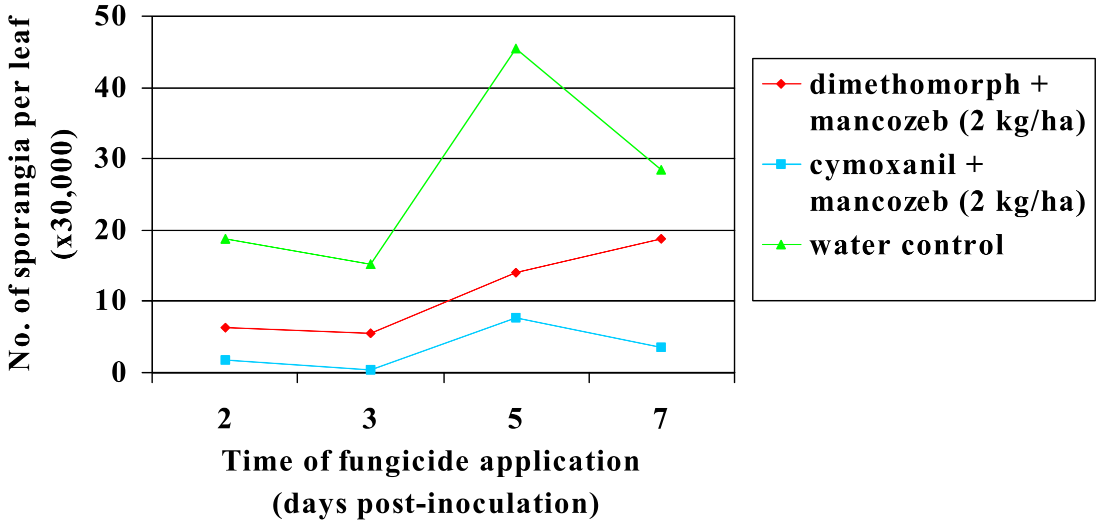

Figure 6. Sporangia production by *P. infestans* in relation to the time interval between inoculation and fungicide application in a detached leaf assay at 15ºC; SED = 5.09, 158 df (Experiment 3, SAC, 1996).

Discussion and conclusions

The development of late blight lesions in infected potato tissue of two very susceptible cultivars was significantly affected by temperature. At a temperature of 16-17ºC, which can be considered as representative of the average summer temperature in Northern Europe, the first symptoms of blight were visible 3 days after infection.

The curative efficacy of cymoxanil was also affected by the incubation temperature thus confirming earlier data on late blight (Genet *et al.,* 1996; Forbes *et al*., 1996) and with the grape downy mildew pathogen (Genet *et al*., 1997). The reduced activity at higher temperature probably reflects the faster progression of the fungus inside the leaf tissue. Good one-day curative action was however seen at all temperatures tested and using different isolates, including the more aggressive US-8 strain. It is expected that the inoculum concentration, as well as the techniques used (fungicide application, spray versus point inoculation), will affect the kickback activity of a given blight fungicide. In this study however, cymoxanil behaved very consistently in all experiments.

Cymoxanil mixtures applied as an eradicant, i.e. on visible symptoms, significantly reduced the production of sporangia from the blight lesions as seen in the SAC study.

Although this antisporulant effect is not clearly understood, it is likely to play a major role in the development of blight epidemics by effectively reducing the number of infective propagules present in a potato field.

Both propamocarb and dimethomorph are reported to have curative activity on potato late blight (Cohen *et al*., 1995, Reiter *et al*., 1995). However, of the fungicides tested in these experiments, cymoxanil exhibited the strongest effect both on lesion expansion and sporangia production. The three experiments reported here were conducted with two very susceptible cultivars and it is likely that the curative period of a fungicide would be prolonged in more resistant cultivars because lesion development is slower in such cultivars.

The curative activity of cymoxanil is an interesting attribute, which has been overestimated sometimes. Eradicant use of cymoxanil, i.e. on established infections, can only be recommended in an emergency situation where no other alternatives are available. In such cases however, applications must be made within one or two days after infection, depending on temperature. Cymoxanil-based products should normally be used prophylactically.

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Incidence of late blight (*Phytophthora infestans*) in potato crops and its control in Poland in 1995-1999

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Summary

The mating type A1 predominated among *P. infestans* isolates in Poland during 1995-1999. From 1995 to 1998 the proportion of phenylamide-resistant isolates declined in every year reaching 27.6% in 1998. In 1999, the proportion increased to 53.0%. The fungicide protection against late blight varied from 21.5% to 42.2% of grown potato acreage. A survey of fungicides used in Polish potato crops showed tendency of decreased use of contacts and increased use of systemics. In 1995-1999, the most popular "program" of controlling late blight in Poland consisted of two fungicide applications per season.

Keywords: Potato late blight, mating type, fungicide resistance, chemical protection

Introduction

In Poland like in many other countries the production of potatoes is restricted by *Phytophthora infestans* that causes necrosis of leaves and rotting of tubers of the potato plants. In Poland we have observed many changes in the *P. infestans* populations (mating type frequency, race composition, phenylamide sensibility). These changes of the fungus caused more severe late blight epidemics. Potato yield and quality losses due to the disease were reduced when fungicides were applied.

The objectives of this work were to establish:

1. some characteristics of Polish *P.infestans* populations,
2. seasons' late blight pressure and the level of potato protection in Poland in 1995-1999
3. the amount of fungicides used in Poland.

Material and methods

In 1995-1999 surveys of potato crops were undertaken to get information about the state of Polish *P. infestans* populations and the incidence of late blight all-around Poland. Workers of the Advisory Agriculture Service collected samples of infected potato leaves from commercial potato crops and sent them to the Institute to be examined for mating type and phenylamide sensibility. The samples were sent together with data on sample site, potato cultivar and fungicide usage. An additional source of data was the Ministry of Agriculture which conducts annual surveys of potato acreage, yields, protection scale and pesticides practices.

Mating type was determined by placing a mycelia plug (5 mm diam.) of the appropriate test isolate on to a Petri dish containing rye agar, equidistant from similar plugs of reference A1 and A2 isolates (Caten and Links, 1968). Oospore development in the presence of a reference isolate indicated that the tested isolate was of opposite mating type.

Phenylamide resistance of *P. infestans* isolates was tested using a floating leaf disc method (Davidse *et al.*, 1981). Discs 10 mm in diameter, cut from leaves of the susceptible potato cultivar Tarpan, were placed in 5 concentrations of metalaxyl, (standard) 100, 10, 1, 0.1, 0.01 and 0 (=control) mg/l. Each disc was inoculated with one drop of a suspension of 10^4 sporangia/ml. After 7 days the sporulation was rated visually as the percentage of leaf area infected in comparison to that of the control and index EC_{50} was afterwards determined graphically for each tested isolate ($EC_{50} \leq 0.01$ ppm - sensitive isolate; $0.01 < EC_{50} \leq 10$ ppm – intermediate; $EC_{50} > 10$ ppm – resistant isolate).

In Bonin, field observations on the incidence of late blight were made each year. At the beginning of season, plots (size 30 m^2) of two standard cultivars: Atol and Cisa were carefully inspected several times a week in order to detect the first, natural infections of late blight. The level of foliar blight infection was expressed in terms of the rate of infection (Van der Plank, 1963).

Results and discussion

Characteristics of Phytophthora infestans populations

The mating type A1 predominated among Polish isolates of *P. infestans* during 1995-1999. Among 694 isolates collected during five years all-around Poland, 154 strains of A2 mating type and 12 self fertile were identified. The highest number of A2 isolates were observed in 1998. Mean complexity of pathotypes varied from 5.73 virulence genes per isolate in 1995 to 7.28 genes in 1998 (table 1). Results has showed the same tendency like around Europe of higher frequency of A2 mating type in *P. infestans* populations and more complex races of the fungus (Hermansen and Amundsen, 1995, Griffin *et al*., 1998, Hermansen *et al.,* 2000, Schöber-Butin, 1999).

Table 1. Characteristics of *P. infestans* populations in Poland in 1995-1999*.

Assessment criteria	1995	1996	1997	1998	1999
Number of tested isolates	53	190	156	145	150
Mean number of virulence genes / isolate	5.73	6.45	6.76	7.28	6.99
Mating type frequency (%)A1	95.0	78.9	75.6	60.0	74.0
A2	5.0	19.5	21.8	38.6	23.3
Self fertile	0	1.6	1.9	1.4	2.7

*Acc.to: Zarzycka & Sobkowiak, 1999 and Zarzycka & Sobkowiak (person.communication)

The overall proportion of isolates containing phenylamide-resistant strains of *P. infestans* for the years 1985-1999 is shown in Table 2. From 1995 to 1998 the proportion of resistant isolates declined in every year reaching 27.6% in 1998. In 1999, the proportion of resistance increased to 53.0% again. The proportion of sensitive isolates in 1997-1999 has remained relatively stable at between 53.2 to 42.2. Higher differences were observed among intermediate strains. They seem to be more unstable.

Table 2. Incidence of phenylamide-resistant isolates of *P.infestans* in Poland, years 1995-99.

Year	Number of examined Isolates	Isolates (%) resistant	sensitive	intermediate
1995	102	53.9	13.7	32.4
1996	0		no data	
1997	164	28.5	53.2	18.3
1998	250	27.6	52.8	19.6
1999	86	53.0	42.2	4.8

Long-term observations conducted in Poland in years 1985-1999 showed that the proportion of isolates containing phenylamide-resistant strains had declined from a peak of 83.3% in 1992 to 27.6% in 1998 (Kapsa *et al.,* 1999).

Late blight pressures and scale of potato protection

Data characterizing growing seasons 1995-1999 in Bonin are shown in Table 3 and the late blight progress curves on unsprayed control cultivars in Fig.1. During five years the earliest late blight appearance was observed in 1999 (45 days after potato planting). But development of blight, influenced by weather conditions, was the slowest compared to other seasons. In 1996, the latest appearance of the disease after planting was observed. Late blight developed rapidly and critical 50% haulm destruction was observed in the second decade of August.

Table 3. Data of growing seasons 1995-1999 at Bonin (North of Poland).

Year	Date of potato planting	Date of late blight appearance	Rate of late blight development on 2 control cultivars	Term of 50% haulm destruction month / decade
1995	5-05	27-06	0.213	08-III
1996	13-05	13-07	0.284	08-II
1997	6-05	26-06	0.207	07-III
1998	6-05	09-07	0.218	08-I
1999	11-05	23-06	0.185	09-I

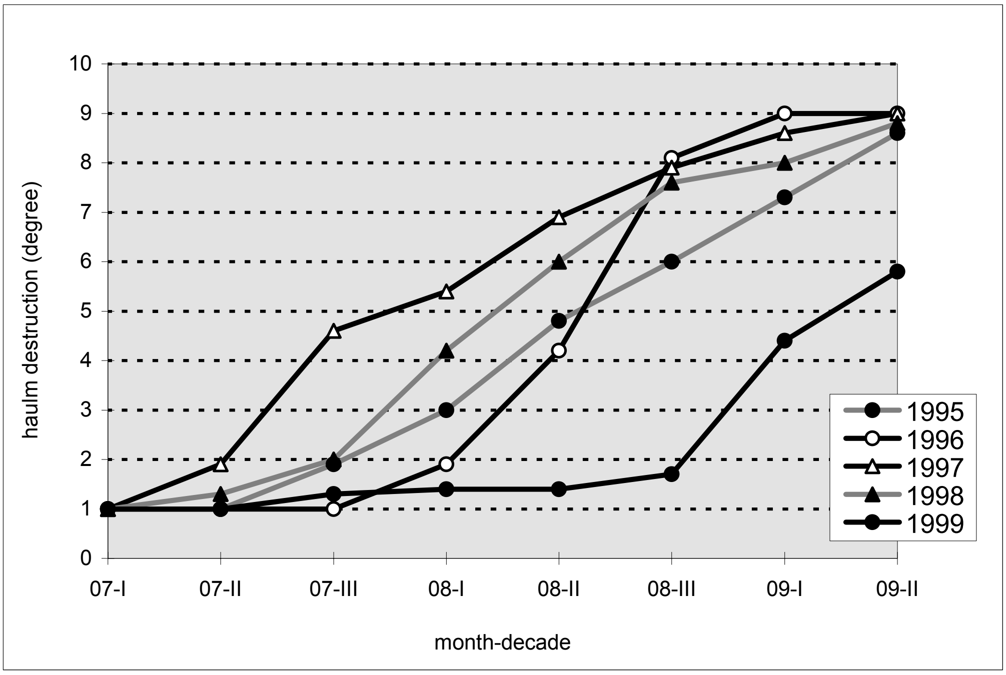

Figure 1. Late blight progress on control plots 1995-1999 (score 1 means – without any symptoms, 9 – dead leaves and stems).

The data show that the most ”blight” seasons were the years 1997 and 1998. Critical 50% of haulm destruction was observed at the end of July (1997) and beginning of August (1998).

The potato is a very important agricultural crop in Poland. Potato acreage has decreased during the recent years, but it still remains at a very high level. Potato was cultivated in 1999 on 1,255,600 hectares. Inadequate late blight control is one of the reasons that average tuber yields are not high in the country (Table 4). The shape and dimensions of potato fields in Poland are not favourable for chemical protection. The average potato field is small. About 93% of potato fields are less then 1 hectare in size. Consequence of that is a very limited protection of potato crops against late blight. In 1995-1999 the protected area varied from 21.5% in 1995 to 42.2% in 1998. The average number of sprays varied from 1.47 in 1995 to 1.73 in 1997.

Table 4. The area of potato crops, tuber yields and scale of late blight control in Poland, 1995-1999 (acc. to the Ministry of Agriculture).

Year	Potato grown area ths. ha	Average yields (t/ha)	Potato area protected against late blight /%/	Average number of sprays / season
1995	1,522.4	16.4	21.5	1.47
1996	1,341.9	20.3	28.5	1.63
1997	1,306.0	15.9	38.9	1.73
1998	1,250.0	20.0	42.2	1.72
1999	1,255.6	17.0	39.8	1.67

* on protected area

Determining the amount of fungicides used in Poland

The use of fungicides is one of the most important instruments for controlling *P. infestans*. Observations conducted in the years 1995-1999 at 980 potato crops all-around Poland showed tendency of decreased use of contact fungicide. Systemic and translaminar fungicide use increased (Fig. 2).

Main fungicides applied on commercial potato crops for 1995-1999 were in the proportion of: metalaxyl (19.3-26.6%), oxadixyl (10.2-17.4%), cymoxanil (12.3-17.5), mancozeb (8.2-17.4%) and chlorothalonil (11.3-18.6%). Propamocarb and fluazinam were both being applied to a significant proportion of the crop area by 1999: 10.1% and 5.7.

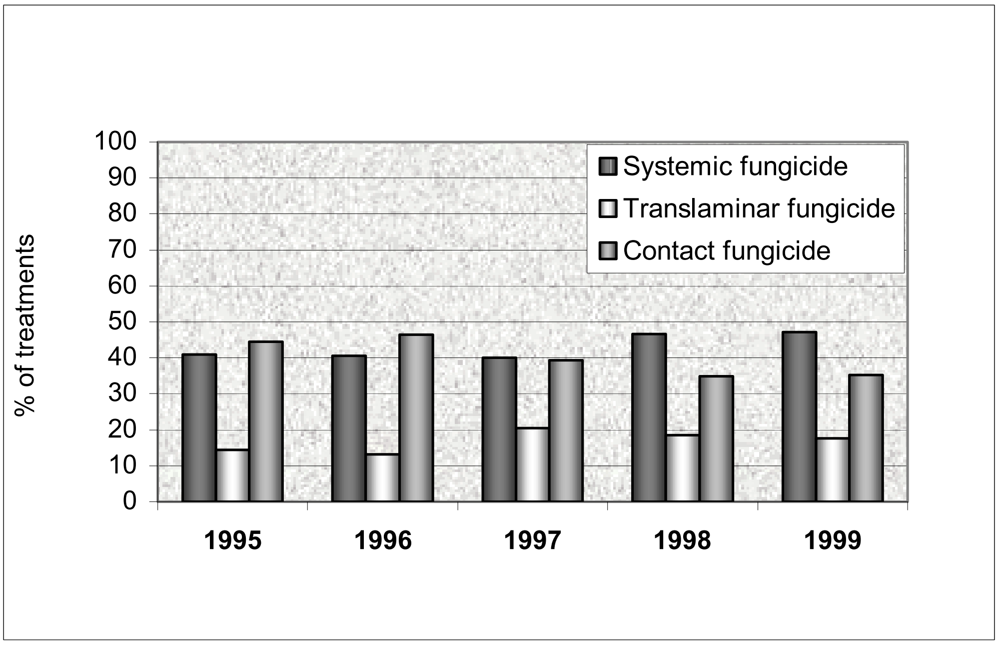

Figure 2. Fungicide use at potato crops in Poland, 1995-1999.

Estimates of number of fungicide applications per season on observed potato commercial fields are shown in Table 5.

Table 5. Number of fungicide applications by potato growers for late blight control, 1995-1999.

Number of Applications	% of observed fields				
	1995	**1996**	**1997**	**1998**	**1999**
Number of observed fields	409	166	162	162	81
Unprotected	27.1	18.0	8.0	2.5	8.6
One	**34.2**	30.7	23.5	31.5	25.9
Two	31.4	**34.4**	**36.4**	**36.4**	**38.3**
Three	5.4	13.3	17.9	17.9	21.0
Four	1.7	2.4	10.5	8.6	0
Five +	0.2	1.2	3.7	3.1	6.2
Mean number of sprays / season	1.2	1.6	2.1	2.1	2.0

The most popular "program" of controlling late blight in Poland has remained 2 fungicide applications per season. However, more frequent use (8-12 treatments) has been observed at larger potato farms.

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Fenomen: A new fungicide for the control of potato late blight

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Summary

FENOMEN, a new broad-spectrum fungicide developed by Aventis CropScience, exhibits a high level of activity against a range of Oomycete diseases. Its effect on both direct and indirect germination of *Phytophthora infestans* sporangia, as well as on subsequent mycelial growth, provides consistent control of potato late blight.

It is being developed in combination with fungicides having different modes of action. These FENOMEN-based products provide a high level of control of *P. infestans* under practical conditions. They also exhibit good control of early blight (*Alternaria solani*).

Monitoring of *P. infestans* sensitivity to FENOMEN over four years has not shown any shift within the pathogen population.

Introduction

FENOMEN belongs to a new class of fungicides, derived from imidazolinone chemistry, discovered and developed by Aventis CropScience. It is a pure optical isomer, which acts on targeted fungi by inhibiting mitochondrial respiration. It provides a high level of control of Oomycete diseases such as downy mildews and late blights on a broad range of crops.

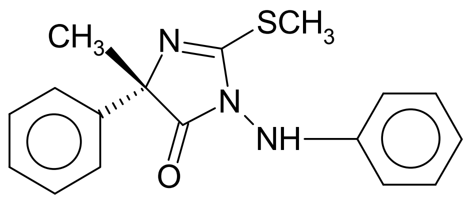
Chemical and physical properties

Code number:	RPA 407213
Proposed common name:	Fenamidone
Trade name:	FENOMEN®

Chemical name: IUPAC:
(*S*)-5-Methyl-2-methylthio-5-phenyl-3-phenylamino-3,5-dihydroimidazol-4-one

Chemical Abstracts: 4 H-Imidazol-4-one, 3,5-dihydro-5-methyl-2-(methylthio)-5-phenyl-3-(phenylamino)-, (*S*)-

Structural formula:



Molecular formula:	$C_{17}H_{17}N_3OS$
Molecular weight:	311
Chemical Abstracts registry number:	161326-34-7
Physical state:	White woolly powder
Melting point:	137° C
Density:	1.285
Water solubility:	7.8 mg/litre at 20° C
Partition coefficient n-Octanol/water:	log Pow = 2.8 at 20° C
Vapour pressure:	3.4×10^{-7} Pa at 25° C

Toxicological, ecotoxicological profiles, environment fate

Overall, FENOMEN exhibits low toxicity to mammals and is safe for the environment under practical use conditions. The level of residues in crops is low.

Biological profile of FENOMEN against *P. infestans*

Action on the life cycle of P. infestans

FENOMEN has been tested *in vitro* and found to be active against different steps in the development of *P. infestans*. The steps assessed were: zoospore release, zoospore mobility, encystment and cyst germination, as well as the direct germination of the zoosporangia.

Efficacy against mating types of P. infestans

Using isolates provided by the Plant Research International (formely the IPO-DLO, Netherlands), FENOMEN has been found to be equally effective against both A1 and A2 mating types.

Efficacy against Phenyl-amide resistant strains of P. infestans

FENOMEN has been shown to be equally effective against both phenyl-amide sensitive and resistant strains of *Phytophthora infestans*.

Efficacy against potato diseases under field conditions

Late blight control

Activity on foliage and stems

FENOMEN was evaluated as the formulated mixture SERENO® (100 g FENOMEN + 500 g mancozeb/kg) at rates of 1.25 to 1.5 kg formulation/ha.

In a large number of field trials carried out throughout Europe over the years 1996 - 2000 the mixture provided a high level of control of late blight on foliage and stems when applied on a 7 day spray programme.

Efficacy of FENOMEN + mancozeb foliar sprays in controlling potato tuber blight

Tuber blight infection was assessed in certain of the trials performed in 1998 and 1999 in the UK and France. Results are shown in the table1.

Table 1. Tuber blight control with FENOMEN + mancozeb foliar sprays.

Active Ingredients	Dose rate (g a.i./ha)	% blight infected tubers			
		Pembroke 98 % by weight	Cornwall 99 % by number	Amiens 99 % by number	Reims 99 % by number
FENOMEN + mancozeb	150 + 750	3	0	9	22
Fluazinam	150	5	0	-	-
	200	-	-	6	41
Mancozeb	1275 –	7	2.3	-	-
	1575			22	65

Sprays applied at intervals of 7 -10 days

By comparison with mancozeb, good control of tuber blight is offered by the FENOMEN + mancozeb mixture in the trials.

Protection on young leaves

The trial illustrated was carried out by the Hilbrands Laboratorium (Netherlands). Field grown potatoes (var. Bintje) were sprayed twice using a six-day interval with the formulations under test.

Three days after the last spray application the young growing shoots were artificially inoculated with *P. infestans* strains HLB 98001 and HLB 98007.
Eight days after inoculation the number of infected leaflets in the upper five leaf layers was counted for each treatment.

Table 2. Efficacy of foliar sprays of a FENOMEN + mancozeb mixture in protecting young potato foliage from attacks by late blight (*Phytophthora infestans*) (Hilbrands Laboratorium, Netherlands 1999).

Active Ingredients	Dose rate (g a.i./ha)	% infected leaflets Inoc + 8 days Strain HLB 98001	Strain 98007
FENOMEN + mancozeb	150 + 750	4	8
Fluazinam	200	13	27
Untreated		49	45

Translaminar systemic activity of FENOMEN + mancozeb in controlling late blight of potato foliage (Trial carried out by SPV Pas de Calais, France 1999)

The upper surfaces of potato leaves, grown under protected conditions, were sprayed with the compounds under test. Two to five days later, leaves were detached from the plants and their lower surfaces were inoculated with *P. infestans* sporangia / zoospores. 7 days after inoculation, the percentage diseased leaf area sporulating on the lower leaf surface was estimated. Results are presented in the table 3 below.

Table 3. Translaminar systemic activity of FENOMEN + mancozeb in controlling late blight on potato foliage (SPV Pas de Calais, France 1999).

Active Ingredients	Dose rate (g a.i./ha)	% diseased leaf area lower leaf surface	
		T + 2 days	T + 5 days
FENOMEN + mancozeb	125 + 625	3	2
Mancozeb	1575	68	70
Untreated Check		79	91

Mancozeb did not exhibit any marked translaminar activity. The FENOMEN + mancozeb mixture demonstrated a high degree of control of the disease.

Early blight control

The efficacy of FENOMEN against early blight of potato (*Alternaria solani*) was also determined in Brazilian trials from 1996 to 1999. Data are reported in the table 4.

Table 4. Efficacy of FENOMEN foliar sprays in controlling early blight on potatoes.

Active Ingredients	Dose rate (g a.i./ha)	% infected leaves		
		1996 T 7 + 4 days	1997 T 7 + 4 days	1999 T 5 + 5 days
FENOMEN	100	-	29	-
	150	18	-	7
Mancozeb	2400	16	-	17
Chlorothalonil	1500	10	35	-
Untreated Check		65	79	21

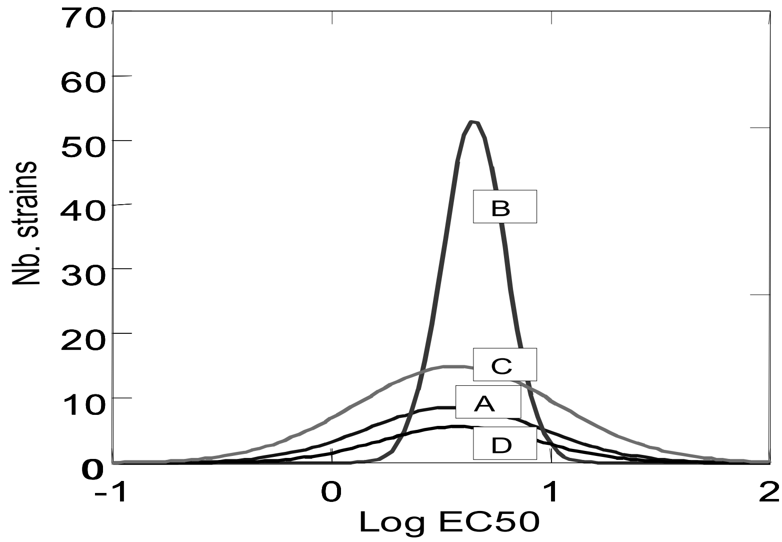
Spray interval: 7 - 10 days

In addition to the control of late blight, good efficacy was recorded against early blight. FENOMEN performed at the level of the references or even better.

Monitoring of the senitivity of *P. infestans* to FENOMEN

Baseline sensitivity

The sensitivity baseline of *Phytophthora infestans* to FENOMEN has been determined by testing strains collected from potato field locations not treated by the fungicide in France and the Benelux countries over 4 years. Data are presented in the figure 1 below.



A = 1996, B = 1997, C = 1998 and D = 1999.

Figure 1. Baseline sensitivity of *P. infestans* to FENOMEN collected over four years.

No shift in sensitivity was recorded from 1996 to 1999 (MIC = 40ppm). Distribution of the EC50s was shown to be unimodal over the four years with a sensitivity factor from the most to least sensitive strains of 100.

Conclusion

FENOMEN is a novel fungicide exhibiting a high level of biological afficacy against Oomycete diseases. The combination with mancozeb provides a consistent and high level of control of potato late blight in the field ensuring good protection of leaves, stems and tubers throughout the life of the crop. This combination also controls early blight.

Its biological efficacy, combined with its safety to crops, consumers, users and the environment, makes FENOMEN a valuable new tool well adapted for integrated crop management.

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AFLP fingerprinting and mtDNA haplotyping reveals the presence of the 'new' *Phytophthora infestans* population in Bavaria

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Summary

Isolates of *Phytophthora infestans* were collected randomly from blighted potato and tomato plants in Bavaria during the summer of 1999. The Bavarian population of *P. infestans* is marked by the presence of A1 and A2 mating types and substantial genetic variation as revealed by AFLP fingerprinting. The presence of IA and IIA mitochondrial DNA haplotypes indicates that the Bavarian *P. infestans* isolates belong to a 'new', sexually reproducing population that also has been reported for adjacent regions in Western Europe.

Keywords: *Phytophthora infestans*, DNA fingerprinting, mtDNA, haplotype, genetic variation, mating type

Introduction

The oomycete *Phytophthora infestans* (Mont.) de Bary, is the causal agent of late blight of potatoes and tomatoes. Until the 1980s, the global population of *P. infestans* outside Central Mexico, the presumed centre of origin (Fry and Spielman, 1991a), was marked by a single clonal lineage, US1 (Goodwin *et al*., 1994). This 'old' population of the pathogen was restricted to asexual reproduction since only A1 isolates were found present (Goodwin *et al*., 1994).

Recently, evidence has been accumulated (Hohl and Iselin, 1984; Drenth *et al*., 1994; Sujkowski *et al*., 1994; Brurberg *et al*., 1999) that in Western Europe this old population has been displaced by a sexually reproducing population (Drenth *et al*., 1994) that was introduced from Mexico around 1976 (Niederhauser, 1991).

Increased levels of genetic variation, both at the DNA level and phenotypic variation in pathogenicity marks this 'new' population. For the success of late blight management strategies, it is of key importance to have up-to-date information about the epidemiological parameters of the present *P. infestans* population. To date, no such information on the variation of *P. infestans* was available for Bavaria, Southeast Germany. We tested the hypothesis that the present Bavarian population still belongs to the 'old', clonal population of *P. infestans* which is marked by the presence of only A1 mating types, IB haplotypes and limited genetic variation as revealed by DNA fingerprinting. For this purpose we studied the genetic variation present in the field population of *P. infestans* in Bavaria using mitochondrial DNA haplotypes and AFLP fingerprinting and compared the genetic variation with the levels found in two reference populations of *P. infestans*, which are typical for asexually (Central Africa) and sexually (Toluca Valley, Mexico) reproducing populations.

Material and Methods

Sources and cultivation of isolates. During the summer of 1999 a total of 69 *P. infestans* isolates were collected from blighted potato and tomato plants in Bavaria. Strains were isolated using RASM selective medium (Forbes, 1997) and were maintained on RA at 20ºC.

Mating type determination. For assessment of mating type, isolates were plated on RA together with A1 and A2 reference isolates. The mating region of the colonies was examined for the presence of oospores using a microscope (at a magnification of 10 x 10) after 21 days of incubation at 20ºC.

Genetic structure. In order to compare the genetic structure of the Bavarian isolates with other *P. infestans* populations, 8 isolates from Central Africa (all US1 clonal lineage) and 26 isolates from the Valley of Toluca, Central Mexico were included as samples taken from asexually and sexually reproducing populations respectively.

*DNA extraction***.** Isolates were grown for 10 to 14 days at 20ºC in pea broth. The mycelium was harvested, lyophilised and stored at –80ºC. Lyophilised mycelium (30 to 60 mg) was ground in microcentrifuge tubes with a pestle and sterile sand. Total DNA was extracted using the Puregene kit (Gentra/Biozym, Landgraaf, the Netherlands) according to manufacturers instructions. DNA was dissolved in 100 µl of TE (10 mM Tris-HCl [pH 8.0], 1mM EDTA [pH 8.0]) and stored at –20ºC.

Mitochondrial DNA haplotypes. Mitochondrial DNA (mtDNA) was amplified using four sets of primers designed to amplify specific regions (P1 to P4) of the mitochondrial genome of *P. infestans* (Griffith & Shaw, 1998). The PCR was performed according to Ordoñez *et al*. (2000). PCR products were digested with the restriction enzymes *Cfo*I (P1), *Msp*I (P2), and *Eco*RI (P3 & P4). Ten µl of the amplified product was digested with 1 unit of the restriction enzyme for 4 h. The digested products were run on a 1.8 % agarose gel in TBE buffer at 10 V cm^{-1} and visualised with ethidium bromide under UV light.

*Fluorescent amplified fragment length polymorphisms (AFLP)**.*** A random sample of 52 Bavarian *P. infestans* isolates was characterized using AFLP fingerprinting. DNA (250 ng) was digested in a 50 µl reaction volume with *Eco*RI (10U) and *Mse*I (10U) for 6 h at 37ºC in restriction ligation buffer (10 mM Tris/Ac [pH 7.5], 10 mM MgAc, 50 mM Kac, 5 mM DTT, 50 ng/µl BSA). Digestion was confirmed on agarose gels. Mse and Eco adapters were ligated to restriction fragments using 0.1 µM Eco adapter, 1.0 µM Mse adapter, 0.2 mM ATP and 2.4 U T4 DNA Ligase (Pharmacia, Uppsala, Sweden) (Baayen *et al*., 2000). Ligation was performed overnight at 10ºC and the ligation products were diluted 10 times with MilliQ ultra pure water. Nonselective PCR amplification was performed using primers E00 (5'-GACTGCGTACCAATTC) and M00 (5'-GATGAGTCCTGAGTAA) to amplify all restriction fragments. Non-selective PCR amplifications were performed in a PTC200 thermocycler (MJ Research, Watertown, MA). The amplified restriction fragment products were checked on 1.0% agarose gels.

Selective PCR was performed in a 20 µl reaction volume with 5 µl of 20 X diluted amplification products with 200 µM dNTP and 5 ng of Cy5-labeled fluorescent E21 primer and 30 ng of Mse 16 primer. Products were loaded on Sequagel (Biozym) polyacrylamide gels and run on an ALFexpress automatic sequencer (Amersham).

Data analysis. Each isolate was classified based on its mtDNA haplotype. AFLP patterns were analysed with Imagemaster ID software (Amersham) with manual correction for faint bands and exclusion of controversial bands. Bands were treated as putative single AFLP loci and a binary matrix containing the presence or absence of these reproducible bands was constructed and used for further analysis.

Statistical analyses were conducted with TFPGA (Tools for Population Genetic Analyses, version 1.3). Gene diversity analysis was used to determine the distribution of diversity.

Heterozygosity and percent polymorphic loci (95% criterion) was estimated for each of the three populations. Cluster analysis of multilocus AFLP genotypes was based on allele frequencies observed for each population. A phenogram was constructed using the unweighted pair-group method of averages (UPGMA) algorithm from a Rogers' modified genetic distance matrix. Bootstrap sampling (1000 replicates) was performed for parsimony analysis of the constructed phenogram. Differentiation among populations was estimated using an exact test (Raymond & Rousset, 1995).

Results

A total of 58 A1 and 11 A2 mating type isolates were found present in the 69 Bavarian isolates collected in 1999 (Table 1). A1 mating type isolates were found evenly distributed over potato and tomato plants while only one A2 isolate was sampled from tomato (Table 1).

Table 1. Association between mating types and host plant species for 69 *P. infestans* isolates collected in Bavaria in 1999.

Mating type	Host plant		
	Potato	Tomato	Total
A1	37	21	58
A2	10	1	11
Total	47	22	69

All 69 Bavarian isolates were characterized as either haplotype IA or IIA based on the restriction fragments visualized after digestion of the amplified mtDNA regions (Table 2). Nine isolates were of the IIA haplotype. The 32 isolates originating from the Toluca Valley were of the IA haplotype and all eight African reference isolates showed restriction fragments typical for the 'old', asexually reproducing population with haplotype IB (Table 2).

Table 2. Characteristics of the African, Mexican and Bavarian *P. infestans* populations.

Population	AFLP analysis		mtDNA Haplotypes		
	No. of isolates	No. of genotypes	IB	IA	IIA
Africa	8	4	8	0	0

Mexico	32	26	0	32	0
Bavaria	52	30	0	60	9

No association for either mtDNA haplotype and mating type (Table 3) or host (Table 4) was found in the Bavarian population of *P. infestans*.

Table 3. Association between mtDNA haplotypes and mating types for 69 *P. infestans* isolates collected in Bavaria in 1999.

Haplotype	Mating type		
	A1	A2	Total
IA	51	9	60
IIA	7	2	9
Total	58	11	69

Table 4. Association between mtDNA haplotypes and host plant species for 69 *P. infestans* isolates collected in Bavaria in 1999.

Haplotype	Host plant		
	Potato	Tomato	Total
IA	**43**	**17**	60
IIA	**4**	**5**	9
Total	47	22	69

AFLP fingerprinting revealed 30 distinct *P. infestans* genotypes in 52 Bavarian isolates based on 112 putative dominant loci (Table 2). The percentage clonality (as presented by 100 x (1-(#AFLPgenotypes/#isolates)) was 42 % which was lower than observed in the African isolate sample (50 %) but higher compared to the clonality found among *P. infestans* isolates from Central Mexico (19 %).

Heterozygosity in *P. infestans* isolates varied considerably for the three populations studied (Figure 1). Observed percent heterozygosity was highest in the Mexican isolates (20 %), followed by Bavarian strains (16 %) and was lowest in the African isolates (10 %). The percent polymorphic loci varied from 56.5 to 19.4 for Mexican and African isolates respectively.

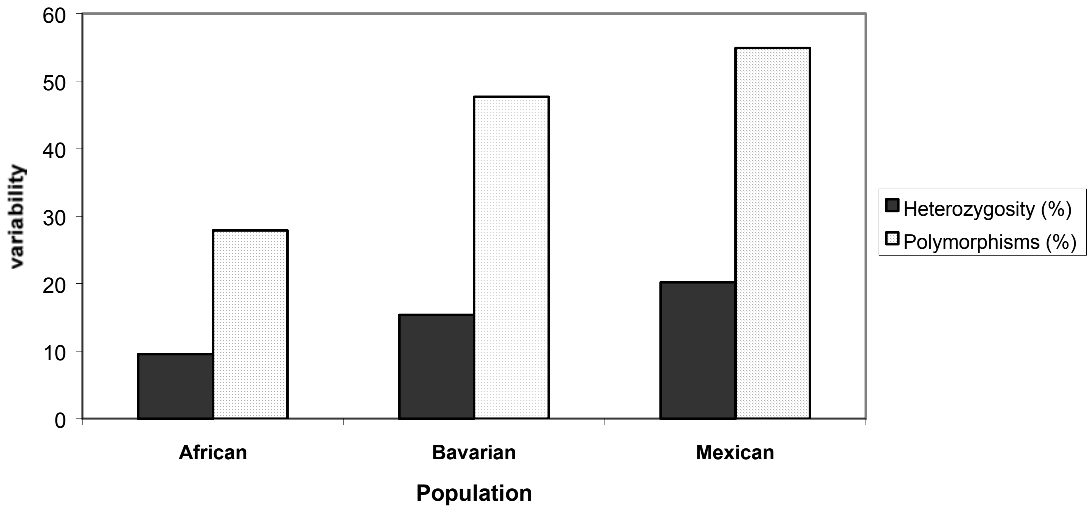

Figure 1. Genetic variation in African, Mexican and Bavarian populations of *P. infestans* as revealed by the percent heterozygosity and polymorphic loci based on the analysis of 121 AFLP loci.

The results based on the exact test for population differentiation indicates strong population sub-structuring between *P. infestans* populations originating from Mexico, Bavaria and Africa (Figure 2). χ^2 test statistic probabilities for pair-wise comparisons between the three populations led to the rejection of the null hypothesis of an absence of population differentiation ($P < 0.001$).

Discussion

The hypothesis that the old population of *P. infestans* is still predominant in Bavaria is to be rejected since mtDNA haplotype Ib was absent in the Bavarian *P. infestans* population in 1999. A substantial level of genetic variation was observed in the Bavarian population of *P. infestans* using mtDNA haplotyping and AFLP fingerprinting. The variation at the DNA level was smaller compared to that found for isolates originating from Toluca Valley, the presumed centre of diversity of the pathogen, but was much greater compared to the variation found in isolates from a clonal, asexually reproducing population.

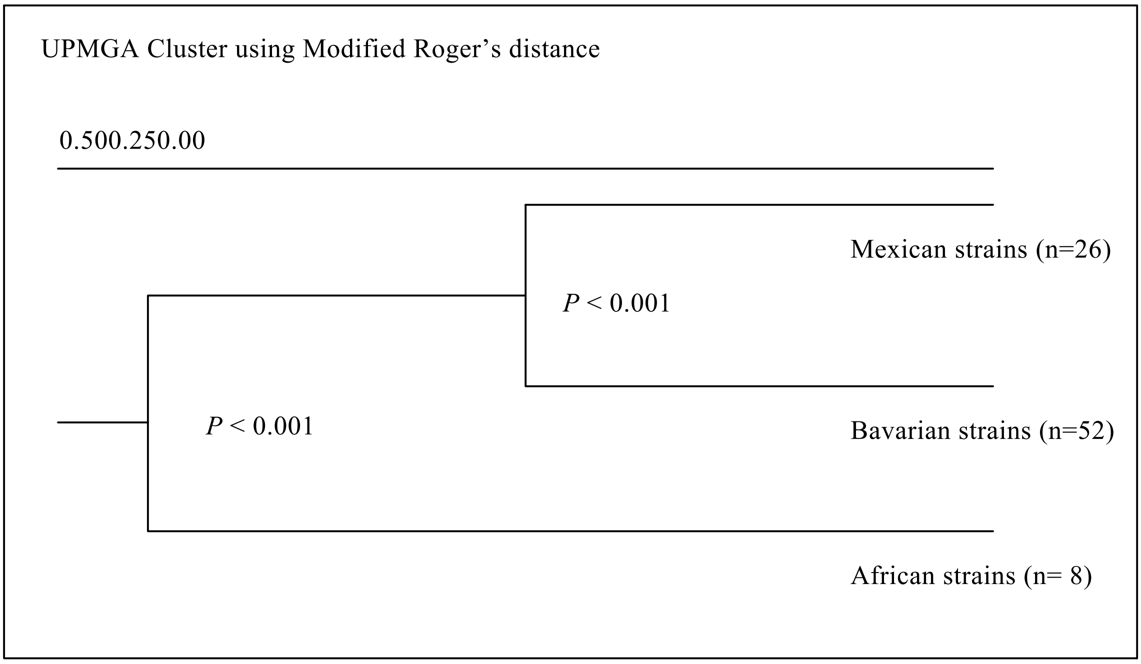

Figure 2. Phenogram based on UPGMA clustering of Rogers' modified genetic distances between the African, Mexican and Bavarian populations of *P. infestans*. Differentiation among populations was estimated using an exact test and significance levels are presented at the nodes.

Both A1 and A2 mating type strains were found present in the Bavarian population sampled in 1999. No indications were found that support the hypothesis that the old, clonal (US1) population is still present in Bavaria. We have demonstrated that the Bavarian *P. infestans* population shows characteristics that are typical for sexual reproducing populations as found in Central Mexico (Goodwin *et al*., 1992) and Western Europe (Fry *et al*., 1991b; Drenth *et al*., 1994; Brurberg *et al*., 1999). We therefore conclude that the old population has been displaced by a new *P. infestans* population.

The presence of both mating types implies that sexual reproduction of *P. infestans* may occur in field crops and that the formation of oospores is to be expected. The presence of functional oospores can have important implications for the control of late blight. It has been shown (Flier and Turkensteen, 2000) that oospores can survive up to 4 years under field conditions in the Netherlands. Oospores serve as an alternative source of inoculum, which might be able to infect potato plants throughout the growing season. In addition, oospores can maintain genetic variability found in field populations of the pathogen and are able to compensate for loss of genetic variation due to random-drift and bottle-necks during the crop-free period experienced by asexually reproducing *P. infestans* populations.

The introduction of new populations in Western Europe has been associated with an observed increase in pathogenicity of the pathogen (Day & Shattock, 1997; Flier *et al.*, 1998; Flier and Turkensteen, 1999). The presence of complex races and more aggressive *P. infestans* strains have a deteriorating effect on (R-gene based) late blight resistance (Turkensteen, 1989), fungicide efficacy and control strategies based on models validated for the old, displaced *P. infestans* population. The presence of a variable population of *P. infestans* in Bavaria urges for a critical evaluation and updating of late blight management strategies in the region.

Acknowledgements

The authors thank the Bavarian potato growers for their co-operation. We thank Laurens Kroon and Trudy van den Bosch for their excellent technical support. Students of the TU Műnchen-Weihenstephan are thanked for providing technical support. The Dutch Ministry of Agriculture supported this work.

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Control of potato tuber blight (*Phytophthora infestans*) in the UK with zoxium/mancozeb mixtures

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Summary
Field experiments to investigate the control of tuber blight with zoxium/mancozeb mixtures compared with fluazinam and fentin fungicides were conducted in 1997, 1998 and 1999. These three years were very favourable for foliar and tuber blight. Differences in tuber blight incidence between fungicide programmes were generally not statistically significant but the following trends were apparent. When fungicide programmes were finished with 1.8 kg of RH7281*mz tuber blight control was similar to that achieved with Brestan. Programmes completed with 0.3 litres of Shirlan gave better control than 1.8 kg RH7281*mz in two out of the three trials. In the two years the comparison was made, programmes finished with 0.4 litres of Shirlan resulted in less tuber blight than those completed with 1.8 kg of RH7281*mz. The control of tuber blight was not always consistent with the dose of either RH7281*mz or Shirlan and was sometimes confounded by the severity of foliar blight. The new chemistry from Rohm & Haas offers a very useful addition to the limited number of fungicides available to control this important aspect of late blight.

Key words: late blight, fungicides, fluazinam, fentin acetate

Introduction

All blight fungicides control tuber blight to a degree through their effect on the development of the foliar epidemic. However, some fungicides are recognised as the most effective. Phenylamide fungicides in mixture give very good protection of progeny tubers provided the proportion of insensitivity in the *P. infestans* population is low. In the UK the general recommendation for phenylamide mixtures is one to three applications during the period of rapid haulm growth. Apart from the phenylamides, the fentin fungicides (Bain and Holmes, 1990) and fluazinam are considered to be most effective in protecting progeny tubers (Schepers and van Soesbergen, 1995). In the UK fentin fungicides are normally recommended for the final two or three applications in the fungicide programme. For the control of tuber blight, fluazinam is normally recommended from the end of rapid haulm growth until the end of the season. In seasons in which the risk of tuber blight is early and high, fentin fungicides and fluazinam are frequently applied early in reduced rate fungicide mixtures. One objective of the experiments reported in this paper was to investigate the control of tuber blight obtained with the novel Rohm & Haas fungicide zoxium in mixture with mancozeb (RH7281*mz) compared with Shirlan (fluazinam) and Brestan (fentin acetate + maneb). The general approach was to apply straight mancozeb at intervals to allow the controlled development of a foliar epidemic before switching to the tuber blight control fungicides.

Materials and methods

The field experiments were made over 3 years. The cultivar King Edward, which is very susceptible to foliar and tuber blight, was used throughout and the experiments were conducted in South Ayrshire on the west coast of Scotland. The experimental design was a randomised complete block with four replicate plots. Each plot consisted of four drills containing a total of 100 plants. Fungicide treatments were applied in 300 l of water per hectare. Flat fan spray tips and a spray pressure of 2.8 bars gave a medium/fine spray quality. The plots were artificially inoculated with a mixture of several *P. infestans* isolates (including phenylamide-insensitive isolates) obtained recently from UK potato crops. Inoculation took place shortly after the first or second fungicide application. The percentage of foliage destroyed by blight was assessed using a modified version of a widely used key (Anon, 1947). Foliar blight was assessed regularly from its first occurrence until the trials were desiccated with diquat (Reglone) at 800 g ai/ha. Tuber blight was assessed before and after a minimum storage period of 8 weeks by external inspection of a random sample of 50 or 60 washed tubers per plot. The results presented are the total incidence of tuber blight.

Table 1. Fungicides

Fungicide	Active ingredient(s)	g of a.i. ha[1]
Dithane DF	mancozeb	1275
Dithane DG	mancozeb	1275
RH 7281*mz	zoxamide + mancozeb	125 + 1000 or
		150 + 1200
Brestan 60	fentin acetate + maneb	270 + 80
Shirlan	fluazinam	150 or 200

Results

1997

Spray dates were disrupted by weather unsuitable for spraying. The very high incidence of tuber blight probably masked differences between the fungicide programmes. The lowest incidence was in the untreated. Some programmes gave significantly more tuber blight than the untreated but there were no significant differences between the fungicide programmes.

Programmes 2 to 5

Of these four programmes, only that with four final applications of RH7281*mz gave significantly more tuber blight than the untreated, reflecting the poor control of foliar blight achieved with this programme. The application of RH7281*mz throughout the season gave good control of foliar blight but tuber blight control did not reflect this (Table 2). Four applications of 0.4 l of Shirlan gave slightly better control of both tuber and foliar blight than the higher rate of RH7281*mz.

Programmes 6 to 8

Of these three programmes, only that with three sprays of RH7281*mz did not give significantly poorer control of tuber blight than the untreated. This result reflected foliar disease control. The RH7281*mz programme resulted in slightly better control of foliar and tuber blight than 0.3 l of Shirlan.

Table 2. Total incidence (%) of tuber blight and severity (%) of foliar blight at the end of the growing season in relation to fungicide treatment, 1997.

Fungicide treatment	Rate (kg or l /ha)	Interval (days)	% foliar blight on 25 Sep	% tuber blight
1. Untreated	-	-	100.0	45.3
2. Dithane DF (5 sprays)	1.7	10.4		
then RH7281*mz (4 sprays)	1.8	9.3	60.0	66.2
3. Dithane DF (5 sprays)	1.7	10.4		
then Shirlan (4 sprays)	0.4	9.3	46.2	54.4
4. RH7281*mz (5 sprays)	1.5	10.4		
then RH7281*mz (4 sprays)	1.5	9.3	36.2	61.0
5. RH7281*mz (5 sprays)	1.8	10.4		
then RH7281*mz (4 sprays)	1.8	9.3	37.5	59.6
6. Dithane DF (5 sprays)	1.7	11.0		
then Dithane DF (3 sprays)	1.7	10.5	71.2	73.1
7. Dithane DF (5 sprays)	1.7	11.0		
then RH7281*mz (3 sprays)	1.8	10.5	52.5	59.6
8. Dithane DF (5 sprays)	1.7	11.0		
then Shirlan (3 sprays)	0.3	10.5	57.5	66.9
SED (21 df)			11.04	7.76

1998

The incidence of tuber blight was high in 1998. The highest incidence occurred in the untreated but only Dithane DG followed by Shirlan 0.3 l gave significantly less tuber blight (Table 3). When applied for the final three applications RH7281*mz gave similar, but slightly poorer, control of tuber blight to the Shirlan and Brestan 60 standards. The best control of foliar blight was achieved with the season-long Shirlan and RH7281*mz 1.8 kg programmes. The final severity of foliar blight was significantly less for these two programmes than all the others. As in 1997, good control of foliar blight was not reflected in substantially better tuber blight control.

Table 3. Total incidence (%) of tuber blight and severity (%) of foliar blight at the end of the growing season in relation to fungicide treatment, 1998.

Fungicide treatment	Rate (kg or l /ha)	Interval (days)	% foliar blight on 3 Sep	% tuber blight
1. Untreated	-	-	100.0	29.3
2. Dithane DG	1.70	9.7		
then RH7281*mz	1.50	7.0	82.5	23.6
3. Dithane DG	1.70	9.7		
then RH7281*mz	1.80	7.0	87.5	23.0
4. Dithane DG	1.70	9.7		
then Brestan 60	0.50	7.0	78.7	21.2
5. Dithane DG	1.70	9.7		
then Shirlan	0.40	7.0	83.7	19.8
6. Dithane DG	1.70	9.7		
then Dithane DG	1.70	7.0	82.5	26.3
7. RH7281*mz	1.80	9.7		
then RH7281*mz	1.80	7.0	46.2	17.1
8. RH7281*mz	1.50	9.7		
then RH7281*mz	1.50	7.0	72.5	20.2
9. Dithane DG	1.70	9.7		
then Shirlan	0.30	7.0	86.2	15.4
10. Shirlan	0.30	9.7		
then Shirlan	0.30	7.0	41.2	18.9
SED (27 df)			7.10	6.42

Seven sprays of fungicide 1 and three sprays of fungicide 2.

1999

The incidence of tuber blight was moderate to high. The lowest incidence of tuber blight was in the untreated (Table 4). Three programmes resulted in significantly more tuber blight than the untreated, i.e. Dithane followed by RH7281*mz 1.5 kg (7 sprays), Dithane followed by Brestan and Dithane followed by RH7281*mz 1.8 (6 sprays). Seven final applications of the higher rate of RH7281*mz resulted in significantly less tuber blight than the 1.5 kg rate. Six final sprays of 1.5 kg of RH7281*mz gave significantly better control than the same number of Brestan sprays and similar control to Shirlan 0.3 l. However, the results were not entirely consistent. Poorer control was given by the same number of sprays of the higher, compared with the lower, rate of the Rohm & Haas coded fungicide, but the difference was not significant.

Table 4. Total incidence (%) of tuber blight and severity (%) of foliar blight at the end of the growing season in relation to fungicide treatment, 1999.

Fungicide treatment	Rate (kg or l /ha)	Interval (days)	% foliar blight on 13 Sep	% tuber blight
1. Untreated	-	-	99.2	2.3
2. RH7281*mz (12 sprays)	1.80	7.1	4.2	4.1
3. Dithane DF (3 sprays)	1.70	11.0		
then RH7281*mz (7 sprays)	1.50	7.5	17.8	22.6
4. Dithane DF (3 sprays)	1.70	11.0		
then RH7281*mz (7 sprays)	1.80	7.5	13.5	10.6
5. Dithane DF (4 sprays) then	1.70	10.5		
RH7281*mz (6 sprays)	1.50	7.2	20.8	6.2
6. Dithane DF (4 sprays) then	1.70	10.5		
RH7281*mz (6 sprays)	1.80	7.2	8.5	15.8
7. Dithane DF (4 sprays) then	1.70	10.5		
Brestan (6 sprays)	0.5	7.2	18.0	16.8
8. Dithane DF (4 sprays) then	1.70	10.5		
Shirlan (6 sprays)	0.30	7.2	10.3	9.1
SED (27 df)			7.99	4.99

Conclusions and discussion

Two rates of RH7281*mz and Shirlan were evaluated in the trials. Once approved, the zoxium mixture will be marketed in the UK at the 1.8 kg/ha rate (Edmonds, unpublished). The maximum UK label rate for Shirlan is 0.3 l/ha. Differences between fungicide programmes were generally not statistically significant. However, the following trends were apparent. When fungicide programmes were finished with 1.8 kg of RH7281*mz tuber blight control was similar to that achieved with Brestan. Programmes finished with 0.3 litres of Shirlan gave better control than 1.8 kg RH7281*mz in two out of the three trials. In the two years the comparison was made, programmes finished with 0.4 litres of Shirlan resulted in less tuber blight than those completed with 1.8 kg of RH7281*mz.

Good protection of progeny tubers requires an effective fungicide to be applied prior to high risk conditions for tuber infection. The effectiveness of two or three applications of a tuber blight fungicide at the end of the programme in seasons in which the risk of tuber infection is early has been questioned. This is particularly the case for cultivars that are very susceptible to tuber blight. The results from these trials suggest that the earlier in the season that the RH7281*mz applications commence the better the control of tuber blight. Mixtures of zoxium and mancozeb are therefore more likely to give optimum control of tuber blight when used from the end of rapid haulm growth, as Shirlan frequently is, rather than for the final two or three sprays in a fungicide programme.

Fungicides reduce tuber infection by limiting the viability of zoospores that come into contact with progeny tubers. They also reduce the incidence of tuber blight by limiting the development of foliar blight and therefore the numbers of zoospores available to infect progeny tubers. It has been demonstrated that zoxium inhibits the formation of zoospores within sporangia and that treated sporangia do not release zoospores, whereas zoospores treated with zoxium remain unaffected (Young, unpublished). The relationship between foliar and tuber blight can be complex (Bain *et al*., 2000) and in these trials the interpretation of results was sometimes hampered by differences in the severity of foliar blight for different fungicide programmes.

The number of fungicides that specifically offer good control of tuber blight is very limited compared with the range available for foliar blight control. The new chemistry from Rohm & Haas offers a very useful addition to the fungicides available to control this important aspect of late blight.

Acknowledgements
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Field experiments with seed treatment against late blight

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Summary

The impact of seed tuber treatments on *Phytophthora infestans*-infections in potato fields was studied. For this purpose seed tubers were inoculated with zoospores of Phenylamid-sensitive isolates of *Phytophthora infestans* and dressed with different fungicide solutions before planting a field with the seed tubers. Assessments were made weekly in order to look at the occurrence and the spread of the fungus within the differently treated variants.

Keywords

Phytophthora infestans, late blight, primary inoculum sources, fungicide, tuber dressing

Previous story

During our research work in the last three years we made experiments in order to look for the main inoculum source of *Phytophthora infestans* in potato fields.
The examination of stored potato tubers by aid of the PCR method (according to a method of Tooley *et al*., 1997) should have brought out the real infection frequency in seed tubers. The tubers had been stored during the winter and then the whole tuber was washed, freeze dried and crushed with mortar and pestil before the DNA was extracted.
The results of the analysis are shown in table 1.
It should be remarked, that a high frequency of not visible but latent infected tubers could be detected by aid of the PCR method. The number of latent infected tubers is not correlated with the number of visible infected, also there is no correlation of the latent infection among plants of the same cultivar harvested from different fields. That means

that there is no controllable release of inoculum in the form of latently infected seed potatoes every year.

Table 1. The frequency of latent infection in tubers from common fields after storage (8-12 month) in 1997 and 1998.

		number of examined tubers	visible infected	latent infected detect by PCR
1997				
	Amigo 1	118	3.4 %	**8.5 %**
	Amigo 2	124	0.8 %	**0.0 %**
	Agria 1	150	1.3 %	**2.7 %**
	Agria 2	110	7.2 %	**10.0 %**
	Producent	110	10.9 %	**8.2 %**
	Florijn	101	1.9 %	**1.9 %**
	Maxilla	86	3.4 %	**2.3 %**
1998				
	Amigo	123	0,0 %	**1,6 %**
	Agria	100	0,0 %	**5,0 %**
	Cilena 1	100	0,0 %	**9,0 %**
	Cilena 2	106	4,7 %	**12,3 %**

In order to look for the way of infection, potato plants were examinated that were found as first visible inoculum sources in common fields. The whole plant was collected, desinfected with 5 M sodiumhyperchloride for 2h and then frozen. The frozen stem was cut into pieces of 1 cm length from the stem base up to the shoot apex and homogenized before the DNA and proteins were extracted. The results of the examination of the stems are shown in fig. 1.

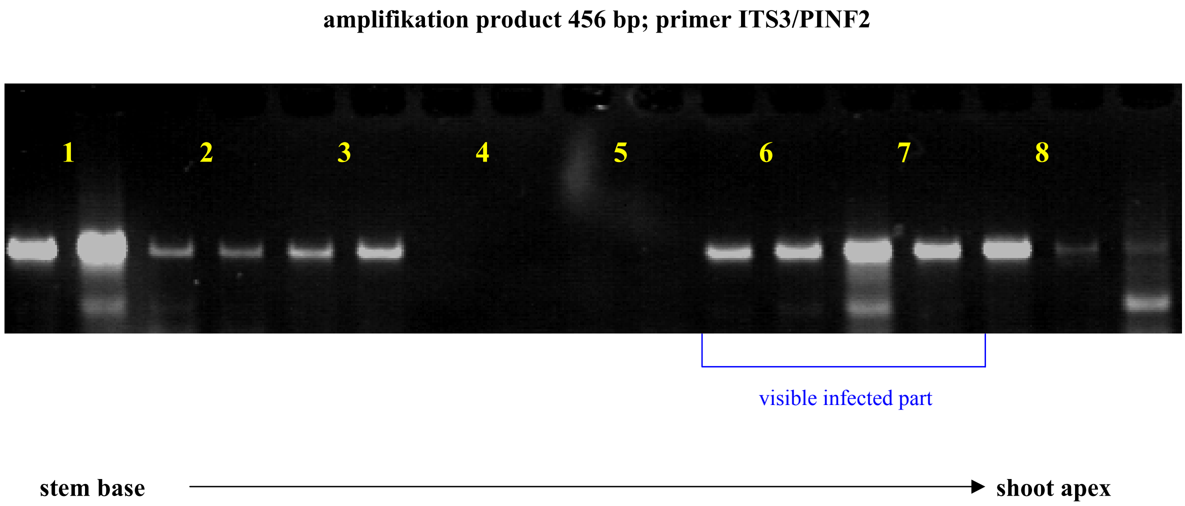

Figure 1. PCR examinations of a stem infected with *Phytophthora infestans* (first inoculum source in a field; cultivar: *Treff*).

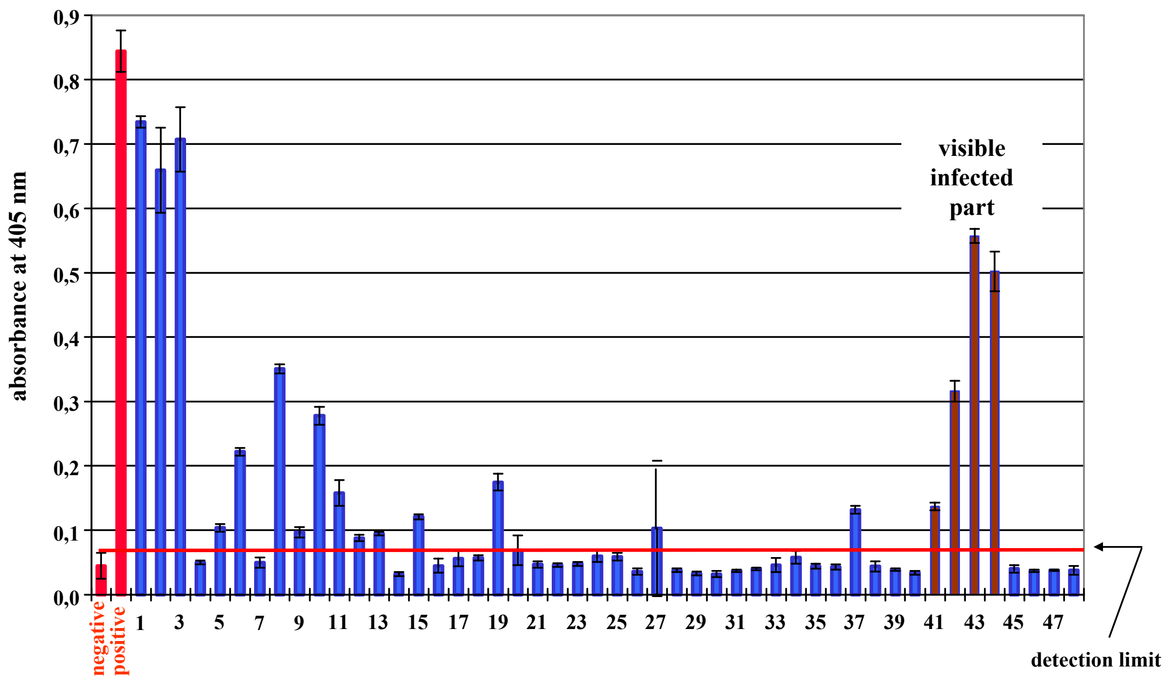

Figure 2. ELISA examination of a stem with blight disease (initial infestation in the field; cultivar Linda.

The PCR analysis gave a positive response in the first few parts of the stem base while in the middle region no DNA of *Phytophthora infestans* could be detected. Only in the visible infected part a positive signal could be detected again. In an ELISA performance of a visible infected stem of cultivar Linda nearly the same situation could be observed.

Samples of the stem base showed an absorbance, that was high above the detection limit. From the base to the middle of the stem the absorbance decreased below the detection limit. A steady rise was observed again in the visible infected part of the stem (fig. 2). Examinations of other primary visible infected stems brought out nearly the same results (Adler *et al*., 1999). These analyses point up, that the fungus has the possibility to put up in stems during the length growth of the plant. To proof the received results an experiment was made with artificially infected tubers in a glasshouse during winter (Appel *et al*., 2000)

200 artificially infected tubers (1000 zoospores per ml) of cultivar Agria were planted in pots 15 days after inoculation. At four different growth stages samples were taken from 50 plants.

The DNA was extracted and the samples investigated by aid of the PCR method.

The first samples were taken from the light sprouts before the planting. Also samples were taken from the dark sprouts 9 d, 20 d and 32 d after planting. A mixture was made out of the extracted sprouts each date of sampling. The examination with the PCR method showed the results seen in figure 3. In many plants *Phytophthora infestans* could be detected, particularly in the first growth stage. Least was found in the growth stage 3, which means, that in the stem base the fungus can be present but that must not suppose that it exists in the upper parts of the stem. Consequently there is a dilution of mycelium during the length growth of the stem, which means that there is not an active growth of the fungus in stems.

Also mycelium of *Phytophthora infestans* could be found on some of the planted artificially infected tubers. Sporangiophores with sporangia could be seen under the microscope on the tuber surface. Transport of inoculum in the form of sporangia or zoospores through the soil might also be possible.

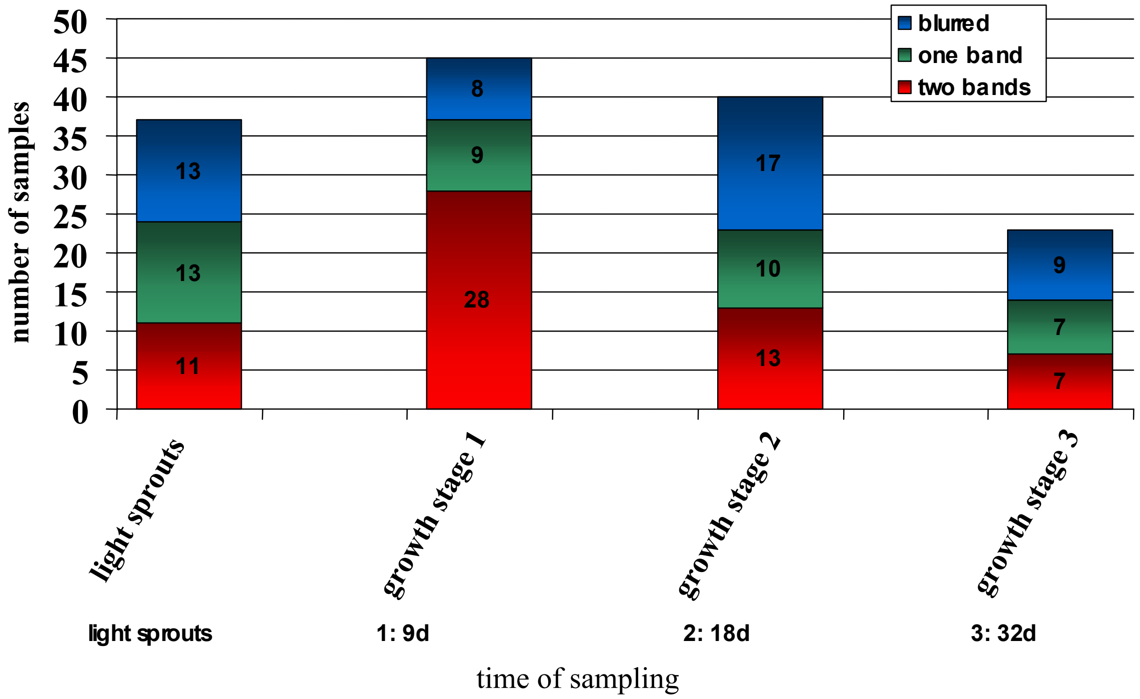

Figure 3. PCR-Detection of *Phytophthora infestans* in different growth stages of artificially infected potato plants (devided for the quality of signal).

Because of the high frequency of latent infected tubers after the storage during winter, the farmers are planting the sources of primary inoculum into the fields. Those sources of inoculum are uncontrollable.

In the year 2000 we decided to look for possibilities to reduce the inoculum sources in potato fields and to delay the date of the outbreak of late blight.

Material and methods

We planted seed tubers of the cultivar Agria. They were artificially infected with the isolates *Dür* and *S41* (both are phenylamide sensitive) with 1000 zoospores per ml. The injection happened by a syringe. After inoculation the tubers were stored in a climate chamber at 15°C for 14 days with a 12h light and 12h dark period. 18 experimental variants existed with 3 replications each. The size of each plot was 3m x 5m, so that the number of tubers in each plot amounted to be 84. The date of plantation was the 2nd of May. Directly before planting the tubers were dressed with different fungicide solutions. The concentrations of the fungicide dressing solutions were suited to the concentrations for spraying treatments. The following fungicides were used: Cymoxanil® (10g/l), Dimetomorph® (1000g a.i./ha), Acrobat Plus® (3 kg/ha), Ridomil Gold MZ® and an experimental compound.

For that procedure, the tubers were heated up to room temperature and afterwards dipped (1-2 minutes) in a solution of the different compounds and products that were mixed with water. After the emergence of the plants no additional fungicide treatment was made. Plant assessment happened weekly.

Results and discussion

At the 1st of July the first infection of *Phytophthora infestans* was found on a stem in an inoculated but untreated control plot. From the middle of July until the beginning of August the weather conditions were optimal for the development of the *Phytophthora infestans* epidemic (fig. 4).

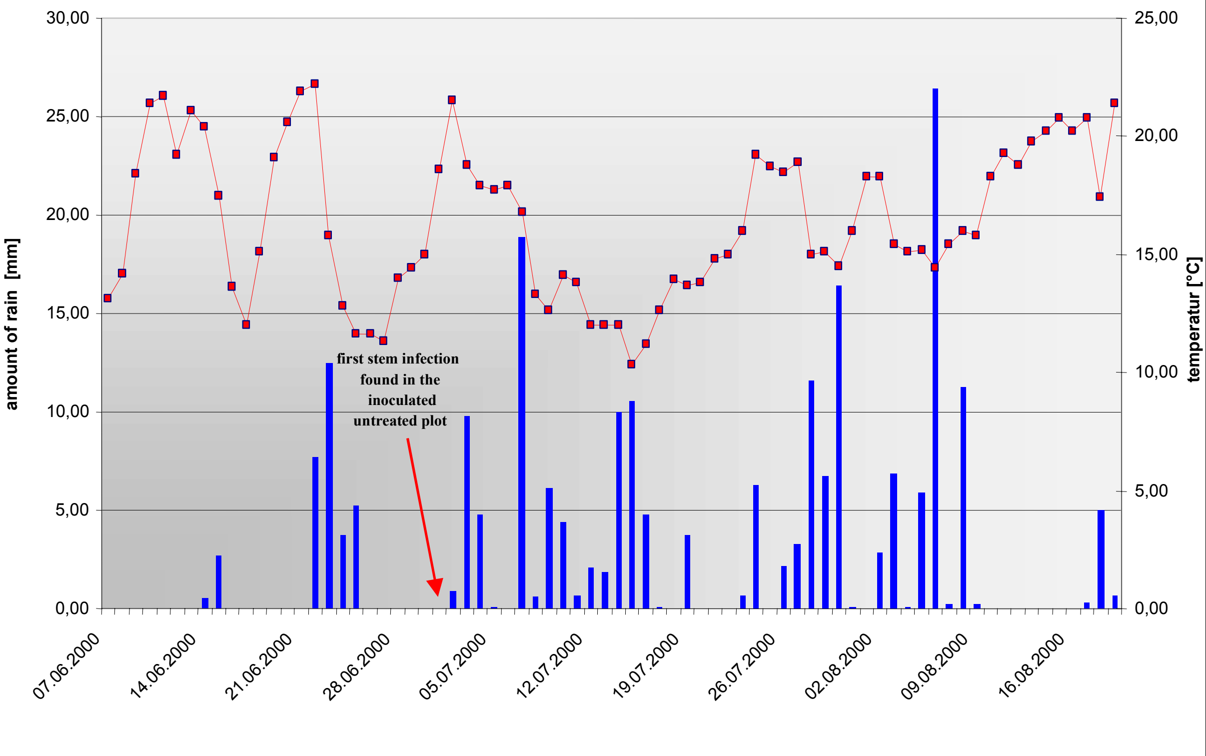

Figure 4. Weather conditions in Scheyern in the year 2000.

The development of the disease in the leaves of untreated variants is shown in fig. 5.

The disease spread fast after the first outbreak in the inoculated untreated control plot without dressing, as well as in the not inoculated control plot without dressing. But in this variant the disease development was prolonged.

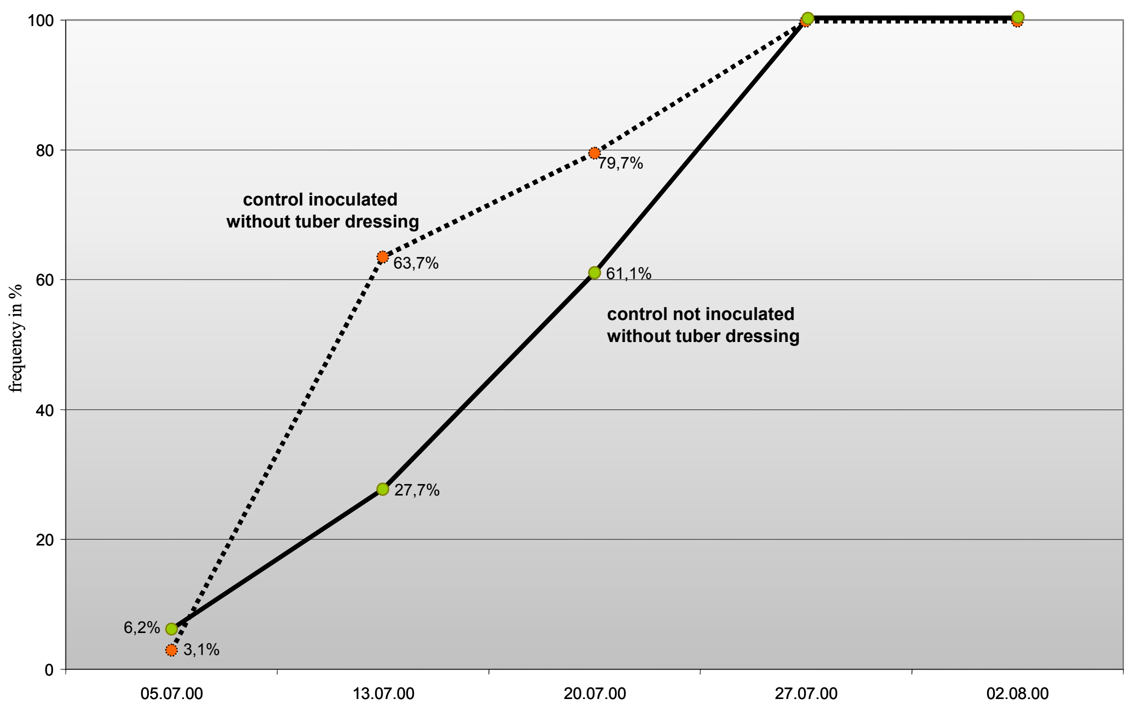

Figure 5. Disease frequency of *Phytophthora infestans* on the leaves of the variants without tuber dressing (cultivar Agria).

The same situation could be found by comparing the inoculated untreated variant without dressing with the inoculated but coated variants.

The disease frequency on the leaves of the coated variants was not as high as the frequency of the inoculated untreated (fig. 6). The Ridomil Gold MZ® coated variant was the most healthy variant until the 27th of July by regarding the disease situation on the leaves of the plants.

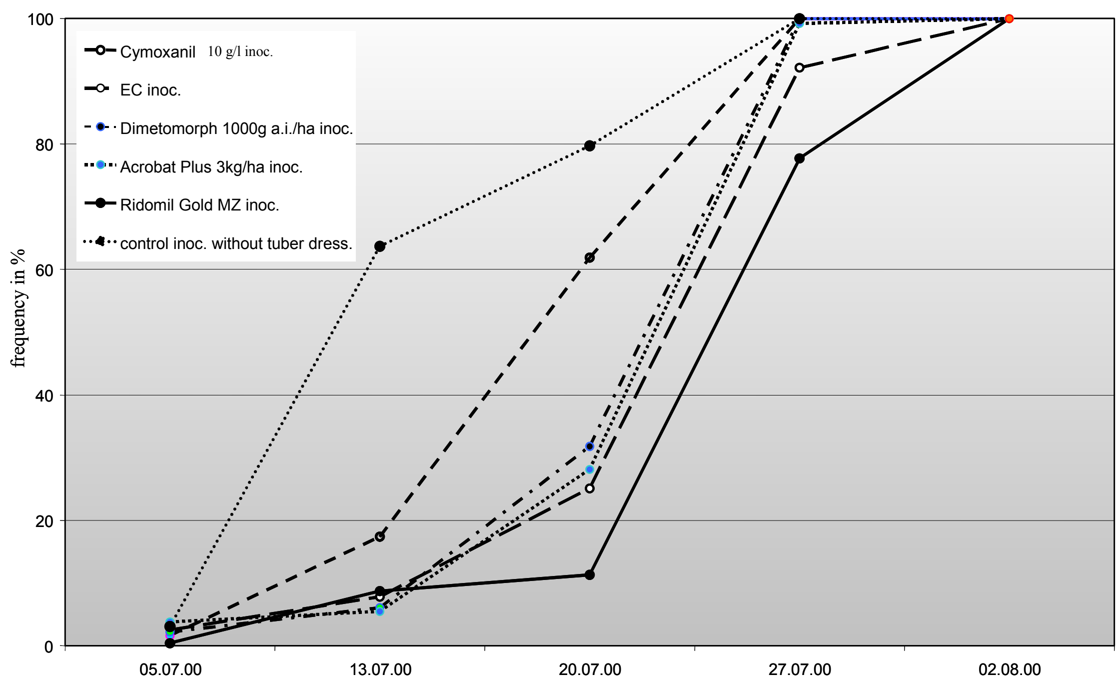

Figure 6. Disease frequency of *Phytophthora infestans* on the <u>leaves</u> of the artificially infected and coated variants (cultivar, Agria).

A greater distinction could be observed in the infection frequency of the stems of the ifferent variants.

A delay of the outbreak of *Phytophthora infestans* on the stems could be observed in the not inoculated variant without tuber dressing in comparison to the inoculated variant without tuber dressing (fig. 7).

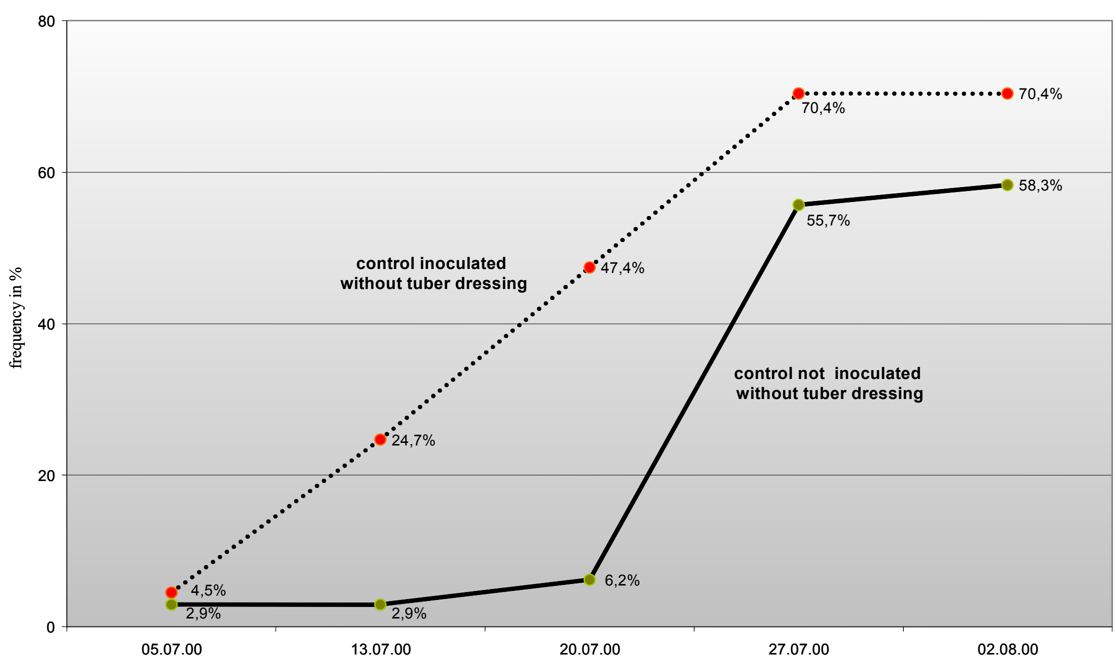

Figure 7. Disease frequency of *Phytophthora infestans* on the stems of the variants without tuber dressing (cultivar Agria).

Also in the inoculated but tuber dressed variants a delay of 2 weeks of the outbreak could be proved.

After the outbreak of the disease the spread on the stems was lower than in the inoculated variant without tuber dressing (fig. 8).

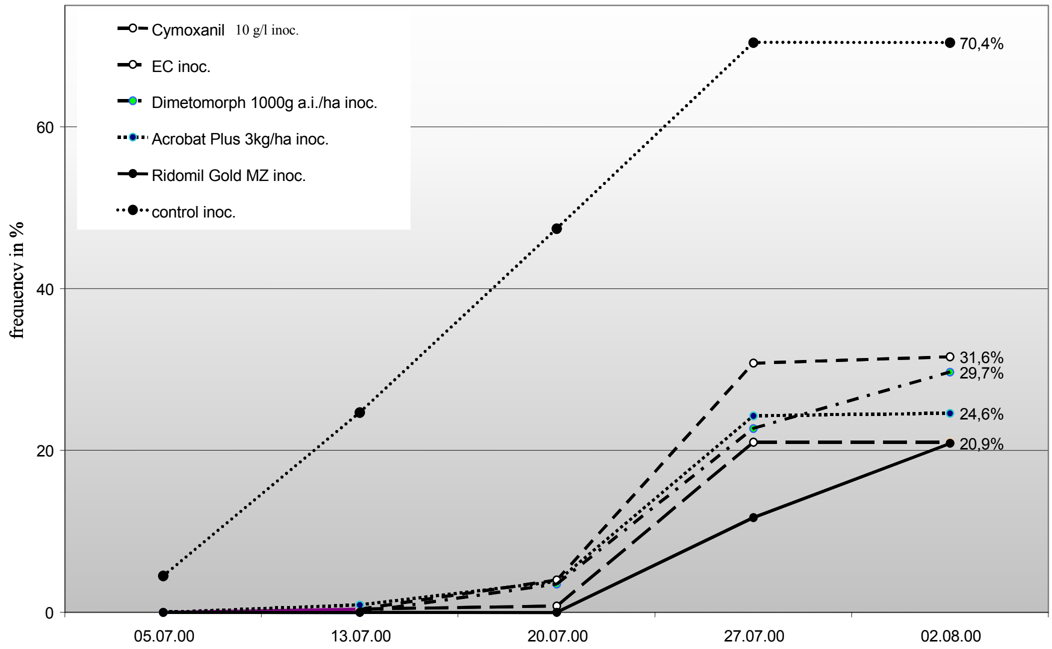

Figure 8. Disease frequency of *Phytophthora infestans* on the stems of the artificially infected and coated variants (cultivar, Agria).

In spite of the single treatment in the form of a tuber dressing, the yield in the different variants was different but could not guaranteed statistically (fig. 9). Least yield could be harvested in the inoculated not seed tuber dressed variant. Most of the dressed variants had the same or more yield than the not inoculated variant without seed tuber dressing.

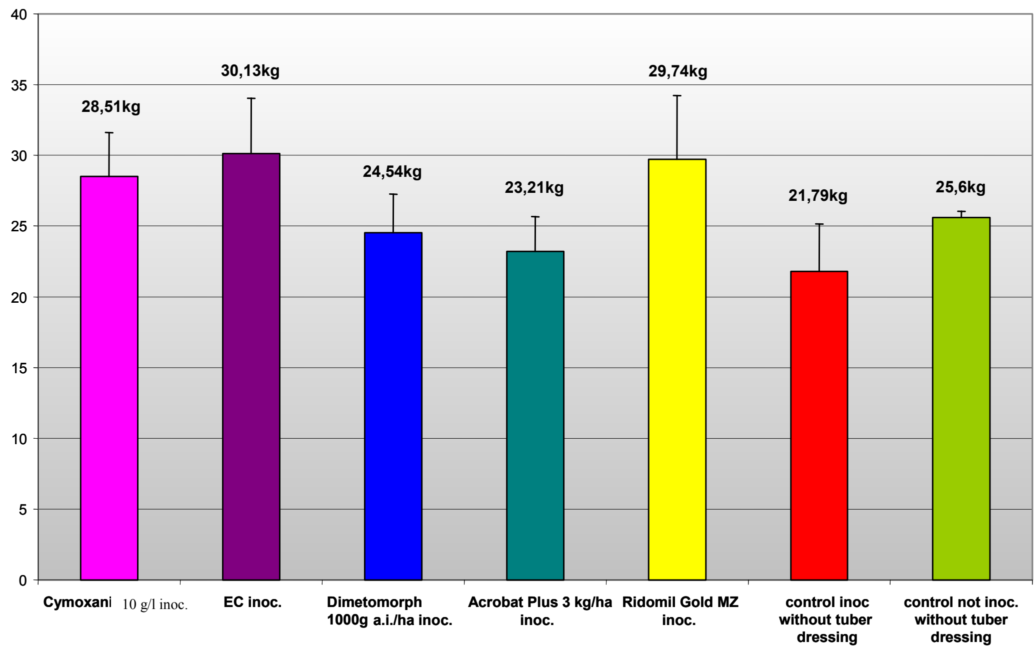

Figure 9. The yield of the seed treated variants in kg.

The results show that seed tuber dressing can be an alternative treatment before the planting to delay the outbreak of late blight during a season, it is maybe also a solution to reduce the primary inoculum in potato fields. The technique of application and the quantity of fungicides have to optimised in further experiments.

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Fifth Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Munich, Germany, 6-10 September 2000

The Influence of serial systemic and translaminar spraying regime on development and epidemics of *Phytophthora infestans*

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Summary

In 2000 a trial was set up with artificial inoculated potato seed to compare the impact of serial systemic and translaminar fungicide treatment against *Phytophthora infestans.* The disease development was monitored during the vegetation and affection of stems and leafs was assessed. Additional to the infestation with the pathogen also the realized tuber yield was recorded.

Keywords

Phytophthora infestans, late blight, fungicide, trials

Introduction

Based on the fact, that *Phytophthora infestans* resides latently in seed potatoes [ZAAG, 1956] and also can be found in stems and leaves before outbreak [ADLER, 1998] it supports the question, up to what extend it is possible to control the first outbreak and epidemics with systemic and translaminar fungicides.

In practice it has proved, that the advised spraystart against *Phytophthora infestans* with systemic or even "lokosystemic" agents leads to the best advantage.

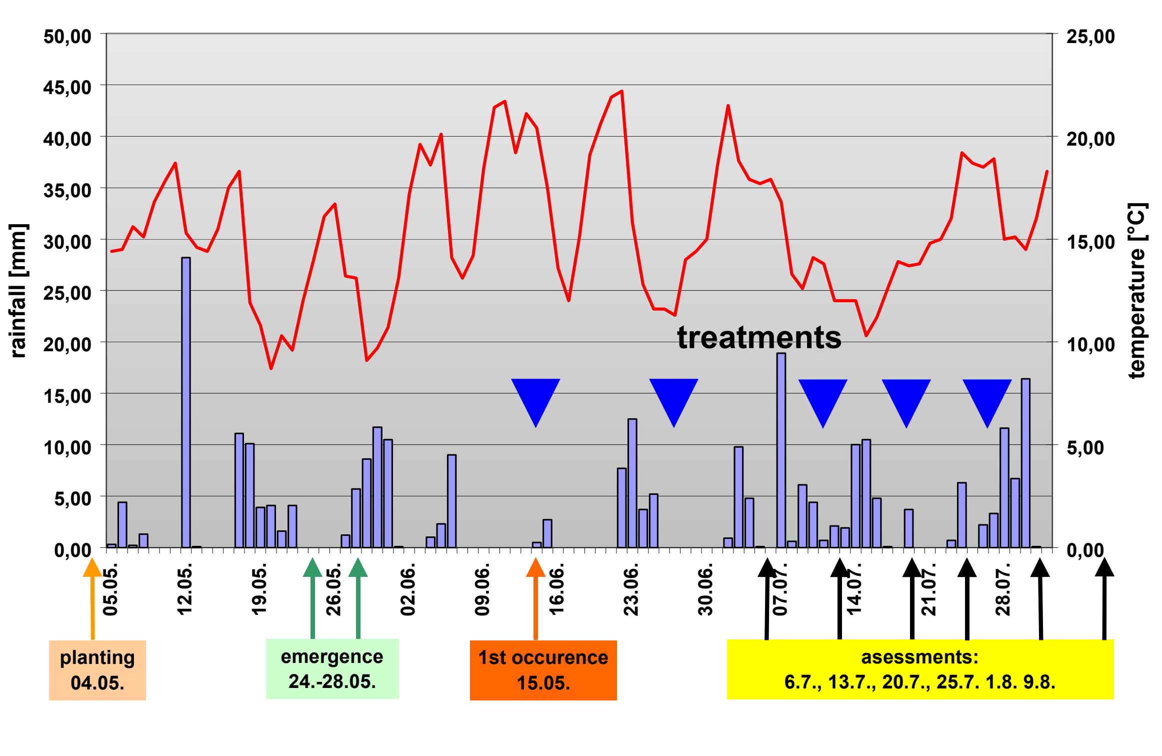

Figure 1. Weatherdata, treatments and first occurrence of *Phytophthora infestans*.

But to get better information about the performance of the agents, a field trial was set up where common available fungicides were tested on potato plants, grown from artificially infected seed.

Material and Methods

a) Inoculation

14 days before planting 1300 Tubers of cv. AGRIA have been inoculated with 100-200 zoospores of phenylamide-sensitive Isolates (Dür & M69) and put in a climate chamber where they were stored at 16°C until planting [APPEL *et al*., 2000].

b) experimental design:

Four fungicides were taken and tested in the trial (table1). So together with the inoculated control the field experiment had five variants in three replications. Each of the plots had four rows with 21 inoculated tubers. The plots were divided within the row by three plants of cv. DESIREE. Between the plots two rows of healthy seed (cv. AGRIA) were planted. Additional to the inoculated plots in the trial also a neighboured healthy control was evaluated ("external control").

Table 1. Fungicide treatments.

Number	*fungicide variant*	**amount**
external	control (healthy)	
1	**control(inoculated)**	
2	**ACROBAT Plus WG®**	2 kg/ ha
3	**TATTOO ®**	4 l/ha
4	**RIDOMIL MZ Gold ®**	2 kg/ ha
5	**CILUAN ®**	2 kg/ ha

The trial was planted in the beginning of May and potatoes emerged very uniformly between 24th and 28th of May. The first symptom on a single potato plant occurred on June the 15th. This happend incidental at the same day when the **Phytophthora Model Weihenstephan** recommended the first spray. Also the following spraying intervals were supposed by this DSS. According to the experimental question of testing the fungicide "performance", spraying intervals have been prolonged up to the maximum value (table 2).

Table 2: spraying treatments and intervals.

treatment	date	spraying interval
spray-start: 1st	**15-06**	
2nd	**27-06**	12 d
3rd	**11-07**	14 d
4th	**19-07**	8 d
5th	**27-07**	8 d
6th	**10-08**	13d
7th	**19-08**	9d

Results & Discussion

After potatoes emerged, they were controlled daily for the first symptoms of *Phytophthora infestans*. Although first symptoms occured at the 15th of June, an appreciable epidemic began not until July 6th. From this date on the weekly assessments of leaf- and stem-blight showed the outbreak in the untreated variant. Within one week visible symptoms, caused by the pathogen in the untreated plot raised up on leafs (figure 3) from 2% to 95% and on stems from 8% to almost 50% (figure 2).

The external control plots with healthy seed was also infected heavily. Disease outbreak on stems as well as on leafs took place with two weeks delay, compared to the artificially infected seed. In fact this is the evidence for the good success of inoculation. In consequence this also means, that the population what was formed, had its origin from the infected tubers. Another indication for this assertion is, that RIDOMIL MZ Gold ® attained best protection on leaf- and stem-blight, depending to the fact, that we used Phenylamide-sensitive isolates for inoculation.

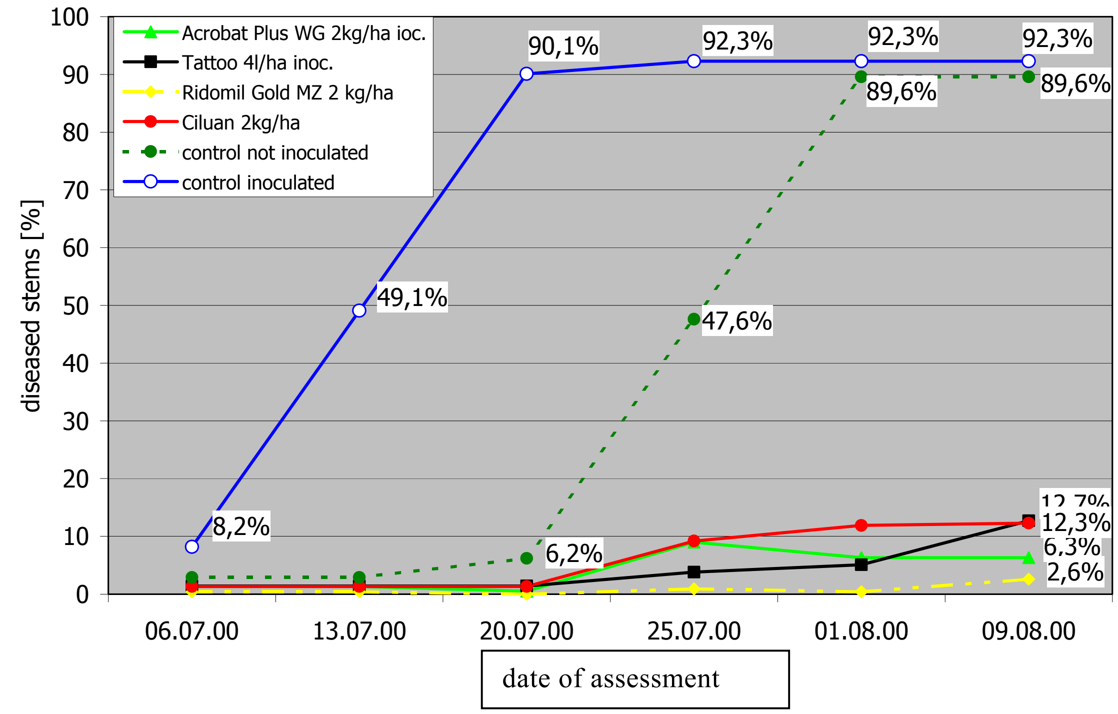

Figure 2. Development of stem-blight.

Considering the initial-hypothesis it means, that Ridomil has the best systemic properties with nearly eradicant impact on infestation. This instance would favour the use of RIDOMIL ®, but because of well-known problems with phenylamide resistance it can be recommended for practical use only with strong restrictions. In Practice this agent is still used as "spray-start fungicide". Evidently its good impact against *P. infestans* can be maintained by an adapted resistance management [Gisi *et al.*, 1995, Dowley, 1999].
The high disease suppressing level of Metalaxyl was not reached by TATTOO®. Though this agent is considered as systemic fungicide, it could not perform significant better impact on the development of blight as ACROBAT Plus ®. The effect on leaf blight is nearly on the same level, but stem blight was slightly better protected by Dimetomorph then by Propamocarb. Nevertheless the yield of TATTOO-plots seemed to exceed the ACROBAT ® one (figure 4).

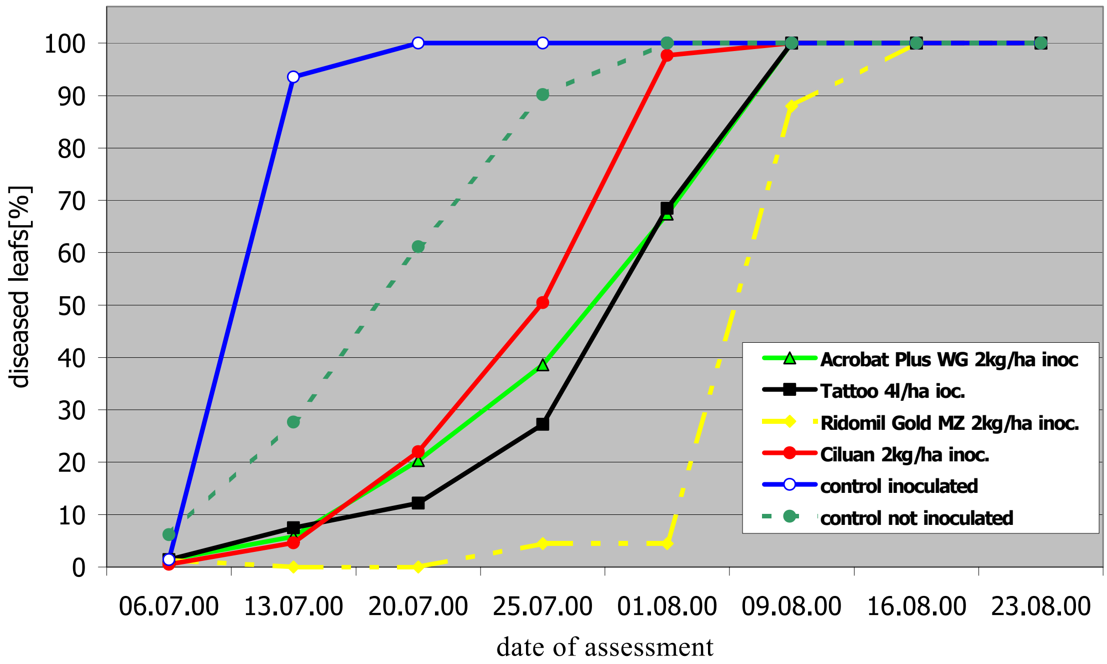

Figure 3. Development of leaf-blight.

Though the difference in yield cannot be confirmed statistically (because of the low number of plots) the figures pictures the findings of pathogen very good. In consideration of the very low variance and the very precise realisation of the trial, the results show representative effects on yield.

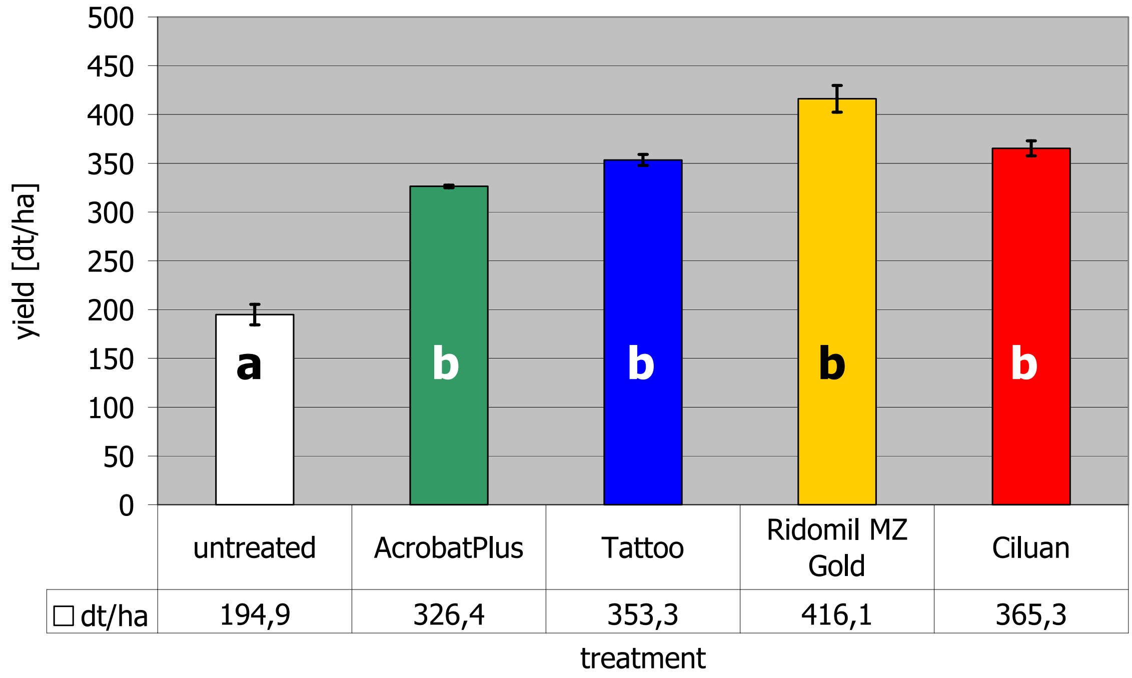

Figure 4. Yield and standard deviation.

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Fifth Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Munich, Germany, 6-10 September 2000

Experiences with RH-117281 (zoxamide) - a new fungicide for the control of potato blight

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Summary

In 1999, the rainfastness properties of the new potato blight fungicide fungicide RH-117281 (zoxamide) either alone or in co-formulation with mancozeb were evaluated under controlled conditions. Both zoxamide 2F and zoxamide+mancozeb were shown to be rainfast almost immediately after application and were comparable with the other proprietary fungicide formulations. The activity of zoxamide on both indirect (sporangial) germination and zoospore motility was also demonstrated. In field experiments in 1997, 1998 and 1999 the effectiveness of zoxamide+mancozeb for the control of foliar blight was demonstrated in conditions of different blight severity.

Key words : RH-117281, zoxamide, late blight, *Phytophthora infestans,* rainfastness, efficacy.

Introduction

RH -117281 is a new fungicide discovered and developed by Rohm & Haas for the control of oomycete plant pathogens. Potato late blight (*Phytophthora infestans*) and grape downy mildew (*Plasmopora viticola*) are the main target diseases for which commercial registration is currently being sought. The proposed ISO common chemical name for RH-

117281 is zoxamide and it is being developed commercially for late blight control as a co-formulated mixture with mancozeb. Zoxamide is a benzamide fungicide and was first announced at the British Crop Protection Conference at Brighton (Egan *et al.,* 1998).

The mode of action of zoxamide is to inhibit nuclear division by disruption of cellular microtubules as a result of highly specific covalent binding to the ß-subunit of tubulin (Egan *et al*., 1998). It is therefore active on target fungal pathogens at the post spore germination stage and stops germ tube growth. It also controls mycelial growth and prevents fungal penetration (Egan *et al*., 1998). Although similar in mode of action to the benzimidazole group of fungicides, it is a unique mode of action amongst the fungicides currently available for late blight control. Zoxamide is sparingly soluble in water but is highly lipophylic and penetrates the waxy leaf cuticle only slowly. There is some indication that zoxamide is translocated slowly within the leaf tissues. These attributes are considered by Rohm & Haas to confer excellent rainfastness properties.

This paper describes studies which investigate the rainfastness properties of zoxamide, its' mode of action under laboratory conditions and field performance in spray programmes for the control of potato late blight compared with the commercially available standard fungicide fluazinam. The work was carried out on behalf of Rohm & Haas by PAV Lelystad, The Netherlands and by ADAS Consulting Ltd., in England & Wales.

Materials & Methods

Rainfastness studies comparing zoxamide formulations with commercial fungicides

Potato plants (cv. Bintje) were planted at a depth of 10 cm in soil in 5 litre pots and were grown under glasshouse conditions until the plants reached a height of 10 cm. The plants were then placed outside until the start of each experiment. The potato plants were sprayed when they had reached a height of 40-50 cm in a spraying cabin developed by Applied Research for Arable Farming and Field Production of Vegetables (PAV), Lelystad in co-operation with TFDL-DLO in Wageningen. The fungicides were applied using a spraybeam with three Teejet XR110.03 nozzles placed 50 cm apart and moving at a speed of 5.6 km/h at approximately 30 cm above the potato plants. The fungicides were sprayed at a rate equivalent to 250 l/ha at a nozzle pressure 300 kPa.

Fungicide treatments

The rainfastness of zoxamide formulations were evaluated in comparison with other fungicides shown in Table 1 below. From each treatment, nine (3 * 3) plants were subjected to simulated rainfall applied at 0, 1 and 4 hours after fungicide application and three untreated plants were included as controls. Rainfall was simulated by a rain simulator developed by PAV. The rain simulator had three Fulljet FL-5VS nozzles placed 0.75 m above the potato plants. The water pressure was set at 300 kPa. Rain intensity under these conditions was 20 mm in 20 minutes. During the simulated rainfall, the potato plants were placed on a rotating table (5 rpm).

Table 1. Fungicide treatments.

Commercial/formulated product	Active ingredients	Dose rate applied
Untreated	-	-
zoxamide+mcz	zoxamide(8.3%)	0.9 kg/ha
	mancozeb (67%)	
zoxamide+mcz	zoxamide (8.3%)	1.8 kg/ha
	mancozeb (67%)	
zoxamide 2F	zoxamide (23%)	0.31 kg/ha
zoxamide 2F	zoxamide (23%)	0.62 kg/ha
Curzate M	cymoxanil (4.5%)	1.25 kg/ha
	mancozeb (64%)	
Curzate M	cymoxanil (4.5%)	2.5 kg/ha
	mancozeb (64%)	
Shirlan	fluazinam (50%)	0.2 l/ha
Shirlan	fluazinam (50%)	0.4 l/ha
Acrobat	dimethomorph (7.5%)	1.0 kg/ha
	mancozeb (67%)	
Acrobat	dimethomorph (7.5%)	2.0 kg/ha
	mancozeb (67%)	

Inoculum preparation, inoculation and incubation.

Race 1.4 of the fungus *Phytophthora infestans* was used in the rainfastness experiments and was maintained on slices of potato tubers (cv Bintje) under humid conditions at 15 ºC in the dark. An inoculum suspension of zoosporangia was made by rinsing potato slices of a one week old culture of *Phytophthora infestans* with demineralized water. Inoculum density was assessed by counting the number of zoosporangia using a haemocytometer and adjusted to 10, 000 zoosporangia per millilitre.

From each potato plant four leaves (intermediate leaf layers) were removed just before inoculation. The detached leaves were placed on wetted Oasis in a plastic container and were inoculated by placing a 50µl droplet of the spore suspension in the middle of the leaf on the leaf vein. To maintain a high relative humidity during incubation the containers were placed in plastic bags in a dark climate room at a temperature of 15 ºC.

Disease assessments

Disease assessments were made one week after inoculation. Lesion formation and percentage of the leaflet covered by the lesion were assessed on each of the five leaflets of the potato leaf. The percentage of the leaflet covered by the lesion was estimated by using an index ranging from 0 to 11. Visual checking for sporulation of *Phytophthora infestans* on the lesions was assisted by using a stereo microscope (x 40). Sporulation intensity was not quantified.

The experiment was carried out twice and the results expressed as a mean of the two experiments. A fungicide was considered rainfast when the 'rained treatments' did not have significantly more lesions compared to a treatment that was not exposed to rain.

Effect of different concentrations of zoxamide on sporangial germination & zoospore motility

The effect of zoxamide on the indirect germination and motility of zoospores was assessed by incubating a mixture of the fungicide in demineralized water together with zoosporangia. A range of concentrations was used ranging from 0.0001 to 10 ppm zoxamide and compared with an untreated control. The indirect germination of the zoosporangia was evaluated by mixing 5 ml of each fungicide solution with 5 ml of zoosporangial suspension. After 24 hours incubation at 18°C, germination was assessed by counting the full and empty zoosporangia using a haemocytometer. Indirect germination (%) was calculated by: (empty zoosporangia / total zoosporangia) * 100. When a zoosporangium was half-empty or more it was counted as empty.

A zoosporangial suspension was made and placed in a refrigerator at 7°C for two hours to encourage zoospore release. Five millilitres of each zoxamide concentration was mixed with 5 ml of zoospore suspension and, after 30 minutes, zoospore motility was assessed using a haemocytometer.

Field performance of zoxamide+mancozeb in the UK

Evaluation of the effectiveness of zoxamide+mancozeb (WG formulation) for the control of foliar blight infection was carried out in field experiments at several locations in England and Wales in 1997, 1998 & 1999. The experiment sites were at Trawsgoed, near Aberystwyth in Wales, at ADAS' research farms at Rosemaund, Herefordshire and Arthur Rickwood in Cambridgeshire, England. The fungicide treatments were applied to small plots of susceptible potato cultivars (King Edwards, Maris Piper) arranged in a fully randomised complete block design with four replicates. In all experiments the plots were four rows wide measuring 3.0 - 3.2 m wide and from 7.0 - 9.0 m in length.

At all sites, the experimental plots were surrounded either by 2 guard rows or a 2 m wide headland which were sprayed with mancozeb (as Dithane 945) at 14 reducing to 10 day intervals. The fungicide treatments were applied using an Oxford Precision Sprayer in 250 litres water per hectare operating at 250 kPa through 110° flat fan nozzles. Fungicide programmes commenced before the haulm met along the rows and were applied at either 7 or 10 day intervals except when rainfall and/or wind speeds exceeded levels than necessary for accurate spray application.

Foliar blight was visually assessed on each plots at regular intervals during the epidemic as the percentage of leaf area destroyed by blight using a modified Ministry of Agriculture Fisheries & Food key (number 2.1.1 - Potato Blight on the Haulm) as shown in Table 2 (Anon., 1947 & 1976 ; Large, 1952).

The progress of the foliar blight epidemic for each of the treatments was represented by a sigmoidal disease progress curve. The intensity of blight infection was measured by calculation of the Area Under the Disease Progress Curve (AUDPC) using numerical integration. AUDPC expressed as units of 'percentage.days' for each treatment was subjected to an Analysis of Variance in order to obtain the standard error of the difference (SED) used to assess the significance of differences. Differences between treatment means for mean AUDPC values have been distinguished using Duncan's Multiple Range Test.

N.B. Although Duncan's Multiple Range Test is carried out at the 5% probability level, the overall probability of detecting a treatment difference by chance is much higher than 5% and any apparent treatment differences may or may not be real.

Table 2. Foliar blight assessment key used in the field experiments.

Blight %		Description			
0		Not seen			
0.1	1+	lesion per plot			
0.2	25	Lesions per plot			
0.3	50	Lesions per plot			
0.4	75	Lesions per plot			
0.5	100	Lesions per plot	or	1 lesion per plant	Assuming
0.6				2 lesions per plant	100 plants
0.7				4 lesions per plant	per plot
0.8				6 lesions per plant	
0.9				8 lesions per plant	
1.0				10 lesions per plant	
5.0	1	lesion per compound leaf	or	50 lesions per plant	
10.0	2	Lesions per compound leaf	or	100 lesions per plant	
25.0		Nearly every leaflet with blight lesions - plants still retaining their normal form - 75% plot leaf area remaining green			
50.0		About half of the leaf area destroyed by blight			
75.0		About three-quarters of the leaf area destroyed by blight			
95.0		Stems green, only a few leaves remaining			
100.0		All leaves dead, stems dead or dying			

Results

Rainfastness studies

The incidence and severity of late blight infection following the different regimes of simulated rainfall post fungicide application is shown in Tables 3 & 4 respectively. In the absence of rain, there were differences in the effectiveness of the treatments tested. Acrobat (full dose) was the most effective fungicide and had significantly fewer lesions than zoxamide 2F (both concentrations) and Curzate M (full dose) ($P<0.05$). None of the rainfall simulation treatments resulted in significantly more lesions ($P<0.05$) and in the case of Curzate M (full dose), rainfall after one and four hours significantly reduced infection ($P<0.05$). There were also differences in the severity of infection between the different treatments in the absence of rain. Both zoxamide+mancozeb treatments, Curzate M (half dose), Shirlan (full dose) and both Acrobat treatments significantly reduced disease severity compared with the untreated control ($P<0.05$). The full dose of Acrobat resulted in significantly less infection than all other treatments except zoxium+mancozeb (both doses), Curzate M (half dose) and the full rate of Shirlan ($P<0.05$). Disease severity was not significantly increased by the simulated rainfall for any of the treatments tested

(P<0.05). Following both of the zoxamide 2F treatments, Curzate M (full dose) and the half dose of both Shirlan and Acrobat, disease severity was significantly reduced compared with the 'no rain' treatment by one or more of the rainfall applications (P<0.05).

Table 3. Percentage of leaflets with lesions of *P. infestans* following four different rain strategies.

Treatment	Dose rate kg or l/ha	Rain: No rain	After 0 hours	After 1 hour	After 4 hours
Untreated	-	100.0	100.0	100.0	99.2
zoxamide+mcz	0.9 kg	60.8	60.8	70.8	50.0
zoxamide +mcz	1.8 kg	57.5	52.5	33.3	55.8
zoxamide 2F	0.31 kg	87.5	62.5	63.3	70.0
zoxamide 2F	0.62 kg	79.2	53.3	67.5	60.8
Curzate M	1.25 kg	55.8	55.0	56.7	60.8
Curzate M	2.50 kg	81.7	65.8	38.3	36.7
Shirlan	0.2 L	65.8	68.3	25.8	70.0
Shirlan	0.4 L	51.7	65.0	70.8	67.5
Acrobat	1.0 kg	59.2	26.7	50.0	53.3
Acrobat	2.0 kg	47.5	60.0	62.5	50.0
LSD (α = 0.05)			24.6		

Table 4. Percentage leaf area infected with late blight following four different rain strategies.

Treatment	Dose rate kg or l/ha	Rain: No rain	After 0 hours	After 1 hour	After 4 hours
Untreated	-	81.7	95.0	88.3	81.7
zoxamide+mcz	0.9 kg	52.5	39.2	48.3	43.3
zoxamide+mcz	1.8 kg	58.3	41.7	41.7	49.2
zoxamide 2F	0.31 kg	63.3	40.0	20.8	39.2
zoxamide 2F	0.62 kg	65.0	28.3	29.2	47.5
Curzate M	1.25 kg	48.3	30.0	55.8	38.3
Curzate M	2.50 kg	80.0	37.3	31.7	36.7
Shirlan	0.2 L	66.7	53.3	25.0	39.5
Shirlan	0.4 L	54.2	43.3	51.7	54.2
Acrobat	1.0 kg	55.8	29.2	42.5	45.0
Acrobat	2.0 kg	39.2	52.5	56.7	46.7
LSD (α = 0.05)			22.3		

Effect of zoxamide on sporangial germination & zoospore motility

The dose response of different concentrations of zoxamide on the rate of indirect (sporangial) germination and motility of zoospores is shown in Table 5. At concentrations of 0.1 ppm and above, indirect germination was significantly lower than the untreated control (P<0.05).

Zoospore motility was significantly reduced at zoxamide concentrations of 1 & 10 ppm compared with all the other treatments (P<0.05).

Table 5. Indirect germination and motility of *P. infestans* zoospores at six different concentrations of zoxamide.

zoxamide concentration	Indirect germination (%)	Motility (%)
Control (water)	82.2	90.9
0.0001 ppm	76.3	89.8
0.001 ppm	81.8	86.0
0.01 ppm	79.2	80.5
0.1 ppm	50.7	76.1
1 ppm	21.4	8.6
10 ppm	21.5	2.0
LSD (α = 0.05)	13.6	3.0

Field performance of zoxamide+mancozeb in the UK

The effect of zoxamide+mancozeb (WG formulation) applied at either 1.5 or 1.8 kg/ha and at 7 or 10 day intervals for the control of foliar blight epidemics at different sites in England & Wales in 1997, 1998 & 1999 is shown in Table 6. Comparison is made with a commercially available formulation of fluazinam. The severity of foliar blight is expressed as the AUDPC (percentage.days).

In both experiments in 1997 fungicide spray programmes significantly reduced foliar blight severity compared with the unsprayed controls (P<0.05). Significantly better control of foliar blight was achieved with the higher rate of zoxamide+mancozeb (1.8 kg/ha) compared with the 1.5 kg/ha rate (P<0.05). There was also a significant reduction in the AUDPC at one of the sites where zoxamide+mancozeb (1.8 kg/ha) was applied at 7 compared with 10 day intervals (P<0.05). The standard fluazinam gave significantly better control of blight than zoxamide+mancozeb (P<0.05).

At all sites in 1998, fungicide treatments again significantly reduced the severity of the foliar blight epidemic compared with the unsprayed control (P<0.05). At the Trawsgoed site, the greatest reduction in foliar infection was from the zoxamide+mancozeb treatments applied at 7 days irrespective of application rate. These treatments were significantly better than the standard fluazinam (P<0.05). At Rosemaund, there were no significant differences between any of the fungicide treatments in the severity of the foliar blight (P<0.05). At Arthur Rickwood, there were no significant differences between the treatments except for zoxamide+mancozeb (1.5 kg/ha) applied at 7 day intervals which had less severe foliar infection than the 1.8 kg/ha rate applied at 10 day intervals ($P<0.05$). In 1999, again all fungicide treatments gave significantly better control of foliar infection compared with the unsprayed controls ($P<0.05$). At the Trawsgoed site, there was a clear and statistically significant reduction in foliar infection irrespective of rate of use when applied at the 7 day intervals ($P<0.05$). At Rosemaund, the 7 day applications of zoxamide+mancozeb had significantly lower AUDPC values compared with the fluazinam standard at the same interval ($P<0.05$). At Arthur Rickwood, there were no significant differences in AUDPC values between the zoxamide+mancozeb treatments and the fluazinam standards, although the 7 day applications of fluazinam gave a significantly better control of foliar blight than the 10 day spray programme ($P<0.05$).

Discussion

The experiments described in this paper provide a biological evaluation of the rainfastness properties of zoxamide either alone or in co-formulation with mancozeb. The test conditions were extreme because of the very high concentration of *P. infestans* inoculum used. Both zoxamide 2F and zoxamide+mancozeb were shown to be rainfast almost immediately after application (disease incidence) and were comparable with the other fungicides tested. Differences between treatments were less marked when measured as disease severity, although Acrobat was generally the least effective of the treatments tested. The experiments also showed activity of zoxamide on both indirect (sporangial) germination and zoospore motility. These results are difficult to explain in terms of the known mode of action of zoxamide. In other experiments where zoxamide was added to swimming zoospores of *Phytophthora capsici* there was no effect on motility (Young, 2000). However, when *P. capsici* in agar culture was exposed to zoxamide during the development and maturation of sporangia, production of sporangia was reduced at concentrations of ≥ 2.0 ppm and those sporangia which did form contained nuclei of abnormal shape, size and distribution. At low zoxamide concentrations (0.4 ppm), sporangia were also unable to release motile zoospores.

Table 6. The effect of different concentrations of zoxium+mancozeb applied at different time intervals compared with fluazinam on the development of late blight epidemics.

		Site location & foliage blight severity (measured as AUDPC values - %.days)		
Year	Fungicide treatment	Trawsgoed	Rosemaund	Arthur Rickwood
1997	Untreated	3003 g		
	zox+mcb (1.5 kg/ha @ 7 days)	891 cd		
	zox+mcb (1.8 kg/ha @ 7 days)	613 b		
	fluazinam (0.4 l/ha @ 7 days)	302 a		
	SED (33 df)	125.4		
	LSD (0.05)	254.56		
	Untreated	3241 g		
	zox+mcb (1.5 kg/ha @ 7 days)	940 c		
	zox+mcb (1.8 kg/ha @ 7 days)	723 b		
	zox+mcb (1.8 kg/ha @10 days)	1230 d		
	fluazinam (0.3 l/ha @ 7 days)	498 a		
	fluazinam (0.4 l/ha @ 7 days)	303 a		
	SED (33 df)	99.5		
	LSD (0.05)	201.99		
1998	Untreated	4231 i	3649 c	2381 d
	zox+mcb (1.5 kg/ha @ 7 days)	844 a	19 a	297 a
	zox+mcb (1.8 kg/ha @ 7 days)	644 a	34 a	429 ab
	zox+mcb (1.5 kg/ha @ 10 days)	2832 ef	50 a	410 ab
	zox+mcb (1.8 kg/ha @ 10 days)	2550 e	32 a	569 bc
	fluazinam (0.3 l/ha @ 7 days)	1815 d	340 a	357 ab
	fluazinam (0.3 l/ha @ 10 days)	3248 g	25 a	475 ab
	SED (45 df)	180.4	339.0	114.4
	LSD (0.05)	363.33	682.75	230.40
1999	Untreated	2410 c	2270 c	1037 c
	zox+mcb (1.5 kg/ha @ 7 days)	116 a	36 a	157 ab
	zox+mcb (1.8 kg/ha @ 7 days)	85 a	30 a	156 ab
	zox+mcb (1.5 kg/ha @ 10 days)	333 b	73 ab	155 ab
	zox+mcb (1.8 kg/ha @ 10 days)	315 b	55 ab	187 ab
	fluazinam (0.3 l/ha @ 7 days)	104 a	103 b	109 a
	fluazinam (0.3 l/ha @ 10 days)	257 b	97 b	239 b
	SED (42 df)	44.07	26.43	44.09
	LSD (0.05)	89.07	53.42	89.11

Treatment means followed by different letters are significantly different ($P<0.05$) according to Duncan's Multiple Range Test.

If this is reflected in the field situation, zoospore production of *P. infestans* exposed to zoxamide may also be reduced.

The effectiveness of zoxamide+mancozeb for the control of foliar blight was demonstrated under a range of different disease pressure situations. Zoxamide +mancozeb was comparable with the standard fluazinam but there were clear effects of dose and spray interval - better control of foliar blight was usually achieved at shorter intervals and at the higher application rate.

Conclusions

Zoxamide is a new benzamide fungicide with proven activity against late blight of potatoes (*P. infestans)*. It is currently being evaluated as a co-formulated mixture with mancozeb by the UK regulatory authorities at the end of 2000. Assuming zoxamide+mancozeb satisfies the regulatory requirements, it will be marketed commercially in the UK in 2001 with a recommended rate of 1.8 kg/ha commercial product (150 g/ha zoxamide +1200 g/ha mancozeb) in 200-600 l water/ha. The anticipated recommendations will be for applications at 7, 10 or 14 day intervals with up to a maximum of 10 applications to each crop and a 7 day harvest interval.

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Dimethomorph, What's new?

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Summary

In 2000 ACROBAT (Dimethomorph / mancozeb 75/667 g/kg WG) was tested on potatoes against stem blight, caused by phytophthora infestans. A single application of ACROBAT 2 kg/ha reduced the percentage of infestation and the size of the lesions formed when compared with untreated. Three applications with ACROBAT 1.5 kg/ha at a 7 day interval strengthened this effect and resulted in bigger differences between untreated and ACROBAT.

In 17 trials carried out over 5 years ACROBAT showed to be very effective against tuber blight. The level of control obtained is equal to fluazinam, but based on another mode of action. Fluazinam prevents the tubers against tuber blight with its spore-killing effect, while dimethomorph gives the high level of control as a result of its anti-sporulating activity.

Key words

Potato late blight, *Phytophthora infestans*, Dimethomorph, stem-blight, tuber protection, ACROBAT, spore-killing, anti-sporulation

Introduction

Since a number of years, dimethomorph is registered in Europe for the control of potato late blight. The product is mostly used in formulations where combinations with mancozeb are made. Before and after introduction of dimethomorph, research is carried out on various aspects of the molecule. In 2000 trials were carried out to prove the activity of dimethomorph on stem blight. In these trials information was collected on the activity of ACROBAT (dimethomorph / mancozeb 75/667 g/kg WG) when applied once or when applied three times.

In the number of years that ACROBAT is on the European market, the product has proved to give good tuber protection. The tuber protection is the result of the anti-sporulating activity of dimethomorph. A summary of the Dutch trials, regarding the period 1995 till 1999 will be presented.

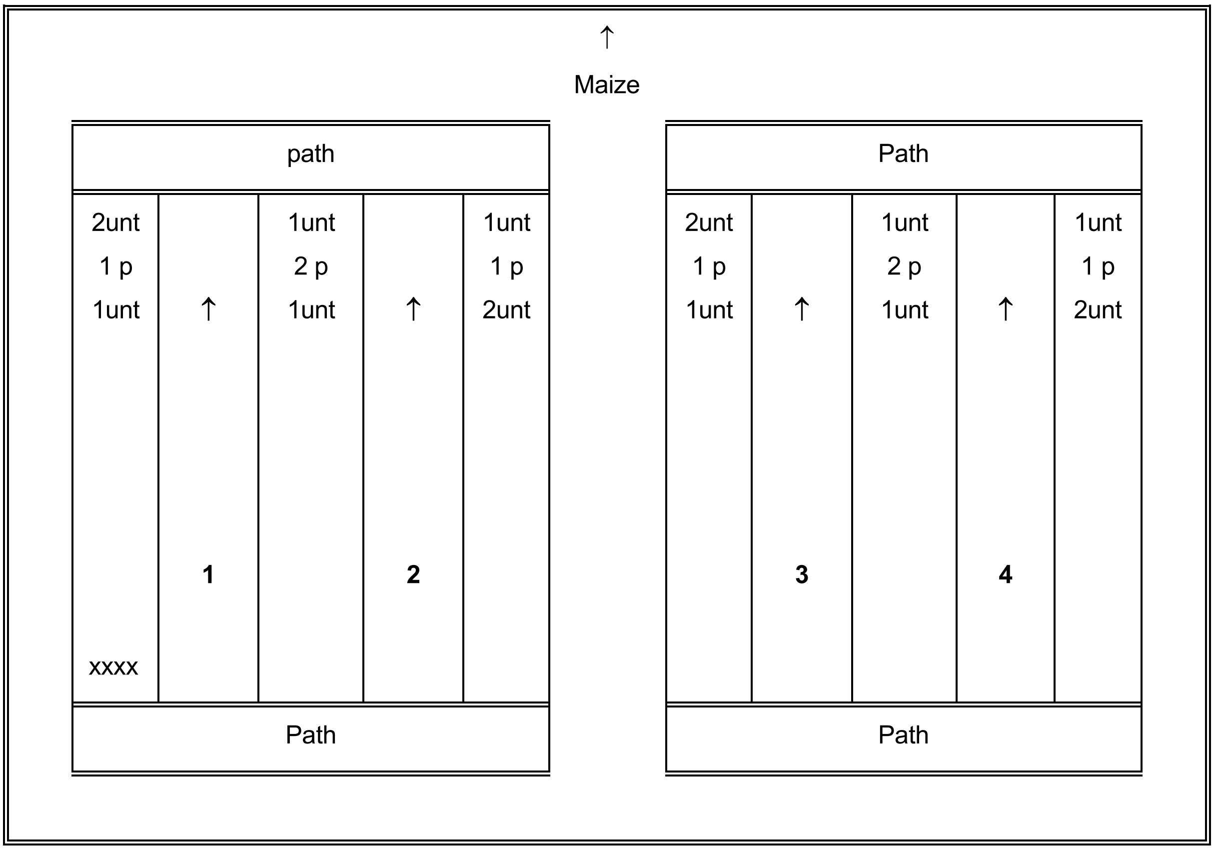
Materials and Methods

In 2000 special trials were carried out by HLB-Assen (Hilbrandslaboratorium) to show the activity of ACROBAT on stem blight after a number of applications.

When applied once, 2 kg of ACROBAT was used preventative or curative. The application was made on a crop with a size of approximately 15 cm high. The plots, which had a size of 8 gross-plants, were inoculated artificially in the stem at 4 places at 3 days after the preventative or 1 day before the curative application. Assessments were made at 8 days after the inoculation. The percentage of infestation and the lesion-size of the developed lesions were assessed.

When applied three times, 1.5 kg of ACROBAT was used preventative. The applications were carried out at a 7 day interval, starting at a crop of 15 centimeters high. The plants were inoculated 1 day after the last treatment when the crop was approximately 30 centimeters high. Seven days after the inoculation assessments were made.

Since 1995 trials are carried out to have a comparison under worst-case field circumstances of the different commercially available fungicides. Special potato-trials with the variety Bintje are laid down in maize to create ideal circumstances for the fungus. Figure 1 shows the trial lay-out used by Cyanamid/BASF.



Trial design from left to the right

1, 2, 3, 4 : plots of 4 rows, replicate 1, 2, 3 and 4

← : row direction

2unt : 2 rows untreated

1unt : 1 row untreated

2 p : 2 rows path (no potatoes planted)

1 p : 1 row path (no potatoes planted)

xxxx: 4 rows (2 untreated, 1 path, 1 untreated)

Figure 1. Trial lay-out of potato field-trials to control *Phytophthora infestans*.

In these trials the treated plots are sprayed at a 7 day interval with one fungicide (from beginning till end). During the season assessments on the infestation of the canopy are made, followed by assessments on tuber-blight at harvest and after a storage period of 6 weeks under plastic.

Results and Conclusions

The results of the trials on stemblight are summarized in table 1, showing the percentage infestation and the lesion size.

Table 1. Percentage infestation and lesion size after 1 or 3 applications.

Treatment	% infestation	Lesion-size
One application		
Untreated	59	40
ACROBAT .,0 kg/ha*	48	32
Three applications		
Untreated	96	22
ACROBAT 1.5 kg/ha	13	13

* No effect between the timing of treatment (preventative or curative) could be observed.

From the trials it can be concluded that plants which are treated with ACROBAT show a lower level of infestation than untreated plants. No difference between one application preventative or 24-hours curative could be found. Multiple applications give a better control of stem-blight than a single application, as a result of the build-up of dimethomorph in the plant. The % infestation decreases and the size of the lesions which are present is smaller. ACROBAT proves to be highly active against stem-blight caused by *Phytophthora infestans*.

The results of 17 trials on tuber blight carried out over 5 years are summarised in table 2: active ingredient, dose and percentage infected tubers (at harvest + after storage) of different fungicides.

Table 2. Percentage infected tubers of plots treated with different fungicides (a.i. + dose).

Product	Active ingredient (a.i.)	Dose a.i. per ha	% infected tubers
Untreated	-	-	15-90
Shirlan	Fluazinam 500 g/l	200	4.1
Curzate M	Cymoxanil 45 g/kg	112.5	7.8
	Mancozeb 680 g/kg	1700	
ACROBAT	Dimethomorph 75 g/kg	150	3.6
	Mancozeb 667 g/kg	1334	

ACROBAT provides a good level of control of tuber-blight. The level of control is equal to the level of control obtained with Shirlan. The mode of action of both fungicides is different. ACROBAT protects the tubers as a result of its anti sporulating activity, while

Shirlan protect the tubers with it’s spore-killing mode of action. ACROBAT gives a better control of the tubers than Curzate M.

In the field-trials mentioned above ACROBAT gives a better protection of the leafs than Shirlan as a pure preventative compound. Table 3 gives an overview of the result of a trial carried out in 1999 by ARS (Agro Research Service). The infestation of the leaves on August 30 and the results of tuber infection after storage are summarised.

Table 3. Number of infected leafs (30-8-99) and % infected tubers of plots treated with different fungicides (a.i. + dose).

Product	Active ingredient (a.i.)	Dose a.i. per ha	Number of Infected leafs	% infected tubers
Untreated	-	-	n.a.	90
Shirlan	Fluazinam 500 g/l	200	378	3.8
Curzate M	Cymoxanil 45 g/kg	112.5	570	7.5
	Mancozeb 680 g/kg	1700		
Tattoo C	Chloorthalonil 375 g/l	562.5	669	14.3
	Propamocarb 375 g/l	562.5		
ACROBAT	Dimethomorph 75 g/kg	112.5	461	1.9
	Mancozeb 667 g/kg	1000.5		
ACROBAT	Dimethomorph 75 g/kg	150	168	1.9
	Mancozeb 667 g/kg	1334		
Paraat	Dimethomorph 500 g/kg	200	1075	3.1

When plots with high levels of infestation in the canopy are sprayed with dimethomorph the results on tubers remain at a high level of control. This can be concluded from the differences between ACROBAT 1.5 and 2.0 kg/ha and Paraat. No difference on tuber infection could be found between the two tested dose-rates of ACROBAT, while there was a big difference in the number of infected leafs. Also the high amount of infected leafs in the plots sprayed with Paraat resulted in good results on tuber infection.

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Exploiting partial resistance to reduce the use of fungicides to control Potato Late Blight

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Summary

Partial resistance in the cultivars can be exploited to reduce the use of fungicides to control potato late blight. The model best describing the relationship between the effect of resistance and fungicide on the disease level is: $Y = A * (1 - (B * \mathit{Resistance}^{C})) * (1 - (0{,}96 * \mathit{Dose}^{D} * \mathit{Frequency}^{E}))$. The yield decreased linearly with increasing disease level in the foliage, and the percent of tubers with late blight was mainly determined by the cultivars' level of resistance to tuber infection in the field. Reducing the use of fungicide by reduction of the dose gave better disease control in the crop and higher saleable yield than reducing the use of fungicide by reduction of the frequency of applications.

Key words

Potato, late blight, partial resistance, fungicides, disease management

Introduction

Most of the potato cultivars grown commercially do not have high levels of general resistance to late blight. Consequently, the potato production heavily relies on fungicide application. Resistance to potato late blight has a high priority in most potato breeding programs and more recent cultivars with improved general resistance have become available. There is currently limited information on how to exploit these cultivars' resistance in leaves and tubers to reduce fungicide usage.

The effect of fungicide and partial resistance is similar, each slow down the epidemic. Several reports show that partial resistance in the foliage may be used to complement fungicide applications to enable savings of fungicide by reduced application rates or extended intervals between applications (Fry, 1975 and 1978, Gans *et al.,* 1995, Bus *et al.,* 1995). The aim of this work was to investigate how we can best exploit cultivar partial resistance in both leaves and tubers.

Materials& Methods

Three years of field trails with recommended and reduced doses of the fungicide, fluazinam, in combination with recommended and extended spraying intervals and cultivars with different levels of resistance in leaves and tubers were conducted. The trials were arranged as split plot with three replications each year. There were ten treatments, which were a combination of three application doses and three application intervals and an unsprayed control. The application intervals were 7, 14 and 21 days. The doses were 100%, 50% and 33% of recommended dose, which is 300 ml/ha, of the non-systemic protectant fungicide Shirlan (fluazinam, 500 g a.i./litre). Plant rows between the plots were inoculated at row closing and conditions conductive to disease increase were maintained by sprinkler irrigation. To minimize the amount of viable spores at harvest the crop was killed two weeks before harvest.

Results

The disease levels in the crop were quantified by calculating the relative areas under disease progress curves (RAUDPC). The relationship between the effect of resistance in leaves and fungicide applications was examined using regression models. The model best describing this relationship is: $Y = A * (1 - (B * Resistance^{C})) * (1 - (0.96 * Dose^{D} * Frequency^{E}))$. Y is actual disease level in RAUDPC. A (= 0.645) is potential disease level at the given disease pressure. $(1 - (B * Resistance^{C}))$ is reducing effect of resistance in leaves, where *Resistance* is resistance in leaves on the scale 1 – 9 divided by 10, B =1.298 and C = 2.854.

$(1 - (0.96 * Dose^{D} * Frequency^{E}))$ is reducing effect of fungicide applications, where 0.96 is effect of fungicide at recommended dose and 1 week intervals, *Dose* is relative amount of recommended dose, *Frequency* is application frequency in weeks, D = 0.233 and E =0.785.

Gross yield decreased linearly with increasing AUDPC, mainly because of reduced tuber size. Dry matter content also decreased linearly with increasing AUDPC. Percentage of tubers with late blight was mainly determined by the cultivars level of resistance to tuber infection in the field. The percentage of tubers infected increased in cultivars with low and medium level of resistance to tuber infection in the field at reduced dose and reduced frequency of fungicide application. An exception was when the resistance in leaves was low. At reduced frequency of fungicide application there was a rapid defoliation when the resistance in foliage was low. The rapid defoliation resulted in a shorter period with sporulating lesions in the foliage and consequently a lesser chance of spores being washed down to the tubers. In average over years the result was a lower proportion of infected tubers at reduced frequency of fungicide application when the level of resistance in leaves and tubers were low.

Reducing the use of fungicide by reduction of the dose gave better disease control in the crop and higher saleable yield than reducing the use of fungicide by reduction of the frequency of applications.

Discussion

In these trials the conditions have been kept conductive for disease development at all times by sprinkler irrigation. Under natural conditions the weather conditions may vary considerably over time, therefore timing of application is probably more important than the frequency of application. Because fungicide is used most efficiently when applied frequently at low concentration, the most efficient means to exploit the resistance in the cultivars is probably to try to apply the fungicide at right time according to a late blight forecasting system and then adjust the concentration of fungicide according to the resistance in the cultivar.

Conclusions

At low level of resistance in leaves and tubers it is important to spray at the right time with recommended doses. Exploiting high level of resistance in leaves is very risky when the level of resistance to tuber infection in the field is low, because a very low level of leaf infection gives enough spores to cause a large percentage of infected tubers. When the resistance to tuber infection in the field is high, medium resistance in the leaves can be exploited to reduce the dose by 50%, presumed fungicide application at the right time. At high level of both types of resistance one can also reduce the application frequency.

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F.R.E.D.E.C

Studies of new decision criteria to spray against late blight according to disease risk and cultivar resistance

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Champagne Ardenne : N. NGUYEN

Help for synthesis : C.HACCART, J.C. SALOME

Targets of the studies

- To reduce the number of treatments within the systems of Agricultural warning and to create the basis for a DSS (to provide individual field advice to the growers asking for it).

By using:

- accurate criteria obtained by the models Guntz-Divoux and particularly MILSOL;
- the global varietal susceptibility to the late blight.

According to:

- the results of last years especially these in 1999.

Discussion about the 1999's results

- With the warning system (1) the control of late blight is always very good but the number of treatments for the lower susceptible cultivar seems too high
- The criterion (2)was :

– first treatment : on the 4th generation in Guntz-Divoux model

– new treatments when the model MILSOL gives : SPOSPO(potential sporulation)>3 and SPORUL(sporulation)> 2.

It's considered that the development of the disease is more affected by the environment than the plot.

Milsol simulates the epidemic without taking into account the treatments.

– This decision criterion is too severe for the very susceptible cultivar bintje

– It seems to be a good criterion for the less susceptible cultivar, this has to be confirmed.

- The criterion (3) was :

  –First treatment : on the 4th generation in Guntz-Divoux model

  –New treatments when the model MILSOL gives SPOSPO>3 and SPORUL>2:

  –but it is considered that each treatment puts back the disease level to zero. MILSOL starts again at the level zero after each treatment.

  –this decision criterion is too severe for Bintje

  –it seems to be interesting on the less susceptible cultivars, but this has be confirmed under a very severe disease pressure.

Experimentation 2000

A) Experimental design

- Four replications, each plot contains 4 rows ly 10 meters. Around each replication there is a inoculated row destroyed as soon as the disease occurs. The untreated controls are situated outside the replications.

B) The decision criteria studied in 2000

- Condition 1 : treatment according to the recommendations given by the warning system.
- Condition 2 : integrated protection, treatments according to the recommendations from the model MILSOL. The treatment is triggered when the variables Spospo (potential

sporulation) > 3 and Sporul (real sporulation) > 2. High risk taking. The model MILSOL is not put back to zero after each treatment.

- Condition 3 : integrated protection, treatments according to the recommendations from the model MILSOL with a putting back to zero after each fungicide spray. Treatments are triggered when Spospo > 3 and Sporul > 2. Under this condition, the risk taking is very high that's why this condition is only conducted on the varieties Saturna and Samba.
- Condition 4 : integrated protection, treatments according to the recommendations from the model MILSOL without a putting back to zero after each fungicide spray. Treatments are triggered when Spospo > 2.7 and Sporul > 2. Under this condition, the risk taking is fairly high. This condition is only conducted on the variety Bintje which is very susceptible to the disease.

C) Registered fungicides

Choice of fungicides

Under the condtions 1, 2 , and 3 or 4, the technician has to choose among 3 products :

- DITHANE DG (mancozeb), simple preventive contact, washed off beyond 20mm of rain.
- SAGITERRE (fluazinam), contact at the top range, washed off beyond 40mm of rain, effective on tuber blight.
- ACROBAT M (dimetomorph + mancozeb), translaminar, very high rainfastness, settling very rapidly in the plant.

In exceptional cases such as risk during the week-end, a fungicide with cymoxanil can be used.

Natural inoculation.

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

D) Tested potato cultivar

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

- Bintje, very susceptible
- Saturna, average susceptibility
- Samba, low susceptibility

The weather data is collected from a weather station in the micro-region, sometimes very near the plot, sometimes at 5 kms far away, but with a rain gauge in the field.

The set up of trials

- Two trials at Nord Pas-de-Calais, which are within the scope of the European Project with Belgian Flanders (P.C.A.)
- Auchy les Mines (Pas de Calais) on Agrimieux (Special potatoes - integrated production) site
- Herlies (Nord) Interreg European Project
- Paraclay (Picardy)
- Rethel (Champagne-Ardenne)

Other trials are set up:

- In Nord Pas-de-Calais by the cooperative Haut de France, the treatments are triggered by the Nord Pas-de-calais SRPV FREDEC team
- In Picardy by ITCF-ITPT, the treatments are triggered by the Picardy SRPV-FREDEC team.

We have not the results today, these trials allows to measure the practical reaction

Results

Auchy-les-Mines treatment dates :

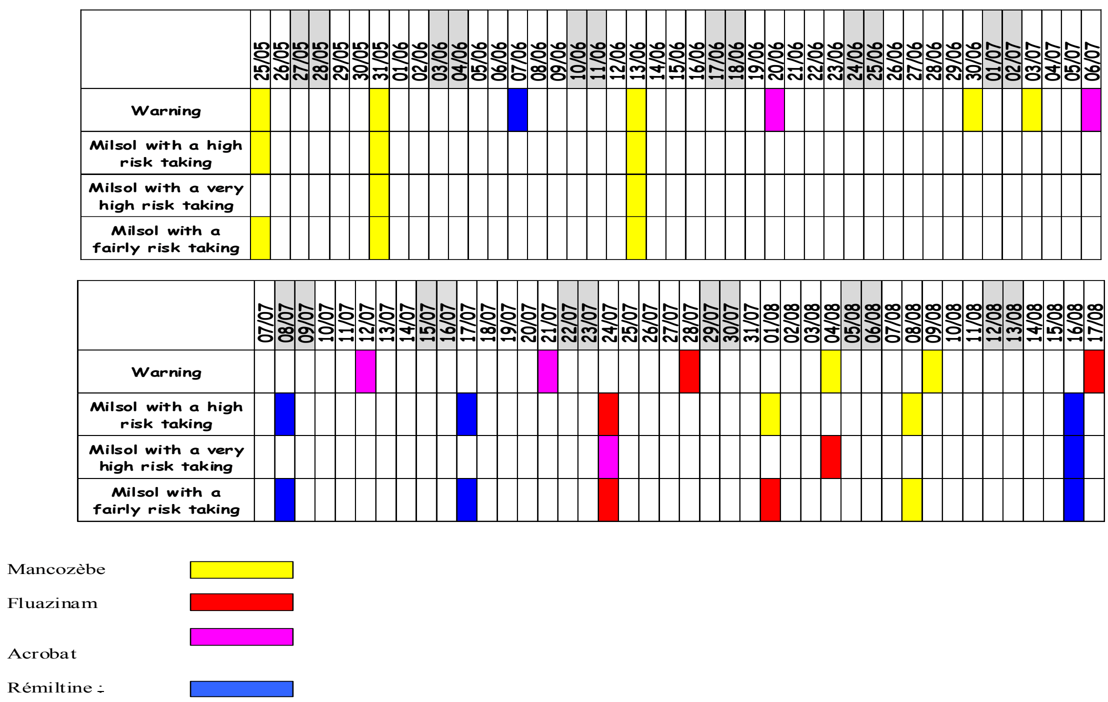

Figure a. Example of Auchy-les-Mines: Auchy-les-Mines treatment dates.

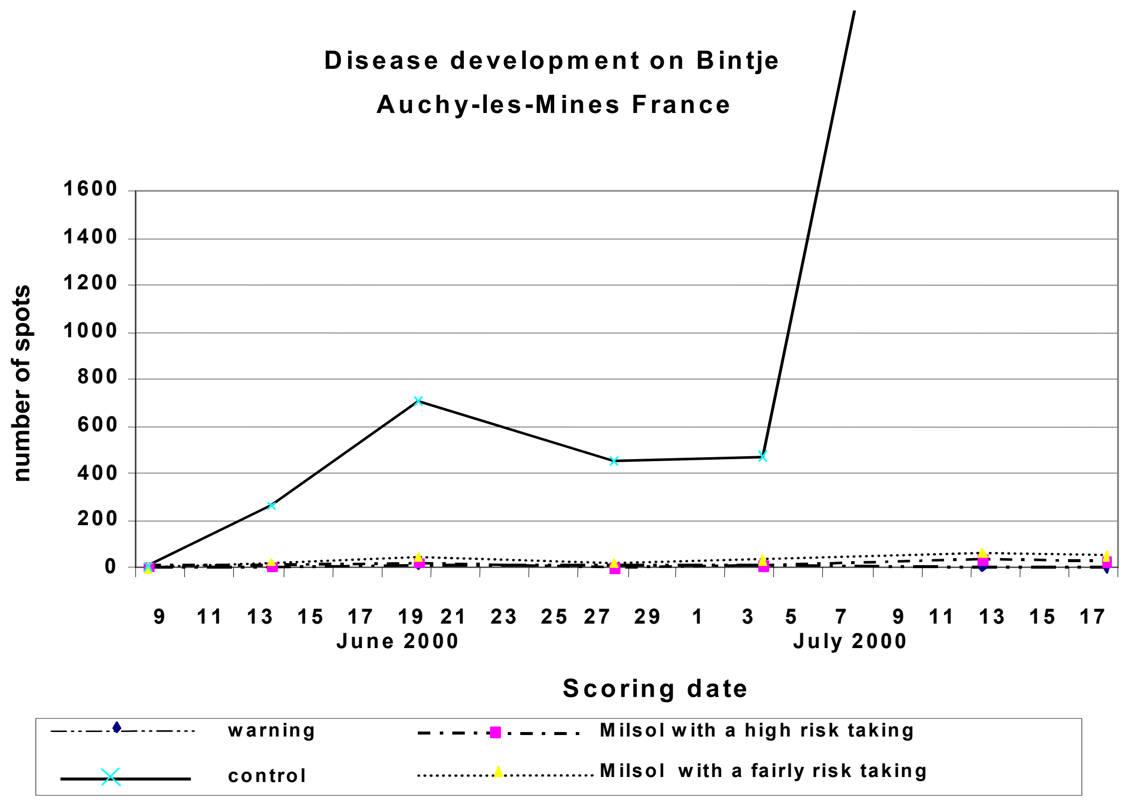

Figure b. Results example of Auchy: Disease development on Bintje, number of spots.

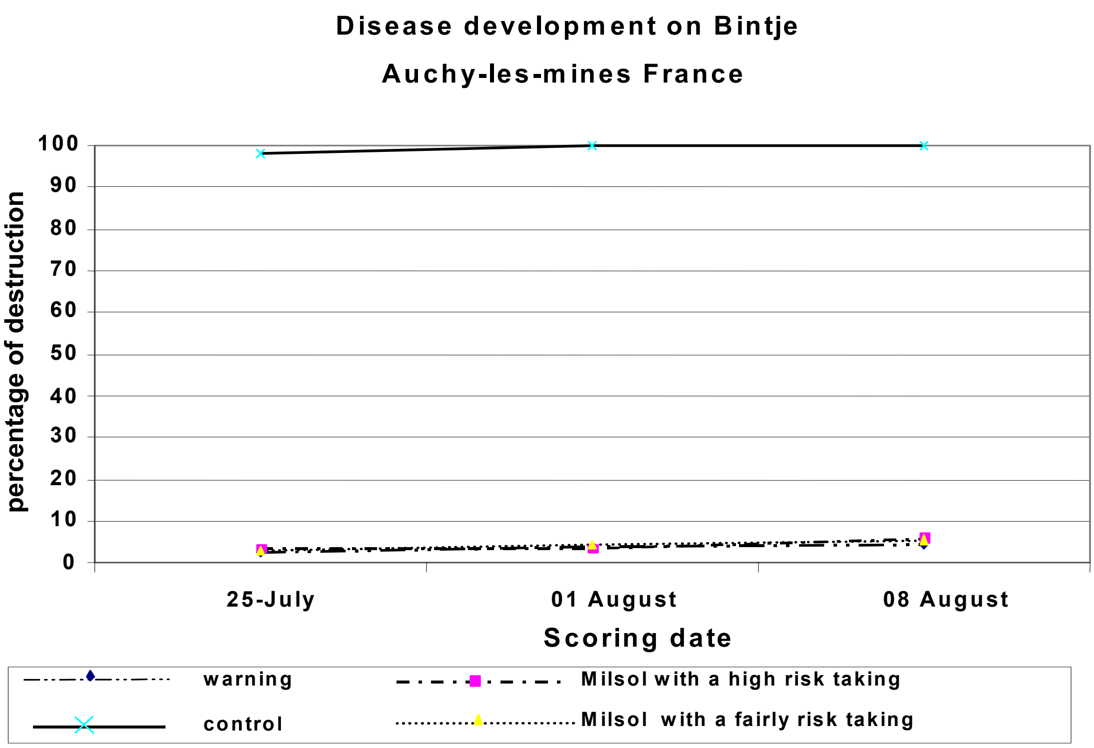

Figure c. Results example of Auchy: Disease development on Bintje, percentage of destruction.

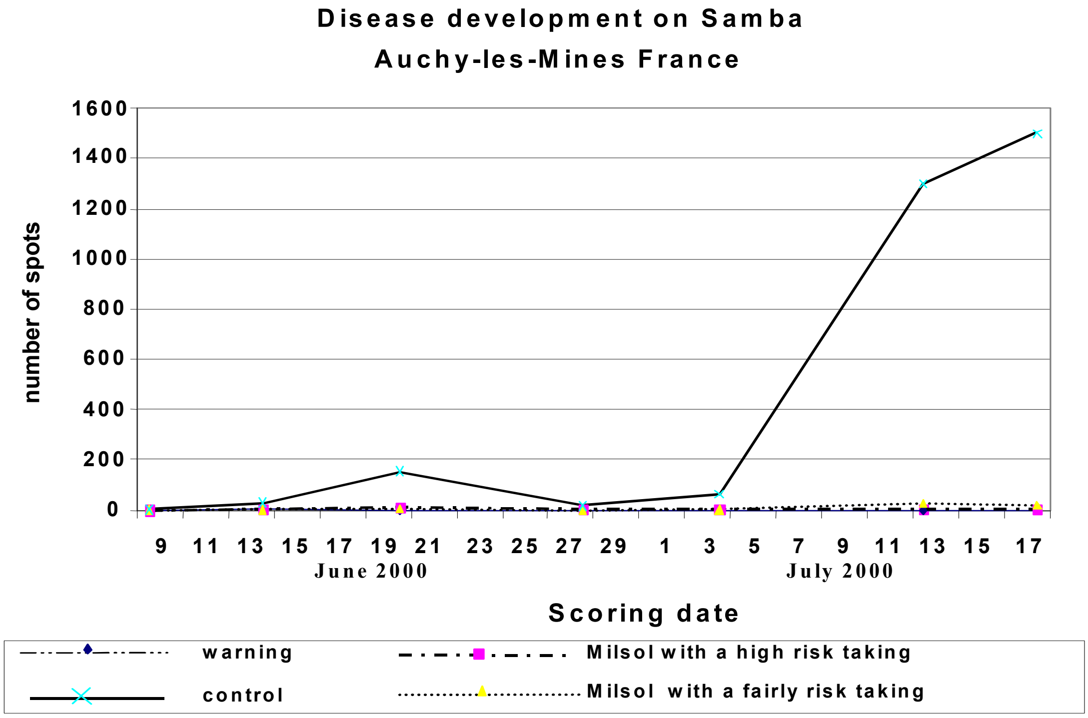

Figure d. Results example of Auchy: Disease development on Samba, number of spots.

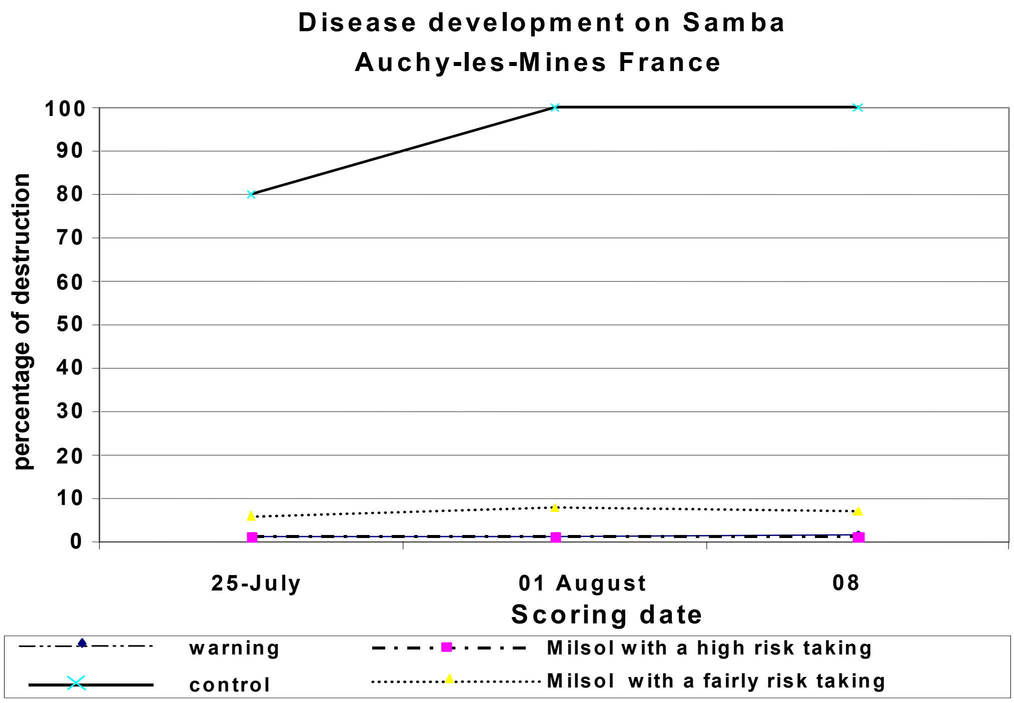

Figure e. Results example of Auchy: Disease development on Samba, percentage of destruction.

		disease notation			
	treatment	13 july	25 july	1 august	Discussion
Bintje					
c		3000	98%	100%	
1	14	1	2,5%	4%	C **very good** efficiency
2	9	40	4%	4%	C **very good** with 3 retroactive treatments
4	9	60	3%	4,50%	C **very good** with 3 retroactive treatments
Saturna					
c		500	80%	100%	
1	13	0	1,75%	1,50%	C **very good**
2	8	29	1,75%	2,75%	**BC good** with 3 retroactive treatments
3	5	18	5,50%	7,75%	**AB good** until 10,07, less good after
Samba					
c		1200	80%	100%	
1	13	1	1%	1%	**very good**
2	8	6	1%	1%	**very good** with 3 retroactive treatments
3	5	24	6%	8%	**good** until 10,07, lees good after

Figure f. Results – Auchy trial – discussion.

Comments

- The trial is in a field with late blight (high pressure)
- Weather station very near the trial (300 m)
- The protocol has been exactly respected
- Between the 30 June and 6 July: 3 sprays according to rainfastness

		disease notation				
	treatment	18 july	25 july	1 august	Discussion	
Bintje						
c		1425	80%	100%		
1	12	17	1%	2%	C very good	
2	11	16	19%	16%	B less good	
4	11	22	8%	11%	B less good	
Saturna						
c		65	55%	67%		
1	12	1	1%	1%	D very good	
2	11	2	5%	5%	B very good	
3	7	1	3%	3%	C very good	
Samba						
c		185	42%	55%		
1	12	1	1%	1%	D very good	
2	11	8	3%	4%	B very good	
3	7	1	1%	1%	C very good	

Figure g. a) Results – Herlies trial – discussion.

Comments:

- The trial is in a field with late blight (high pressure)
- Weather station at 5 km (Lorgies)
- The protocol has been exactly respected

		disease notation			
	treatment	11 july	1 august	11 august	Discussion
Bintje					
c		21%	100%	100%	
1	10	0	4%	6%	very good
*3	7	5	41%	62%	very bad
4	9	0	7%	9%	very good
Saturna					
c		10%	57%	97%	
1	10	0	1%	1%	very good
2	8	0	2%	2%	very good
3	6	1,7	7%	7%	less good
Samba					
c		8,70%	60%	99%	
1	10	0	42%	3%	very good
2	8	0	5%	6%	good
3	6	2	16%	20%	insuffisant

Figure h. Results – Paraclay trial – discussion.

Comments:

- The trial is in a field with late blight (high pressure)
- Weather station
- The protocol has been exactly respected

	treatment	disease notation: 28 june	disease notation: 28 july	disease notation: 4 august	Discussion
Bintje					
c					
1	7	152	33%	74%	médiocre
2	4	261	68%	81%	bad
3	2	252	86%	100%	very bad
Saturna					
c					
1	5	392			
2	3	282			
3	2	276			
Samba					
c					
1	5	156			
2	2	75			
3	2	152			

Figure i. Results – Champagne Ardenne trial – discussion.

Comments:

- The trial is in a field with late blight (high pressure)
- Weather station
- Protocol not exactly respected (1, 2 and 3 on each cultivar)
- Disease on Bintje as soon as the emergence begins
- Senescence after 28 June on Samba and Saturna

			Bintje				Saturna				Samba			
Trials	Disease pressure	C (25/07)	1	2	3	4	C (25/07)	1	2	3	C (25/07)	1	2	3
Herlies (Flandres)	Very high Very early	80%	12 VG	11 (G)		11 (G)	55%	12 VG	11 VG	7 VG	42%	12 VG	11 VG	7 VG
Auchy (Pas-de-Calais)	Very high	100%	14 VG	9 VG		9 VG	80%	12 VG	11 G	7 G	80%	12 VG	11 VG	7 G
Paraclay (Picardie)	Very high	95%	10 VG		7* VI	9 VG	41%	10 VG	8 VG	6 (G)	52%	10 VG	8 G	6 I
Rethel (Champagne ardenne)	Average	33%	7 (I)	4 I	2 VI			5	3	2		5	2	2

1 = Warning
2 = Milsol with a high risk taking
3 = Milsol with a very high risk taking
4 = Milsol with a fairly risk taking
Number of treatment
VG (very good), G (good), I (insuffisant), VI (very insuffisant)

Figure j. Results synthesis 2000.

Conclusion

- On less susceptible variety the criteria : SPOSPO>3 and SPORUL>2 without a putting back to zero after each spray is careful, it can be used in a global warning system in NorthWest of France and in DSS when the field is in a «dangerous environment», for example: NorthWest of France near garden plots or near inoculated fields.
- The criteria SPOSPO>3 and SPORUL>2 with a putting back to zero after each spray could be used only on less susceptible cultivars, in continental climate, or in individual field advice, when the field observations demonstrate that the enviroment is clean

2001 – Project and later on

- To confirm these results in a global system =DSS.
- To specify the resistance criteria of the cultivar and overlook the change in the susceptibility (European proposal and or interreg).
- Show for growers like « agrimieux 2000 special potatoes - integrated production» in 2002 or 2003 (European proposal or French action).

Fifth Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
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Strategies for control of late blight (*Phytophthora infestans)* integrating variety resistance, intervals, fungicide doses and weather forecast.

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Summary

With the DDS system NegFry, it was possible to reduce the fungicide input in potato for controlling late blight without reducing the net yield. Although this DDS system in most evaluation trials gave a good control of late blight, there still is a need to improve the system. There is a strong need for a better integration of host resistance and adjustment of fungicide doses and intervals in relation to actual weather and weather forecast.

Experiments with new strategies with dynamic adjustment of fungicide dosages based on prognosis for blight-favourable weather showed good results in a susceptible variety if an effective fungicide was used. In a moderate resistant variety, less effective fungicide also gave acceptable control. However, the strategies based on a simple weather forecast gave more treatments than expected because of ongoing rainy weather and low temperatures through the whole growing season.

In the susceptible variety Dianella, the prognosis model based on the estimated daily risk values gave a good control and reduced the frequency of treatment 45% in proportion to a routine treatment with Dithane and 25% compared to a routine treatment with Shirlan. There is, however, a need for more development and testing of the strategies before they can be implemented in the existing DSS. Combining a prognosis for blight-favourable

weather with a dynamic model, which include adjusted doses and intervals seems to be a very interesting model for further research.

Keywords: Late blight, *Phytophthora infestans*, control, fungicides, DSS

Introduction

Potato late blight (*Phytophthora infestans*) is controlled by intensive use of fungicides in most European countries. In Denmark, the use of fungicides in potato makes up approximately 21 % of the total fungicide consumption in all field crops (Anon., 2000) despite potato only accounts for 1.3% of the total agricultural area (Anon., 1998). The importance of late blight in potato is well known. In 1994, the use of fungicides in potatoes gave 47 % (324 mill. DKK) of the total net yield after use of fungicides in Danish agriculture (Jørgensen *et al*., 1997).

In Denmark, there is a strong demand for a reduction of fungicide input compared to weekly routine strategy. The ongoing challenge is to build a DSS system that is able to reduce the fungicide input in potato without reducing the net yield or quality. In Europe, several DDS systems are in use or under development (Kleinhenz and Jörg, 2000). The Danish system NegFry has in several Nordic validation trials shown to be able to reduce fungicide input and still obtain the same yield and quality as a routine treatment (Hansen *et al.,* 2000). However, the NegFry system still needs to be improved by an integration of host resistance and adjustment of fungicide doses and intervals in relation to actual weather and weather forecast. In this study, several strategies involving different fungicides, dynamic doses, intervals, varieties and weather prognosis have been evaluated in field trials.

Materials and methods

In 2000, one experiment was carried out on each of three locations; the research centre in Flakkebjerg (East Denmark) and the research stations in St. Jyndevad (South Denmark) and Borris (West Denmark). The experiments contained different control strategies, which included two varieties (the susceptible variety Dianella and the moderate resistant variety Kuras), two fungicides (Dithane DG and Shirlan), dynamic doses, intervals and protection periods (table 1 and 2). The field trials contained the different strategies completely randomised within four replicate blocks with a net plot size 22.5 m^2 (St. Jyndevad), 24 m^2

(Flakkebjerg) and 27 m^2 (Borris). The sprayers were mounted with Hardi flat nozzles (ISO) 03, 3.75 Bar and 400 l water per ha. Late blight was scored at 7 days intervals and tuber blight was assessed after harvest. The total amount of attack in the different treatments ("mean attack") was calculated as an average of all assessments from the first to the last assessments.

Table 1. Different strategies for control of late blight in field trials with the susceptible variety *Dianella*

Strategy	Fungi-cide	1. application	Intervals	Dosage
Untreated	-	-		-
Routine	Dithane	120+7[a)]	7 days	1/1
Model 1	Dithane	120+7	Basic model [b)]	1/1
Model 2	Dithane	120+7	Basic model [b)]	½ dose until blight is observed in untreated Dianella, after that 1/1 doses
Model 3	Dithane	120+7	Basic model [b)]	½ doses until blight is observed in the plot, after that 1/1 doses
Model 4	Dithane	120+7	Dynamic [c)]	½, 1/1 [c)]
Routine	Shirlan	120+7	10 day	1/1
Model 1	Shirlan	120+7	Basic model [b)]	1/1
Model 2	Shirlan	120+7	Basic model [b)]	½ doses until blight is observed in the untreated Dianella, after that 1/1 doses
Model 3	Shirlan	120+7	Basic model [b)]	½ doses until blight is observed in the plot after that 1/1 doses
Model 4	Shirlan	120+7	Dynamic [c)]	½, 1/1 [c)]
Model 5	Shirlan	120+7	Prognosis [d)]	1/1
Farmers choice	Shirlan	Optional	Optional	Optional

a) – d): see table 2

Table 2. Different strategies for control of late blight in field trials with the susceptible variety *Kuras*

Strategy	Fungi-cide	1. application	Interval	Dosage
Untreated	-	-		-
Routine	Dithane	120+7 a)	7 days	1/1
Model 1	Dithane	120+7	Basic model b)	1/1
Model 6	Dithane	Attack in Dianella	Basic model b)	½ dose until blight is observed in untreated Kuras, after that 1/1 doses
Model 7	Dithane	Attack in Dianella	Basic model b)	½ dose until blight is observed in the plot (treated Kuras), after that 1/1 doses
Model 8	Dithane	Attack in Dianella	Dynamic c)	½, 1/1 c)
Routine	Shirlan	120+7	10 days	1/1
Model 1	Shirlan	120+7	Basic model b)	1/1
Model 6	Shirlan	Attack in Dianella	Basic model b)	½ dose until the blight is observed in untreated Kuras, after that 1/1 doses
Model 7	Shirlan	Attack in Dianella	Basic model b)	½ doses until blight is observed in the plot (treated Kuras), after that 1/1 doses
Model 8	Shirlan	Attack in Dianella	Dynamic c)	½, 1/1 c)
Model 9	Shirlan	Attack in Dianella	Prognosis d)	1/1
Farmers choice	Shirlan	Optional	Optional	Optional

a) Start of spraying when Accumulated Daily Risk Value (ADRV) >= 120 and the daily risk value (DRV) > 7 (NegFry) or if late blight have been registered in Denmark.

b) *Basic model:* Treatment when prognosis (5 days) for night temperature is > 10 ^{o}C and 2 days in a three-day period with >1mm precipitation. No treatment within protection periods (Dithane = 7 days, Shirlan = 10 days).

c) *Dynamic model*: Treatment dependent on number of favourable days according to 5 days weather forecast (Danish Meteorological Institute) .

The number of favourable days: Night-temp.>10^{o}C and >1mm rain	Dose	protection period (days)	
		Shirlan	Dithane DG
1-2	½	5	4
3-5	1/1	10	7

d) Prognosis model: Treatment if there are two days in a three-day period with DRV>7 or if a day has passed with DRV>7. Prognosis based on estimates for daily risk values according to forecast on www.planteinfo.dk

The different strategies in the moderate resistant variety Kuras was the same as for Dianella but the start of spraying was determined by the first observation of late blight in Dianella in model 6 - 9.

Results

The results for each variety Dianella and Kuras are shown in table 3 and 4, respectively.

Table 3. Different strategies for the control of potato late blight (*Phytophthora infestans)* in the variety *Dianella* at Flakkebjerg (F), Jyndevad, (J) and Borris, (B).

Strategy	% blight						Relative yield			Fungicide treatments					
	% Leaf blight Mean attack [1]			% Tuber blight						Number of treatments			Treatment index		
	F	J	B	F	J	B	F	J	B	F	J	B	F	J	B
Untreated	46.6	68.9	66.1	8.1	4.5	2.0	**100**	**100**	**100**	-	-	-	-	-	-
Routine	1.3	5.8	3.3	12.5	3.3	2.8	130	156	130	11	12	13	11.0	12.0	13
Model 1 [2]	1.7	16.4	3.8	9.5	2.5	3.5	136	148	135	10	11	12	10.0	11.0	12
Model 2	4.1	18.4	5.4	8.6	2.0	2.5	134	150	131	10	11	12	7.5	10.0	10
Model 3	3.8	35.9	5.3	15.3	2.3	4.8	136	134	131	10	11	12	7.5	8.0	8.5
Model 4	1.3	10.9	3.0	7.7	2.3	4.3	133	155	135	13	12	13	9.5	10.0	10.5
Routine	0.4	11.0	0.9	0.4	0.3	0.5	141	162	142	8	8	9	8.0	8.0	9
Model 1	0.5	11.9	0.9	0.4	0.8	0.5	137	157	139	9	8	9	8.0	8.0	9
Model 2	0.6	11.7	1.0	0.4	1.5	0	135	156	139	9	8	9	6.5	7.0	7.5
Model 3	0.7	18.7	1.5	0.8	0.5	0.3	140	146	139	9	8	9	6.0	5.5	6.5
Model 4	0.4	10.4	0.7	1.4	2.0	0.3	142	158	140	11	9	11	7.5	7.5	9
Model 5	0.5	-	-	0	-	-	138	-	-	6	-	-	6.0	-	-
Farmers choice	0.5	17.6	1.2	1.9	0.8	1.8	137	151	139	13	9	9	6.1	6.3	5.5
LSD	3.3	4.1	2.1	5.7	2.0	2.2	9	6	5						
							388 hkg/ha	430 hkg/ha	475 hkg/ha						

[1] Mean attack: mean of assessments from first to last observation. [2] See table 1.

Table 4. Different strategies for the control of potato late blight *(Phytophthora infestans)* in the variety *Kuras* at Flakkebjerg (F), Jyndevad (J) and Borris, (B).

Strategy	% blight									Fungicide treatments					
	% Leaf blight Mean attack[1]			% Tuber blight			Relative yield			Number of treatments			Treatment index		
	F	J	B	F	J	B	F	J	B	F	J	B	F	J	B
Untreated	2.2	77.5	40.4	0	2.8	0.8	**100**	**100**	**100**	-	-	-	-	-	-
Routine	1.2	2.2	0.4	0	2.0	2.3	106	112	112	11	12	13	11.0	12	13
Model 1 [2]	2.0	2.5	0.5	0	3.0	9.8	105	114	111	10	10	12	10.0	10	12
Model 6	1.5	4.2	0.8	0	1.3	1.5	106	113	108	7	9	8	6.0	6.5	7
Model 7	1.3	4.8	1.5	0	2.0	12.8	101	114	107	7	9	8	4.5	6.0	6.5
Model 8	1.0	2.7	0.4	0	1.5	3.5	105	113	111	8	10	8	6.5	8.5	7.5
Routine	1.0	5.2	0.2	0	0.5	0.3	107	113	112	8	8	9	8.0	8.0	9
Model 1	1.4	7.0	0.2	0	0.3	0.8	103	111	111	8	8	9	8.0	8.0	9
Model 6	1.1	7.1	0.2	0	1.3	0.5	101	109	113	6	6	6	5.0	4.5	5
Model 7	1.6	8.6	0.9	0	1.3	0.0	105	109	113	6	6	6	3.0	4.0	4.5
Model 8	1.6	5.8	0.2	0	1.0	0.5	101	110	117	6	7	8	5.5	6.0	6.5
Model 9	1.8	-	-	0	-	-	101	-	-	5	-	-	5.0	-	-
Farmers choice	1.6	7.5	1.8	0	2.8	0.5	103	110	112	6	8	6	3.0	3.5	3.0
LSD	1.6	3.4	1.7		2.4	8.6	7	4	4						
							611 hkg/ha	611 hkg/ha	620 hkg/ha						

[1] Mean attack: mean of assessments from first to last observation. [2] See table 2.

Discussion

The onset of late blight in Denmark was rather late in the season 2000. The first attack was observed in Dianella in early July but due to cold weather, the epidemic was delayed until late July – early August. The development then was very fast and by the end of August all untreated plots were destroyed by late blight. In Kuras, the first primary symptoms of late blight was observed in early august a month later than in Dianella. First late August – beginning of September, the development was epidemic.

Late blight was effectively controlled in Dianella by routine sprayings with either Dithane DG or Shirlan (93-94 % control based on mean attack, table 3) but more tuber blight was observed in plots sprayed with Dithane DG. The strategies where Dithane DG were used as fungicide gave in general less protection in Dianella than strategies using Shirlan. It seems that ½ doses of fungicide in model 2 only have a potential, if an effective fungicide is used.

In the moderate resistant variety Kuras, there were no differences between the two fungicides. In this variety, it looks as if it is possible to wait with the first treatment until blight is observed in a nearby susceptible variety.

The models 4 and 8 have a dynamic adjustment of fungicide dosages based on the prognosis for blight-favourable weather (table 1-2). This strategy has a potential in a susceptible variety, however only if an effective fungicide (Shirlan) is used. In a moderate resistant variety with less disease development, also Dithane DG gave acceptable control.

The strategies based on a simple weather forecast gave more treatments than expected because of ongoing rainy weather and low temperatures just above 10^{o}C in long periods of the growing season. These strategies gave nearly the same treatment frequency as the routine strategy. In a drier climate, one could expect that this model would release a smaller number of treatments than in year 2000.

The prognosis model includes the temperature (models 5 and 9) and calculate a daily risk value according to the algorithm in NegFry. The prognosis for DRV is available on www.planteinfo.dk (Thysen *et al.*, 2000). The prognosis model was only tested in Flakkebjerg and showed to be valid in both Dianella and Kuras. In Dianella, the prognosis model reduced the frequency of treatment 45% in proportion to the routine treatment with Dithane and 25% compared to a routine treatment with Shirlan.

In "farmers choice", all the available informations are gathered with the one purpose of reducing fungicide use as much as possible. "Farmers choice" gave the same control and yield with 13 treatments of different doses, as with six treatments with full doses (model 5). Even if the field trials were looked after seven days a week and treated if necessary, "farmers choice" at Borris and Jyndevad shows to be risky. These plots serve therefore more as a demonstration and inspiration for new strategies.

The combination of the prognosis models for blight-favourable weather and the dynamic model for adjusted dose and intervals seems to be a very interesting combination for further research. There is a need for more development and testing of this strategy before it can be implemented as a sub model in the existing NegFry-system.

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Regional variation in mating type A1/A2 ration, Metalaxyl and Propamocarb resistance in Finland

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Summary

Population studies on *Phytophthora infestans* have been carried out since 1990 in Finland. Fungal samples collected from single lesions on potato leaves in different regions have been characterised for their mating type, sensitivity to metalaxyl and propamocarb hydrochloride. Metalaxyl resistant isolates were dominant in 1990-94 but their proportion has decreased towards the end of 1990's. In certain regions the proportion of resistant isolates has remained high although metalaxyl products have not been used for blight control. Propamocarb insensitivity has not increased during the study but individual isolates sporulating in presence of 1000 ppm propamocarb has been found. A2- mating type was first time detected in 1992 and its proportion has been around 20 % in 1993-1999. The A1/A2 ratio in *P. infestans* population differs considerably from one field to another.

Key words: Potato, Potato late blight, *Phytophthora infestans*, metalaxyl, propamocarb mating type

Introduction

Recent population studies on *Phytophthora infestans* have revealed considerable variation in population structure in consideration to mating types and to metalaxyl resistance between countries, regions and even individual fields in Europe (Gisi and Cohen, 1996, Lebreton, *et al*., 1998, Hermansen *et al*., 2000). In USA and Canada late blight population is dominated by a few genotypes (Daayf and Platt, 1999, Gavino *et al*., 2000). Population studies on potato late blight were started in Finland in 1990. The original aim was to monitor metalaxyl resistance and mating type frequencies. After registration of propamocarb hydrochloride (Tattoo) in 1995 the monitoring of sensitivity of *P. infestans* to propamocarb was initiated (Hannukkala, 1999).

Materials and methods

Yearly 50-500 blight samples have been collected from potato fields in 1990-1999 from six separate regions in Finland. North Western region, Ruukki, represents seed-potato production, Central West coastal region, Ylistaro, produces mainly table potato, South-Western region, Kokemäki, has mainly starch potato production, Mikkeli in south east is specialised in organic cropping and isolates from Jokioinen and Lammi in Southern Finland were collected from experimental plots. Spore suspension prepared from single lesions in leaves have been used as an ‘isolate’ in most studies. 10 % of blight samples have been isolated on rye agar.

Sensitivity to metalaxyl and propamocarb was studied with floating leaf disk method using concentrations 0, 0.1, 1, 10 and 100 ppm metalaxyl and 0, 10, 100 and 1000 ppm propamocarb respectively (Sozzi *et al*., 1992, Bardsley *et al*., 1996). Mating-type was confirmed by pairings on rye agar and on floating leaf disks (Hannukkala, 1999).

Results

Metalaxyl resistance was on very high level in the beginning of 1990’s in all regions. As a result of decreasing use of metalaxyl products the proportion of resistant samples has decreased and in 1999 metalaxyl resistant isolates were only detected at Ruukki and Kokemäki. In Northern region, Ruukki, the proportion of resistant isolates has remained high, despite no known use of metalaxyl fungicides for years.

Propamocarb was registered for blight control in Finland in 1995. Isolates showing some tolerance to propamocarb were commonly found before 1995 and no shift towards increased tolerance to propamocarb has been detected thereafter. Occasionally a few isolates growing in 1000 ppm propamocarb have been found. Approximately equal proportion of metalaxyl resistant and metalaxyl sensitive isolates are able to grow in 100 ppm propamocarb.

A2- mating type was detected first time in Finland in 1992. The average proportion of A1/A2 among all isolates tested yearly has since then been in the range of 80/20. There were differences in A1/A2 ratio between different regions, but the A1/A2 ratios between individual fields within one region was even more variable. Metalaxyl resistance was more common among A1 than A2 mating type isolates.

Discussion

Metalaxyl resistance was on very high level in the beginning of 1990's in all regions though the yearly variation in the percentage of resistant isolates was high. In Northern region, Ruukki, the proportion of resistant isolates has remained high, despite no known use of metalaxyl fungicides for years. In general the metalaxyl resistance situation is very similar to that in other European countries (Gisi and Cohen, 1996)

P. infestans isolates showing some tolerance to propamocarb were commonly found before 1995, when Tattoo was registered for blight control and no shift towards increased tolerance to propamocarb has been detected thereafter. This is in accordance with the monitoring results by Löchel and Birchmore (1990) and Bardsley *et al*. (1996, 1998) from Europe and USA.

A1/A2 mating type ratio was very variable between individual sampling sites though the yearly average ratio of all tested isolates was very constantly close to 80/20. Very similar results has been obtained by Leberton *et al*. (1998). More metalaxyl resistant isolates were found among A1 than A2 mating types, which has also been reported in Norwegian population (Hermansen *et al*., 2000). According to Gisi and Cohen (1996) there is no evident connection between level of metalaxyl resistance and mating type.

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Mating types and metalaxyl resistance among isolates of *Phytophthora infestans* collected during different periods of the growing season

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Summary

Potato leaf samples infected by *Phytophthora infestans* were collected from 31 potato fields at Jæren, Rogaland county in Norway, at different periods of the growing seasons in 1998 and 1999. In addition, two conventional fields and one organic field were sampled at intervals of one to two weeks throughout the season of 1999 ("test fields"). Isolates of *P. infestans* were assessed for mating type and metalaxyl sensitivity. In 1998 and 1999, 21.7 % (n=61) and 52.7 % (n=178) of the isolates respectively, were A2 mating type. In most fields, both mating types A1 and A2 were present. A relatively stable frequency of mating type A1 and A2 was found during the season. Among 72 isolates from 1998, 29.2 % of the isolates were metalaxyl-resistant. In 1999, 19.2 % of 83 isolates were metalaxyl-resistant. No significant differences in metalaxyl sensitivity between different sampling dates were found in the test fields. However, bulked data from all early and late samples in other fields showed a significantly higher percentage of metalaxyl-resistant isolates late in the growing season. A lower frequency of resistant isolates was found in samples from early potato cultivars than in early samples from late potato cultivars. The implications of the mixed mating type situation and reduced sensitivity to metalaxyl are discussed.

Key words: mating types, metalaxyl sensitivity, oospores, *Phytophthora infestans*

Introduction

Potato late blight causes problems for potato growers globally. A diverse *Phytophthora infestans* population has evolved in different parts of the world, including Norway (Brurberg *et al*., 1999). The first isolate of mating type A2 in Norway was found in 1993 (Hermansen and Amundsen, 1995). Metalaxyl resistance is common in many of the areas where potatoes are grown in Norway, including Jæren in Rogaland county (Hermansen *et al*., 2000).

In a recent study of the *P. infestans* populations in Finland and Norway no differences in the frequency of mating types A1 and A2 were found in samples taken at different periods of the growing season. No clear pattern in shift of metalaxyl resistance during the growing season was found (Hermansen *et al*., 2000). However, that study was based on bulked data, and separate fields were mainly sampled once. The objectives of this study were to characterize the populations of *P. infestans* in samples from fields at different periods of the growing season, concerning both metalaxyl resistance and mating type. Knowlegde of these traits are important when decisions regarding control strategies are taken.

Materials and Methods

Collection of samples

In 1998 and 1999 potato leaves infected by *Phytophthora infestans* were collected from 14 and 20 different fields, respectively, at Jæren in Rogaland county. In 1998 seven of the fields were treated once with products containing metalaxyl and one field was treated twice. Five fields were treated with other fungicides and two fields were untreated in 1998. In 1999 metalaxyl was used in only four fields, 11 fields were treated with other fungicides and five fields were not sprayed. From each field 16 leaflets were sampled consisting of four infected leaves from four different plants. From some fields less leaf samples were collected due to low disease levels. The samplings were carried out according to international guidelines (Williams and Gisi, 1992; Sozzi *et al*., 1992) with a distance of at least six metres between each collected plant from the same field. Samples were collected from several fields at the time of the season´s first late blight infections at Jæren. At the end of the growing season several fields were sampled, including some of the fields that were sampled early. In 1999, two conventional and one organic fields (from now on called “test fields”) were sampled throughout the season. None of the test fields were treated with metalaxyl, and from these fields samples were collected at intervals of one to two weeks. The sampling was carried out approximately at the same places in the field each time.

Isolation

Isolations were made on plates with rye agar B (Caten and Jinks, 1968), but with 2 % glucose instead of sucrose, amended with 400 mg L^{-1} pimaricin and 200 mg L^{-1} ampicillin, and incubated at 18 °C. Hyphal tips were transferred to new plates of agar seven to ten days after isolation. When pure, the isolates were transferred to and maintained on rye B agar without antibiotics. Each isolate represented one single leaf lesion. Koh *et al*. (1994) and Sujkowski *et al*. (1994) have previously shown that isolates from single lesions are single genotypes. Each isolate is therefore considered as an individual.

Mating type

In 1998 and 1999, 149 and 423 isolates, respectively, were tested for mating type. Known isolates of A1 and A2 mating type of *P. infestans* from CBS (Centraalbureau voor Schimmelcultures, Baarn), The Netherlands were used in the test in 1998 (CBS 430.90 and CBS 429.90). In 1999 known A1 and A2 isolates (S18 and S90) from the Swedish University of Agricultural Sciences, Uppsala, Sweden were used. Mycelial plugs (5 mm diameter) from each tested isolate were paired with both the known A1 and A2 isolate on separate 90 mm plates with rye agar B. The plates were incubated at 18 °C for 11-20 days and then examined for oospores at the hyphal interfaces between the isolates. Isolates producing oospores with the known A1 isolate were characterized as A2 isolates, and isolates making oospores with the known A2 isolate were characterized as A1 isolates. Isolates making oospores with both the A1 and A2 isolates were noted as A1A2, but not further examined to test whether these were selffertile or not. Some isolates did not grow well on agar, and thus mating types could not be determined.

Metalaxyl sensitivity

In 1998 and 1999, 129 and 194 isolates respectively, were tested for metalaxyl sensitivity. Mycelial plugs (5 mm diameter) from growing colonies of *P .infestans* were placed on separate 90 mm plates with rye B agar containing different concentrations of metalaxyl. Concentrations of 10 ppm (10 mg L^{-1}) and 100 ppm (100 mg L^{-1}) technical-grade metalaxyl dissolved in 0.1 % dimethyl sulfoxide (DMSO) were used in 1998. The control plates contained 0.1 % DMSO, but no metalaxyl. In 1999 a more efficient one-isomer of metalaxyl, metalaxyl-M, was used. Tests showed that metalaxyl-M was about twice as efficient as metalaxyl used in 1998 (Hermansen, unpubl.). As a consequence, the concentrations of metalaxyl used in 1999 were changed from 10 and 100 ppm to 5 and 50 ppm, respectively. Control plates in 1999 contained pure rye agar B. The plates were incubated at 18 °C in 1998 and 21 °C in 1999 for up to 14 days. Colony diametres were measured in two perpendicular directions on all plates. Sensitive, intermediate and resistant isolates were defined as isolates with < 10 %, 10-60 % and > 60 % growth, respectively, on 10 ppm metalaxyl (5 ppm metalaxyl-M), relative to growth on control plates (Shattock, 1988). There were two replicate plates for each tested isolate. Two control isolates, one metalaxyl-sensitive and one metalaxyl-resistant, were included in each test.

Statistics

The data were assumed to have a binomic distribution and were analysed using SAS (SAS Institute Inc.) General Linear Models Procedure. The results of the analyses are expressed as probability values (p) in relation to chi-square values.

Results

Mating types

Based on data from all 34 fields the frequency of mating type A2 was 21.7 % (n=61) in 1998 and 52.7 % (n=178) in 1999. To avoid that isolates from some of the fields dominated this calculation, a maximum of 12 isolates per field in 1998 and 16 isolates per field in 1999 was used. These isolates were picked according to percentage of A1 and A2 isolates in each field. Only isolates from one sampling date in each field were used in the calculation.

In 1999, mating type was determined for 371 isolates. In five out of 15 fields with five or more isolates characterized, only one mating type was present. In two of these five fields, only mating type A1 was found, and in three fields only mating type A2 was observed. In addition to these five fields, one field had only isolates of mating type A2 and A1A2. Out of 371 tested isolates, seven were characterized as A1A2.

In most of the fields both mating types were present, and which one dominating varied between fields. There was no clear cut tendency in the variation of frequency of different mating types in the same field through the growing seasons.

In one of the test fields from 1999 (field 2) isolates of mating type A2 were found at a low frequency (< 10 %) and A2 was only observed on two out of five sampling dates. In field 1 the frequency of A2 isolates varied between 15.4 % and 42.9 %, and in the organic field (field 3), the percentage of A2 isolates varied between 28.6 % and 50.0 % at different sampling dates (Fig.1). Sample sizes at different dates varied from 10-16 in field 1, from 11-15 in field 2 and from 7-15 in field 3. In field 1 and 3 the percentage of A2 isolates tended to increase towards the end of the growing season, but there were no statistically significant differences in the frequency of mating type during the time of sampling.

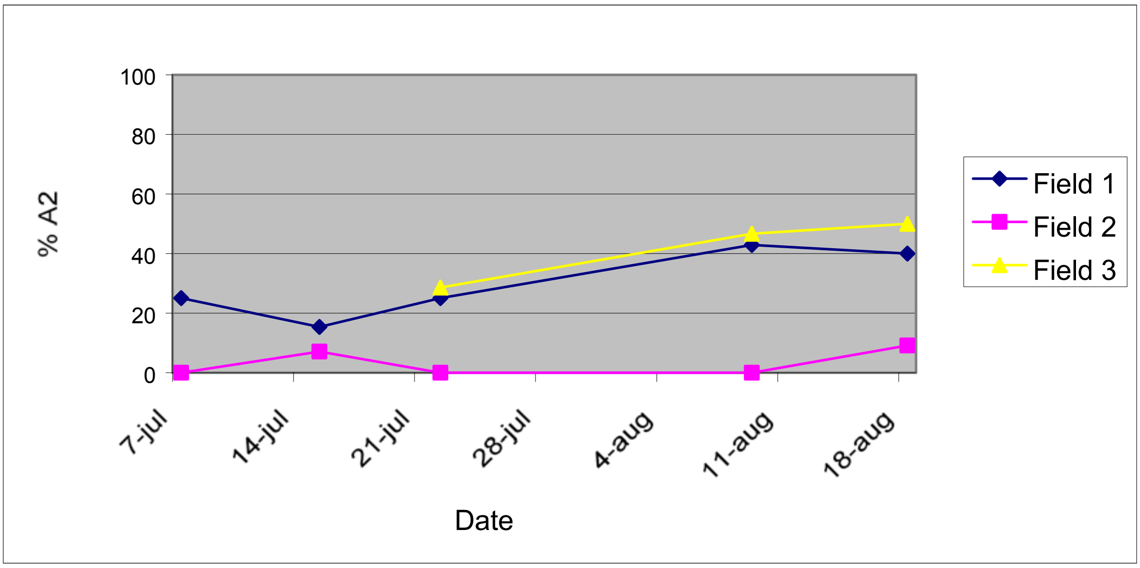

Figure 1. Percentage *P. infestans* isolates of mating type A2 in the test fields from 1999 at different sampling dates.

Bulked data from early samplings (before 1 July) of six fields and late samplings (after 2 September) of six other fields shows a stable percentage of isolates of mating type A2 at about 50 % (Fig. 2).

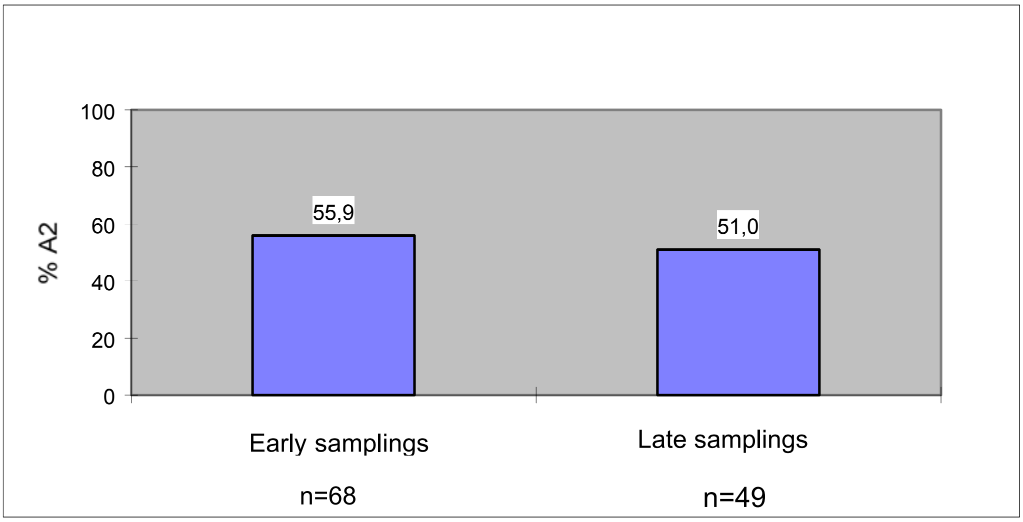

Figure 2. Percentage *P. infestans* isolates of mating type A2 in early samplings (six fields) and late samplings (six other fields) in 1999.

In fields with a mixed population of A1 and A2 isolates both mating types occurred on 22 of 84 examined plants (26.2 %) from which more than one isolate were tested.

Metalaxyl sensitivity

In 1998 and 1999 the frequency of metalaxyl-resistant isolates at Jæren was 29.2 % and 19.2 % respectively (Table 1). Only data from one sampling date from each field is included in this calculation.

Data from the three test fields in 1999 showed a high frequency of metalaxyl-intermediate isolates (Fig. 3,4,5). In all three fields, including the organic field, metalaxyl-resistant isolates were found at the first sampling date. No statistically significant differences were found with respect to metalaxyl sensitivity between sampling dates in either of the three test fields.

Table 1. Metalaxyl sensitivity among *P. infestans* isolates in 1998 and 1999.

Year	% S	% I	% R		Fields
1998	31.9	38.9	29.2	72	14
1999	39.8	41.0	19.2	83	9

S = sensitive, I = intermediate, R = resistant

In 1999 a higher percentage of metalaxyl-resistant isolates was found ($p < 0.01$) in late samples (46 isolates collected after 15 August from five fields) than in early samples (70 isolates collected before 15 July from seven fields) (Fig. 6). Among the isolates from the early samples, 27 isolates came from fields with early potato cultivars. There was significantly ($p < 0.005$) lower percentage of resistant isolates from the fields with early potato cultivars than from fields with late cultivars (Table 2).

Table 2. Metalaxyl sensitivity among *P. infestans* isolates collected from early and late potato cultivars. Samples collected before 15 July, 1999.

	% S	**% I**		**Isolates**	**Fields**
Early potato cultivars	70.4	25.9	3.7	27	3
Late potato cultivars	24.2	60.6	15.2	33	3

S = sensitive, I = intermediate, R = resistant

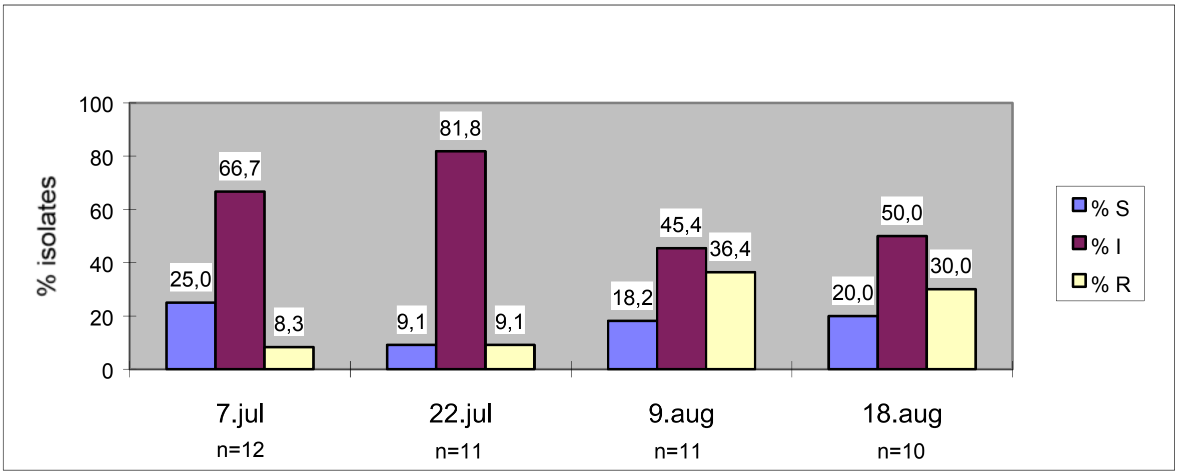

Figure 3. Metalaxyl sensitivity among *P. infestans* isolates from field 1 at different sampling dates during the growing season of 1999. S = sensitive, I = intermediate, R = resistant.

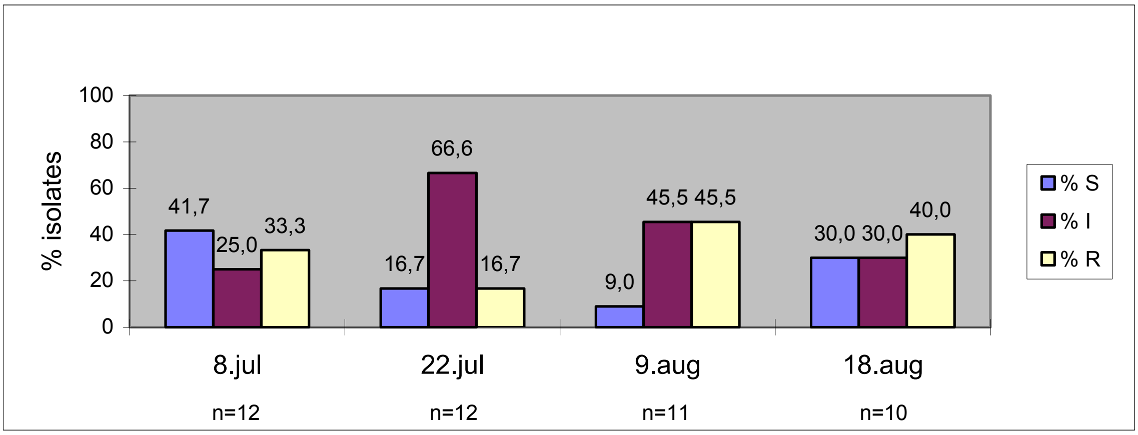

Figure 4. Metalaxyl sensitivity among *P. infestans* isolates from field 2 at different sampling dates during the growing season of 1999. S = sensitive, I = intermediate, R = resistant.

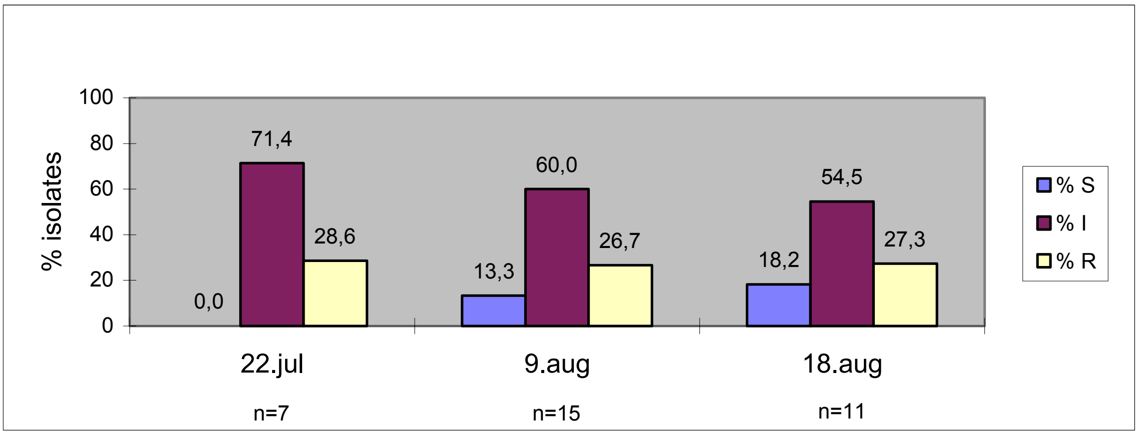

Figure 5. Metalaxyl sensitivity among *P. infestans* isolates from field 3 at different sampling dates during the growing season of 1999. S = sensitive, I = intermediate, R = resistant.

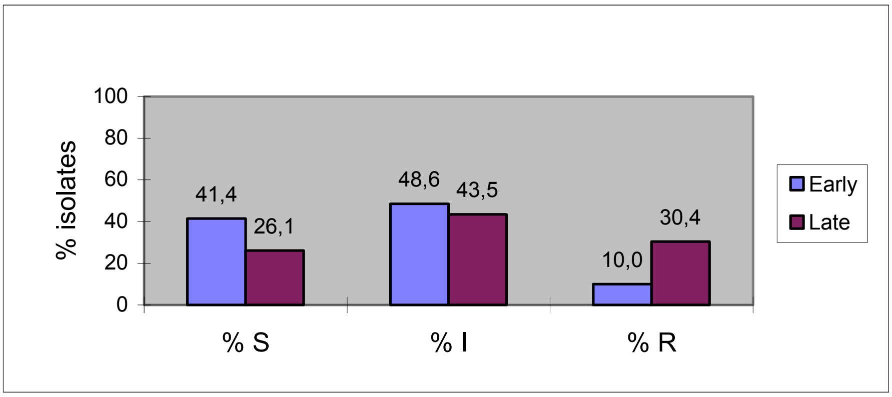

Figure 6. Metalaxyl sensitivity among *P. infestans* isolates early (n=70 from seven fields) and late (n=46 from five fields) in the growing season of 1999. S = sensitive, I = intermediate, R = resistant.

Discussion

In 1998 and 1999 the percentage of A2 mating type at Jæren was 21.7 % and 52.7 %, respectively. In most of the fields both mating types were present and the frequencies of A1 and A2 varied from field to field. In earlier studies of the Norwegian population of *P. infestans* (Hermansen *et al*., 2000) the percentage of A2 isolates in Rogaland county averaged 30 % in the period 1993-96. However, comparisons of *P. infestans* populations might be biased by several factors as variation of number of tested isolates in each survey and different conditions for development of late blight epidemics.

Data from 1999 showed a stable frequency of mating type A2 at about 50 % both early and late in the season. In central parts of Mexico, where sexual reproduction is considered usual, an approximately 1:1 distribution of A1 and A2 is found (Gallegly and Galindo, 1958). Several fields at Jæren had both mating types present throughout the growing season and both mating types were isolated from the same plant in several cases. The potential for oospore production is therefore present during a long period of the growing season. Drenth *et al*. (1995) concluded that the climatic conditions in the Netherlands are suitable for oospore production. Cohen *et al*. (1997) found a higher level of oospore production at low (8-11 °C) than at high (18-23 °C) temperatures, and stated that long periods of moisture were important for oospore production. Thus the climate in Norway is conducive for oospore production. Hermansen *et al*. (2000) examined 27 leaflets, each with two separate lesions, and oospores were found in all out of four leaflets where both mating types were present in the same leaf. Brurberg *et al*. (1999) studied the genetic variability in the Norwegian and Finnish population of *P. infestans*. They concluded that the high percentage of A2 isolates, the presence of many different genotypes and the large genetic distances between genotypes indicate sexual reproduction of the pathogen populations both in Norway and Finland.

In 1999 the first late blight infections in Norway were observed about two weeks earlier than previous years. It is hard to accuse oospores for this event. Even though several possible consequences of sexual reproduction have been put foreward (Drenth *et al*., 1995), considerable changes in the pattern of late blight epidemies have not yet been seen in Norway.

In 1996 the percentage of sensitive, intermediate and resistant isolates in Rogaland county was 18.8 %, 64.7 % and 16.5 %, respectively (Hermansen *et al*., 2000). The frequency of metalaxyl-resistant isolates was somewhat higher in 1998 and 1999. The highest percentage of resistant isolates was found in 1998, but this might have been caused by differences in sampling procedures. First, more field were treated with metalaxyl in 1998 than in 1999. Second, there was a higher number of samples from early potato cultivars in 1999 than in 1998. A lower percentage of metalaxyl-resistant isolates in early than in later cultivars was found. This may be due to the fact that early potato cultivars are normally not treated with metalaxyl, and these crops are harvested before inoculum from later cultivars is spread. Thus, inoculum from tubers of early potato cultivars most likely will be metalaxyl-sensitive. Third, there was also a higher number of early samples from later potato cultivars in 1999. The data from all early and late samplings in 1999 showed a statistically significant higher percentage of resistant isolates in late than in early samplings. However, in this comparison, some of the early samples were collected from fields with early potato cultivars. There are several other studies that also show an increase in metalaxyl resistance during the growing season (Olofsson, 1989; Williams and Gisi, 1992; Dowley *et al*., 1995; Chycoski and Punja, 1996).

Gisi and Cohen (1996) claimed that the level and duration of metalaxyl resistance depend on selection pressure, that is fungicide concentration and number of treatments, and survival and fitness of resistant individuals. Studies have been carried out to compare survival and fitness of metalaxyl-resistant and -sensitive individuals, giving varying results (Kadish and Cohen, 1988; Williams and Gisi, 1992; Dowley *et al*., 1995). Williams and Gisi (1992) reported that metalaxyl-resistant isolates had better fitness during the growing season, but less ability to survive through the winter than metalaxyl-sensitive isolates. Even if the percentage of resistant isolates increased during the growing season, it was rather low at the beginning of next years' season (Williams and Gisi, 1992). These results suggest that metalaxyl should be used early in the season, while the sensitivity still is relatively high, without causing an increase in the frequency of metalaxyl-resistant isolates from one year to the next. None of the three test fields in 1999 were treated with metalaxyl and the percentage of resistant isolates was relatively stable during the growing season.

There have been variable results with metalaxyl treatments against populations of *P. infestans* containing resistant individuals (Davidse *et al*., 1981; Dowley and O'Sullivan, 1981; Nuninger *et al*., 1995). Urech and Staub (1985) proposed some anti-resistance strategies for phenylamides, that includes metalaxyl. Products with phenylamides should never be used curatively and only in mixture with other fungicides. The products should not be used more than 2-4 times per season, and preferably early in the season. Nuninger *et al*. (1995) concluded that if these anti-resistance strategies are followed, fungicides containing metalaxyl will be effective even if a part of the *P. infestans* population is resistant. Urech and Staub (1985) proposed that if the percentage of resistant isolates should not exceed 10 % if metalaxyl-containing products still could be effective. In one of the test fields from 1999 less than 10 % resistant isolates were found early in the season, but in another test field the percentage of resistant isolates was above 30 % at that time.

Conclusion

Mating type data from Jæren indicate a potential for sexual reproduction of *P. infestans* during a long period of the growing season. Major changes in the late blight epidemics have not yet been seen. More research is needed to find out how important oospores in the soil are as an inoculum-source compared to inoculum from tubers. To reduce the risk of soil borne inoculum, an effective late blight control including proper crop rotation should be carried out.

The percentage of metalaxyl-resistant isolates varied between fields. Some fields had a relatively high frequency of resistant isolates throughout the growing season. This indicates that treatments with metalaxyl might have limited effect in some fields. A high frequency of the tested isolates was classified as intermediate sensitive to metalaxyl. It is not known how these isolates respond to metalaxyl treatments under field conditions. The overall results indicate an increase in metalaxayl-resistance during the season. Use of metalaxyl at any time would cause a selection pressure towards an increase of resistant isolates. When metalaxyl is used early in the season it will probably be effective against a higher proportion of the isolates than later in the season. In Norway not more than two metalaxyl treatments per season should be used. Products containing metalaxyl is not recommended to used curatively, and should only be used early in the season before symptoms are visible. However it is not for certain that these recommendations are right in populations with medium levels of metalaxyl resistance early in the season, as found at Jæren.

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Fifth Workshop of an European Network for development of an
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Old en new populations of *Phytophthora infestans* in Germany

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Summary
215 isolates of *Phytophthora infestans* have been investigated for mt-DNA-haplotype, mating type, pathotype and resistance against metalaxyl. In the old countries (West Germany) a shift from the old population to the new population started in 1993/94. This replacement has not yet been finished and the changes are still going on. All isolates of the old haplotype Ib belong to the mating type A1, including those which were collected after the first appearance of the mating type A2. All isolates of the old haplotype Ib are sensitive to the fungicidal compound metalaxyl. The portion of complex pathotypes is higher in the new haplotypes Ia and IIa than in the old haplotype Ib.

Key words: haplotypes, mating types, metalaxyl resistance

Introduction

Since the Irish famine of the year 1845 caused by crop failure, there is an intense effort to control *Phytophthora infestans* (Mont.) de Bary in potatoes. During the last decades it was possible to obtain relatively high potato yields by combining cultivar resistance, crop management and fungicide applications.

However, since this fungus is extremely adaptable to its environment, there is always a new challenge. Since the mid-eighties, both mating types were found coexisting not only in Mexico, but also worldwide. Therefore, *Phytophthora infestans* can breed sexually which results in a higher genetic variability of the fungus. When this happens, it was observed in many countries simultaneously that the so-called ”old populations” vanished within a few years and were replaced by the so called ”new populations”. Fry *et al*. already reported in the year 1993 about the occurrence of ”old and new populations” as well as Day and Shattock who in 1997 surveyed *Phytophthora infestans* isolates in England taken in the period from 1978 to 1995. In 1998, Griffith and Shaw examined isolates from England, Russia, the USA and Taiwan which had been isolated during the period from 1978 to 1994. They all found proof of the existence of both *Phytophthora infestans* types.

The new isolates proved to be even more aggressive than the old ones and were much less sensitive to the fungicide Metalaxyl. Since in Germany we have observed during the last couple of years an earlier appearance of the fungus and a more aggressive tendency of late blight it therefore seemed to be logical to survey the local strain collection of the Institute of Plant Protection in Agriculture and Grassland of the Federal Biological Research Centre for Agriculture and Forestry located in Braunschweig for a possible shift of *Phytophthora infestans* from the old population to the new population.

Material and methods

A total of 215 isolates from the period 1967 to 1999 were examined. The strains were sampled in potato fields, subcultured on potatoes and stored in liquid nitrogen. The investigations about mating type, pathotype and fungicide resistance were made routinely every year (Schöber-Butin, 1999). For the generation of amplifiable DNA all *Phytophthora infestans* isolates were cultivated in liquid medium (Henniger, 1963) the mycelium was filtered, freeze-dried and crushed to powder using a pistille and a mortar. Applying the extraction method of Day and Shattock (1997) the total DNA was extracted with the CTAB buffer. After resuspending the DNA with TE buffer the DNA was amplified by a primer pair recognising the mitochondrial DNA. The resulted amplificate has the size of 1070 base pairs and after restricting the DNA with the endonuclease *Msp*I for 3 h at 37°C the three haplotypes of *Phytophthora infestans* old Ib, new Ia and IIa, can be distinguished by the banding pattern:

Ib (old) bands at: 641 base pairs, 350 base pairs, 79 base pairs

Ia (new) bands at: 720 base pairs, and 350 base pairs

IIa (new) bands at: 720 base pairs, 203 base pairs and 147 base pairs

Results and discussion

All 215 *Phytophthora infestans* isolates tested were affiliated to the three haplotypes, and the results are depicted in table 1. Type Ia (new) is represented most, at a range of 66%, whereas only about 7% of the isolates were found to be the old type Ib. This result is caused by the relatively low number of old isolates in the BBA collection. 128 of the total of 215 isolates, that is more than half of the isolates, were collected during 1998 and 1999.

Table 1. Haplotypes within the isolates.

Haplotype	Number	%
old Ib	15	7
new Ia	142	66
new IIa	58	27

Therefore, it is necessary to break down the distribution of the haplotypes into the years. For reasons of clarity, only the strains in Germany are shown in the table 2.

Table 2. Haplotypes and years.

Year	old Ib		new Ia		new IIa	
	Number	%	Number	%	Number	%
up to 1984	3	100				
1985-1989	2	67	1	33		
1990-1994	3	12	19	76	3	12
1995-1999	1	0.6	106	67	51	32

All isolates collected until 1984 belong to the old haplotype Ib. Between the years 1985 and 1989 the new haplotype first appeared in 1986 (Brockhöfe). Between 1990 and 1994 the haplotype IIa first appeared (1993, Hannover). The share of the old haplotype decreased from 1972 to 1999 from 100% to 0.6 %, whereas the new haplotypes increased dramatically starting from 1990 from 88% to 99%. During this change, the numbers of the haplotype Ia decreased and the haplotype IIa increased. In the old federal countries the starting point of replacing the old haplotype Ib by the two new ones (Ia and IIa) is to be set in the years 1993/94. This replacement is not yet finished, because even in the year 1997 the old Ib haplotype could be found.

At a considerably earlier time, in the year 1977, the new haplotype Ia was discovered in the GDR what are now the new countries of Germany. This may have been caused by the different origins of the seed potatoes in the western and eastern part of Germany. The former GDR obtained their seed potatoes from Poland. Poland itself imported the seed potatoes directly from Mexico, the country of origin of the fungus *Phytophthora infestans* and its mating type A2. The genetic variability of the Polish potato populations is much higher than in the West European countries, where each country produced its own seed potatoes.

When the *Phytophthora infestans* isolates are surveyed as to which of the two mating types -A1 or A2- they belong, then the mating type A1 dominates by about 72 %. Remarkable is the relatively high rate of self fertile isolates (Tab. 3).

Table 3. Mating Types.

Mating type	Number	%
A 1	155	72
A 2	21	10
Self fertile	39	18

When the distribution of the mating types is broken down into their haplotypes then it can be shown that all the old haplotypes I b belong to the mating type A1. With the appearance of the new haplotype I a the mating type A2 could be detected. The portion of self fertile isolates is about 27 % in the haplotype IIa and this is extremely high compared to the other haplotypes (Tab. 4).

Table 4. Mating types and haplotypes.

Mating type	A1		A2		self fertile	
Haplotype	Number	%	Number	%	Number	%
old Ib	14	93			1	7
new Ia	106	75	14	10	22	16
new IIa	35	60	7	12	16	28

Very interesting is the distribution of the fungicide resistant isolates. About 37 % of all 215 isolates surveyed are resistant to the fungicidal substance metalaxyl (Tab. 5).

Table 5. Number of metalaxyl resistant strains.

Resistance	Number	%
none	136	63
to metalaxyl	79	37

All isolates belonging to the old haplotype Ib showed a sensitive reaction to the fungicidal substance. From the new haplotypes over 43% are resistant in the haplotype I a and about 30% are resistant in the haplotype II a (Tab. 6).

Table 6. Metalaxyl resistance and haplotypes.

Haplotype	old Ib		new Ia		new IIa	
Resistance	Number	%	number	%	number	%
none	15	100	80	56	41	71
to metalaxyl	0	0	62	44	17	30

Here again, the situation in the new countries (East Germany) and the old countries (West Germany) is different: In old countries the fungicidal substance Metalaxyl was admitted in 1979, and one year later, in 1980, the first resistant *Phytophthora infestans* races appeared.

In new countries the first occurrence of Metalaxyl resistant *Phytophthora infestans* was recorded earlier in 1977. Among the detected Metalaxyl resistant *Phytophthora infestans* isolates there was the earlier mentioned isolate which -for the first time- was classified as the new group of haplotype Ia.

When breaking down the haplotypes into their pathotype pattern, the following picture is obtained:

Table 7. Haplotypes and Pathotypes (Partial results).

Haplotype	Pathotype
old, Ib	**4; 1.4; 2.6;** 1.2.4; 1.3.7; 4.10.11; 1.2.3.4; 1.3.4.7; 3.4.7.11; 1.3.4.7.11; 1.2.3.4.8.11; 1.3.4.7.8.10.11; **1.2.3.4.7.8.10.11**
new, Ia	**1.4; 4.7; 4.11;** 1.2.4; 1.3.4; 1.3.7; 1.4.11; 3.4.7; 4.7.8; 1.2.3.4; 1.2.3.11; 1.3.7.11; 1.4.7.8; 1.4.10.11; 3.4.10.11; 1.3.4.5.11; 1.3.4.6.7.; 1.3.7.10.11; 2.3.4.7.11; 3.4.7.8.11; 1.3.4.7.8.10; 2.3.4.7.8.11; 3.4.7.8.10.11; 1.2.3.4.6.7.10; 1.2.3.4.6.7.11; 1.3.4.5.7.8.11; 1.3.4.6.7.8.11; 2.3.4.7.8.10.11; 1.2.3.4.6.7.8.11; 1.3.4.6.7.8.10.11; 1.2.3.4.5.6.7.10.11; 1.2.3.4.5.7.8.10.11; 1.2.3.4.5.6.7.8.10.11; **1.2.3.4.5.6.7.8.9.10.11**
new, IIa	**1.3.4; 1.3.7;** 1.3.7.11; 1.4.10.11; 1.2.3.4.7; 1.3.4.7.11; 1.3.7.10.11; 3.4.7.10.11 1.2.3.6.7.10; 1.3.4.7.10.11; 1.3.5.7.10.11.; 2.3.4.7.10.11; 1.2.3.4.6.7.11; 1.2.3.6.7.10.11; 1.3.4.5.7.10.11; 1.3.4.7.8.10.11; 2.3.4.5.6.10.11; 1.2.3.4.6.7.8.11; 1.3.4.5.7.8.10.11; 2.3.4.6.7.8.10.11; 1.2.3.4.5.6.7.10.11; 1.2.3.4.5.7.8.10.11; 1.2.3.4.6.7.8.10.11; **1.2.3.4.5.6.7.8.10.11**

Conclusions

1.) In the old countries (West Germany) a shift from the old population to the new population was starting in 1993/94. This replacement has not yet been finished and the changes are still going on.
2.) All isolates of the old haplotype Ib belong to the mating type A1, including those which were collected after the first appearance of the mating type A2.
3.) All isolates of the old haplotype Ib are sensitive to the fungicidal compound metalaxyl.
4.) The portion of complex pathotypes is higher in the new haplotypes Ia and IIa than in the old haplotype Ib.

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Fifth Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Munich, Germany, 6-10 September 2000

The evolution of the foliar late blight resistance of the cultivar - Two years of trials in northern France (1999 - 2000) - The main results

S. DUVAUCHELLE – L. DUBOIS

Help for synthesis : C. HACCART, J. BRUYERE, J.C. SALOME

Objectives

The goal of this trial is to verify the differences in the susceptibility to foliager blight of a showcase of potato varieties in an infected and untreated environment.

Through the results obtained from the different scorings, we will be able to integrate this resistance into the strategies of integrated control against potato late blight in the farmers' fields.

The late blight strains change and fit on cultivars. So it's necessary to overlook the change.

Precise data as sporulation and incubation periode can be introduced in epidemiological models when these models take account of these aspects.

More « global » data as disease precocity, development speed and resistance level in comparison with standard are retrieved.

Protocol and design

Larges plots for the studies and demonstration for the growers

Some potato varieties, possessing a different level of susceptibility to late blight, are planted near an inoculum source.

100 seed potatoes are planted on each plot, that corresponds to 30 m^2.

2 replicates for each variety. The variety distribution is done at random within the 2 blocks.

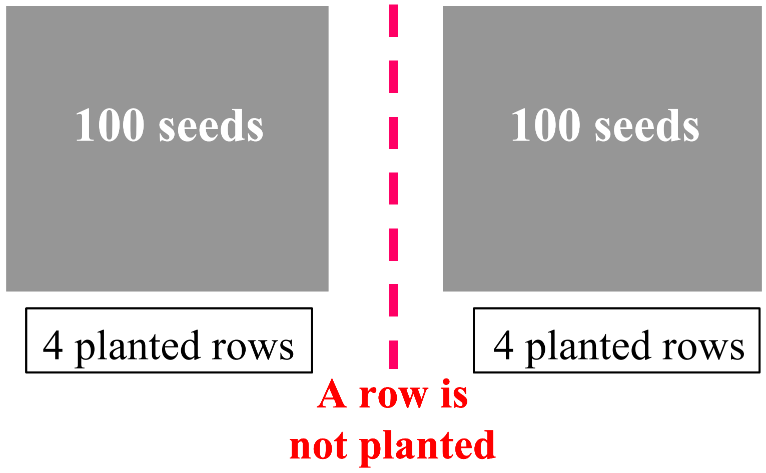

Figure a. The varietal resistance evaluation is done by the comparison with the variety Bintje (susceptible).

Little plots for the studies

Scorings expressed in number of spots are performed on the plots. Then, when the pressure becomes very significant, the scorings are expressed in percentage of destruction.(figure b)

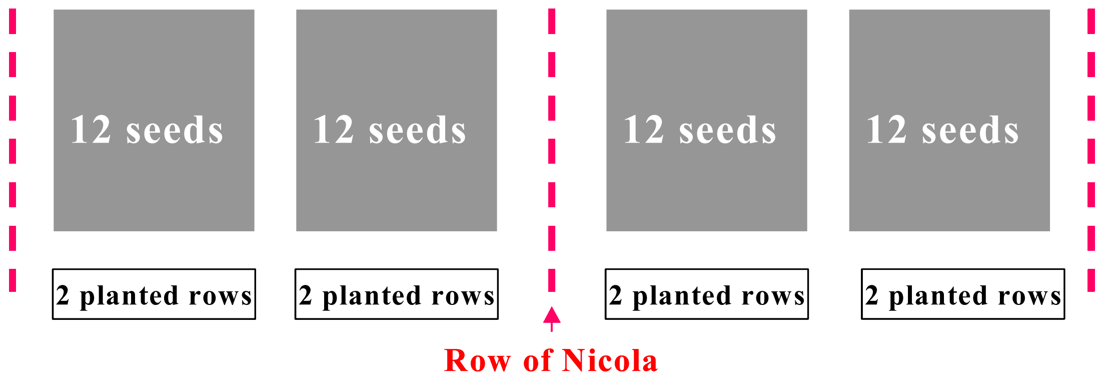

Figure b.

Results 1999 in Nord / Pas-de-Calais :

Synthesis of three trials in Nord –Pas-de-Calais :

susceptible	intermediate	resistant
Innova	Aïda	Sant é
Maritiema	Ditta	99891
Agata	Elkana	Jenny
Russet	Saturna	Felsina
Charlotte	Samba	Bondeville
Bintje	Victoria	Turbo
Kaphta	Juliette	Fr égate
Ostara		Producent
Calgary		Naturella
Donald		Raja
Mondial		Gasore
Punto		
Nicola		
Monalisa		

Figure c.

Results 1999 in Picardy :

In Picardy, 10 potato varieties were tested according to their resistance to late blight. The 6 scorings carried out on the plots gave the following results :

susceptible	intermediate	resistant
Agatha	Charlotte	Aïda
Bintje	Elvira	Amandine
Chérie	Samba	Franceline
Séraphina		

Figure d.

Results 2000 in Centre

In region Centre, 9 varieties were planted on 19 May 2000, the first scoring was carried out on 12 July 2000 when the first spots come out:

Varieties	Number of spots	plants affected
Agata	19	19
Amandine	1	1
Bintje	4	4
Casteline	20	19
Charlotte	1	1
Chérie	14	12
Isabelle	2	2
Marine	4	4
Monalisa	1	1

Figure e. Results 2000 in Nord / Pas-de-Calais.

Discussion

Until now we retain two approaches :

* Susceptibility groups when the disease causes 50% of destruction on Bintje.
* Disease precocity with a threshold according to speed development of the disease.

We can study an example on six varieties :

– Bintje, Charlotte, Felsina, Nicola, Santana, Bondeville

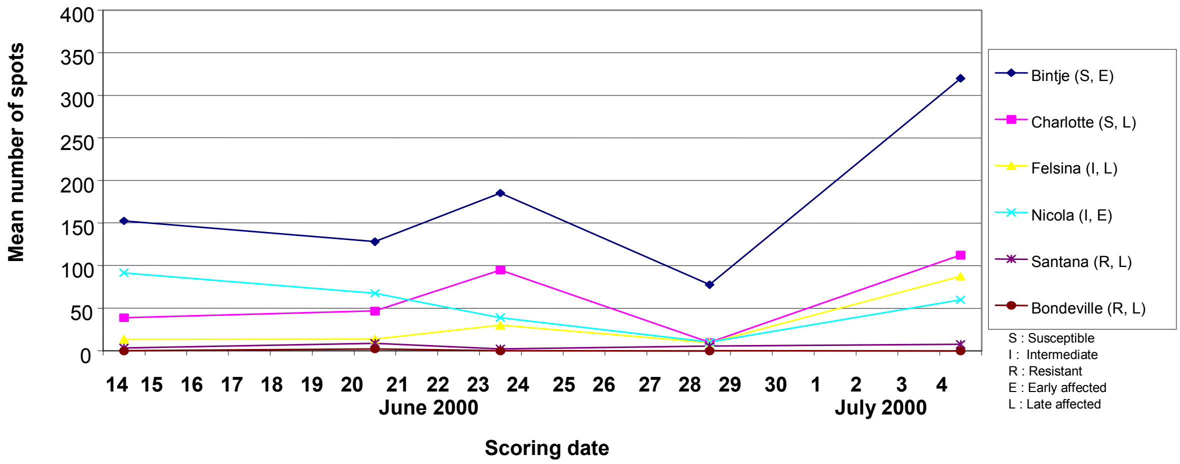

Figure f. Discussion of an example of 6 varieties (Auchy-les-Mines).

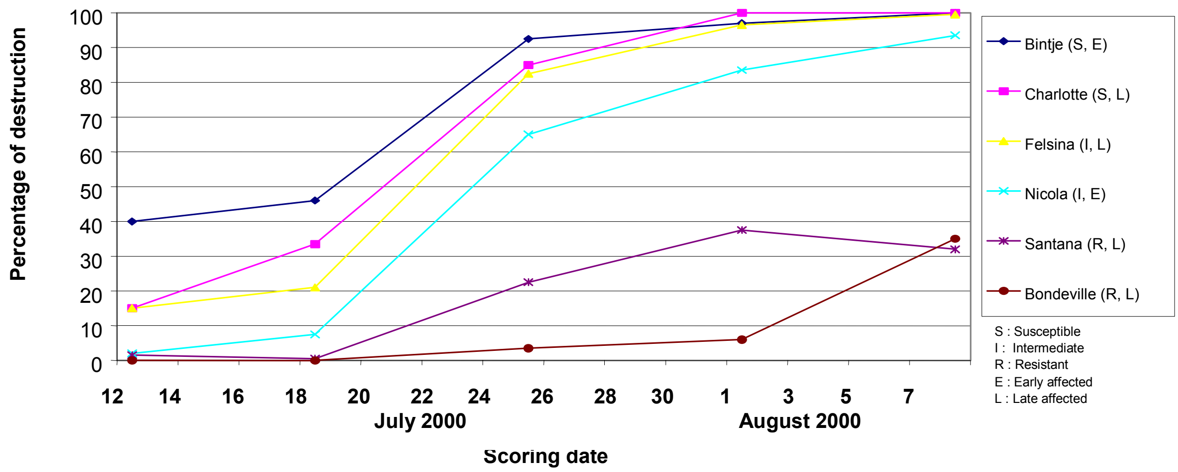

Figure g. We can study the susceptibility at differents dates.

Variety trial - foliar blight

Bintje is very susceptible from the beginning to the end of the campaign.

Bondeville and Santana are resistant during all the campaign.

Nicola is infected early but the disease remains at a low level and increases only at the end of the campaign.

On Felsina the development of disease is very simular to that on Nicola but on a some what higher level.
The development on Charlotte has the same figure from end of July but increase is even faster.

Discussion

So with this approach we can distinguish 3 groups :
The very susceptible varieties as Bintje with a fast disease development during all the campaign.
The less susceptible varieties as Santana and Bondeville with a very low development during all the campaign.
Intermediate susceptibility with Charlotte, Felsina, Nicola but with different speed of development which can be mesured by the slope of the curve, or for a disease value the delay according to Bintje.

Conclusion

The relationships « cultivar - disease » are very important to succeed in an efficient DSS. They have to be even precise.

	Number of spots		% of destruction	
	14 june	23 june	12 july	24 july
Bintje	100 < S	100< S	40% S	90%< S
Charlotte	< 50 R	50 < <100 I	10%< < 20% I	80% < < 90% S
Felsina	< 50 R	< 50 I	10%< < 20% I	80% < < 90% S
Nicola	50< < 100 I	< 50 I	< 5% R	60% < < 70% I
Santana	< 50 R	< 50 R	< 5% R	20% R
Bondeville	< 50 R	< 50 R	< 5% R	5 % R

Figure h.

Fifth Workshop of an European Network for development of an
Integrated Control Strategy of potato late blight
Munich, Germany, 6-10 September 2000

Potato blight population studies 1999- 2000 and Field results on integration of cultivar resistance and fungicide programmes

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Summary

In the year 2000, phenylamide-resistant strains were present in 57% of Northern Ireland isolates of *P. infestans* (a slight increase on recent years). In 1999-2000, the commonest multi-locus genotypes were A1, *Gpi 100/100, Pep 100/100*, mtDNA IIa and A1, *Gpi 100/100, Pep 100/100*, mtDNA Ia, in agreement with a previous study. No A2 mating type isolates were detected. Haplotype IIa predominated, but this was less marked in the year 2000 (56% of isolates) than in 1999 (82% of isolates) and earlier years. A field trial using fungicide programmes designed to give different levels of protection showed that in Northern Ireland with a cultivar as susceptible as Bintje, only the 'low risk' programme provided acceptable control. On the more resistant cultivars, Santé and Navan, a longer spray interval gave acceptable foliar blight control. Exceptionally wet weather in autumn 2000 prevented the trial being harvested, so it was not possible to assess effects of treatments on tuber blight. Cv. Santé proved more susceptible to foliage infection than cv. Navan despite its higher NIAB ratings (Santé 7, Navan 5 for foliar blight where 9 is maximum resistance).

Key words: *Phytophthora infestans*, potato late blight, phenylamide fungicide resistance, *Gpi* genotype, *Pep* genotype, mtDNA haplotype.

Introduction

A study of the *Phytophthora infestans* population in Northern Ireland during the period

1995-1996 showed that it is related to populations in Great Britain and mainland Europe in terms of its allozyme genotype (glucose-6-phosphate isomerase, *Gpi*, and peptidase, *Pep*), but can be distinguished by the predominance of the mitochondrial DNA haplotype IIa and by using RAPD analysis (Carlisle *et al.*, 2001). The population is almost exclusively of the A1 mating type (Cooke *et al.*, 2000). Characterisation of isolates over a longer time period (1992-1998) confirmed this pattern (Carlisle and Cooke, 2000). This paper reports the characterisation of isolates from the years 1999 to 2000, carried out to determine if the previously reported population structure was being maintained.

Investigations into the control of potato late blight in Northern Ireland in the last ten years have focused on highly blight-susceptible cultivars such as Up-to-Date (e.g. Cooke and Little, 1998). No recent work has been carried out on the integration of fungicide use with more resistant cultivars, as has been reported to be effective elsewhere (Gans *et al.*, 1995). Laboratory studies of the aggressiveness of Northern Ireland *P. infestans* isolates on detached leaflets of a range of potato cultivars have shown that isolates have lower infection frequency, longer latent periods, slower lesion growth and reduced sporulation capacity on more field resistant cultivars (Carlisle, 2000). A small-scale field trial was therefore initiated to investigate the effects of fungicide programmes giving different levels of blight control on three potato cultivars believed to have different levels of non-race-specific resistance.

Materials & Methods

Sampling of potato crops and isolation of Phytophthora infestans

Samples of infected potato foliage together with data on sample site, potato cultivar, fungicide usage and disease incidence were obtained (mainly from seed crops) by members of the Department of Agriculture's Potato Inspection Service, as previously described (Cooke *et al*., 1997). Isolates were derived by bulking together the sporangia obtained from all foliage samples within a single crop and initially maintained on detached glasshouse-grown potato leaflets (Cooke, 1986). After phenylamide resistance testing, isolates were transferred into axenic culture (Cooke *et al.*, 2000) for further characterisation.

Tests for phenylamide resistance

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

Mating type determination

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

Glucose-6-phosphate isomerase and peptidase allozyme genotype determination

Genotypes at two polymorphic allozyme loci, *Gpi-1* (glucose-6-phosphate isomerase, GPI) and *Pep-1* (peptidase, PEP), were determined by cellulose acetate electrophoresis following the protocols of Goodwin *et al.* (1995) using tissue extracts prepared from fungal mycelium grown on antibiotic pea or rye agar plates (Carlisle *et al*., 2001). Tris-borate-EDTA (TBE) buffer was used for improved resolution of *Pep* alleles (Carlisle *et al.,* 2001).

Identification of mitochondrial DNA haplotypes

Mitochondrial DNA (mtDNA) haplotypes of isolates were determined by PCR-RFLP using a modification of the method of Griffith and Shaw (1998) as described by Carlisle *et al.* (2001). Amplified DNA was digested with *Msp*I (for primer pair F2/R2 products) or *Eco*RI (for primer pair F4/R4 products).

Field trial on integration of cultivar resistance and fungicide programmes

The field trial was planted on 5 May 2000 in a split-plot design with three fungicide programmes as main plots and three cultivars as sub-plots. There were four replicate blocks. Each main plot comprised six drills x 3 m and was divided into sub-plots of two drills x ten tubers of each cultivar. Main plots were separated by pairs of unsprayed drills of cv. Désirée. The three test cultivars, selected on the basis of differing blight susceptibility as indicated by their National Institute of Agricultural Botany (NIAB) ratings (Anon., 1999) for foliage and tuber blight, respectively, (on a 1-9 scale where 9 is maximum resistance), were Bintje (2, 2), Navan (5, 4) and Santé (7, 8). The three fungicide programmes, which were applied by knapsack sprayer high volume in *c.* 350 l ha^{-1}, were:

1. Low risk: 3 x 'Fubol Gold' (1.9 kg ha^{-1}; 76 g metalaxyl-M + 1216 g mancozeb ha^{-1}) at 10-d intervals (21, 30 June, 10 July) followed by 7 x 'Shirlan' (300 ml ha^{-1}, 150 g fluazinam ha^{-1}) at 7-d intervals (20, 27 July, 3, 10, 17, 23, 30 August).
2. Medium risk: 2 x 'Fubol Gold' at 14-d intervals (21 June, 4 July) followed by 3 x 'Shirlan' at 14-d intervals (27 July, 10, 23 August).
3. High risk: 3 x 'Cuprokylt' (5 kg ha^{-1}, 2.5 kg copper ha^{-1} as copper oxychloride) depending on infection pressure (7 July, 10, 23 August).

In the infector drills, two leaves on every fourth plant of cv. Désirée were inoculated (24 July, 2 August), alternately with phenylamide-resistant and –sensitive Northern Ireland isolates (obtained in 1998-99) of *P. infestans*. Irrigation was provided by a rain-gun when required. Foliar blight was assessed twice weekly on all drills from 7 August. The infector drills were cut down when infection was *c.* 10%.

Results

Incidence of phenylamide resistance

In the year 2000, only 30 blight samples which yielded viable isolates of *P. infestans* were received. The reduced number compared with previous years (*c*. 50 samples were requested and 40-50 generally received) was attributed to weather early in the season which was not conducive to blight. The first field outbreaks were not reported until 22 June, later than in any recent year except 1995. Although conditions from the third week in July onwards were very favourable to infection, the number of primary infections was low and fewer outbreaks than usual were recorded. The overall proportion of isolates containing phenylamide-resistant strains of *P. infestans* for the years 1981-2000 is shown in Figure 1. Of the 30 isolates tested in the year 2000, 17 (57%) proved to contain phenylamide-resistant strains, an increase on recent years. No isolates with intermediate resistance were detected in contrast to 1999.

The slight increase in the proportion of isolates containing resistant strains may be due to increased phenylamide fungicide usage, particularly in Co. Down.

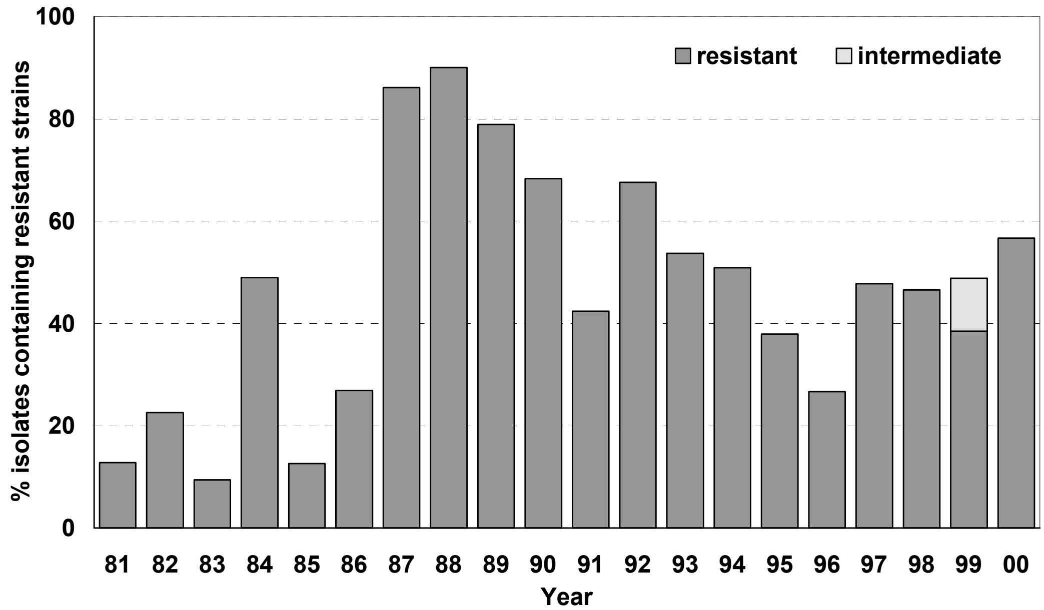

Figure 1. The proportion of Northern Ireland Phytophthora infestans isolates containing phenylamide-resistant strains, 1981-2000.

Mating type and allozyme genotype, 1999-2000

Mating type was determined for 40 multiple-lesion *P. infestans* isolates obtained in 1999 and 29 isolates in 2000; all proved to be of the A1 mating type. No A2 isolates have been found in Northern Ireland since 1995 (Carlisle and Cooke, 2000).

Dilocus genotypes for *Gpi* and *Pep* were determined for 40 isolates from 1999 and 29 isolates from 2000. Of these, 61 isolates (37 from 1999 and 24 from 2000) were *Gpi 100/100, Pep 100/100*. The remaining isolates (3 from 1999 and 5 from 2000) were *Gpi 100/100*, but had different *Pep* genotypes, possibly *96/100* (further characterisation is in progress).

Mitochondrial DNA haplotype determination, 1999-2000

To date, mtDNA haplotypes have been determined for 34 isolates from 1999 and 27 isolates from 2000. The results are shown in Table 1, with data for 1997-1998 (Carlisle, 2000) included for comparison. No isolates had the old haplotype Ib and only haplotypes IIa and Ia were found in 1999-2000, with IIa being the commonest in both years.

Table 1. Mitochondrial DNA haplotypes of *Phytophthora infestans* isolates from Northern Ireland.

Year	No. of isolates	Total number (%) of each mtDNA haplotype			
		Ia	Ib	IIa	IIb
1997	20	0	0	100 (20)	0
1998	47	13 (6)	0	81 (38)	6 (3)
1999	34	18 (6)	0	82 (28)	0
2000	27	44 (12)	0	56 (15)	0

Field trial on integration of cultivar resistance and fungicide programmes

Foliar blight was first observed on some of the ‘high risk’ (copper oxychloride-treated) sub-plots of cvs. Bintje and Santé on 7 August, but was not seen on cv. Navan until 17 August. With the ‘medium risk’ programme (‘Fubol Gold’/’Shirlan’ at extended intervals), foliage lesions were first seen on cv. Bintje on 14 August, on cv. Santé on 17 August, but none developed on cv. Navan. With the ‘low risk’ programme (‘Fubol Gold’/’Shirlan’, minimum intervals), blight was observed on cv. Bintje on 22 August, but not on cvs. Santé or Navan. Foliar blight development is shown in Figure 2 and results of the final assessment before haulm destruction in Table 2. Cv. Bintje developed most foliar blight and only the low risk programme adequately protected it. Cv. Santé was completely protected by the low risk programme, developed little infection with the medium risk programme, but with the high risk programme *c*. 25% of foliage was destroyed by the end of the season. Cv. Navan developed no foliar symptoms with either the low or medium risk programmes and only a low level of infection with the high risk programme.

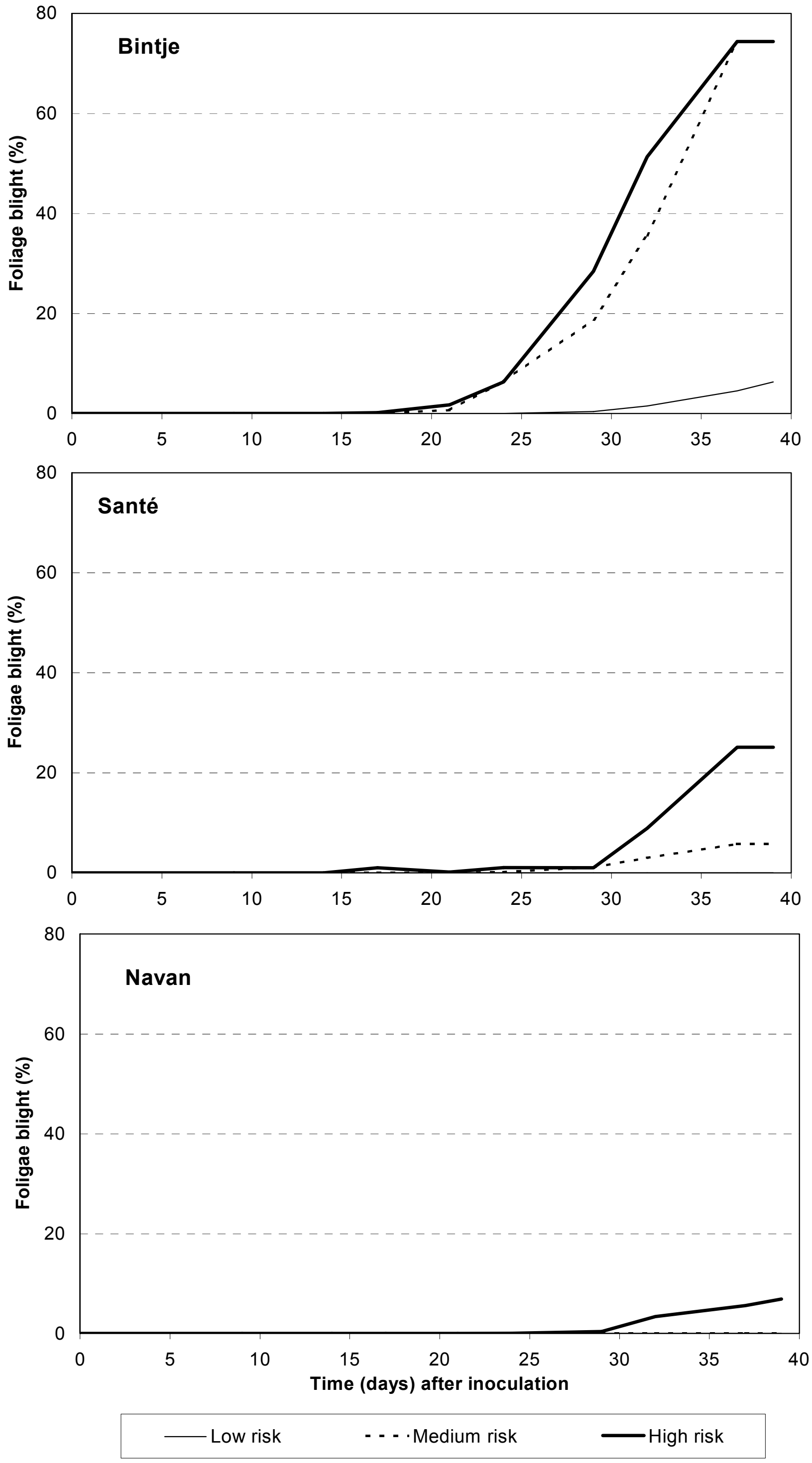

Figure 2. Foliar blight development in three different potato cultivars treated with fungicide programmes giving different levels of protection.

Table 2. Foliar blight in plots of three potato cultivars treated with fungicide programmes giving different level of protection, assessed 1 September 2000.

Fungicide programme	Foliar blight (%) on potato cultivar		
	Bintje	Navan	Santé
Low risk	6.3	0.0	0.0
Medium risk	74.4	0.0	5.8
High risk	74.4	6.9	25.1
L.S.D. (α = 0.05)	24.10 (18.63[a])		

α = for comparison of means within the same cultivar

It was intended to assess tuber blight assessment and yield, but due to the excessively wet weather in autumn 2000, it was not possible to harvest the trial.

Discussion

The incidence of phenylamide-resistant strains in *P. infestans* in Northern Ireland has remained relatively stable in the period 1993-2000, but there was a slight increase in the year 2000. Characterisation of the Northern Ireland *P. infestans* population in 1999 and 2000 has shown that the commonest multi-locus genotypes are:

A1, *Gpi 100/100, Pep 100/100*, mtDNA IIa

A1, *Gpi 100/100, Pep 100/100*, mtDNA Ia

Phenylamide-resistant and phenylamide-sensitive strains occur within both these lineages, although phenylamide-resistant strains tend to be associated with mtDNA haplotype Ia. No A2 mating type isolates have been detected, although they may remain present at a very low level in the population. The predominance of haplotype IIa appears to be characteristic of *P. infestans* in Northern Ireland (Carlisle *et al.*, 2001), but this predominance was less marked in the year 2000 than in 1999 and earlier years.

Typical Northern Ireland isolates of *P. infestans* were used to inoculate the field trial which demonstrated that in a climate highly conducive to late blight and with a highly susceptible cultivar, only the 'low risk' programme provided acceptable control. On more resistant cultivars such as Santé and Navan a longer spray interval may give acceptable control even under high infection pressure, allowing the possibility of extending intervals or reducing application rates using a DSS to optimise timings. The feasibility of this approach in a high rainfall area such as Northern Ireland depends on the risk of tuber infection; use of cultivars with good tuber blight resistance is critical, but this could not be assessed in the present trial. It is noteworthy that cv. Santé proved considerably more susceptible to foliage infection than cv. Navan despite its higher NIAB ratings (Santé 7, Navan 5 for foliar blight). National ratings of cultivar resistance may not accurately indicate cultivar performance at a particular locale and time and there is need for caution when using cultivars not previously tested under local field conditions with local *P. infestans* populations which may be more aggressive and virulent and than isolates used for National List Tests.

Acknowledgements

The authors thank members of the Department of Agriculture's Potato Inspection Service for supplying samples of potato blight and crop information. Several students of the Queen's University of Belfast, particularly Miss Cara Owens, are thanked for their technical assistance.

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Efficacy of fungicides against *Phytophthora infestans* on a developing growing point of potato plants

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Introduction

Potato plants sprayed preventively are protected against *Phytophthora infestans* for a certain period of time. It is assumed that only systemic fungicides provide some protection of the developing growing point. Since hardly any information is available on protection of the developing growing point, recommendations assume that no protection is present after application of translaminar and contact fungicides. Therefore curative fungicides are recommended to control latent infections in the "unprotected" developing growing point. The objective of this research was to determine the protection of the developing growing point after application of contact, translaminar and systemic fungicides.

Materials and methods

Pot experiments

Potato plants (cv. Bintje) were grown by planting pregerminated tubers in 5 l pots in a peat soil. The pots were placed outside. When plants were 30-40 cm high the plants were sprayed. Fungicides were applied in ca. 250 litre water per hectare using a spraying cabin equipped with three Teejet XR110.03 nozzles. The fungicides used are mentioned in Table 1.

Table 1. Fungicides used to investigate the protection of developing growing points in the pot experiments and field trial.

Treatment	Active ingredient	Mobility	Dose rate
Untreated	-	-	-
Curzate M	cymoxanil (4.5%)	local-systemic	2.5 kg/ha
	mancozeb (68%)	contact	
Acrobat	dimethomorph (7.5%)	local-systemic	2.0 kg/ha
	mancozeb (67%)	contact	
Tattoo C	propamocarb-hydrochloride (37.5%)	systemic	2.7 l/ha
	chloortalonil (37.5%)	contact	
Ridomil Gold MZ	metalaxyl-M (4%)	systemic	2.5 kg/ha
	mancozeb (64%)	contact	
Shirlan	fluazinam (50%)	contact	0.4 l/ha

One week after application of the fungicides the leaflets of the growing points were inoculated with a 50µl droplet of a spore suspension containing 10^4 sporangia/ml of *P. infestans*.

The plants were incubated at 18 ˚C and a relative humidity of 98% for 24 hours in a climate room. After incubation plants were placed outside for 5 days. Before assessment, plants were placed in a climate room at 18 ˚C and a relative humidity of 98% for 24 hours to induce sporulation.

Field experiment

Potato plants (cv. Bintje) were grown by planting tubers 35 cm apart on ridges in a sandy loam soil. Fertilisation and weed control were carried out as good agriculture practice. When plants were 20 cm high the first fungicide application was carried out. Fungicides used in the field trial are listed in Table 1. After the first application two other applications were carried out, with a 7-day spray interval. Fungicides were applied in 250 litre water per hectare using a tractor-pulled trial-site sprayer equipped with eight Teejet XR 110.04 nozzles.

Seven days after each fungicide application, 24 leaflets from growing points were detached from each plot and inoculated with a 50µl droplet of a spore suspension containing 10^4 sporangia/ml of *P. infestans*. The inoculated leaflets were stuck in wetted oasis and placed in a plastic container. The container was covered with a plastic bag to maintain a high relative humidity and placed in a climate room at 18˚C for seven days.

Assessments

Number, size and sporulation of the lesions was assessed seven days after inoculation. In the pot experiment and the field experiment three fungicide applications were applied. In the field experiment the same plants were used in order to study a possible cumulative effect of multiple fungicide applications. New plants were used in each pot experiment.

Results and discussion

Pot experiments

The growing rate of the plants in the three pot trials was different caused by different growing conditions (weather etc.). In the first trial the growth rate of the plants was low. A small leaf that was just unfolding when the plants were sprayed, did grow in one week to a leaf with leaflets with 2-4 cm^2. In the second trial a leaf that was just unfold did grow in one week to a leaf with leaflets with a surface of 2-5 cm^2. In the third trial completely new leaves were formed between spraying and inoculation. These leaflets had a surface of approximately 2-5 cm^2.

Table 2. Percentage lesions, size of lesions and sporulation of lesions in three pot experiments in which the protection of a developing growing point was tested 7 days after fungicide application.

Treatment	**Lesions[1]**			**Size[2]**			**Sporulation[3]**		
Experiment	**1[4]**	**2[5]**	**3[6]**	**1**	**2**	**3**	**1**	**2**	**3**
A Untreated	100	94.4	98.6	78.4	83.0	99.6	0.0	0.0	81.4
B Curzate M	6.3	9.0	100.0	18.0	47.9	96.7	0.0	0.0	25.0
C Acrobat	2.8	11.8	93.8	26.0	40.3	79.2	0.0	0.0	22.2
D Tattoo C	1.4	27.1	91.7	18.0	44.3	88.0	0.0	0.0	45.8
E Ridomil Gold MZ	0.0	7.6	45.8	-[7]	17.0	76.5	-	0.0	15.3
F Shirlan	8.3	40.3	95.8	42.0	45.1	81.0	0.0	0.0	64.6
LSD (α = 0.05)	9.9	14.1	16.7	67.2	38.4	26.0	0.2	4.1	23.4

1) LesionsPercentage leaflets with a lesion
2) SizeSize of lesions expressed as percentage of leaflet covered by the lesion
3) SporulationPercentage of lesions with sporulation
4) 1Growth rate = low
5) 2 Growth rate = average
6) 3Growth rate = high
7) -No size and sporulation because no lesions were observed.

In pot experiment 1, with a low growth rate, all fungicides resulted in a good protection of the developing growing point (Table 2). In pot experiment 2, with an average growth rate, again all fungicides significantly reduced the number of lesions compared to the untreated (Table 2). The plants treated with Shirlan and Tattoo C resulted in significant more lesions on the developing growing points compared to the plants treated with the other fungicides. In pot experiment 3, with a high growth rate, only Ridomil Gold MZ, that contains the systemic active ingredient metalaxyl-M, significantly reduced the number of lesions compared to the untreated (Table 2).

Field experiment

The growing rate of the crop was so high that after each of the three fungicide applications the detached and inoculated leaflets of the developing growing points had not been in (direct) contact with fungicides. Growing rate of the field crop was estimated at 1-2 new leaves per week.

Table 3. Percentage lesions, size of lesions and sporulation of lesions in the field experiment in which the protection of a developing growing point was tested 7 days after a fungicide application.

Treatments	**Lesions[1]**			**Size[2]**			**Sporulation[3]**		
Fungicide application	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
AUntreated[4]	100.0	99.0	100.0	100.0	95.0	100.0	100.0	95.7	100.0
B Curzate M	100.0	84.4	60.4	100.0	80.0	63.9	100.0	97.4	75.0
C Acrobat	100.0	71.9	40.6	100.0	80.0	26.5	61.5	87.0	71.0
D Tattoo C	100.0	53.1	28.1	100.0	65.0	15.0	100.0	91.7	74.4
E Ridomil Gold MZ	93.7	44.8	6.3	75.0	17.5	5.9	85.2	9.6	50.0
F Shirlan	100.0	91.7	61.5	100.0	92.5	22.9	93.7	91.5	81.9
LSD (α = 0.05)		19.5			21.4			34.5	

1) LesionsPercentage leaflets with a lesion

2) SizeSize of lesions expressed as percentage of leaflet covered by the lesion

3) SporulationPercentage of lesions with sporulation

4) Untreatedleaflets from pot plants

After the first fungicide application none of the fungicides resulted in a significant reduction of the number of lesions compared to the untreated (Table 3). When more fungicide applications were applied fewer lesions were observed. After the second fungicide application Ridomil Gold MZ, Tattoo C and Acrobat resulted in a significant reduction of the number of lesions compared to the untreated (Table 3). After the third fungicide application all fungicides resulted in a significant reduction of the number of lesions compared to the untreated and Ridomil Gold MZ resulted in significantly less lesions than all other fungicides. The differences observed for the number of lesions were also present for size of lesions and sporulation of lesions.

Discussion

At low growth rates all fungicides resulted in a good protection of the developing growing point.

Since no completely new leaves were formed, this protection can be attributed to redistribution of contact fungicides on the expanding leaflets as well as redistribution of (locally)-systemic fungicides in the leaflets. At average growth rates the contact fungicide Shirlan resulted in the lowest level of protection of the developing growing point. Probably the redistribution of fluazinam on the leaf surface is not sufficient to the result in complete protection. Redistribution of (locally)-systemic fungicides can keep up with the average growth rate of the growing point and the level of protection is maintained. At high growth rates only systemic fungicides reduced the number of lesions on the developing growing point significantly. In this situation also the locally-systemic fungicides can not keep up with the growing rate, only the fully systemic fungicides can redistribute inside the plant in such an extent that a partial protection of the newly formed leaves is achieved.

When multiple fungicide applications were applied all fungicides resulted in a better protection of a developing growing point. This might be caused by accumulation of (locally)-systemic fungicides inside the leaves. However, it was remarkable that Shirlan and Curzate M (with a short preventive efficacy of cymoxanil) also showed a reduction in number and size of lesions after multiple applications. A possible explanation could be the redistribution of the contact fungicides fluazinam and mancozeb from lower leaf layers to the developing growing point by splash of rain droplets or vapour activity. This could also be the case with the other contact fungicide chloorthalonil (Tattoo C).

It can be concluded that there are indications that the protection of a developing growing point depends not only on the growth rate of the plants and the behaviour of the fungicide on/in the plants but also on the number of sprays.

Fifth Workshop of an European Network for development of an
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Preventive and curative effect of fungicides against potato late blight under field conditions

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Summary

Six fungicides, two with contact, translaminar and systemic compounds, respectively were tested for their preventive/curative effect against potato late blight (*Phytophthora infestans*) under field conditions. All tested fungicides had a good preventive effect. The effect of contact fungicides as Dithane DG and Shirlan dropped significantly when applied just 12 hours after inoculation. When the fungicides were applied curatively in the beginning of a long latency period, only products containing systemic ingredients gave efficient control. Translaminar active ingredients gave some control.

Keywords: Late blight, *Phytophthora infestans*, control, fungicides,

Introduction

Fungicide application is very important in relation to time of infection, infection pressure, precipitation, growth stage, variety, etc. Most often trials with preventive/curative effects of fungicides are carried out under controlled conditions because the scientist can be brought into a dilemma when experiments with potato late blight are carried out in the field. There can be a problem with the relationship to the neighbours when artificial inoculum is introduced into the field and natural blight is absent. On the other hand, the occurrence of secondary spread of inoculum from the surrounding into the field plots is a problem when you want to control the time of infection and natural blight is present.

In Denmark, a registration net for the occurrence of late blight is established (www.Planteinfo.dk) and has made it possible to inoculate field plots in the narrow time gap between blight occurrence in the Eastern and Western part of the country.

The aim of this paper is to describe the preventive/curative effect of fungicides against potato late blight under field conditions.

Material and Methods

In 2000, a small plot (two rows, 1.5 x 5 m) field trial was established at the Research Centre Flakkebjerg. Six fungicides, two with contact, translaminar and systemic compounds, respectively were tested for the preventive/curative effect (table 1). All plots were inoculated with a diluted sporangiasuspension (100 sporangia/ml) of a mixture of six different isolates of *P. infestans* (all A1) isolated in Denmark in 1999. The plots were inoculated the 5$^{th.}$ of July at a time where blight was only registered in Jylland (Registration net in Pl@nteInfo) and not at the Research Station. The fungicides were applied 12 hours before inoculation (-12), 12 hr. after inoculation (+12), 36 hr. after inoculation (+36), 60 hr. after inoculation and 84 hr. after Inoculation (+84). All treatments were arranged in a split-plot design with a non-treated plot for each fungicide. In total 144 plots. The field trial was heavily irrigated four hours before the first spray. After inoculation, all plots were covered with a fibre cloth to maintain high moisture content.

Each plot was only treated with fungicide once. The sprayer was mounted with Hardi flat nosles (ISO) 03, 3.75 Bar and a speed of 4 km/hr.

Tabel 1. Fungicides, type and doses used in field trial to study preventive/curative effect of fungicides against potato late blight.

		Active ingredients		
Fungicide[a]	Normal dosage	Contact	Translaminar	Systemic
Shirlan	0,4 l/ha	fluazinam	-	
Dithane DG	2,0 kg /ha	mancozeb	-	
Tattoo	4,0 l/ha	mancozeb	-	propamocarb
Ridomil MZ[a)]	2,5 kg/ha	mancozeb	-	metalaxyl
Acrobat WG	2,0 kg/ha	mancozeb	dimethomorph	
Tanos[a)]	0,7 kg/ha	famoxate	cymoxanil	

a) NB! Tanos (KP 481-27) and Ridomil MZ are not approved for control of potato late blight in Denmark.

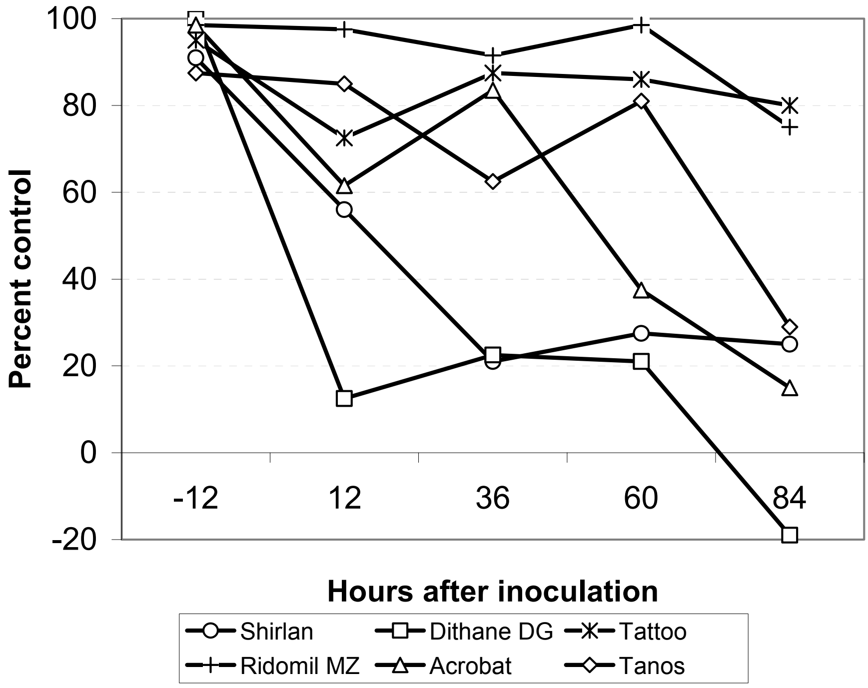

Figure 1. Percent control of potato late blight 12 days after inoculation in field plots with different fungicide treatment. Fungicides are applied 12 hours before infection (-12) and 12 to 84 (+12,+36, +60, +84) hours after infection.

Results

After inoculation 5th. of July, a very cold period occurred with temperatures at night just above 10 °C. There was no visible blight in the non-treated plots before the 17th. of July. At this time, there was still no sign of blight in other non-inoculated plots in the field. Secondary infection was first registered in the surrounding fields at the 27th. of July. Figure 1 shows clearly that typical contact fungicides as Dithane DG and Shirlan have a marked preventive effect whereas products with both systemic and translaminar components, like Acrobat WG, Tanos, Tattoo and Ridomil MZ, show curative properties.

Discussion

All tested fungicides had a good preventive effect against potato late blight. The effect of contact fungicides as Dithane DG and Shirlan dropped significantly just 12 hours after inoculation. Even if the temperature at night after inoculation in the evening was appr. 13-14 °C, the infection was very successful. However, the cold period afterwards did not allow the fungus to sporulate and spread secondarily for 22 days. Under these circumstances, a preventive treatment for all tested fungicides had nearly 100 percent control for over three weeks (data not shown).

In this trial, it was not possible to test the eradicative effect of the fungicides because all treatments were performed within the latency period. When the fungicides were applied curatively in the beginning of a long latency period, only products containing systemic active ingredients gave efficient control. Translaminar products had moderate curative effect. The slight curative effect of contact fungicides could be due to the control of not germinated spores on the leaf surface at the time of spraying.

It is know from other pathogens, e.g. *Septoria tritici* that curative control is possible with systemic fungicides but only in the beginning of the latency period (Jørgensen *et al.*, 1999). This emphasises the importance of the timing of the application close to the infection period.

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Mating types, metalaxyl resistance and pathotypes of *Phytophthora infestans* in Wallonia - 1999

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Summary

82 isolates have been collected in 1999 in Wallonia (South of Belgium) from potato fields, volunteers and refuse piles. 68 were tested for mating type, 62 for metalaxyl susceptibility and 17 for physiological races. We found 11% of A2 mating type. Only 11% were metalaxyl sensitive. The majority of the main virulence genes have been found and most of the isolates were complex races.

Introduction

The former populations of late blight have been replaced entirely in Europe during the years 1980 and 1990 by populations introduced from Mexico (Spielman *et al*., 1991). Contrary to the former populations of late blight, the new populations are characterized by an important diversity of genotypes. The increase of the commercial exchanges are responsible for this. This diversity is also emphasized by the introduction of the mating type A2, which in presence of A1 strains permits the achievement of the sexual cycle. The big genetic diversity of the pathogen allows him to adapt to every particular environment. One observes an increase of the aggressiveness of the late blight thus. Otherwise, the sexual reproduction produces oospores that could provoke a faster starting of the epidemics by the increase of the initial inoculum because of their long survival in soils and their resistance to the frost (Andrivon *et al*., 1998).

For these reasons, the characterization of the present populations of late blight and the knowledge of their geographical distribution is necessary in order to adapt the strategies of potato protection and to improve the warning systems.

Materials and methods

82 isolates have been sampled in Wallonia during 1999. They were collected mainly in large potato fields but also in experimentation parcels, in organic farming cultures, refuse piles, volunteers and gardens. These isolates came from 22 districts, 36 different locations (parcels, heap, etc) and 25 cultivars.

Mating types: 68 isolates tested by confrontation with reference A1 and A2 strains.

Pathotypes: 17 isolates tested by means of differential clones.

Resistance to the metalaxyl: 62 isolates tested according to the FRAC protocol.

The isolates were classified according to the EC50 representing the concentration of metalaxyl assuring 50% of protection:

- sensitive isolates: $EC50 < 0.01$ ppm
- intermediate sensitivity isolates: $0.01 \leq EC50 < 10$ ppm
- resistant isolates: $EC50 \geq 10$ ppm

Results

Mating types

4 isolates out of 68 belonged to the mating type A2 and 2 were autofertiles (mixture of A1 and A2). The isolates with A2 strains been found on 4 different sites: one located in the Hesbaye Region, 2 in Ardenne and the last in Jurassic region. This represents 11% of the sites sampled. These results are quite different with the situation observed in France (only one isolate with A2 mating type out of 151 samples in 1999). In 1998, Heremans *et al*. (2000), found 17% of A2 isolates among 48 tested samples.

Resistance to the metalaxyl

The large part of the isolates collected includes resistant or intermediate strains. One of them was resistant to the highest concentration.

Table 1. Distribution of the isolates according to their sensitivity to metalaxyl – 1999.

Sensitive	*Intermediate*	*Resistant*
11%	61%	28%

Rq: 1 isolated resistant to 100 ppm.

These results are very close to the one of France. Duvauchelle *et al*. (1999) observed that the resistance level increased in relation to previous year. In 1998, Heremans *et al*. (2000), observed 45% of resistant isolates among samples collected on large potato fields in the Flemish Region.

The same ratio of resistant isolates were found in the untreated plots and in those treated with systemic fungicides.

Table 2. Distribution of the isolates following their sensitivity to metalaxyl and to the type of fungicides applied – 1999.

Fungicides applied	*Sensitive*	*Intermediate*	*Resistant*
None (untreated plots)	5%	53%	42%
Contacts and/or translaminar	14%	72%	14%
Systemics	22%	33%	44%

Intermediate isolates have been collected since the early June. The first resistant isolate has been sampled end of June: the resistant isolates were therefore present since the beginning of the growing season. The three A2 isolates collected were of intermediate sensitivity to metalaxyl.

Pathotypes

All isolates were virulent to R1 and R4. No one was virulent to R9 and the isolates able to overcome to the R2, R5 and R6 were rare.

We identified 10 different virulence profiles out of 17 tested isolates. 72% possess more than 5 genes of virulence. The main races are 1.3.4.7.10.11 and 1.3.4.7.8.10.11.

Table. 3. Distribution of pathotypes in Wallonia.

Pathotypes	*%*
1.3.4.7.10.11	24
1.3.4.7.11	6
1.3.4.7.10	6
1.3.4.7	12
1.3.4	6
1.4.11	6
1.4	6
1.3.4.7.8.10.11	24
1.3.4.5.7.10.11	6
1.2.3.4.6.7	6

Table 4. Distribution of virulence to R genes.

R genes	*%*
1	100
2	6
3	88
4	100
5	6
6	6
7	82
8	24
9	0
10	59
11	65

Discussion

This first monitoring shows a significant presence of A2 strains in our region. This situation can change the epidemiological behavior of the pathogen.

On the other hand, the strategies proposed to limit the proliferation of the resistances to the systemic fungicides fully justify themselves: use in a strict setting of preventive protection; associations of the systemic active substances to contact fungicides; limitation of the number of systemic fungicide pulverizations; etc.

The presence of complex pathotypes and of a large range of virulence genes limit the interest and the sustainability of the strategies based on the use of varieties endowed with vertical resistances.

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Fifth Workshop of an European Network for development of an
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Developing PhytoPRE+2000: An Internet based information system for late blight control in Switzerland

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Abstract

From 2001 on, Swiss potato growers will be supported by an Internet based version of the late blight decision support system (DSS) PhytoPRE+2000. Core parameters of this DSS are the actual state of the national late blight (LB) situation and the historical and forecasted weather data to recognise main infection and sporulation periods (MISP) of the fungus *Phytophthora infestans*. From 1996 to 2000, the MISP model was used in field trials as a trigger of LB-fungicide applications. Compared to our old DSS PhytoPRE+95 no reduction in fungicide treatments could be realised in wet years, but up to 40% in rather dry years. In field trials the MISP triggered LB-control was always as good as in PhytoPRE+95 or at least as good as those of other DSS tested in Swiss field trials. In 1999 and 2000, the MISP model was imbedded in a completely new designed DSS. To assure an efficient information exchange an Internet solution was selected. PhytoPRE+2000 is not only a DSS for local and field specific LB-recommendations, it is also a comprehensive LB-information and warning system. Daily actualised disease maps and MISP-graphs can be accessed on the Internet and illustrate the LB-risk situation for all Swiss potato growing areas. The structure of PhytoPRE+2000 was determined in a close co-operation with the Swiss potato growers association and the cantonal plant protection services.

Introduction

In Switzerland, late blight of potatoes, caused by the fungus *Phytophthora infestans*, is one of the most important diseases in arable farming. To receive reliable information about late blight (LB) epidemics, two LB-monitoring systems were used since 1989 (Gujer, 1991): 1. a LB-monitoring net supported by growers and plant protection services to detect the very first LB-attacks in growers fields and 2. a LB-observation (LBO) network with untreated potato plots to measure and compare epidemics of different years (Fig.1).

A rule based PC-program called PhytoFAP was developed in 1990 to obtain a better timing for fungicide applications. For the timing of a first spray, PhytoFAP used the "Negativprognose"-model (Ullrich und Schrödter, 1966). The following sprays were determined by a minimal spray interval, rainfall and/or LB-attacks within a diameter of 15 km (Forrer *et al.,* 1991). In 1991 and 1992, PhytoFAP was tested in 60 on-farm trials and compared with conventional spray routines. In these trails PhytoFAP treated fields showed slightly higher LB-infections, mainly due to a delayed first spray (Forrer *et al.,* 1993).

In 1993, a new system called PhytoPRE was developed and tested in practice. Based on the LB-monitoring (Fig. 1, Tab. 1) and comparing different LB-forecast systems (Gujer *et al.*, 1995) we used the very first LB attack in Switzerland to recommend a first fungicide application. To determine further treatments, the potato variety, the growth stage, the minimal/maximal spray intervals, the sum of precipitation since the last spray and the characteristics of the fungicide were taken into account. In addition to its function as a field specific decision support system (DSS), PhytoPRE is a LB-information and warning system with weekly bulletins, LB-disease- and risk-maps (Tab. 2; Forrer *et al.,* 1993).

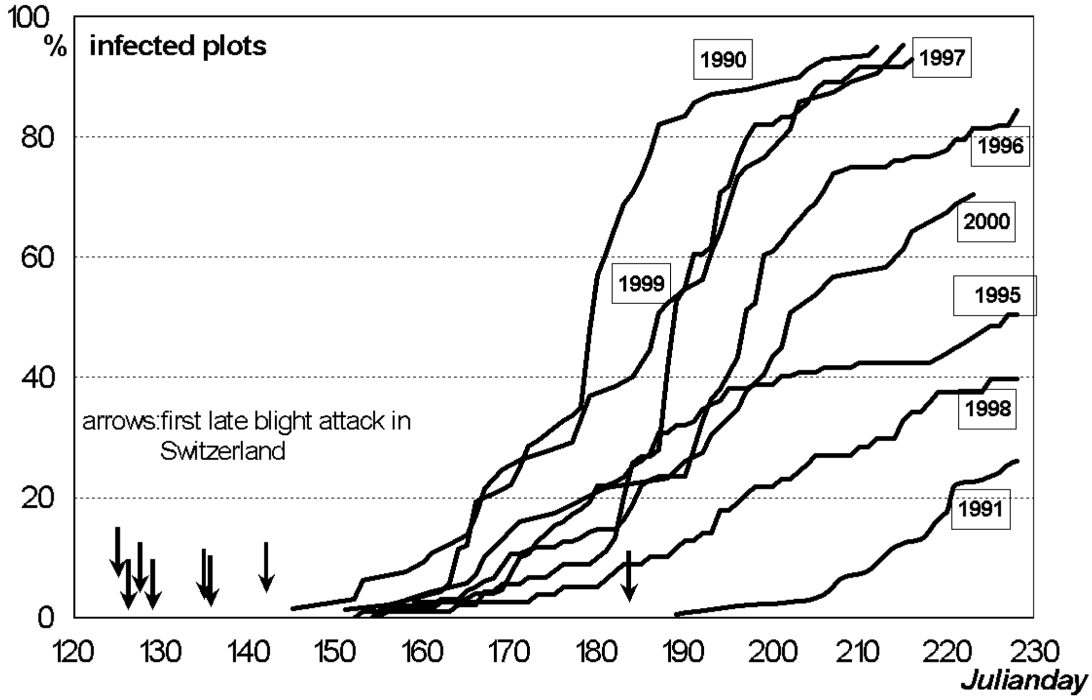

Figure 1. Comparison of Swiss late blight epidemics from 1990,1991 and 1995-2000. Data collected with the late blight observation network.

From 1994 to 2000, Swiss potato growers could participate to PhytoPRE for a fee of SFr. 50.-. The DSS-program was installed on a server and the support and data management were centralised at our research station FAL. Spray recommendations generated by the DSS were sent by mail to the participants.

The advisory system PhytoPRE proofed to be a reliable DSS for the control of LB-disease, but didn't contribute to a significant reduction of fungicide treatments. For this unexpected result a main reason was the very early LB-epidemics in 10 out of 12 years. Our monitoring data indicate that plastic covered early potatoes are responsible for the early onset of LB-epidemics in Switzerland (Tab. 1). In such circumstances, PhytoPRE recommended an early start of treatment by which, except 1991 and 1992, fungicide savings due to delaying the first treatment could not be realised.

Table 1. Date and location of the first late blight attacks in Switzerland from 1989 to 2000 (1994-2000 announce of the first attack in the eastern part and western part* of Switzerland).

Year	first late blight attack	Region	typ of production
1989	23.5	ZH	early potatoes
1990	16.5	AG	early potatoes
1991	4.7	SG	early potatoes
1992	17.6	SG	early potatoes
1993	24.5	BE	seed potatoes
1994	16.5/3.5	AG/VD*	early potatoes
1995	9.5/29.4	ZH/VD*	early potatoes
1996	29.5/23.5	TG/FR*	seed potatoes
1997	26.5/16.5	BE/VS*	trial site/ early pot. ?
1998	11.5/6.5	SG/VD*	early potatoes
1999	8.5/28.5	AG/VD	early potatoes
2000	3.5./24.5	AG/VD	early potatoes

PhytoPRE offered only reduced possibilities to save fungicides after the application of a first spray, because rather conservative maximal spray intervals were used. Therefore, we looked for a new model allowing an effective and economic use of fungicides for the 2nd and following fungicide treatments.

Material and Methods

Epidemiological field studies:

In 1995 and 1996, epidemiological studies with the highly susceptible varieties Charlotte and Bintje were carried out in field experiments near Zurich. To receive detailed epidemiological information, the daily increase of diseased leaflets was measured. The length of the latency periods were determined for the whole observation period, by means of periodical inoculations of single leaves in the experimental fields and daily controls of the infected leaves. Both these parameters allowed to identify days of heavy infections. Meteorological parameters (rainfall, relative humidity and temperature) of these days were analysed.

Validation of the main infection and sporulation period (MISP)-model as trigger of fungicide applications:

From 1996 to 2000, several field experiments with a randomised block design and the potato varieties Bintje and Agria served to validate our new model. The effect of fungicide applications using the MISP-model as a spray trigger was compared to the effect of applications according to the decision support systems (DSS) PhytoPRE+95 and NegFry (T. Steenblock *et al*., 2000). In addition, in 1999 we compared the MISP model to Simphyt I & II, ProPhy and PlantPlus in field trials at Zürich-Reckenholz (not published). An untreated control and a routine treatment (fungicide treatment every 7 days) were used as standards.

Design and evaluation of an operational MISP-DSS:

Different possibilities to use the MISP-model in a DSS were defined and presented to our sponsors and potato growers. In addition, we estimated the costs for the implementation of the DSS's and the system support. A commission including representatives of the growers, the advisory services, the financial sponsors and us was determined to evaluate and select the most appropriate system.

In 2000, a small test and demonstration version of PhytoPRE+2000 was programmed generating MISP-graphs of 23 meteorological stations. Hourly data of these weather stations were kindly provided by MeteoSwisss, the official Swiss meteorological service. In addition to the historical weather data we received weather forecast data for the next 48 hours.

Table 2. List and characteristics of different MISP-based late blight (LB)decision support systems as proposed to the Swiss potato growers association (swisspatat) in 1998.

			Input					*Output*					
			Weather data			Participant Info		Fungicide treatments					
DSS-Description	System/ FAL-support	User/ Communi-cation	Historical	forecast	LB-Moni-toring	Field data	Fungicide treatments	First	Follow-ing	Fungi-cide choice	First attacks / Diseas emap	Critical days (MISPs)	Bulletin
PhytoPRE+95 plot specific (system running from 1993- 2000)	**Central server/ Full**	unlimited/ Post-way (mail)	SMA*/ Local rain gauge	-	whole season	+	+	+	+	+	+/+	-	+
PhytoPRE+2000 plot-specific	**Central server****/ Full	unlimited/ PC Internet	SMA/ Local rain gauge	+	whole season	+	+	+	+	+	+/+	+	+
PhytoPRE+2000 'light'	**Central server****/ Part	unlimited/ PC Internet	SMA/ Local rain gauge	+	Only first attacks	-	Only the last	+	+	+	+/-	+	-
PhytoPRE+2000 Warning-system	**Central server****/ Part	unlimited/ PC Internet	SMA	+	whole season	-	-	-	-	-	+/-	+	-
Met-Station with MISP-Calculator	No support	Single user/ none	Local Met-station with MISP-calculator	-	none	-	-	-	-	-	-/-	+***	-

*SMA: Weather stations of the Swiss meteorological institute (=MeteoSwiss)

** In the original version we planned local PC-installations with modem links for weather data instead of a central internet application

*** no MISP forecast

Results

Epidemiological field studies

In the epidemiological field studies from 1995 and 1996, single days with heavy infections could be detected. The analysis of the corresponding meteorological data revealed special weather conditions which showed to be crucial for the development of the fungus *P. infestans*. These weather conditions were called Main Infection and Sporulation Periods (MISP). MISP's are periods of 24 hours with at least 6 hours of precipitation and 6 consecutive hours of a relative humidity of $\geq 90\%$ and an average temperature of $\geq 10°C$ (Cao *et al.*, 1997).

Validation of the MISP model

Results from five year field trials demonstrated, that MISP is a very reliable and weather sensitive tool to control late blight disease. The data in Table 3 show, that it is possible to save fungicide applications in years with dry or rather dry weather conditions. Although fungicide treatments can not be saved during years with a lot of precipitation, the disease can be very well controlled. Comparing the success of the disease control to other DSS's, the result of our model was always at least as good as these of the others (Steenblock *et al.*, 2000).

Table 3. Evaluation of the MISP-model in field trials near Zürich from 1996-2000.

	1th LB-attack in Switzerland	*Weather conditions near Zurich during the potato season (May-July)*	**treatment**	**AUDPC % rel. to the untreated plots**	*Number of applications*
1996	23.05.96	rather dry, wet in May	PhytoPRE	16.3	7
			MISP-model	13.0	4
			Untreated control	100	1*
1997	16.05.97	wet, except May	PhytoPRE	45.2	7
			MISP-model	38.8	7
			Untreated control	100	0
1998	06.05.98**	dry in May, rather wet in June and July	PhytoPRE	0.0	8
			MISP-model	0.0	7
			Untreated control	100	0
1999* **	08.05.99	wet the whole season	PhytoPRE	2.06	8
			MISP-model	2.89	8
			Untreated control	100	0
2000	03.05.00	rather wet, especially in July	PhytoPRE	0.01	11
			MISP-model	0.02	9
			Untreated control	100	0

* emergency treatment to reduce infection pressure; ** trial site at Ellighausen (TG)

*** first LB-attack in geographically closed regions

Evaluation of PhytoPRE+2000 implementation

Our “old” DSS PhytoPRE+95, offered to Swiss farmers from 1993 to 2000, will be replaced by PhytoPRE+2000 from 2001 on. PhytoPRE+95 is a comprehensive DSS (Tab.2). Beside its function as a field specific decision support system it offers typical features of a regional warning system with disease maps and bulletins. In the evaluation process of a new MISP-based PhytoPRE version, the DSS functions, information and warning system, were rated highest. In 1998 the evaluation commission of the new PhytoPRE system decided, that the DSS should at least provide 1. region specific MISP-values indicating the regional and sub-regional LB infection risk and 2. LB disease maps.
In 1999 a tool to calculate and present MISP-data was programmed. This tool allowed us to adjust different parameters (relative humidity, temperature, rainfall) of the original MISP-model and to test the sensibility of the model. Based on these tests and in order to recognise all MISP’s, we slightly modified the model.

In 2000, a first test version of PhytoPRE+2000 was offered on the Internet showing MISP-graphs and LB disease maps. MISP-situations of 23 met-stations, respectively of 3 main-regions of Switzerland (eastern, western and central part), were presented and daily actualised. In addition, weekly actualised disease maps and bulletins were offered on the Homepage of our research station (www.admin.ch/sar/fal).

The main reason to choose an Internet-solution is the fast response and easy support of such a system. Since the new DSS is based on weather events and the actual state of the national and regional late-blight situation, farmers connected to the DSS are able to respond very fast. Promising experiences with the test version of PhytoPRE+2000 and the demand of the potato growers, lead us to the decision to complete our MISP-DSS with modules generating field specific recommendations for fungicide treatments. The features of this plot specific DSS are compiled in table 2.
For the operation and the support of the DSS we decided to use a central-managed version. The software is installed on our local server as well as the meteorological data analysis. Farmers can log in and fill in their field specific data by their own, but we have the possibility to supervise the input and the recommendations. This feature is especially important for the input of the first LB-attacks. Since 2001 will be the first year we offer this Internet-based DSS, we also will supervise the system output and would be able to correct parameters during the season.

Starting 2001, information and recommendations of the PhytoPRE+2000 DSS will be available on Internet. Some parts of the 'old' system are implemented in the new model, for example the map of LB-attacks, the weekly bulletin and the susceptibility of the potato cultivar. However the decision rules for recommendations are completely different: The first fungicide application is only recommended if 1. the growth stage of the plants is at least GS $\geq$ 10 (= plants emerged and first leaves are developed), 2. a LB-attack was announced in the region and 3. a MISP has occurred or is forecasted. For further treatments the actual fungicide protection level and the MISP situation will be taken into consideration. In Table 3 all the parameters influencing the calculation are summarised.

Table 3. Conditions and parameters considered for the recommendation of a fungicide application.

1st treatment	1. growth stage $\geq$10 2. first LB-attack in the region 3. MISP	
2nd and following treatment	1. fungicide protection : 2. MISP	- fungicide used - minimal spray interval - susceptibility of the potato cultivar - amount of rainfall since last treatment - growth stage of potato-crop

Farmers will be able to use the program as an LB-risk information site or as a plot-specific advisory system:

Registration of new LB-attacks will be actualised several times a day; so farmers will know when and where new attacks have occurred. In addition, weather data of three defined regions: eastern, western and central part of Switzerland (for each region 9 weather stations) are analysed according to the MISP-rules. These results are pictured in a clear, easy understandable graph (Fig. 2). With these two informations farmers can get most actual information about the regional LB-risk situation.

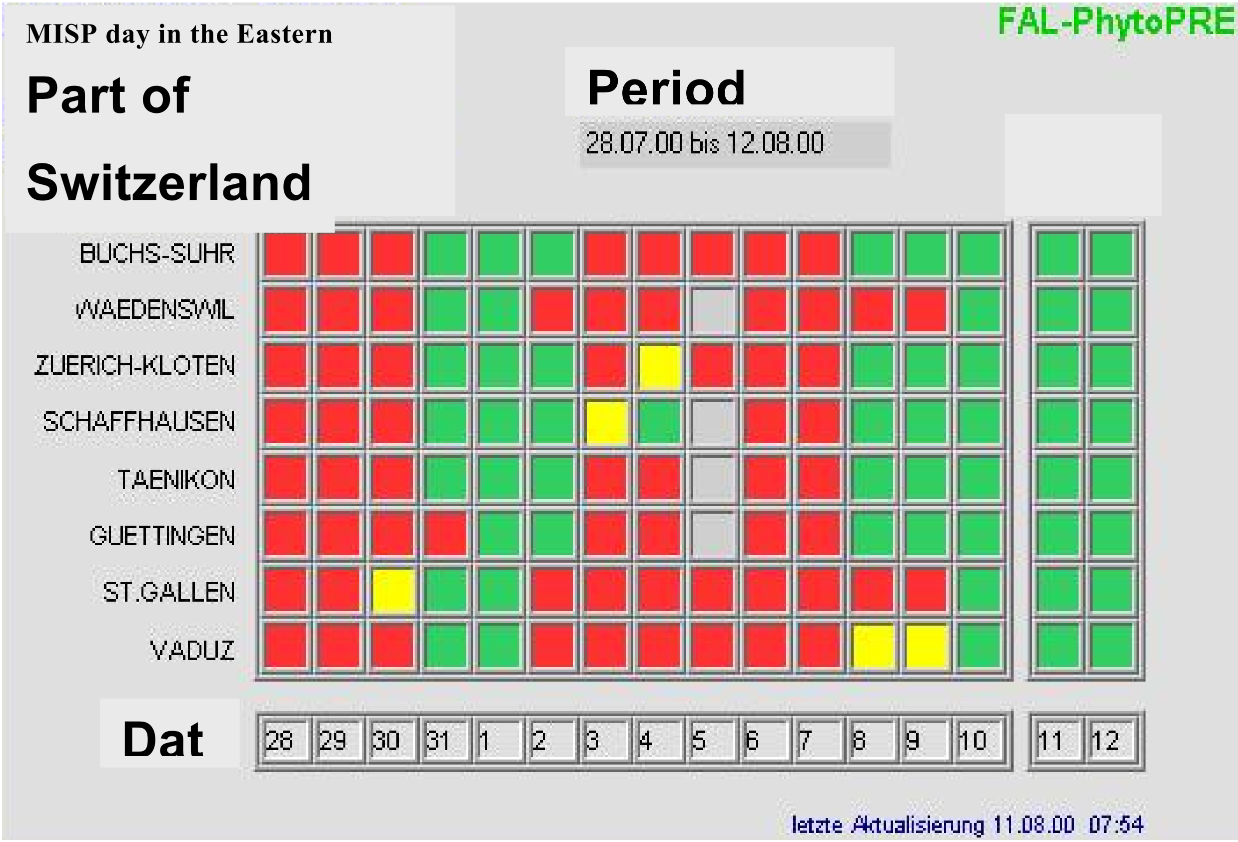

Figure 2. MISP-days for weather stations of Eastern-Switzerland. Historical and forecasted weather data are analysed and plotted.

= MISP day, Y= near MISP day, = no MISP, = no weather data

For a plot-specific recommendation, farmers have to register at the beginning of the potato-season and feed the computer with their plot-specific data: the location of the field, the planted variety, the susceptibility of the cultivar and especially the weather station which represents this region. These weather data will be daily analysed with the MISP rules and also shown in a special graph. For a first treatment, a first LB-attack and a MISP must have occurred in the considered region. For the following recommendations different information, summarised above in table 3, is used to determine the interval between the sprays. A further treatment is only recommended if the fungicide protection is expired and a MISP is forecasted or has occurred in this region. Otherwise, no following treatment is recommended. The decision what kind of fungicide should be used for the fungicide treatment depends on the day of MISP occurrence (Fig. 3).

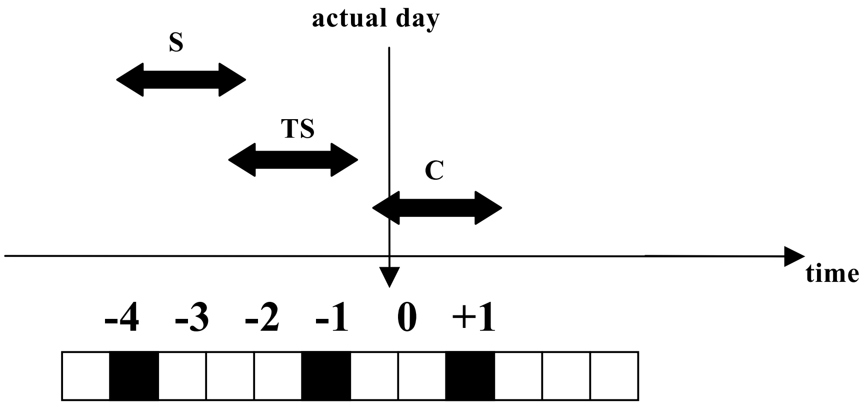

Figure 3. Fungicide recommendations depending on the occurrence of MISPs: For the choice of a fungicide the first occurring unprotected MISP (fungicide protection expired) is relevant. S= systemic fungicide, TS= translaminar fungicide, C= contact/ protectant fungicide.

█ MISP day

Discussion

During the last five years, field studies revealed, that the MISP model is a reliable tool to control late blight disease in potatoes. It was shown, that this model is very weather sensitive and that it is possible to profit from LB risk free periods and to save fungicide treatments. Since in PhytoPRE+2000 the number of the fungicide applications doesn't depend only on the MISP-situation in a given period, fungicide reduction cannot be obtained every year. The date of the first LB-attack and the region in which it appears is also very important. Unfortunately, in Switzerland first LB-attacks were observed always at the very early beginning of the potato season. Therefore, the dangerous period for possible infections is prolonged. In case the first LB-attack would appear in the middle of the main potato growing region the spread of the epidemic would be much faster and the risk of infection much higher than if the first attack would occur in the Rhine valley of St. Gallen or in the Chablais (VD). These two regions are geographically 'closed' regions and the epidemic can't spread easily.

In our field evaluation trials we only used MISP's as a trigger of fungicide applications and analysed only weather data collected directly at the trial site. The MISP module was not imbedded in a whole decision support system and was not tested with the national net of weather stations. Therefore, there is a certain risk bringing the DSS on the market. Nevertheless, during the potato season 2000 MISP-data were presented on the Internet and the feed back from the farmers was good. In addition, we compared the weather data from the field station to surrounding weather stations of the national net. To avoid an underestimate of the infection risk we slightly softened the MISP conditions: for example, if the relative humidity period (6 consecutive hours with rh ≥90%) is interrupted by 2 hours with relative humidity values of 85-90% we considered the humidity conditions fulfilled.

To get more information about the reliability of the system, the input from all participants and the DSS recommendations will be stored. The analysis of these data and the response of all participants connected to the PhytoPRE+2000 system, will soon provide more information about the performance of our new DSS.

Acknowledgement

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Real-time quantitative PCR for research of *P. infestans* infection

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Key words: Potato, *Phytophthora infestans*, real-time quantitative PCR

Introduction

The role of the oospores and possible soil infection in the epidemiology of *P. infestans* fungus is still unclear. Thus the better knowledge about *P. infestans* infection processes are needed for an efficient forecasting system and spraying technique. The quantitative PCR technique gives a new way to examine infection processes by means of determining the amount of *P. infestans* DNA in different parts of potato plant. The fungus can also be detected from soil by PCR.

Material and methods

ITS1 area from six different isolates (including both mating types) were sequenced and compared to each other and also sequences from gene bank. Taqman probe and primers were planned to the area homologous to all *P. infestans* isolates but heterologous to other published sequences of *Phytophthora* species.

Naturally infested plant material and soil were collected from blighted potato crops in Jokioinen. The samples were taken from different parts of plant and DNA was extracted from plant material by using DNeasy Plant Mini Kit (Qiagen). The buffer was added to the soil sample and the sample was frozen under liquid nitrogen and melted twice. The soil was removed by centrifugation.

Relative quantitative measurement of *P. infestans* DNA was performed by the Taqman-PCR assay with ABI PRISM 7700 Sequence Detector (PE Biosystems). The standard curve was made with the constant purified DNA.

Results

Relative quantification by Taqman probe and primers worked well for plant material. Only soil samples will need more purifying because of variation between parallel samples. Only two parallel samples and volume of 10 microlitres were used in purpose to reduce the cost of the method.

During growing season the *P. infestans* DNA was found clearly in different parts of the plant. The highest amount of DNA was found in consecutive samples first from lower leaves, secondly from upper leaves, thirdly from stems and last from tubers. The latent infection was detected from all parts of plant before visible symptoms.

Conclusion

The quantitative PCR method proved to be a practical way to examine the level infestation of *P. infestans* during the growing period. The latent infection can also be detected and it gives a possibility to compare PCR-results to the forecasting system.

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