This document describes the Danish decision support system for control of potato late blight caused by Phytophthora infestans. The report was prepared in the frame of the IPMBlight2.0 ERA-net EU project

Foulum, 10 January 2016

Danish potato late blight DSS

Jens G. Hansen

Identification of existing models and applications relevant for the IPMBlight 2.0 model development

IPMBlight 2.0, WP3, Task 3.1 - M3.1.1 and D3.1.1

Date: 10 January 2016

DSS name: Skimmelstyring (Blight Management)

Contact person: Jens G. Hansen, Aarhus University

Background

The objective of WP3 is to develop a new, quantitative approach to integrate knowledge on weather-based infection risk, epidemiological parameters, and pathogen phenotype and genotype characteristics (IPM2.0 concept). A suite of new on-line simulation models, making use of the phenotypic and genotypic data, weather data, and trap nurseries data from WP1 and WP2, will be designed (task 3.1) and implemented as web-based tools (task 3.2). Existing DSSs in partner countries will then be adjusted based on results from step 1, and improved DSSs will be tested in field experimental trials (task 3.3).

Task 3.1. Develop a suite of simulation models for the integration of new data on pathogen information, host resistance and weather, will run in three steps: i) identify existing models and applications relevant for the IPMBlight 2.0 model development; ii) system description such as architecture, parameters to be included, management of data, model performance and sensitivity analysis; iii) data collation, storage, quality control and access from task 1.4

Based on reports on selected DSSs and their sub-models relevant sub-models will be implemented as matlab components and evaluated with weather data and biological data. Subsequently components for further use in the project will be implemented as Web components in Task 3.2

Milestones and deliverables

M.3.1.1: Existing models and applications relevant for the IPM Blight 2.0 model development identified and evaluated

D.3.1.1: System description of models and applications to be implemented in the EuroBlight platform.

1. OVERVIEW

Name of the decision support system: Skimmelstyring (Blight Management)

Responsible institute/company: Aarhus University

Contact person system: Jens G. Hansen e-mail (jensg.hansen@agro.au.dk) and Bent J. Nielsen: (bent.nielsen@agro.au.dk)

Contact person programming: Poul Lassen e-mail: poul.lassen@agro.au.dk

Software/programming language: C#, Visual studio .NET

Link to operational version on Internet:

Project web site for Skimmelstyring: www.skimmelstyring.dk

Integrated into the extension service web pages:

https://www.landbrugsinfo.dk/Planteavl/Afgroeder/Kartofler/Sider/pl_skimmelstyring_kartofler.aspx

Available in EuroBlight:

http://euroblight.net/research-projects/ipmblight20/decision-support-systems-overview/denmark-blight-management/

2. SYSTEM DESCRIPTION

Description of the DSS, its sub-models and other DSS components used for decision making regarding control of potato late blight.

For Danish conditions conventional farmers need information on when to start chemical control, choice of fungicide type and dosage and how to vary the control during the season.

During a decade of projects including the Aarhus University, The extension service in DK and the potato industry it was concluded in the mid 2000 that we needed a more practical approach for a robust DSS, - reflecting the structural development of the potato farming systems. The number of growers was decreasing and the farm size and number of fields per farm did increase. From a logistical point of view the advisors and farmers told us, that it was not possible to treat every single field very specific regarding control of potato late blight.

The second component that was important for decisions on the concepts and structure of the DSS was the success of using reduced dosages. This was documented in several field experiments (Hansen et al. 2002, Nielsen et al. 2008). Based on experiences from several years of field experiments in the 1990s and early 2000 a general approach was then decided to develop a system that recommended to apply fungicide with a weekly interval (as conventional), but vary the dosage of fungicide (mostly Revus/Ranman has been used in trials) according to the infection risk, the amount of inoculum in the region and the type of potato and resistance level of potato cultivar. We developed the calculation of Infection pressure and the Dose model to recommend the type and Dosage of fungicide use during the season (Nielsen et al., 2008; Nielsen et al. 2010; Nielsen et al. 2010; Nielsen et al. 2015)

The decision about when to start is another story. The thumb rule was for decades to start spray fungicide preventive just before row closing. From 1985-1997 we used the German Negative prognosis (Hansen, 1992). After 1997 when we experienced the first indications of infections from oospore this model is not valid for predicting when to start. Still we use the Negative prognosis as an indication when infections from infected tubers are expected. Not all years we find infections from oospores. We do not have a fixed model for the risk of oospores but by experience we know that:

- Narrow crop rotation increase the risk of oospore driven early infections
- Heavy rainfall and at the same time medium to high infection pressure right at crop emergence increase the risk of oospore infections
- We all present knowledge to point out risk fields and areas and then we scout these fields/areas intensively during crop emergence. Any recordings will be uploaded to the web based surveillance system.

This is a stepwise description of the Danish Blight Management system

1. During crop emergence “risk areas” are identified and inspected for attacks from oospores. Risk areas are areas with narrow crop rotations where oospores might be present. If it rains and the infection pressure is medium to high then the risk is higher for oospore driven infections. Interactive GIS maps for precipitation and infection pressure is available as well as local calculations of rain and infection pressure
2. Early attacks are reported via the Nordic Surveillance system that has been operational since 2010. Recently all Nordic countries started to use the BlightTracker smartphone APP for uploading of recordings of early attacks of late blight (Hansen et al., 2015)
3. A network of potato advisors (7-8) meet every Monday morning for a telephone meeting to inform each other and exchange ideas and views of the regional and local situation re blight risk and when and how control actions should start. In this situation the regional maps are very useful. We also include information from other national surveillance systems used in our neighbouring countries – ISIP for Germany, Fight against Blight for the UK and information from the Netherlands. If blight is early in these countries this is a warning for us in Denmark. The regional potato advisors are a very important dissemination channel for late blight advice, because not every grower look at the internet about alerts.
4. When blight has been found in a region it is evaluated if this is very local attack in a special field, or due to oospores and also about the weather based blight risk in the forthcoming week. If the forecast says blight weather a majority of farmers in this region (distance 25-50 KM) will start control actions – in more resistance cultivars with reduced dosages.
5. When late blight is established in the region (> 5 conventional fields reported in the Surveillance system) then a majority of farmers spray according to the Blight Management System – Dose Model. As a thumb rule: spray weekly with low dosage contact fungicide when blight weather is unfavourable and full dosage during high infection pressure. When blight is widespread and epidemics are observed in organic potatoes (or untreated plots) this will indicate that the spore loads will increase. Next time a high infection pressure is indicated in the forecast then many farmers will use a stronger (expensive) compound with systemic effect. Stronger compounds are also used if the spray is too late compared to an important infection risk.
6. With climate change we have seen a tendency to more extreme weather including some periods with very heavy new growth. Also long periods with dry weather. When rains come again after a drought spell heavy new growth can happen. During those periods farmers have experienced that a 7 days spray schedule too long and 5 days interval is needed to control blight. This kind of decision making is not included in the Blight Management system, and this is decisions to be taken by the advisor and the farmer together.
7. If a field is attacked with blight more than a few lesions here and there (>0,5%), then it is not recommended to use reduced dosages. Blight Management is then only of minor use because

new infections can happen from rain splash via rain events alone. This is not included in the system. Very often a dry weather spell and intensive chemical control can eradicate a minor attack.

The Blight Management system has also been tested in Sweden in 2015 and 2016 (Djurberg et al., 2015). The arguments is that the approach with weekly spray schedule and varying dosages of fungicides depending on infection risk is appealing for many farmers also in Sweden (Louise Alden pers.communicatin)

Model output/outputs:

The DSS components used for making decisions on when to start control strategy is given in Figure 1.

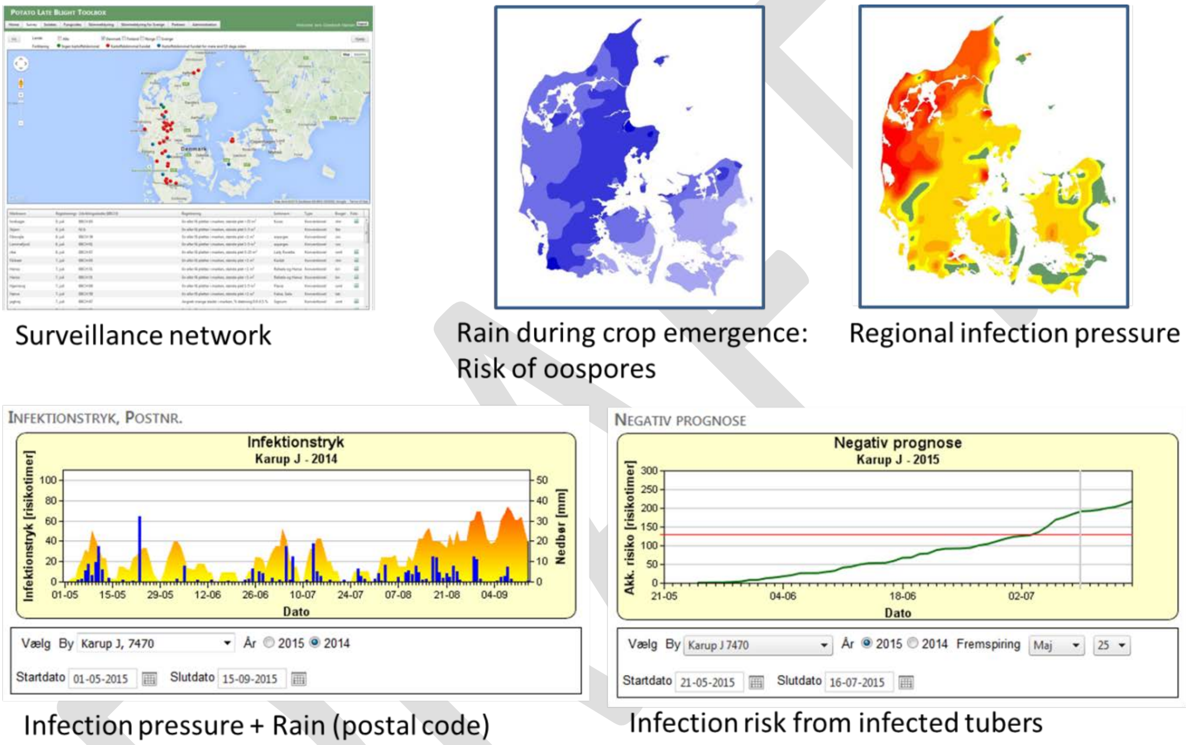


Figure 1. DSS components used to decide how to start control of potato late blight with fungicide.

The surveillance network was developed in collaboration with the other Nordic countries based on experiences from a similar system called WebBlight also including the Baltic countries and Poland (Kapsa & Hansen 2004). The current version is an integrated part of the Potato late Blight toolbox and it also includes the use of the BlightTracker smartphone APP for uploading of results directly from fields expected (Hansen et al., 2015; Hansen et al. 2016)

Rain during crop emergence is a prerequisite for activating oospores in the soil. The user can select start and end for a time period to show on the map (Figure 3 below)

The regional infection pressure is based on calculation of the infection pressure in more than 600 grids (interpolated using apr 80 weather stations with Rh in Denmark). The daily calculations are stored in a Database with daily weather variables and model calculations. The dynamic map is generated using Visual studio / Telerek tools and not dedicatd GIS systems.

The infection pressure is calculated on postal code level using all available weather stations in Denmark- weighted distance interpolation. The user can select Postal code and start and end date. To visualize what happened last year or previous year the user can select similar overview of infection pressure one or two seasons back in time.

The Negative prognosis is used to calculate the risk of primary attacks from infected tubers. The user can select postal code, start date and end date, and the date of crop emergence. To visualize what happened last year or previous year the user can select similar overview of the Negative prognosis one or two seasons back in time.

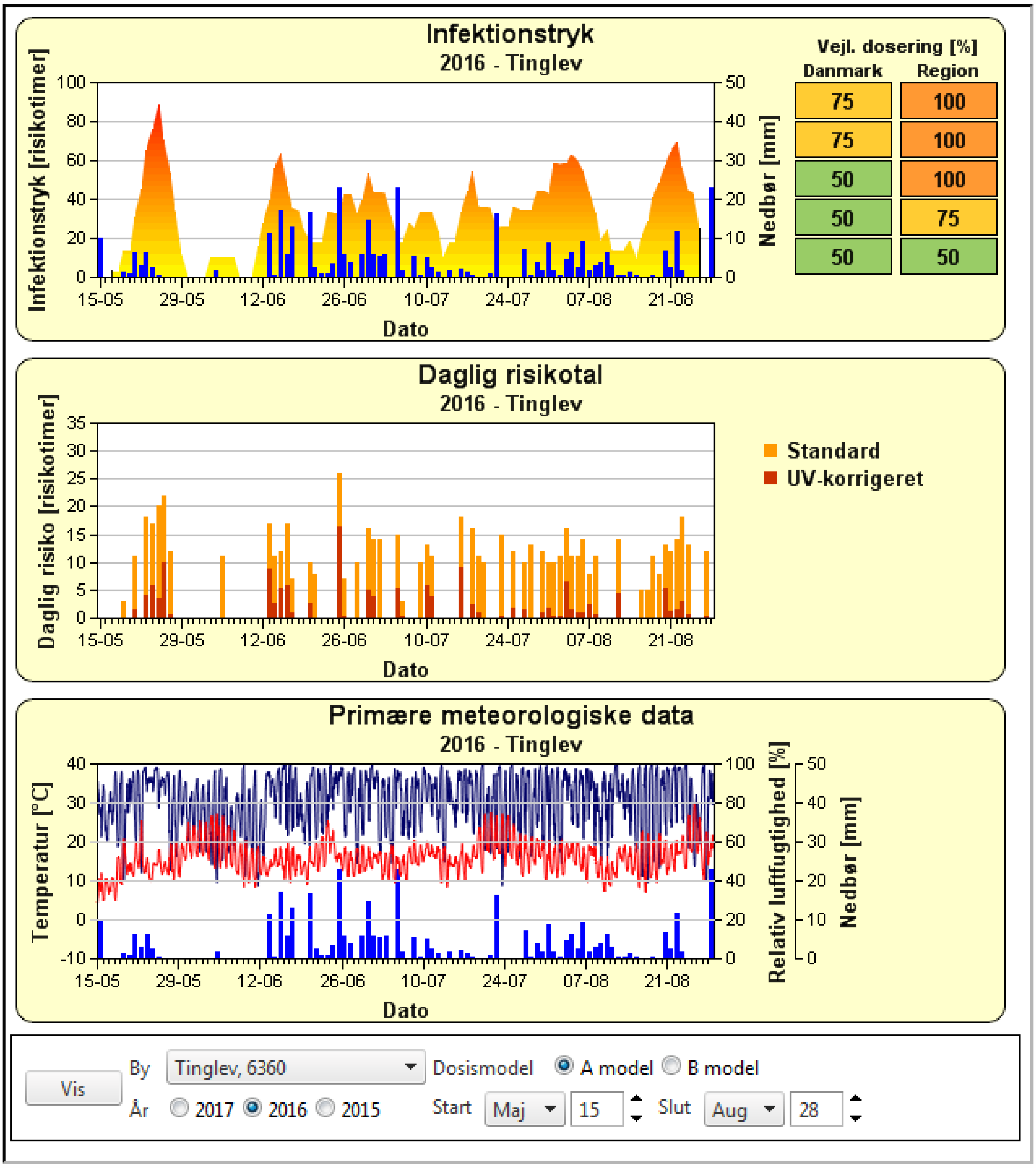


Figure 2. The infection pressure is calculated on postal code level interpolated using all available weather stations in Denmark. The user can select Postal code and start and end date. To visualize what happened last year or previous year the user can select similar overview of infection pressure one or two seasons back in time. In this version the user can select Model A for susceptible cultivars or Model B for more resistant cultivars (mainly resistant starch potatoes)

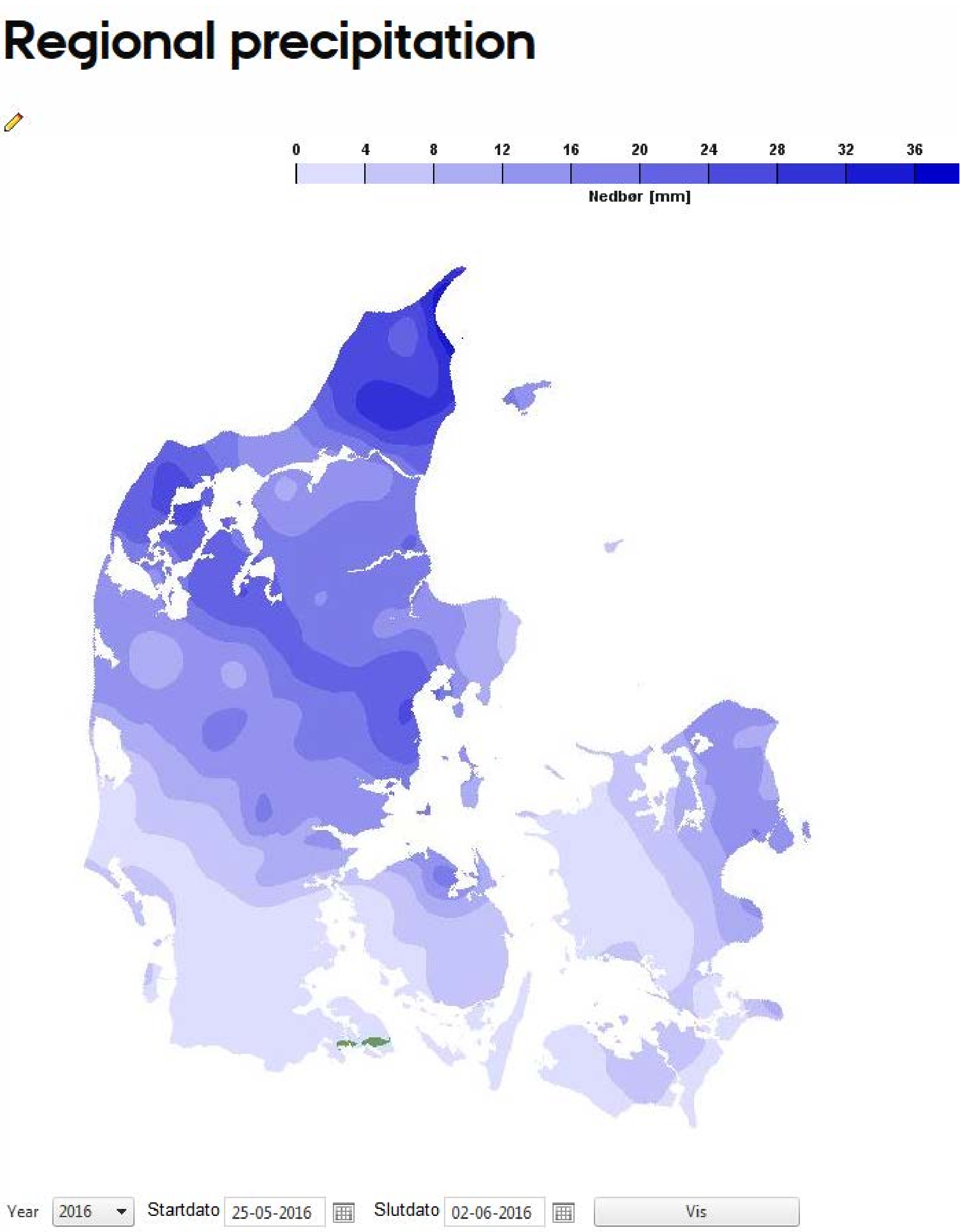


Figure 3. Regional precipitation

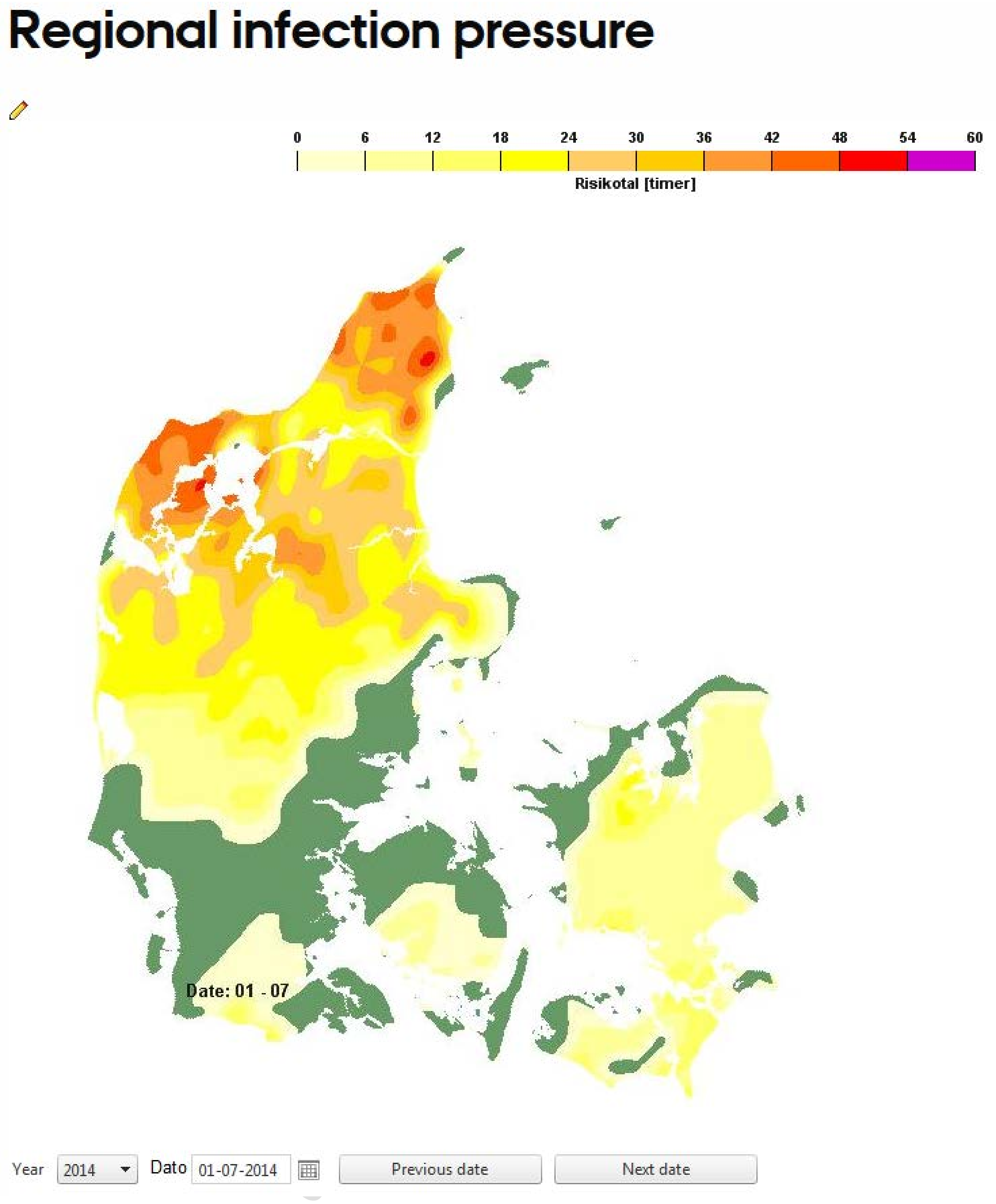


Figure 4. Regional infection pressure

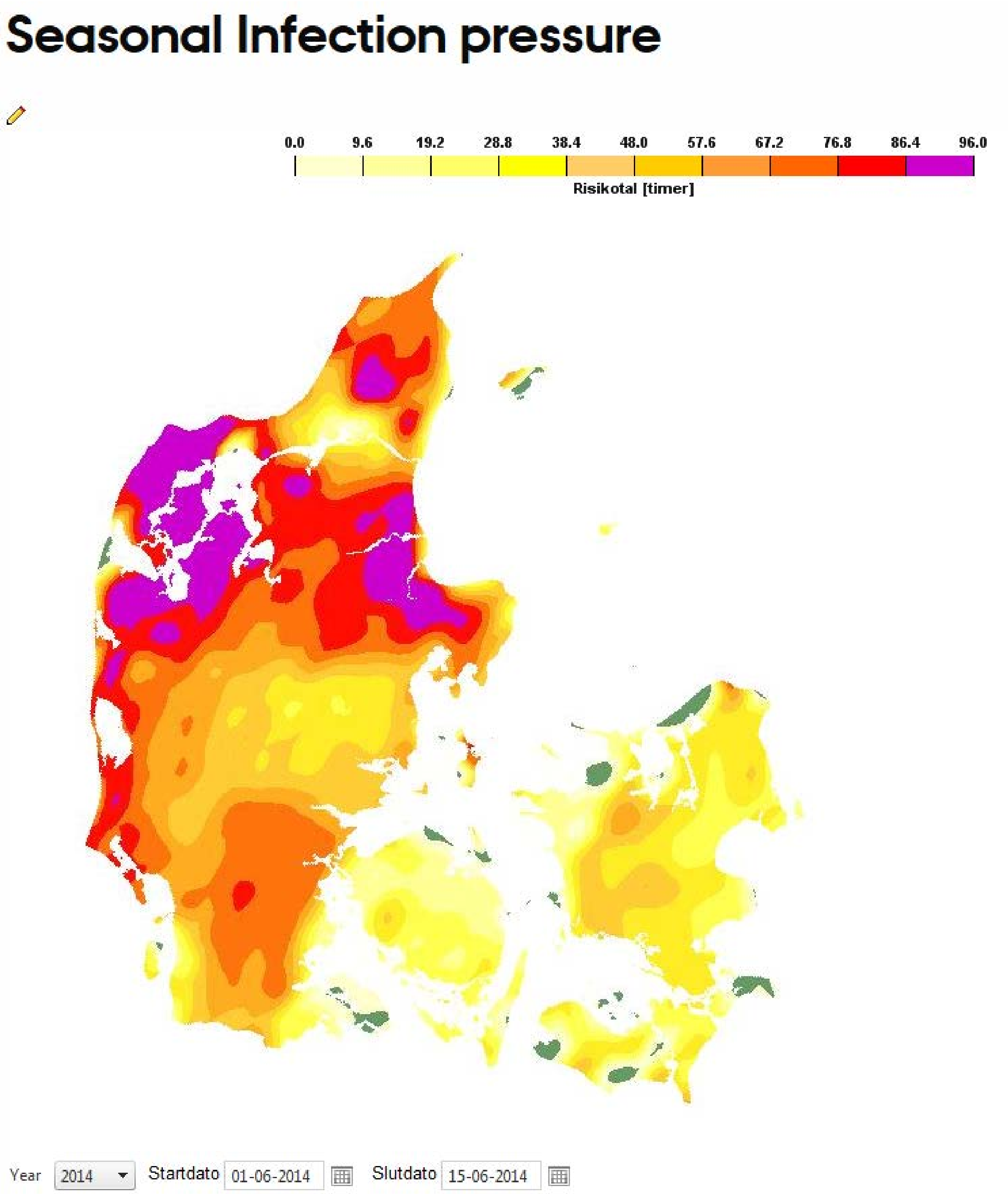
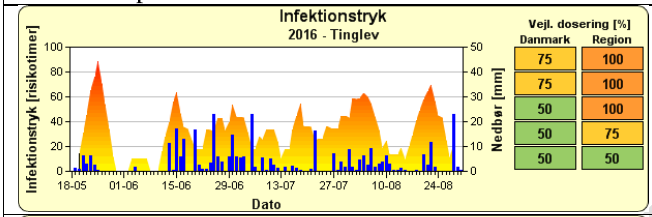
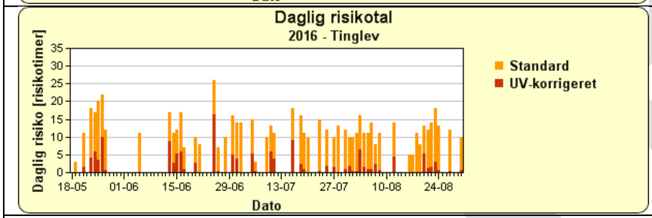
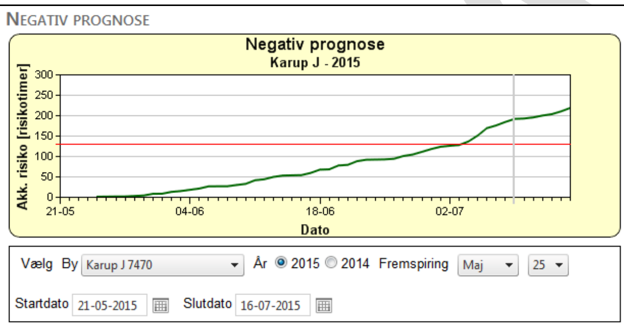
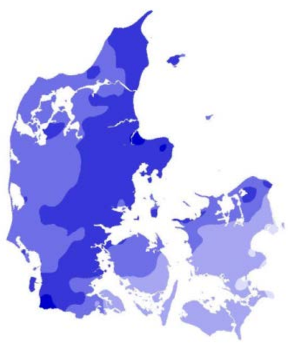


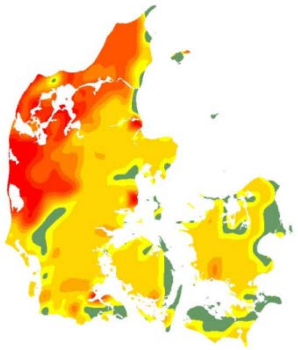
Figure 5. Seasonal infection pressure

3. MODEL INPUTS

Description/overview of the weather stations/ weather data:

Weather data required:

DSS Components	Weather data requirement
	Infection pressure (red/orange curve): Hourly data on temperature [°C] and Rh [%] Precipitation [mm/day] (Blue bars): Supplementary: Rain and Leaf wetness [minutes/hour] on hourly basis
	Daily risk values corrected for survival of airborne sporangia: Hourly data for Temperature, Rh, global radiation [MJ/M²]
	Hourly data on temperature and Rh
	Precipitation [mm/day] during crop emergence: Precipitation on a daily basis Combined with infection pressure and date interval for crop emergence and cop rotation (appr. 7 days) Can generate a risk map for infections from oospores

	Regional infection pressure based on appr 600 grid calculated values of infection pressure

Time step of the weather data (hourly/daily...):

Hourly data for infection pressure and the negative prognosis. We get only data on rain on daily basis in the weather forecast.

AT AU we developed a GIS DB with daily data of standard met parameters and calculated outputs from the Blight management system i.e. daily risk value and infection pressure on a daily basis. Based on the DB we produce on

Estimated environmental data (if the model include environmental data calculated based on the weather data, as vapor pressure deficit, give the name and reference/description of the calculation used):

The Blight Management adjusted model includes the calculation of a humid hour as defined

A humid hour = if Rh≥88% or Leafwetness ≥30 minutes or Rain ≥0,2 mm

The use of Rh as an estimator of leaf wetness was also tested by Hansen & Baby in 2015 in a project about developing a new model for Septoria in wheat. They concluded that the use of Rh>85% is a good estimator of Leaf wetness, but that the xTended RH threshold (EXT_RH) was even slightly better. The method, proposed by Wichink Kruit et al. (2004), uses a base RH threshold of 87%, and wetness is extended to lower humidity ranges depending on the rate of change in RH. For periods with RH between 70% and 87%, leaves are assumed to be wet if average RH increases more than 3% in 30 min, and leaves are assumed to become dry if average RH decreases more than 2% in 30 min. During periods with average RH <70% leaves are assumed to be dry, and during periods with average RH > 87% leaves are assumed to be wet.

Other inputs required:

None

Description/overview of the biological data:

Biological data for validation of models for Dronninglund is given in Table 1.

Table 1. Recordings of Potato late blight in Denmark and at Dronninglund, 2014-2017

Country	Year	Station Name	Eurobligt country reports		PLB in region (<50 km) / >5 fields	PLB at trial site Susceptible cultivar	Estimated Date infection	PLB at trial site Resistante cultivar (date)	Estimated Date infection
			Date PLB Country early attack	Date Country PLB > 5 conv. fields					
DK	2014	Denmark	25 May	1 June					
DK	2014	Dronninglund			17 June/ 24 June	12 August	2-7 August	28 August	18-23 August
DK	2015	Denmark	9 June	29 June					
DK	2015	Dronninglund			7 July/ 8 July	29 July	19-24 July	17 August	10-15 august
DK	2016	Denmark	2 June	15 June					
DK	2016	Dronninglund			27 June/ 29 June	27 July	12-17 July	No attack	-
DK	2017	Denmark	9 June	16 June					
DK	2017	Dronninglund			16 June/ 19 June	11 July	1-5 July	15 August	5-10 August

4. DOCUMENTATION

Existing documentation (references/web page etc.):

In 1991 the first Nordic meeting on potato late blight epidemiology and control was held at Research Center Foulum, Denmark. This meeting started a Nordic collaboration that still last. The First DSS tested in all countries was the NegFry DSS, and promising results were presented at the PHYTOPHTHORA 150 Sesquicentennial Scientific Conferencein Dublin, 1995 (Hansen et al, 1995). After the introduction of the new population to the Nordic region in the Mid 1990 the negative prognosis part of NegFry failed (earlier attacks than recommended by the system) and NegFry has gradually been replaced with new DSS components dealing with oospore driven epidemics, change in potato production logistics and structural changes (fewer growers and bigger farms), new fungicide tax policy and demand for a sustainable potato production. After the period with use of NegFry in Denmark, there was a need for evaluation of the Weather based risk indices, and in 2002 Au carried out a study to evaluate several new and existing risk indices for sporangia formation and infection (Hansen, 2002).

Risk indices for sporangia formation were evaluated based on historical data on airborne sporangies during the season at Foulum, Denmark, 1995 and at Reckenholz, Schwitzerland, 1998. Additionally, model calculations were compared with data from Danish fungicide trials, the national late blight monitoring network and untreated variety resistance evaluation trials.

At Foulum and Reckenholz, sporangies were detected with a Burchard spore trap. At Reckenholz, new diseased leaflets were recorded as a supplement to the sporangia catchments. High amounts of sporangies were detected in few distinct periods at Foulum and at Reckenholz. These local peaks in sporangia catchments were always recorded after a period with at least 10 hours with Rh>90% and relatively high temperatures during the humid period. Relatively high, but declining amounts of sporangies, were recorded 1-3 days after primary sporulation periods. These days were <u>not</u> associated with weather conditions normally considered as favourable for sporulation. Probably, sporangies were formed during periods favourable for sporulation, and then released during several days after formation ('afterbirth'). At both Foulum and Reckenholz sporangies were recorded on days in between major sporulation periods – on days when no risk of sporulation was calculated. These relatively few sporangies were considered to be dead sporangies still present in the canopy after sporangia release on previous days. Therefore, to exclude afterbirth sporangies and 'noise' from dead sporangies, days with primary sporangia formation was defined, as days at which at least five times more sporangies were recorded than on average during the two previous days. In this way 5 out of 28 days at Foulum and 5 out of 54 days at Reckenholz was considered as days with primary sporangia formation.

Hourly recordings of airborne sporangies from Foulum showed, that both primary formed sporangies and 'afterbirth-sporangies' were released when the humidity dropped quickly, typically during morning hours with sunshine. Results from Reckenholz showed that the release of sporangies into the air was delayed several days if humidity during the day stayed above approximately 80%.

The daily risk value from PC-NegFry (DRV) was compared with several alternative weather based risk indices, gt10, gtAll, HSPO and MISP. All risk indices were tested against sporulation data from both Foulum and Reckenholz, including information about new diseased leaflets at Reckenholz. The MISP model was developed in Switzerland and is now used in the web-based Swiss decision support system called Phytopre+2000.

A major result was, that the models NegFry DRV, gt10 and HSPO all were able to predict periods with primary sporangia formation at Foulum, 1995 <u>and</u> at Reckenholz, 1998. Based on the results, it was recommended to exchange the use of NegFry DRV with either gt10 or HSPO in the existing PlanteInfo system. The reasons are that both gt10 and HSPO are more simple models, they are easier to explain biologically, and there are fewer thresholds than for calculations of NegFry DRV. The report from 2002 contains a comprehensive discussion about late blight epidemiology, and the primary information from the experimental trials at Foulum and Reckenholz are discussed and related to knowledge from literature (Hansen 2002)

With financial support from the Danish Environmental Protection Agency, the project REFUKA “Improved basis for reduced fungicide use in potatoes” started in 2005 for a duration of two years (Nielsen et al, 2006). The objective of the project was to improve the knowledge basis for reducing fungicide use in potatoes. Spore dispersal, survival and infection of potato late blight were studied in field trials in 2005 and 2006 and new methods were developed to improve the quality of weather forecast data for calculating of the risk of potato late blight development and dispersal. Based on these studies, decision support models for control of potato late blight were developed and tested under field conditions. The project was carried out in collaboration between the University of Aarhus, Dansk Landbrugsrådgivning (the Danish Agricultural Advisory Service) and Danmarks Meteorologiske Institut (the Danish Meteorological Institute).

The results showed that the fungus forms its spores (sporangia) during the night and that the spores are released in the morning when there is a substantial drop in relative humidity. Infection can occur in the morning if there is an overlap between the remaining dew drops and the release of sporangia. The formed sporangia can only complete infection if free water is present within a few hours, either from dew or precipitation. The results also showed that newly formed sporangia can remain in the lesions and be dispersed over at least 2-3 days. This means that infection events are not necessarily due to spores that had been produced on the same day but up to several days prior to the infection event. An index of infection pressure (HSPO) was developed in the project. It is based on sporangia formation as calculated from weather conditions. By coupling the sporangia formation with a model of survival based on global radiation, a better correlation was achieved between infection in the field (on catch plants) and spore formation, than if only infection pressure was used. The model has not yet been tested in field trials, but it is expected that the involvement of the survival model will improve the identification of periods with small risk of new infections. Fungicide use can thus be reduced. As part of the project, DMI has improved the forecast of relative humidity (RH) during the growing season. Previously, the forecast of RH was 5-10% too low. With the adjustment of RH, the calculation of the daily level of sporangia formation in the forecast has become slightly too high, but as the infection pressure is calculated with weather data dating back 2 days and ahead 2 days, respectively, the error is considerably reduced. It was studied whether a local weather station could be used to adjust the forecast of temperature and RH and thereby achieve a better forecast at field level. The temperature forecast was improved, but the forecast of RH was neither better nor worse.

The results and experience from the project were used for further development of the decision support system Blight Management (BM). In BM, the risk of potato late blight attacks and the appropriate control time are assessed and the fungicide dosage is adjusted according to the risk of infection and cultivar resistance in the respective field. The various BM versions were tested in six field trials in 2005-2006. The results showed that the decision support system BM could reduce the treatment frequency only on few occasions, especially at low infection pressure. However, there were too few trials to carry out a proper validation of BM. The data are thus mainly suited to test whether the models are operational in the field. Parts of the system were implemented in 2007 in the existing decision support system in www.planteInfo.dk. The results of the project indicate that the climate-based decision support model (BM) is not yet safe enough or designed to be used as a pure decision model that points out a certain date for the application of fungicides. However, BM in its present form can be considered as a tool for growers or advisers which in a combination with other information and experience can help the decision process concerning the choice of dosage and fungicide depending on the risk of dispersal and infection by the late blight fungus. Experience form practical advice concerning late blight control both at home and abroad shows that there is a large demand among potato growers and advisers for a reliable forecast tool to determine "late blight weather" in order to be able to reduce the treatment frequency and improve the economic results of potato growing. There are therefore great perspectives for extending and using a reliable decision support system to reduce the still increasing consumption of pesticides but also as an aid to fix the time for application of fungicides with different modes of action. The results and experience from this project can be used in the task of developing decision support for other fungi depending on humidity in especially fruit and vegetables.

In 2012, a Danish national project was initiated to implement the models and tools developed during the last 10 years and tested in the REFUKA project. The project "Ressource minimization, optimizing and increasing the value of the Danish potato production – Skimmelstyring" was a collaborative project between Aarhus University, SEGES, DMI and the potato starch industry (Nielsen et al, 2016)

The Main result of this project was a final test, refinement and implementation of the web based Blight Management system for Danish conditions.

The key components in this system are described in this report in the section System description. The Validation in field trials shows that farmers can save 0-30% fungicide and keep a good control of blight (Nielsen, & Abulay, 2016; Nielsen 2015; Anon 2015; Anon 2014;). One key issue was to improve the meteorological foundation for calculation of infection pressure including new weather forecast data for radiation and a newly developed physical weather forecast model for leaf wetness (Nielsen & Hansen, 2015).

Several versions of the Dose model were tested in Starch potatoes. The results showed that it was possible to save 20-30 % of the fungicide use and still having the same control effect and yield level and quality as compared with a routine full dosage strategy.

Finally the project optimized the information and dissemination of maps and charts informing about risk of attacks from oospores by inclusion of interactive GIS based maps.

Next step for the Danish Blight Management will be to further include the concepts and methodologies of IPM2.0. This would lead to a much more robust risk assesment what cultivars that can

5. SYSTEM VALIDATION

The Blight Management system was validated in field trials during research projects (Nielsen & Abuley, 2015 & 2016; Nielsen et al. 2010; Nielsen et al, 2008; Djurberg et al., 2015) and in the official field trials carried out by the extension service (Anon, 2015, Anon 2014, Anon 2013)

6. EVALUATION

The system has been tested on IPM farms at farmers using the system on 500 ha

http://www.skimmelstyring.dk/Upload/Skimmelstyring/Document/145038_Danske_kartofler_3_2015_low.pdf (in Danish)

The users – especially the advisors - have participated all along the development of the system. During the late 1990th when we started to test the use of reduced dosages in field experiments, the advisors at one starch producing company in the North of Jutland started to recommend his contract growers to use reduced dosages in the most resistant starch cultivars during low risk blight periods because the trial results indicated this was possible. During the years – having success with this approach – just confirmed the results from the field experiments. Adding more and more documentation and new tools and DSS components from research and development projects just have made this approach “normal practice” in this region.

Ideas for the future

We would like to make a real GIS application by integrating GIS map layers for crop emergence, years between potato crop, rain and infection pressure as an indicator for risk of infections from. It would also be interesting to do some spatial modelling – hot spot analysis, inclusion of wind trajectories, use of satellite data etc.

There is a need for basic research on oospore biology and modelling of the risk of infections from oospores.

The Blight Tracker APP for reporting early attacks of late blight is for registered users. Initially it was used by the extension network to upload data. There is an identified need to develop more late blight DSS components and general information on mobile platforms to the farmers.

Reference Sporulation Model (RSM)

Calculate humid hour = if Rh$\geq$88% or Leafwetness $\geq$30 minutes or Rain $\geq$0,2 mm (Include LW and precipitation is data are available on hourly basis. In Matlab make it possible to calculate with Rh Alone or with additional LW/precipitation data)

Then calculate the running sum of humid hours for three days (72 hours)

Dissemination channels and transfer of knowledge / training in proper use:

Every week the extension service in Denmark issue a potato newsletter that directly or indirectly will reach 90 % of all Danish potato growers. In this newsletter is a section on the current blight situation in Denmark including general recommendations regarding control

Every Monday morning 7-8 regional potato advisors (including potato industry advisors) meet for a telephone meeting to exchange observations ideas and for evaluation of the blight forecast etc. This also forms the basis of the newsletter.

The DSS tools, maps and charts are available on the extension service web sites, at web sites at the University, and at a project webs - site for the most recent Research project – www.skimmelstyring .dk

New findings and experiences, changes in the late blight biology is also disseminated via farmers magazines.

The characterisation of the late blight population in Denmark is disseminated via EuroBlight

Literature

.
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