WUR – SPECIAL REPORT NO 19 – 2019, 105-114

IPM2.0: Test of a DSS including information from a trap nursery

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INTRODUCTION

For Danish conditions, conventional farmers need information on when to start chemical control, choice of fungicide type and dosage, and how to adjust control tactics (mainly fungicide) during the season. After a decade of projects in the mid-2000, involving Aarhus University, the Danish extension service and the potato industry, it was concluded that a more practical approach for a robust DSS was needed reflecting the structural development of the potato sector. The number of growers was generally decreasing, whiles the size and number of fields per farm were increasing. From a logistical point of view, the advisors and farmers told us that it was not possible to make a field-specific treatment for late blight control.

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 2000s, a general approach was decided to develop a system that recommended applying fungicide on a weekly interval (as conventional). However, the actual amount or dosage of fungicide (mostly Revus/Ranman Top has been used in the trials) was varied according to the infection risk, the amount of inoculum in the region and the type of potato (Starch or Ware) and the level of cultivar resistance. We developed the calculation of infection pressure and the dose model to recommend the type and dosage of fungicide to use during the season (Nielsen *et al.*, 2008; Nielsen *et al.* 2010; Nielsen *et al.* 2015).

The decision about when to start is another story. The rule of thumb for decades was to start spraying fungicide preventatively before row closure. From 1985-1997 we used the German negative prognosis to initiate fungicide sprayings (Hansen, 1992). After 1997 when we experienced the first indications of infections from oospore, this model became invalid or unreliable for predicting when to start fungicide application, albeit we still use the negative prognosis to forecast when the first attack from infected tubers is expected. We do not identify infections from oospores every year. Moreover, we do not have a working model to predict infections from oospores, but from experience, we know that:

- Narrow crop rotation increases the risk of oospore-driven early infections
- Heavy rainfall together with a moderate to high infection pressure at crop emergence increases the risk of early infections from oospores.

Description of the operational 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 moderate 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 of late blight are reported via the Nordic Surveillance system that has been operational since 2010. Recently, all Nordic countries have started using the BlightTracker smartphone APP for uploading recordings of early attacks of late blight (Hansen *et al.*, 2019).
3. A network of potato advisors and scientists (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 of blight risk, when to and how control actions should start. In this situation the regional maps are very useful, to indicate regions with a high risk of late blight. 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 late blight is recorded early in these countries, this is a warning to us in Denmark. The regional potato advisors are a very important dissemination channel for late blight advice because not every grower looks at the internet about alerts of late blight.
4. When blight has been found in a region, it is evaluated if this is a local attack in a special field or due to oospores. Additionally, the advisors evaluate the weather-based blight risk in the forthcoming week. If the forecast says, the weather favourable for late blight a majority of the farmers in this region (distance 25-50 KM) will start fungicide application with reduced dosages in more resistant cultivars.
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 rule of thumb, spraying is done on a weekly basis with low/reduced dosage contact fungicide when the weather is unfavourable for late blight and full dosage during periods with high infection pressure (weather favourable for late blight). When late blight is widespread and epidemics are observed in organic potatoes (or untreated plots), this will indicate that the spore loads will increase; thus, the 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 spraying is done too late compared to an important infection risk.
6. With climate change, we have seen a tendency to extreme weather including some periods with very heavy new growth as well as long periods with dry weather. When the rains resume after a drought/dry spell, heavy new growth can happen. During these periods farmers’ experience has shown that a 7-day spraying interval is rather long and thus a 5-day interval is needed to control late blight. This kind of decision-making is not yet included in the Blight Management system, and thus this is a decision to be taken together by the advisor and the farmer.
7. Reduced dosages are not recommended if there are more than a few lesions (>0.5% severity) of late blight in the field. In such situation, Blight Management is of minor use because new infections could arise from rain splash via rainfall events alone. This is not included in the system. Very often, however, a dry weather spell and intensive chemical control can eradicate a minor attack.

The approach of the Blight Management DSS, where fungicide is sprayed weekly, but the actual dose is varied depending on infection risk is also appealing for many farmers in Sweden (Louise

Alden personal communication). Therefore, the Blight Management system was tested in Sweden during the 2015 and 2016 growing seasons.

When to start with preventive fungicide applications

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

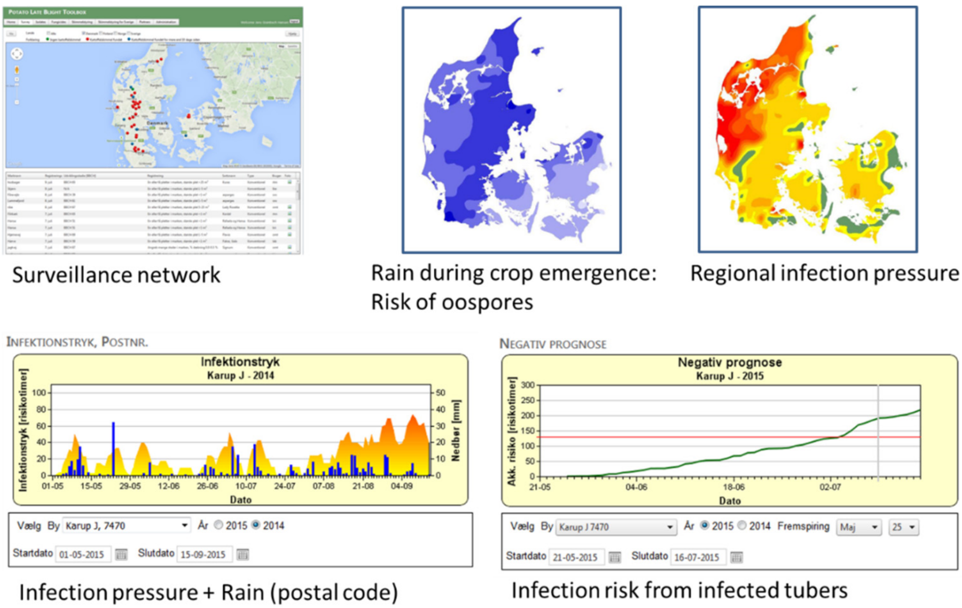

Figure 1. *DSS components used to decide how to start control of potato late blight with fungicide*

The surveillance network was developed in collaboration with the other Nordic countries based on experiences from a similar system called WebBlight, which includes the Baltic countries and Poland. The current version is an integrated part of the Potato Late Blight toolbox and it includes the use of the BlightTracker smartphone APP for uploading of results directly from fields (Hansen *et al.*, 2019).

Rainfall during crop emergence is a prerequisite for activating oospores in the soil. The user can select the start and end for a time-period to show on the map.

The regional infection pressure is based on calculation of the infection pressure in more than 600 grids (interpolated using approximately 80 weather stations with relative humidity (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 dedicated 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 the start and end dates. To visualize what happened last year or previous year the user can select a 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 a postal code, the start date and end date, and the date of crop emergence. To visualize what happened last year or previous year the user can select a similar overview of the Negative prognosis one or two seasons back in time.

The starch industry in Denmark asked how to deploy cultivars that are more resistant in the most effective way based on IPM. One way of deploying resistance cultivars would be to implement the IPM2.0 approach (Hansen *et al.*, 2018; Kessel, 2017). For the 2018 growing season, this approach was tested in a field trial at Flakkebjerg with three cultivars that varied their level of resistance to late blight. The objective was to test the Danish DSS in more resistant cultivars including the IPM2.0 approach as an add-on component.

METHODS

Trap Nursery

In 2018, a trap nursery, which included all the Black differential set and some cultivars with known resistances: R1, R2, R3, R4, R5, R7, R8, R9, R10, R11, Bintje, Alouette, Carolus, Robijn, Sarpo Mira, Toluca, Coquine Irna, Kelly Irna, Makhaï Irna was established in Denmark. The three cultivars tested – Kuras, Novano and Nofy and other cultivars were added to the trap nursery. The second goal for adding new and more resistant cultivars to the experiment was to i) evaluate the level and type of host resistance in the additional cultivars tested using the EucaBlight approach (Hansen *et al.*, 2007) and ii) use the data as input to the modelling work.

The trap nursery was infected naturally and disease scorings were carried out weekly during the season as severity (%). Yield was measured as hkg/ha and tuber blight as percentage infected tubers after harvest. The IPM2.0 strategy was compared with weekly sprays with ½ dosage of Ranman Top. Cymbal or Proxanil was used if a spray was too late or actively sporulating late blight lesions are seen on the potatoes in the field.

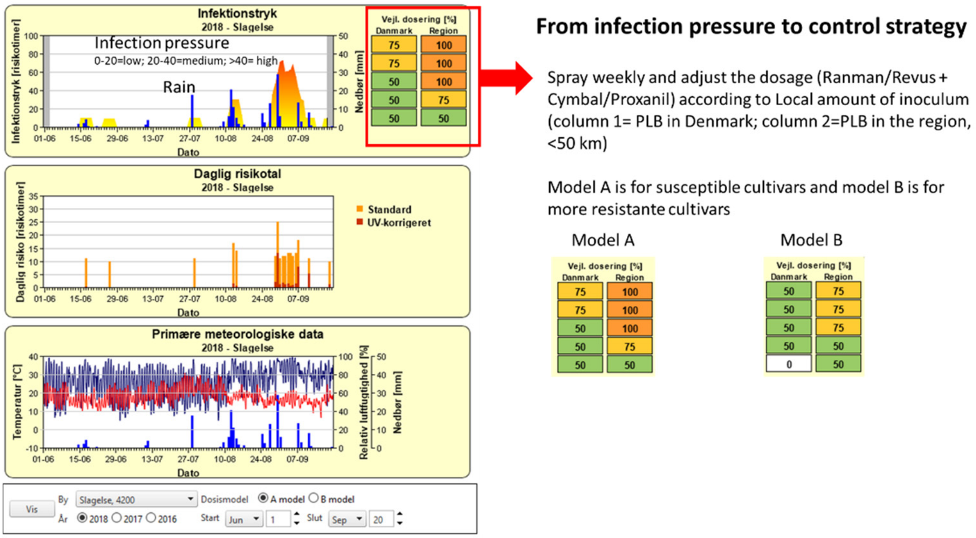

Figure 2. *Calculation of infection pressure at AU, Flakkebjerg, 2018. The dosage using contact fungicides is calculated based on infection pressure with parameters, Model A and B. Model A = susceptible cultivars and Model B = more resistant cultivars. The upper panel (Infektionstryk) is the infection pressure and the blue bars in the upper panel is the amount (mm) of rainfall. The middle panel (Daglig risikotal) is the daily risk values. The red colored-bars within daily risk values is the proportion of new inoculum that survive during the day. The lower panel (Primære meteorologiske data) shows the hourly relative humidity (RH), temperature and daily amount (mm) of rainfall*

The model A and B above is used to simplify the system for the farmers. The original model consists of four phases and for the current experiment we reduced the dosages more than used in the Model A and B (Modal A and B in Figure 2 corresponds to phase 2 and 3 in Figure 3, respectively).

Dosis	Fase 1	Fase 2	Fase 3	Fase 4
Infektionstryk > 60	0	0	50	100
Infektionstryk 41 - 60	0	0	50	75
Infektionstryk 21 - 40	0	0	50	50
Infektionstryk 1 - 20	0	0	0	50
Infektionstryk 0	0	0	0	50

Figure 3. *Adjusted parameters for the dose model*

The adjusted model for use of dosages is then combined with resistant cultivars, disease observations from the trap nursery information and pathogen information defined as:

- Phase 1: No attack in the country (do not spray at all)
- Phase 2: Attack in the country (do not spray at all)
- Phase 3: Attack in the region <50 km from trial (spray ½ dosage (50%) if the infection pressure >20)
- Phase 4: Attack in the differentials with complementary resistance as the cultivar tested (spray half dosage for infection pressure 0-40, spray 75% dosage if infection pressure is 41-60 and full dosage if the infection pressure is >60.

The complementary resistance was evaluated from official knowledge about resistance in the differential cultivars, cultivars tested and the trap nursery results from the previous year (Figure 4).

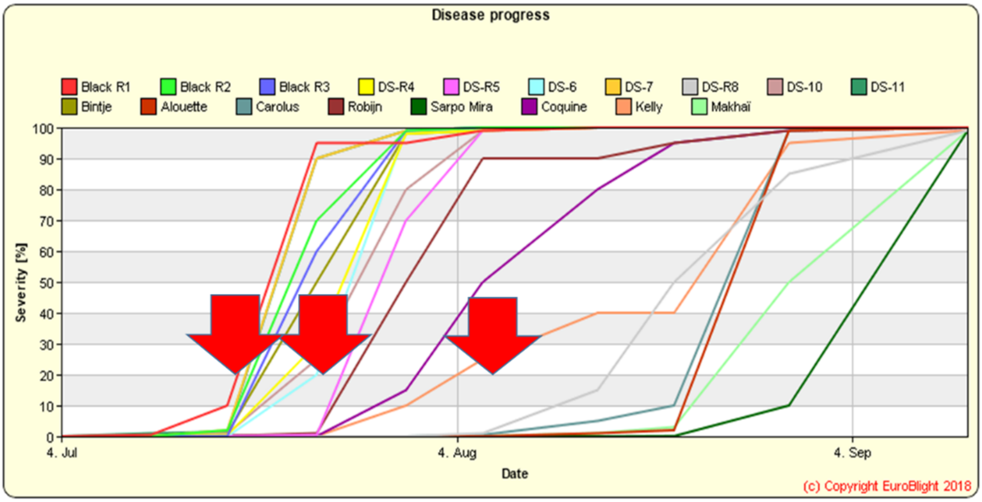

Figure 4. *Disease progress curves from trap nursery, the previous year, 2017) at Dronninglund, Denmark. The red arrows indicate three distinct periods for start of epidemic development. First arrow (from the left) is the very early maturing and susceptible group, the second arrow is the medium maturing and more resistant cultivars than the first group and the third arrow is the late maturing and more resistant cultivars*

Complementary cultivars for Kuras – first red arrow: When first blight is found in one of Group 1 Differentials: Black R1; Black-R2; Black-R3; Black-R4; Bintje; DS-6; DS-7; DS-10 DS-11.

Complementary cultivars for Novano - second red arrow: When first blight is found in one of Group 2 Differentials: DS-R5; Robijn; Coquine; Kelly.

Complementary cultivars for Nofy – third arrow : When first blight is found in one of Group 3 Differentials: DS-R8; Carolus; Alouette; Makhäi; Sarpo Mira.

When one of the cultivars in each of the three groups were attacked, then the dosage parameters shifted from phase 3 to phase 4 (Figure 3).

RESULTS AND DISCUSSION

The weather in 2018 was extremely dry and warm. The weather-based risk for disease development as calculated by the infection pressure was low until 10 August (Figure 2). Late blight was observed in the trap nursery on the 8 August, probably initiated by the rain and low infection pressure 8-10 days before. In the IPM2.0 trial, late blight was observed in the untreated plots on the 20 and 21 August. The last observations were scored on the potato cultivars on 14-17 September. First treatment according to the routine treatment was carried out on the 20 June after late blight was observed in the country.

Late blight was observed on Black R3, Black R6, Black R7, Alouette and Coquine on the 8 August and the IPM2.0 treatments was carried out on the 13 August. As this was later than recommended date, a stop treatment (i.e. 2l/ha proxanil) was applied. A stop treatment was also carried out on Kuras on 12 September because actively sporulating lesions was found in this cultivar (not in Novano and Nofy).

The level of disease in the untreated plots at the end of the season (17 September) was 85% on Kuras, 91% on Novano and approximately 1% on Nofy. In the treated plots, the attacks were 4-6% in Kuras and below 1% in Novano and Nofy (Figure 6). There were no significant differences between the disease level of the routine and IPM2.0 treatments (Figure 6). 13 treatments with primarily half dosage of Revus and Ranman Top, one stop treatment (proxanil) were carried out for Kuras according to the routine treatment, which translated to a total treatment frequency index (TFI) of 8 for Kuras. For the IPMBlight2.0, 6 similar treatments were carried out including one stop treatment (2 l/ha proxanil) for Kuras. The dosage of the other preventive treatments varied according to the infection pressure for Kuras. The total TFI for the IPMBlight 2.0 treatment for Kuras was 5.75. In Kuras, which is susceptible under Danish conditions, it was possible to reduce the fungicide use by 28% for following the BlghtManager+IPM2.0 approach compared to the routine/weekly spray with half dose Ranman Top or Revus.

The TFI for the routine and the IPMBlight 2.0 treatments for Novano and Nofy is shown in Figure 5. Following the IPMBlight 2.0 approach resulted in 35% reduction in fungicide use (TFI) compared the routine treatment for Novano and Nofy.

Although Danish growers use reduced dosages during low-risk periods, it is uncommon for growers to use ½ dosage of preventive compounds in weekly intervals. However, results for resistant cultivar like Nofy, in which the disease severity on the untreated plot was less than 1% at the end of the season, lower/reduced dosages of preventative fungicides could offer effective control of late blight. However, one key question is whether it is worth spraying or protecting such resistant cultivars with fungicides, considering the insignificant difference between the disease level between the untreated and the fungicide treatments? In the IPMBlight 2.0/Euroblight concept, we rely on concepts of "Gene Stewardship" and "active ingredient Stewardship". By "Gene Stewardship", we mean protecting the R-genes in resistant cultivars from being defeated by the pathogen. By "Active ingredient Stewardship", we mean protecting the active that we must protect the R-genes in the cultivars from being defeated by the pathogen and the active ingredients in the fungicides to being ineffective due to resistance by the pathogens to the active ingredients in the fungicides from being ineffective due to resistance development by the pathogen. Therefore, for sustainable use of resistant cultivars, it is recommended to protect (spray fungicide) the most resistant cultivars when they are under pressure due to age (age-dependent resistance) or high infection pressure. Similarly, it is recommended that one should only use the active ingredients/fungicides only when it is needed to protect R-genes to keep the inoculum pressure on the cultivar low. In this way, the risk of *P. infestans* developing less sensitivity to certain active ingredients and adapt to certain cultivars (resistances) will be minimized. The active ingredients and the resistance go hand in hand so to say.

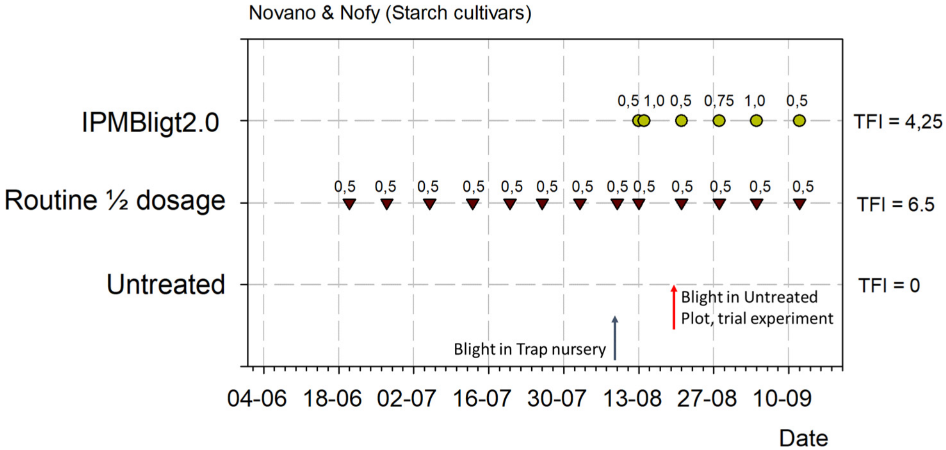

***Figure 5**. Treatments according to Blightmanager+IPM2.0 approach compared to routine treatment as weekly sprays with ½ dosage of Ranman Top and Revus in the Novano and Nofy experiment*

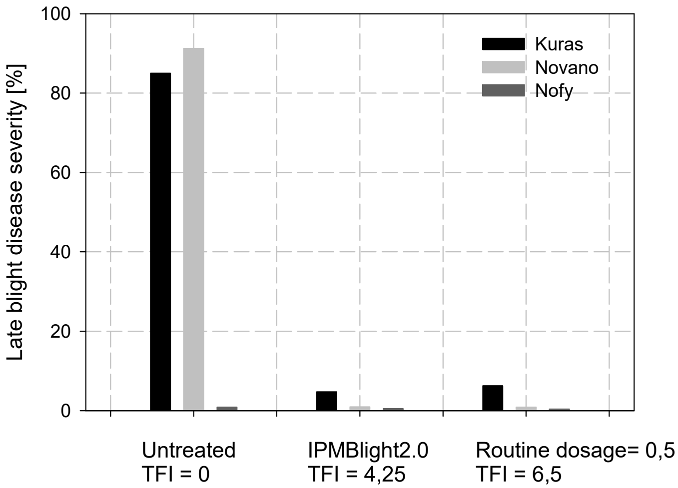

***Figure 6**. Disease level end of season in a DSS experiment using three different cultivars and three different treatments: untreated, weekly sprays with ½ dosage Ranman/Revus and according to DSS + IPMBlight2.0 approach that includes use of data from a local trap nursery*

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