JOURNAL OF PLANT PROTECTION RESEARCH
Vol. 43, No. 3 (2003)

WEB-BLIGHT – REGIONAL LATE BLIGHT MONITORING AND VARIETY RESISTANCE INFORMATION ON INTERNET

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Accepted August 28, 2003

Abstract: The Internet based 'Web-Blight' service (http://www.web-blight.net) was initiated to provide an online warning and prognosis system for potato late blight in the countries around the Baltic Sea. In order to obtain comparable results, methods were harmonized and a set of interacting PC and Internet applications were developed for use by the project partners. Results regarding monitoring of potato late blight and evaluation of variety resistance against late blight (field tests) are presented for Estonia, Latvia, Lithuania and Poland. The use of the Internet to collect and present data was very successful, because information were "on the fly", helping farmers in their decisions about the timing of first applications and choice of fungicide type. Results show that it was possible to find early attacks as primary attacks (spots in the fields). In most cases attacks were initially found in home gardens and later in conventional fields. The growth stage at first attacks was often higher than 37 (BBCH) indicating that very early attacks caused by oospores in the soil was not a widespread problem. Local varieties were tested for late blight resistance in untreated field trials against four test varieties (Sava, Oleva, Danva and Kuras). Primary disease data were uploaded to Web-Blight via the Internet, and applications on the Web-Blight server calculated epidemiological variables such as delay of first symptoms and RAUDPC. Results indicated the presence of race-specific resistance in some varieties, e.g. Kuras, and that some varieties were originally misclassified according to resistance scale, e.g. Santé. The network about observation trials clearly showed that field test of variety resistance against late blight in time and space is important, taking into account the rapid evolution of *Phytophthora infestans* populations in Europe.

Key words: Late blight, decision support, monitoring, variety resistance, Internet, Web-Blight

INTRODUCTION

Potato late blight caused by the oomycete *Phytophthora infestans* (Mont.) de Bary is a severe problem for potato production in Europe, and up to twenty fungicide applications are used to control this disease (Schepers 2003). Since 1998, research institutions in Denmark, Estonia, Latvia, Lithuania and Poland have worked together on development and implementation of a decision support system for the chemical control of late blight. One objective was to test and implement PC-NegFry, a Danish decision support system for late blight control (Hansen et al..1995; Hansen et al. 2000; Koppel et al. 2003). During the same period it was reported that oospores and more aggressive strains of *P. infestans* were widespread in Europe caused by sexual reproduction (Day & Shattock 1997; Andersson et al. 1998; Bødker et al. 1998; Flier & Turkensteen 1999; Brurberg et al. 1999; Hermansen et al. 2000). The NegFry system did not include the *new* biology, and it was decided to initiate Internet provided monitoring of early attacks in all four countries based on experiences from a previous Nordic monitoring network (Hansen et al. 2001). The monitoring system made it possible to evaluate the forecast part in NegFry and, at the same time, serve as a safeguard for practice if the forecast failed. In NegFry, spraying intervals are calculated based on a combination of weather-driven models and crop-resistance parameters. Therefore, it was essential to evaluate local varieties for resistance against late blight. International scale values were available for most varieties, but it was decided to obtain new epidemiological parameters based on primary data from untreated variety trials (Hansen et al. 2001). Applications for operating the networks about monitoring and evaluation of crop resistance were implemented in a new web-based service called Web-Blight (http://www.web-blight.net; Hansen et al. 2001). In this article we describe major results about monitoring and evaluation of variety resistance in Estonia, Latvia, Lithuania and Poland. Advantages of using collaborative information systems like Web-Blight are discussed.

METHODS

Web-Blight

The system behind the Web-Blight service is built up by a package of PC-programs for entering, storage and transfer of primary data to one central server in Denmark (Fig. 1). When data were received on the Web-Blight server, programs written in the SAS programming language processed the data (SAS Institute Inc. 1996). Finally, a combination of SAS programs and Active Server Pages (ASP) presented the data on the Internet. The same database, PC-programs and web programs were used for all countries. Only the gif generated maps differed between countries. In a first version of Web-Blight, applications were developed for international collaboration in the areas of late blight monitoring, evaluation of crop resistance based on field tests and evaluation of results from field trials for validation of late blight decision support systems.

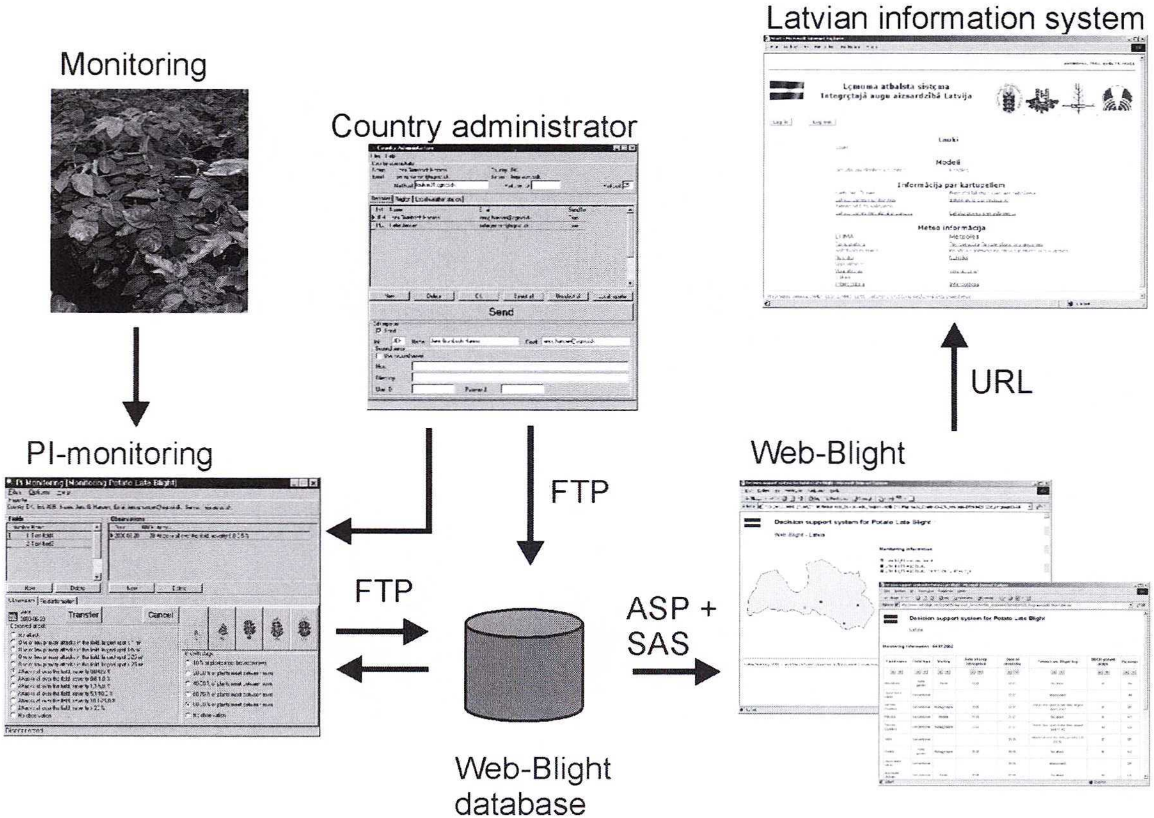


Fig. 1. This is an example of dataflow and generation of web pages in the Web-Blight monitoring system. Disease assessment data are entered into the Pi-Monitoring program. Data are transferred using a standard File Transfer Protocol (FTP). Web pages are generated with Active Server Pages (ASP) and SAS programs. Links from national information systems to Web-Blight are generated with a Uniform Resource Locator (URL). When data are received at the Web-Blight server, the maps and tables are generated automatically

Monitoring of late blight

Monitoring networks were organized by Jõgeva Plant Breeding Institute in Estonia, State Plant Protection Service and Latvian Agricultural Advisory Centre in Latvia, Lithuanian Plant Protection Service and Lithuanian Agricultural and Advisory Service in Lithuania and Main Inspectorate of Plant Protection in Poland. A certain amount of representative fields were selected before the season for inspection. Additionally, information about early attacks from home gardens and experimental fields were included. In Poland monitoring were only carried out in the Lublin region. One additional objective was to evaluate if attacks were earlier in susceptible varieties than in more resistant varieties. Therefore, two fields were selected at each monitoring site, one field with a susceptible variety and one with a more resistant variety.

Fields were inspected approximately once a week. The forecasting part of the NegFry system was used during the early part of the season to identify when the weather was favourable for disease development and, therefore, when scouting should be intensified. When late blight was found, results were uploaded to the Web-Blight server using the Pi-Monitoring program (Fig. 1). Results from all countries in the Baltic Sea region were available in Web-Blight. Single country maps were integrated via simple URL links from Web-Blight into the national Internet based information systems.

Observation trials

Local varieties were tested for late blight resistance in untreated field trials according to guidelines proposed by Dowley et al. (1999). Four test varieties, Sava, Oleva, Danva and Kuras, were included in all trials except the Polish. DIAS provided seed material for all the trials. Plot sizes varied from 10 to 25 m^2. The trials were not artificially inoculated, and therefore, the trials were exposed to local isolates of *P. infestans*. Primary disease data were uploaded to Web-Blight via the Internet, and applications on the Web-Blight server calculated epidemiological variables such as *Delay of first symptoms, Disease rating when rating of the reference variety was 90%, Apparent infection rate (AIR)* and *the relative area under the disease progress curve (RAUDPC)* (Fry 1977).

The apparent infection rate represents the slope of the disease progress curve, assuming that this curve can be approximated by a logistic function. This slope is estimated by calculating the regression of ln (x/(1-x)), where x is the proportion of tissue affected. Regressions are calculated in Web-Blight for the intervals in which the disease (x) progresses from 1% to 99%.

(AUDPC) is calculated according to Shaner & Finney (1977) as:

$$AUDPC = \Sigma\ [(x_i+1 + x_i)/2]\ [t_i+1 - t]$$

where x_i is the proportion of tissue affected at the i-th observation and t is the time in days after inoculation at the i-th observation. The index i run from 1 to n, where n is the total number of observations. Values for AUDPC are normalized by dividing the AUDPC by the total area of the graph, i.e. the number of days from inoculation to the end of the observation period × 1.0. This normalization results in RAUDPC (Fry 1978; Flores-Gutiérrez & Cadena-Hinojosa 1996). In this paper we show selected results from 2001.

RESULTS

Monitoring

In year 2001, first observations of late blight were recorded on June 20 in Estonia, June 20 in Latvia, June 15 in Lithuania and June 29 in Poland. In year 2002, first observations of late blight were recorded on July 3 in Estonia, June 21 in Latvia, June 4 in Lithuania and June 3 in Poland (Tab. 1). Results for first attack of late blight from all countries in the Baltic Sea region in 2001 and 2002 are shown in figure 2. In 2001, crop emergences varied from the middle of May until the beginning of June. In 2002, first attacks were recorded relatively earlier in Lithuania and in the Lublin region in Poland, probably caused by a relatively earlier crop emergence (Tab. 1). The maximum severity at the end of the season in untreated fields in the monitoring network reflects the situation that the growing season in 2001 was relatively favourable for late blight development and the growing season 2002 was relatively unfavourable for late blight development (Tab. 1).

Table 1. Data for first attacks of potato late blight in Estonia, Latvia, Lithuania and Poland, 2001 and 2002. Growth stages were assessed according to the BBCH scale

Year	Country	First symptoms observed			Max severity (%) at the end of seasonin untreated fields	Number of fields observed
		Date	Crop emergence	Growthstage		
2001	Estonia	20.06.	20.05.	65	100	19
	Latvia	20.06.	04.06.	31	100	27
	Lithuania	15.06.	14.05.	35	100	53
	Poland	29.06.	12.05.	55	96	36
2002	Estonia	03.07.	30.05.	51	100	15
	Latvia	21.06.	03.06.	59	48	20
	Lithuania	04.06.	06.05.	51	2	36
	Poland	03.06.	01.05.	39	78	33

Early attacks were found after growth stage BBCH 37 in 69–100% of observations (Tab. 2). In 2001, attacks during the early part of row closing (BBCH 30–37) were found more often in home gardens than in conventional fields and in experimental fields (Tab. 2). There was no evidence that inoculum from dumps and volunteer plants played a major role for early attacks in the region, but this was not investigated very carefully. In 67%–90% of observations first outbreaks of late blight were found as primary attacks (Tab. 3). In the Lublin region in Poland two neighbouring fields were inspected at each monitoring site. The two fields for paired observations differed in variety resistance against late blight (susceptible against moderate susceptible or moderate resistant). For the years 2001 and 2002 in total, late blight was recorded initially in fields with a susceptible variety and

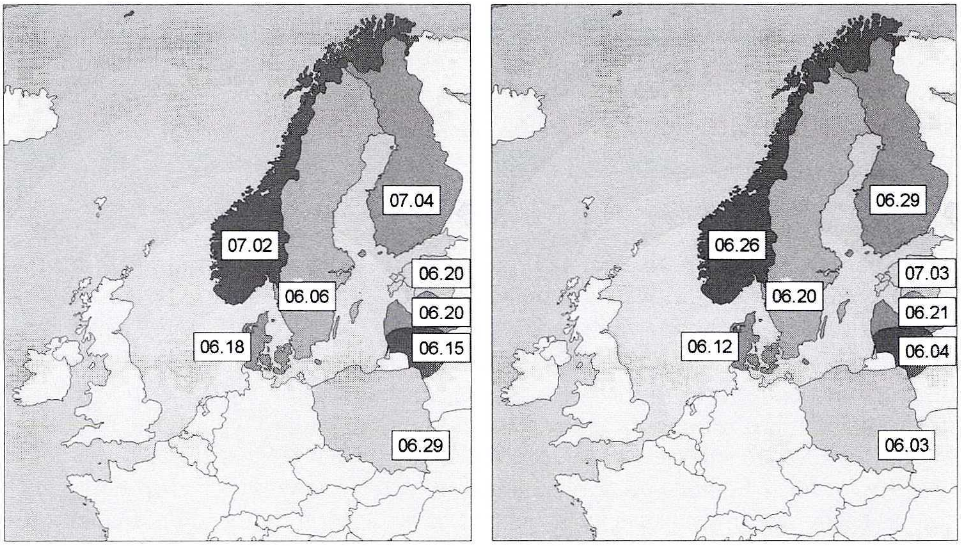


Fig. 2. Dates of first attack of potato late blight in the Baltic Sea region, 2001 (left) and 2002 (right). Late blight was found earlier in covered crops, but these data were not included

Table 2. Distribution of growth stages at first attack of late blight in Estonia, Latvia, Lithuania and Poland, 2001 and 2002. The data were divided into three classes: Conventional fields, home gardens and experimental fields. The number of fields in each class is 100%

Year	Country	Growth stage at first symptoms – Number of fields (%) in three BBCH classes								
		Conventional fields			Home gardens			Experimental fields		
		<30	30–37	>37	<30	30–37	>37	<30	30–37	>37
2001	Estonia	0	20	80	0	31	69	0	0	100
	Latvia	0	0	100	0	33	67	0	0	100
	Lithuania	0	0	100	0	6	93	–	–	–
	Poland	0	0	100	–	–	–	0	0	100
2002	Estonia	0	0	100	0	0	100	0	0	100
	Latvia	0	5	95	0	0	100	0	0	100
	Lithuania	0	4	96	0	0	100	–	–	–
	Poland	0	0	100	0	0	100	–	–	–

later in fields with a more resistant variety in 74% of the paired observations. Late blight was recorded at the same time in the two types of fields in 18.5% and relatively earlier in the more resistant variety in 7.5% of the paired observations. These data clearly show that late blight outbreaks usually start from susceptible varieties, but not always.

Evaluation of crop resistance against late blight

Primary disease assessment data were uploaded to the Web-Blight server using the PC-program called Pi-OBSTrial. Dataflow, databases, web-programs and management via the country administrator was similar as for monitoring (Fig. 1). Epidemiological variables were calculated by Web-Blight and presented on the

Table 3. Distribution of first attacks divided into the classes "Primary attack" (spots in the field) and "Late blight found all over the field". The data recorded as "Primary attack" were divided into three sub-classes depending on the size of spots in the field. The data recorded as "Attacks found all over the field" were divided into five sub-classes depending on severity values assessed

Year	Country	Percentage of fields recorded as "Primary attack" (m^2)			Percentage of fields recorded as "Late blight found all over the field" (Severity, %)					Number of fields
		< 1 m^2	1-5 m^2	5–25 m^2	0–1%	1–5%	5–10%	10–25%	>25%	
2001	Estonia	79.0	0	10.5	0	10.5	0	0	0	19
	Latvia	52.0	11.0	4.0	11.0	4.0	11.0	0	0	27
	Lithuania	66.0	3.8	1.9	3.8	5.7	5.7	7.5	5.7	53
	Poland	50.0	15.6	6.3	18.7	6.3	3.1	0	0	32
2002	Estonia	46.7	20.0	0	6.6	0	0	0	26.7	15
	Latvia	60.0	10.0	20.0	10.0	0	0	0	0	20
	Lithuania	80.6	2.8	2.8	13.8	0	0	0	0	36
	Poland	64.0	12.0	12.0	8.0	4.0	0	0	0	25

Internet (Fig. 3). In the example in figure 3, the reference variety was selected as Karlena. The reference variety was used for calculation of *Delay of first symptoms* and *Disease rating when rating of reference variety is = 90%*. Data were sorted descending according to *Relative area under the disease progress curve* (arrow down). The regression coefficients for *Apparent infection rates* (AIR) indicate how well the transformed data fit a straight line.

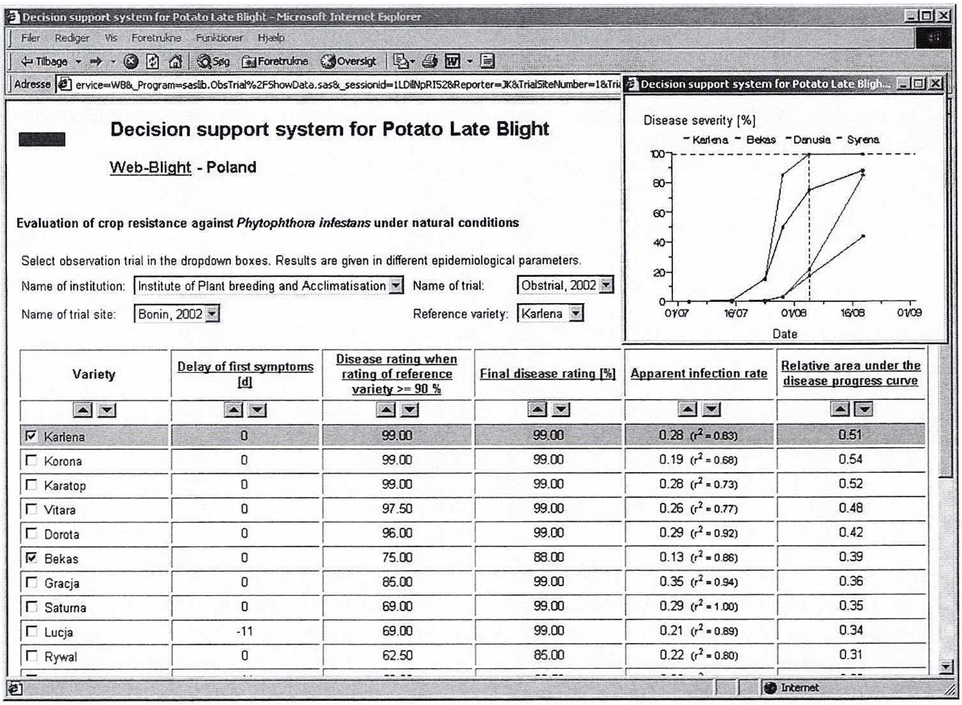
Several local varieties were tested in the three Baltic countries and Poland in 2001 (Tab. 4). The most susceptible varieties were Berber, Folva and Vivaldi in Estonia, Mutagenagria, Asterix and Folva in Latvia, Zukovskji, Venta and Bintje in Lithuania and Bard, Denar and Lord in Poland. The most resistant varieties were Anti, Sarme and Kuras in Estonia, Oleva, Danva and Kuras in Latvia, Vilnia, Aistes and Kuras in Latvia and Danusia, Wawrzyn and Umiak in Poland.

DISCUSSION AND CONCLUSIONS

After its introduction in year 2000, Web-Blight monitoring is now an important decision support component in national Internet based DSSs in the Nordic countries, the three Baltic countries and Poland. The combination of using PC- and Internet applications worked without technical problems and data could be updated on the Internet any time of the day with no manual work on the server side.

Monitoring results from 2001 and 2002 in the Baltic Sea region show that early attacks were found as primary attacks (spots in the fields) in 67%–90% of the recordings in the system (Tab. 3).

Early attacks during row closing were found more often in home gardens than in conventional fields and in experimental fields (Tab. 2). The reason for this could be that potato growing in home gardens and allotment gardens often includes a narrow crop rotation, relatively early planting and use of own seed. In conventional fields a majority of farmers use crop rotation and certified seed, which reduces the amount of initial inoculum and general plant stress from other soil borne pests and diseases. In



Variety	Delay of first symptoms [d]	Disease rating when rating of reference variety >= 90 %	Final disease rating [%]	Apparent infection rate	Relative area under the disease progress curve
Karlena	0	99.00	99.00	0.28 (r^2 = 0.83)	0.51
Korona	0	99.00	99.00	0.19 (r^2 = 0.68)	0.54
Karatop	0	99.00	99.00	0.28 (r^2 = 0.73)	0.52
Vitara	0	97.50	99.00	0.26 (r^2 = 0.77)	0.48
Dorota	0	96.00	99.00	0.29 (r^2 = 0.92)	0.42
Bekas	0	75.00	88.00	0.13 (r^2 = 0.86)	0.39
Gracja	0	85.00	99.00	0.35 (r^2 = 0.94)	0.36
Saturna	0	69.00	99.00	0.29 (r^2 = 1.00)	0.35
Lucja	-11	69.00	99.00	0.21 (r^2 = 0.89)	0.34
Rywal	0	62.50	85.00	0.22 (r^2 = 0.80)	0.31

Fig. 3. Web page from Web-Blight including results for late blight resistance evaluation. The data are from a field trial carried out at Bonin in Poland, 2001. The results can be sorted according to each variable in the table. Disease progress curves can be shown for up to four varieties via the check boxes. Disease progress curves from left to right are: Karlena, Bekas, Syrena and Danusia

conventional fields early attacks were recorded during the end or after row closing in most situations (Tab. 2). This indicates that the general rule for starting spraying programs during row closing is still valid. Hansen et al. (2002) proposed to combine forecasting and monitoring information for decisions making about first application. In the basic strategy, initial fungicide protection was recommended in the most susceptible and early varieties according to a forecasting system, or, if late blight is found before predicted. It was recommended to delay spraying programs in more resistant and late varieties until late blight was found in the region in any variety. The monitoring results from Poland in 2001 and 2002 support this approach as late blight was initially found in fields with susceptible varieties and later in nearby fields with more resistant varieties in 74% of paired observations.

Local varieties were tested in untreated observation trials against four test varieties. Results were used to update local variety databases for resistance characterization and for parameterisation of the NegFry system. The results for RAUDPC were transformed into the international 1–9 scale. In all the Latvian NegFry validation trials during 1999–2002, the variety Santé was used as a moderate resistant variety. The results from the observation trials from both Latvia and Lithuania showed that the obtained RAUDPCs were very similar to Sava, a

Table 4. Relative area under the disease progress curve (RAUDPC) calculated for varieties included in late blight observation trials in Estonia, Latvia, Lithuania and Poland, 2001

JÕGEVA, ESTONIA		VECAUCE, LATVIA		VOKE, LITHUANIA		BONIN, POLAND	
Variety	RAUDPC	Variety	RAUDPC	Variety	RAUDPC	Variety	RAUDPC
Berber	0.59	Mutagenagria	0.72	Zukovskji	0.51	Bard	0.65
Folva	0.41	Asterix	0.71	Venta	0.49	Denar	0.63
Vivaldi	0.40	Folva	0.70	Bintje	0.49	Lord	0.61
Van Gogh	0.39	Redstar	0.69	Vilija	0.45	Wiking	0.54
Sava	0.33	Vineta	0.68	Liepa	0.45	Kuba	0.43
Piret	0.32	Sava	0.63	Sava	0.32	Wolfram	0.40
Ants	0.31	Santé	0.62	Santé	0.31	Alicja	0.25
Danva	0.29	Oleva	0.54	Mirta	0.27	Rumpel	0.23
Oleva	0.23	Danva	0.47	Oleva	0.26	Ania	0.22
Ando	0.08	Kuras	0.06	Danva	0.22	Lucja	0.20
Anti	0.06			Vilnia	0.11	Danusia	0.10
Sarme	0.03			Aistes	0.03	Wawrzyn	0.08
Kuras	0.02			Kuras	0.03	Umiak	0.01

well-known moderate susceptible variety classified as 3–4 on the international scale (Tab. 4). Santé was probably misclassified for use with NegFry and this is supported by the fact that the control effect in trials with Santé often was less successful than expected.

The variety, Kuras, is now widely grown in Denmark for starch production. Reports from practice and results from Danish variety observation trials indicated that the resistance in Kuras was not stable (Hansen et al. 2002). Therefore, Kuras was included in the set of test varieties to evaluate its resistance against late blight in areas where it is not normally grown. Results from the network of observation trials in Estonia, Latvia and Lithuania show that Kuras was attacked relatively late and at very low levels (Tab. 4). Same results were found in areas in Denmark where no starch potatoes are grown (Hansen et al. 2002). It is possible that Kuras contains integrated resistance based on both partial and race-specific resistance, and that local populations of *P. infestans* adapt to those major genes. Theoretically this adaptation will be faster when sexual reproduction occurs. When new varieties are introduced on the market, the content of major resistance genes and durability of partial resistance are not always well known. The Web-Blight network for evaluation of variety resistance is a rather inexpensive and effective method to evaluate the stability of resistance in time and space.

The Web-Blight system is a „Collaborative Information System", referring to the fact that several countries use the same system. This has the advantage that programs only have to be updated and improved on one server. Several countries share the same applications and thereby avoid duplicate work. This will keep operational cost at a relatively low level. As all countries use the same methods, the results can be compared and analysed together. Collaboration and harmonization of methods facilitate that conclusions and quantitative knowledge are more reliable and obtained faster. This was one major objective for the EUCABLIGHT concerted action – A potato late blight network for Europe, initiated in 2003 (http://www.eucablight.org).

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POLISH SUMMARY

WEB-BLIGHT – REGIONALNY MONITORING ZARAZY ZIEMNIAKA ORAZ INFORMACJE O ODPORNOŚCI ODMIAN ZIEMNIAKA NA ZARAZĘ DOSTĘPNE W INTERNECIE

Serwis internetowy „Web-Blight“ (http://www.Web-Blight.net) został zainicjowany, w celu ostrzegania i prognozowania występowania zarazy w uprawach ziemniaka w krajach otaczających Morze Bałtyckie. Aby otrzymywać porównywalne wyniki badań, stosowane w projekcie metody badawcze zostały zharmonizowane a system powiązanych ze sobą PC i aplikacje internetowe rozwinięte dla użytku przez partnerów współpracujących w projekcie.

Przedstawione w publikacji wyniki dotyczą sytuacji w Estonii, Łotwie, Litwie i Polsce w latach 2001 i 2002 i obejmują monitorowanie zarazy oraz ocenę odporności odmian ziemniaka na zarazę (badania polowe). Użycie Internetu, w celu zebrania i przedstawienia danych okazało się bardzo korzystne, ponieważ informacje były ogólnie dostępne, pomagając rolnikom w podejmowaniu decyzji o terminie pierwszej aplikacji i wyborze środka grzybobójczego. Uzyskane wyniki wskazują iż możliwe jest znalezienie wczesnych ataków choroby jako infekcji pierwotnych (pojedyncze nekrozy na roślinach). Najwcześniejsze infekcje były częściej znajdowane w ogródkach przydomowych niż na polach produkcyjnych. W większości przypadków, stadium rozwoju roślin było wyższe niż 37 (BBCH) w momencie pierwszych stwierdzonych infekcjach, co wskazuje, że bardzo wczesne infekcje powodowane przez oospory z gleby nie są powszechne.

Odporność lokalnych odmian ziemniaka na zarazę była testowana w doświadczeniach polowych (bez ochrony) i porównywana z czterema odmianami wzorcowymi (Sava, Dianella, Danva i Kuras). Podstawowe informacje o rozwoju choroby przekazywano na serwer do systemu Web-Blight poprzez Internet gdzie obliczane były zmienne epidemiologiczne dla odmian, takie jak opóźnienie wystąpienia pierwszych objawów zarazy czy RAUDPC (względna powierzchnia pod krzywą postępu choroby). Wyniki wskazały w niektórych odmianach genetyczną, specyficzną odporność na zarazę np. w odmianie Kuras i zróżnicowane klasyfikowanie w 9-stopniowej skali odporności np. odmiany Santé. Sieć doświadczeń obserwacyjnych potwierdziła, że polowe charakteryzowanie odporności odmian na zarazę ziemniaka w czasie i przestrzeni jest ważne ze względu na gwałtowną ewolucję populacji *Phytophthora infestans* w Europie.