

Advances in Decision Support Systems for Control of *Phytophthora infestans* in Europe

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Abstract

Decision support systems (DSS) support the efficient control of late blight with a minimal input of sprays. In Europe a number of DSS are developed, validated and used in practice. In this chapter the most important DSS in Europe, the number of users and results of validation are presented. DSS are increasingly used by farmers and advisors for integrated control of late blight. In the framework of an European Concerted Action on integrated control of late blight, four DSS (NegFry, Simphyt, ProPhy, and PLANT-Plus) were tested in six European countries. By employing these DSS, the number of sprays could be reduced compared to a routine 7-day spray regime. In general the DSS performed well in those regions in which they were developed. Building one European DSS was not realistic, because of many regional differences in the potato growing regions of Europe.

Resumen

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Los Sistemas de Apoyo para la Toma de Decisiones (DSS) en el control de *Phytophthora infestans* apoyan el control eficiente del tizón tardío con un mínimo de aplicaciones. En Europa varios de estos DSS se están desarrollando, validando y usando en la práctica. En este capítulo se presentan los DSS más importantes de Europa, el número de usuarios y los resultados de su validación. Los DSS se vienen utilizando cada vez más por agricultores y asesores en el control integrado del tizón tardío. En el marco de una acción concertada para el control integrado del tizón tardío en Europa, se comparó cuatro DSS (Negfry, Simphyt, ProPhy, and PLANT-plus) en seis países europeos. Se mostró que empleando los DSS el número de aplicaciones se podría reducir en comparación a un régimen calendario de aplicaciones cada siete días. En general la performance de los DSS fue buena en aquellos lugares donde fueron desarrollados. La idea de construir un solo DSS para Europa no fue realística, debido a las numerosas diferencias regionales en las áreas productoras de papa de Europa.

Introduction

Decision Support Systems (DSS) can include information that is available on the epidemiology of the fungus, on susceptibility of cultivars, on fungicides, on plant growth, on influence of weather conditions, on weather forecasts and on infection pressure. They support the efficient control of late blight with a minimal input of sprays. In Europe a number of DSS are developed, validated and used in practice. Bouma and Hansen (1999) published an overview of the standard descriptions of the DSS in Europe. In this chapter the most important DSS in Europe, the number of users and results of validation trials are presented.

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NegFry

NegFry is a personal computer-based and internet model developed in Denmark (Hansen, 1999). It uses the "negative prognosis" (Ullrich and Schrödter, 1966) to forecast the risk of a late blight outbreak and the model of Fry (Fry et al. 1983) to time subsequent fungicide applications during the season. The model runs with hourly data on temperature, relative humidity and rainfall collected at Hardi Metpole meteorological stations.

Parameterization of the model was based on biological and meteorological data obtained from Foulum, Denmark. First fungicide application is recommended once accumulated risk values exceed 160 and the daily risk value, calculated according to the "negative prognosis" model, is above 8. After the initial spray, favorable weather for disease development is expressed as blight units according to the method of Fry et al. (1983). Fungicide sprays are started when the accumulated risk value is greater than 160, and the risk value for the previous night is greater than 8. Subsequent treatments should be done when accumulated rainfall is greater than 20 mm or risk value of the previous night is 8, and a blight unit threshold of 40 (susceptible cultivar), 45 (moderately susceptible cultivar) or 50 (moderately resistant cultivar) has been exceeded. Blight units and rainfall value is set to zero after each fungicide treatment. The recommendation of NegFry and the occurrence of infected fields in Scandinavia, the Baltic countries and Germany are presented on the internet (<http://www.web-blight.net>). The model has been validated in Denmark, Norway, and Sweden in 1993 and 1994 for late blight of potato. The model has been implemented in Europe.

Negative prognosis

The "negative prognosis" model uses hourly measurements of temperature, relative humidity, and rainfall measured at meteorological weather stations with sensors mounted 2 meters above the ground, to predict when blight epidemics are not likely to occur (Ullrich and Schrödter, 1966). It is used in Germany and in the NegFry and PhytoPRE models to predict the timing of the first treatment. Daily and accumulated risk values over a week are calculated starting at crop emergence. Disease is expected when the accumulated risk value has exceeded the threshold of 150. Users have adjusted this threshold to fit local conditions. The model has been validated in Germany. This model has been implemented in Europe.

Forsund rules

The forecasting model was developed in Norway and has been used since 1957 (Førsund, 1983). The model contains four criteria used to assess the risk of late blight. The following conditions, measured at regional weather stations, are considered favorable for the disease:

- Daily maximum temperature is 17-24 °C
- Minimum temperature ≥ 10 °C
- Relative humidity at noon is ≥ 75 %
- Daily rainfall ≥ 0.1 mm

Warnings are issued daily when these conditions occur for two consecutive days. The risk of disease outbreak increases with the number of favorable days. Warnings are issued by the Norwegian Institute of Meteorology and distributed through press and broadcasting systems.

According to disease records from 1957 to 1980, in Norwegian locations where more than three warnings have been issued, moderate to severe potato late blight has occurred. Lower disease severity than expected can occur in locations where low or no inoculum is present due to low disease pressure in previous years. This model has been validated and implemented in Norway.

PhytoPRE

PhytoPRE is a computer-based information and decision support system (DSS) for potato late blight in Switzerland (Forrer et al., 1993). PhytoPRE consists of an epidemiological forecast model, a set of decision rules, and an information system. The epidemiological forecast model was developed from national and cantonal records (1990-1992) of disease progress curves over time that were collected from a network of about 150 unsprayed (organic) potato plots. Forecasts are provided after the first national late blight (FLB) record is reported. To adapt the forecast to specific regions, Ullrich and Schrödter's Risk Values (RV) for that region are compared to the RV in the location with the FLB. The timing of the first and subsequent fungicide treatments depends on host susceptibility, infection probability, amount of rainfall, fungicide used and the amount of time since the last fungicide application. The model has been validated and implemented in Switzerland.

Simphyt

Simphyt consists of two submodels; Simphyt 1 and 3 (Hausladen et al., 2000). Simphyt 1 predicts the date of the first fungicide spraying for 8 different crop emergence-date classes and two risk levels. It requires the input of hourly temperature data, relative humidity and rainfall measured at met stations. Simphyt 3 provides information on epidemic pressure and dry periods. The submodel does not recommend a fungicide strategy but from the calculated epidemic pressure under consideration of foliage growth, cultivar resistance, blight situation in the field and fungicide usage, a spraying interval is derived. The disease is monitored on fungicide treated and untreated potato plots. The recommendations of Simphyt and the results of the monitoring are presented on the internet (<http://www.syngenta.de>). The model has been validated and implemented in Germany.

Irish rules

The rules were developed by Bourke and are known as the 'Irish Rules' (Bourke, 1953; Keane, 1995). It is assumed that spores germinate and infect new potato leaves with a wetness period of at least 12 hours and air temperature not below 10 °C and relative humidity of at least 90% if precipitation occurs in the interval from 7 to 15 hours after the start of the period. The minimum wetness period required is increased to 16 hours if no precipitation takes place during the wetness interval. Potato inspectors report first signs of blight every season. Since it is assumed that fungicide sprays generally protect crops for two weeks, warnings are normally issued at intervals no less than two weeks apart even if further blight-weather conditions occur. Intervals between warnings may be reduced if a major spell of blight-weather is imminent. The rules are used in Ireland since the early 1950s.

Smith rules

The rules were proposed by Smith (1956) as an alternative to reduce the number of invalid late blight forecasts by the Beaumont rules in England and Wales. According to the Smith criteria, two consecutive days with minimum temperature of 10 °C (50 F) with at least 11 hours of relative humidity 90% or higher are favorable for the development of *P. infestans* on potato. The rules initiate fungicide treatments when two consecutive days with minimum temperature of 10 °C (50 F) with at least 11 hours of relative humidity 90% or higher have occurred. The rules are validated and implemented in England and Wales (Hims et al., 1995). On the internet (<http://www.zeneca-crop.co.uk>) the occurrence of Smith periods in the UK is presented.

ProPhy

ProPhy is a computerized expert system for farmer decision support (Schepers, 1995; Nugteren, 1997). It integrates current knowledge of control measures for *P. infestans* on potato. ProPhy recommends a first fungicide spray in sensitive cultivars when the crop reaches a height of 15 cm or ten days later if a more resistant cultivar is used. When late blight is observed in the region, the first spray is recommended earlier.

Subsequent treatments are scheduled by combining the fungicide protection status of a crop with the weather conditions. It is assumed that a sensitive potato cultivar is protected for eight days after spraying with a protectant fungicide. In more resistant cultivars this period may be extended for 1, 2, or 3 days depending on the degree of resistance and several other parameters. Factors such as whether a grower has used a reduced dosage of fungicide, whether or not new leaves have been formed, occurrence of rain, and the number of favourable days that occurred in a period of three to ten days from the present time may shorten or lengthen the protection period of the fungicide. The assumed protection period of a fungicide can only be shortened to a maximum of three days. A favorable day for the development of *P. infestans* occurs when at least six hours with high relative humidity plus at least two hours of leaf wetness or rain occur in a period from 8 pm on the previous day until 12 am on the day of evaluation. The temperature must be in the range of 8 to 25 °C. If viable lesions are observed close to the site, calculation of favorable days is overruled and a spray is advised. ProPhy formulates recommendations on the basis of the calculated protection periods and the weather forecast. If protection is no longer present and weather conditions are favorable for infection, a curative fungicide is recommended. Results of trials showed that growers using the ProPhy model used fewer fungicide applications than those using a 7-day calendar based model yet they achieved similar disease control (Nugteren, 1997). The model has been developed, validated and implemented in The Netherlands by the software company Opticrop.

Plant-Plus

Plant-Plus was introduced in The Netherlands as a DSS for control of late blight in 1994 (Hadders, 1997). The model is a combination of empirical and fundamental submodels. Hourly data on temperature, relative humidity, radiation and wind speed are measured in a met station at 1.50 m. With these data the model calculates the temperature and leaf wetness in the crop. Together with weather forecasts the critical conditions for development of late blight are calculated. Plant-Plus calculates the degree of crop protection by using data on crop growth and degradation of fungicides. In the epidemiological submodel, the sporulation is predicted by using relative humidity data. The release of spores is predicted by using data on age of lesions, rainfall and relative humidity. Penetration of spores into leaves is predicted by using data on leaf wetness, temperature and cultivar resistance. Disease is monitored by scouts to adapt the calculated disease pressure. Infected fields and cull piles are presented on the internet (<http://www.plant-net.com/barometer>). Plant-Plus recommends sprays by combining the risk for infection with the degree of crop protection. Plant-Plus has been developed, validated and implemented in The Netherlands by the software company Dacom.

Guntz-Divoux

In Belgium and France the disease forecasting model of Guntz-Divoux is used (Goeminne et al., 1997). The model calculates the theoretical development of the disease based solely on weather data measured at standard level of 1.50 m. Infection occurs when at least 10.5 consecutive hours with a relative humidity of >90% is measured. The average temperature should be at least 7 °C. Growth of the fungus inside the leaf is only influenced by temperature. Sporulation occurs after the accumulation of 7 temperature-units. With these data the model calculates the occurrence of disease cycles. Together with information on growth stages, disease monitoring, rainfall and weather forecasts, the theoretical calculation of the disease cycles is used to recommend fungicide treatments. The model recommends sprays shortly before the calculated emergence of lesions from the previous infection period. The model is developed, validated and implemented in Belgium and France.

Users of DSS

DSS can be used by advisors and/or farmers. The recommendations from DSS can reach the users in different ways: via internet, with PC's, with fax messages and by telephone services. In The Netherlands, the models Plant-Plus and ProPhy are sold to farmers. These models are mainly bought to increase the efficacy of late blight control, but DSS are also increasingly used because they fit in the concept of integrated control and support also the justification of fungicide sprays. In several European countries including for example Denmark and The Netherlands, governments have set goals to decrease the input of agrochemicals. To

achieve these goals, the use of DSS is promoted. In Denmark, NegFry is offered to the farmers for relatively low costs by a government-funded research institute, in The Netherlands subsidies are available for farmers who want to buy a DSS. The information from all other DSS mentioned in this chapter are offered to farmers for relatively low costs by government-funded research institutes. In the framework of an European Union funded Concerted Action on integrated control of late blight a survey was held to investigate the number of users of DSS in Europe (Bouma and Hansen, 1999). The results of this survey are listed in Table 1.

Table 1. Number of users of DSS in Europe in 1998

DSS	D*	S,DK,FIN	NL	B,F	CH	N
Simphyt	40-50					
Guntz-Divoux				2000		
ProPhy			335			
PLANT-Plus			400			
Forsund						800
NegFry		490				
PhytoPRE					800	

Bouma and Hansen, (1999).

*D = Germany; S = Sweden; DK = Denmark; FIN = Finland; NL = Netherlands; B = Belgium; CH = Switzerland; N = Norway.

Results of validation trials

Before introduction of a DSS, validation trials should be carried out to find out whether the system effectively controls blight. Most systems are validated and used in only one country or region. In the framework of an European Union funded Concerted Action on integrated control, four DSS (NegFry, Simphyt, ProPhy and Plant-Plus) were tested in 1999 in six European countries (Kleinhenz and Jörg, 2000). By employing these DSS, the number of sprays could be reduced compared to a routine 7-day spray regime. Simphyt and NegFry recommended less sprays than ProPhy and Plant-Plus. Plant-Plus advised more contact fungicides than the other DSS. NegFry and Simphyt tolerated higher late blight disease severities than ProPhy and Plant-Plus. In general the DSS performed well in those regions in which they were developed.

Conclusions

DSS are increasingly used by farmers and advisors for integrated control of late blight. Validation trials and experiences in practice show that DSS can be a useful tool to effectively control blight with a minimum of fungicide input. A Concerted Action on integrated control of late blight showed that, because of many regional differences in the potato growing regions of Europe, building one European DSS was not realistic (Schepers, 2001). For improvement of existing DSS, information is needed on (1) epidemiology of the "new" blight population, (2) fungicide characteristics and (3) standard descriptions of crop resistance. Also (4) reliable data on historical weather and weather forecasts should be available to the DSS.

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