IX  Control of late blight (*Phytophthora infestans*) and early blight (*Alternaria solani*) in potatoes

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Materials and methods
The potato trials were carried out at AU Flakkebjerg on sandy clay loam (JB 5-6) with a randomised complete block design and 4 replicates in the starch varieties Kuras and Signum. The plot size was 3.75 x 7 m (26.25 m²) with net yield plots of 15.75 m². The potatoes were planted around 3 May and emerged around 5 June. The late blight trials were artificially inoculated on 5 July by spraying a sporangial suspension of *Phytophthora infestans* (1000 sporangia/ml) over spreader rows between the blocks. The early blight trials were artificially inoculated on 5 July with autoclaved barley seeds inoculated with *Alternaria solani* placed in the furrow between the plants and later, on 11 September, in some trials by spraying a spore suspension of *A. solani* over the plots. Spraying was begun according to the protocols, and the spray technique was 300 l water/ha, Hardi ISO MD 025 nozzle and 3 bar. The trials were irrigated 2-3 times with 25 mm of water from the end of June until the end of August. The trials were performed according to EPPO guidelines PP 1/2(4), PP 1/135(3), PP 1/152(3), PP 1/181(3) and PP 1/263(1).

Infection pressure for potato late blight ([www.skimmelstyring.dk](http://www.skimmelstyring.dk))
In the figure is shown the recommended dose (Vejl. dosering [%]) as a percentage of the standard dose of Revus or Ranman Top for the given infection pressure when late blight is first seen in Denmark and in the region ([http://agro.au.dk/forskning/projekter/skimmelstyring/skimmelstyring-dk-overblik/](http://agro.au.dk/forskning/projekter/skimmelstyring/skimmelstyring-dk-overblik/)).

![Infection pressure](image_url)

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Potato late blight (*Phytophthora infestans*) in 2017

The trials at Flakkebjerg were artificially inoculated on 5 July 2017 by spraying a sporangial suspension of *P. infestans* (1000 sporangia/ml) over infector plants in the spreader rows between the blocks. The first attacks were seen in the spreader rows on 10 July and in the untreated plots of the trials on 15 to 19 July (varieties Kuras and Signum). The weather in 2017 was favourable for late blight (Figure 1), and there was a severe development in the trials in late July and August. In the first week of September 100% of the leaves were attacked by late blight in most of the untreated field plots (Figure 3). The disease development in 2017 began almost at the same time as in previous years apart from the late (and dry) year 2013 (Figure 3). The first symptoms of late blight were observed in untreated plots at Flakkebjerg on 22 July 2009, 20 July 2010, 15 July 2011, 9 July 2012, 22 July 2013, 16 July 2014, 31 July 2015 and 13 July 2016. However, in 2016 the progress curve for late blight was more linear and did not follow the usual sigmoid curve (Figure 3).

With all the rain in the 2017 season, it was expected that the tubers had been infected but only very few tuber infections were seen in the variety Kuras.

**Figure 2.** Potato trial field plots at Flakkebjerg in 2017. Field N26 (left) and field F7 (right). (Photo: Uffe Pilegård Larsen).
Potato early blight (*Alternaria solani*) in 2017

Most of the early blight trials at Flakkebjerg were artificially inoculated on 5 July with autoclaved barley seeds inoculated with *A. solani*. In the field N26 (Figure 2) isolates of *A. solani* sensitive to azoxystrobin were used, while in field F7 (Figure 2) six isolates of type F129l and resistant to azoxystrobin were used. These isolates were collected in potato growing areas in Jutland in 2016. The first attacks on the lower leaves were detected on 13 July in most of the trials. The 2017 season was characterised by several days with leaf wetness, high humidity and temperatures favourable for early blight attack. However, the disease development was slow in most of the trials until late August. In the last part of September, there was a severe disease development at Flakkebjerg (Figure 12), and at the end of September 80-100% of the leaves were attacked in untreated plots (Figures 4-5).

![Figure 3](image-url) Development of late blight (*Phytophthora infestans*) in untreated plots of varieties Dianella (2012-2014), Eurogrande (2015-2016), Signum and Kuras (2017) at Flakkebjerg 2012-2017. Artificial inoculation during the first 10 days of July.

**Figure 4.** Development of early blight (*Alternaria solani*) 2017 in untreated plots at Flakkebjerg, Sands (Ikast, Western Jutland) and Billund (Central Jutland). Artificial inoculation at Flakkebjerg with isolates collected in Jutland 2016 (F129L isolates), natural infestations at Sands and Dronninglund. Variety Kuras.
The development in early blight at Flakkebjerg in 2016 started almost at the same time as in 2012-2015 (Figure 5).

**Figure 5.** Development of early blight (*Alternaria solani*) in untreated plots at Flakkebjerg 2012-2017. Artificial inoculation with inoculated barley seeds at the end of June. Inoculation 2017 with isolates collected in Jutland 2016 (“new isolates” of F129L type) and standard (“old”), azoxystrobin sensitive isolates. Varieties Kuras and in 2015 Kardal.

The development in early blight at Flakkebjerg in 2016 started almost at the same time as in 2012-2015 (Figure 5).

**Figure 6.** Development of early blight (*Alternaria solani*) in untreated plots at Sunds (Ikast, Jutland) 2012-2016. Natural infestations. Varieties Kuras and in 2015 Kardal.
The first symptoms of early blight in the trial at Ikast (Sunds) were seen on 19 July and the development of the disease was in general as in 2016 (Figures 4 and 6) with 79% attack in untreated plots on 14 September. In the trial at Billund the first symptoms of early blight were seen on 31 July and the late disease development was as at Sunds (Figure 4), but the last assessment on 12 September showed only 42% attack in untreated plots (Figure 7). In 2016 the trial at Billund was located in a field where potato was last grown 8 years ago.

![Development of early blight (Alternaria solani) in untreated plots at Billund (Central Jutland) 2016-2017. Natural infestations. Variety Kuras.](image)

**Figure 7.** Development of early blight (*Alternaria solani*) in untreated plots at Billund (Central Jutland) 2016-2017. Natural infestations. Variety Kuras.

**Early blight development and the weather**

During the 2017, we monitored the favourability of the weather for early blight attack with the weather-based model TOMCAST (Tomato Forecaster). The model basically assigns risk values (also called disease severity value - DSV) to each day depending on the total leaf wetness duration and average air temperature during the leaf-wet hours in that particular day. The risk values (or DSV) range from 0, which means no risk of early blight, to 4, which means high risk of early blight attack.

Because of the importance of the age or development stage of the potato plant to early blight development, we also monitored the age of the potatoes by calculating the physiological age (P-days). The physiological age measures the thermal growth of the potato plant based on the minimum and maximum daily air temperatures. According to the physiological age, we can identify three different stages in the development of the plant with respect to the early blight epidemic. The first stage is called the resistant stage, during which potatoes do not show symptoms of early blight. The second stage is called the moderately resistant stage, and during this stage potatoes become moderately susceptible to early blight. The second stage occurs around 330 P-days and marks when first symptoms are often visible and thus fungicide application should start. However, because the potato plant shows some level of resistance at this stage, only half or two thirds of the full dose is recommended. The third stage is called the highly susceptible stage, and it marks the period during which the potato plant becomes very susceptible to early blight. During this stage a full dose of fungicide is recommended. The third stage varies with the maturity level of the potato plant. For example, in a late maturing potato like Kuras the highly susceptible stage occurs around 500 P-days.
The output of the physiological age at Flakkebjerg, Billund and Sund is shown in Figure 8. The 330 P-days were reached on 19 July, 15 July and 12 July in Flakkebjerg, Billund and Sunds, respectively. At Flakkebjerg, the first symptoms were seen on 13 July, that is 6 days before the prediction by the P-days model. At Billund the first symptoms occurred at 12 July, that is 3 days before the prediction by the P-days model. At Sunds the first symptoms on the potatoes occurred on the same day as it was predicted by the P-days model (i.e. 12 July). The age at which the potatoes were expected to be very susceptible (i.e. 500 P-days) were reached on 8 August, 7 August and 4 August at Flakkebjerg, Billund and Sunds, respectively. The increase in attack occurred from mid-August to the end of August (Figures 4-7).

Figure 9 shows the favourability of the weather for early blight outbreak predicted by the TOMCAST model. In general, there were several days with a risk between 1 and 3. No day was predicted to be a very risky day (i.e. risk value of 4) by the TOMCAST model (Figure 9). The cumulative TOMCAST DSV showed that there were 3–4 TOMCAST DSV thresholds/peaks during the 2017 growing season (Figure 9). In our experience, 3–4 TOMCAST thresholds/peaks mean a season with weather very conducive to early blight outbreak. Since each threshold or peak represents a day on which fungicide application is required, the model prediction suggests that 3–4 fungicide applications could be sufficient for control of early blight.
Results from field trials 2017

Curative control of late blight under field conditions
In order to test the effect of curative products on established lesions of late blight, a trial was set up in almost the same way as in 2014-2016 (explanation in Table 1). Untreated spreader rows between the blocks in the trial were inoculated on 5 July with a suspension of *P. infestans* sporangia. The first attacks were seen in the spreader rows on 10 July and in the untreated plots of the trial on 12 July. The trial was cover sprayed with Revus (0.3 l/ha) on 4 July. Spraying was started on 1 July with Proxanil (2.0 l/ha) + Ranman Top (0.25 l/ha) in treatment 4, test product Fungicide C in treatment 5 and Cymbal (0.25 kg/ha) + Ranman Top (0.5 l/ha) in treatment 6 at a very low level of attack of late blight (0.01%). In the following week there was a development in late blight, and on 17 July attacks of late blight were seen more widespread in the plots. The level of attacks across the plots were 0.1% to 0.3% when treatments were started on 18 July by spraying within the same week as shown in Table 1. Untreated plots were included, and these were unsprayed since the cover spray on 4 July (Table 1).

The first small attack was seen on 12 July, and with the favourable weather conditions in 2017 there was a severe development in the attack of late blight at the end of July and in August with approximately 50% attack in the first week of August in untreated plots and 99% attack in the first week of September in untreated plots (Figure 11).

Spraying with three times with Cymbal (0.25 kg/ha) + Ranman Top (0.5 l/ha) from 11 July starting at very low disease attack (0.01%) had a very high impact on late blight (treatment 6). The effect of these single sprays could be seen throughout the season (overall 95% control). A similarly high effect was seen...
after spraying with 2 x Proxanil (2.5 l/ha) + Ranman Top (0.25 l/ha) starting at higher disease development on 18 July (0.1-0.3% attack). Also in these plots, the effect could be seen throughout the season (overall 92% control; treatment 2). Spraying only one time with Proxanil (2.0 l/ha) + Ranman Top (0.25 l/ha) on 11 July at low disease pressure (0.01% attack) and then following up with Ranman Top or Revus at weekly intervals (treatment 4) gave a lower disease control (overall 79% control) compared to treatment 2 and treatment 6 (Figure 11).

The trial demonstrated that applying a curative spray at the right time (low level of attack) with Cymbal or Proxanil combined with a preventive product (Ranman Top) can reduce the development of late blight significantly when followed up by weekly sprayings at full dose.

Due to a prolonged period of rain in the autumn 2017, the trial was not harvested.

**Table 1.** Trial plan for testing effect of curative control on established lesions of late blight under field conditions. Variety Kuras, Flakkebjerg, 2017.

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**"Curative at very low attack"**
- Approx. 0.01% late blight
- within the same week

**"Stop spray"**
- Approx. 0.1-0.3% late blight in treatment 1-3

**Attack of late blight:** 11 July: 0.01%; 18 July: 0.1-0.3% attack. RE: Revus 0.6 l/ha, PROX: Proxanil 2.0 l/ha or 2.5 l/ha, RanT: Ranman Top 0.25 l/ha or 0.5 l/ha. Cymb: Cymbal 0.25 kg/ha. Sprayings B-C were within the same week. From 31 July (D) the sprayings in plots 1-5 were full dose of either Ranman Top or Revus.
Control of early blight (*Alternaria solani*).

**Figure 10.** Potato leaf attacked by late blight (*Phytophthora infestans*), 2017.

**Figure 11.** Development of late blight (*Phytophthora infestans*) in plots with curative treatments. Explanation of treatment numbers is shown in Table 1. Treatments 4-6 were started on 11 July at a very low level of attack of late blight (0.01%). Treatments 1-3 were started on 18 July when late blight was seen to be more widespread in the plots. Variety Kuras, Flakkebjerg 2017.
Field trials with control of early blight were carried out in 2017 in cooperation with SEGES at three locations (Flakkebjerg, Sunds and Billund). Summary of the trials and conclusions from previous years’ trials can be seen in “Oversigt over Landsforsøgene 2017” (Pedersen, 2017).

The trial was performed in the variety Kuras in order to evaluate the effect of spraying with different strategies as explained in Table 2. Sprayings (A-E) were at 14-day intervals. All strategies were started at the same time at the first small symptoms (14 July). The objective of the trial was to see the effect of the products on *Alternaria*, and a cover spray was performed with Revus (0.6 l/ha) against late blight (*P. infestans*). On 19 and 26 July, Proxanil (2.5 l/ha) was added to control established lesions of late blight. Plots sprayed with Revus Top or Vendetta were not cover sprayed. Only low levels of attack of late blight were observed in the trial (< 0.3%).

The trial was artificially inoculated on 5 July with autoclaved barley seeds inoculated with *A. solani*. Figure 12. Field plot attacked by early blight (*Alternaria solani*), 2017.

![Figure 12. Field plot attacked by early blight (*Alternaria solani*), 2017.](image)

Table 2. Trial plan for testing different control strategies against early blight (*Alternaria solani*). Variety Kuras, 2017. Actual dates for the sprayings are indicated for the trial at Flakkebjerg. Set-up and the weekly spraying were almost the same in the trials at Billund and Sunds.

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NA: Narita 0.5 l/ha, VEN: Vendetta 0.5 l/ha. RT: Revus Top 0.6 l/ha. A: Amistar 0.5 l/ha. S: Signum WG 0.25 kg/ha. Narita was in all sprayings mixed with an adjuvant (0.1 l/ha “Additiv til Ranman”).

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In the field (field F7, Figure 2) six isolates of type F129L resistant to azoxystrobin were used. These isolates were collected in potato growing areas of Jutland in 2016. The first attacks on the lower leaves were detected on 13 July in the field area and on 19 July in the trial. The 2017 season was characterised by several days with leaf wetness, high humidity and temperatures favourable for early blight attack. However, the disease development was slow until late August. In the last part of September, there was a severe disease development and at the end of September, 99% of the leaves were attacked in untreated plots (Figure 13).

Spraying with the different strategies had, in general, a high impact on early blight (Figure 13). Spraying with 4 x Signum WG (treatment 6) gave 99% control of early blight, and spraying with Narita-Narita-Signum WG-Narita-Signum WG (treatment 3) or Narita-Narita-Signum WG-Signum WG (treatment 4) or Revus Top-Signum WG-Revus Top-Signum WG (treatment 5) gave 92% to 95% control of early blight. There were no significant differences between these treatments. Spraying in treatment 2 (Revus Top-Revus Top-Amistar-Signum WG-Amistar) or treatment 7 (Signum WG-Narita-Vendetta-Signum WG) gave 80-81% control, which was significantly lower than the other strategies. In treatments 3 and 4 the same types of products were used, with five sprayings in treatment 3 and four sprayings in treatment 4, but no significant differences in effect on early blight could be observed (Figure 13).

Tuber yield in untreated was 556 hkg/ha tubers and 95 t/ha starch with an increase in tuber yield in average of the treatments of 43.7 hkg/ha (7.9%, range 4-13%) and 10.6 hkg starch /ha (11.2%, range 7%-17%). There were no significant differences between the strategies (LSD0.05: 52 tuber and 11.4 starch). In 2016 in a similar trial with early blight the average increase in tuber yield was 5.1% (2-12%) and in starch 7% (2%-15%) (Figure 14).

In the trial at Ikast (Sunds) the first attacks were seen on 19 July with a similar development in attacks as...
at Flakkebjerg but 1-2 weeks earlier (Figure 4). The level of control obtained after the different strategies were slightly lower with 82% control in treatment 6, 71%-75% control in treatments 3, 5 and 7 and 60%-63% control in treatments 2 and 4 (Figure 14). In the trial at Billund the start and development of early blight was similar to the development at Flakkebjerg but ended at a lower level (Figure 14). The different spray strategies gave 85-95% control of early blight with no differences between the treatments. In average of the two trials in Jutland (Ikast and Billund) there was a starch yield increase of 9-12% with no differences between the treatments (Figure 15).

The average net yield increase for the different treatments in the inoculated trial at Flakkebjerg was DKK 2,826 (11%) and for the two trials in Jutland (Ikast and Billund) DKK 3,477 (9.6%) (Pedersen, 2017).

**Spray strategies and fungicide resistance against *Alternaria solani***

Two trials (17554-1 and 17554-2) were carried out in order to evaluate the efficacy of different strategies in field trials inoculated with a strobilurin sensitive and resistant population of early blight according to the plan shown in Table 3 with two sprayings of Amistar (0.5 l/ha), Signum WG (0.25 kg/ha), Narita (0.4 l/ha), Fungicide B and Dithane NT (2.0 kg/ha). Sprayings (A-B) were at 14-day intervals. All strategies were started at the same time at the first small symptoms (14 July). Narita was in all sprayings mixed with an adjuvant (0.1 l/ha “Additiv til Ranman”). The trials were artificially inoculated on 5 July with autoclaved barley seeds inoculated with *A. solani*. Trial 17554-1 was located in a field (N26, Figure 2) where azoxystrobin-sensitive isolates were used as inoculum (standard azoxystrobin sensitive

**Figure 14.** % attack of early blight (*Alternaria solani*) and the development of the disease in plots with different spray strategies. Natural infestations. The different treatment numbers are explained in Table 3. Variety Kuras, Ikast (Sunds) and Billund 2017.

**Figure 15.** Yield, hkg starch per hectare in field trials testing different control strategies against early blight (*Alternaria solani*). Variety Kuras, Flakkebjerg (left), average Ikast and Billund (right), 2017. Details of the spray plan are mentioned in Table 3.
isolates from Flakkebjerg). Trial 17554-2 was located in a field (F7, Figure 2) where six isolates of type F129L and resistant to azoxystrobin were used. These isolates were collected in potato growing areas in Jutland in 2016. Due to low development of disease in trial 17554-1 the trial was inoculated again on 11 September by spraying a spore suspension of A. solani (sensitive isolate) over all plots. The first attacks on the lower leaves were detected on 13 July in the field area and on 19-20 July in the trials (Figure 16). The 2017 season was in principle favourable for early blight attack. However, the disease development was slow at the beginning of September with a difference in disease development between the two trials. In trial 17554-2 (F129L type) there was in the last part of September a severe disease development with 95% of the leaves attacked in untreated plots at the beginning of October. However, in trial 17554-1 (sensitive population) the general disease development was much slower, and there was no real development of the disease until the last part of September (Figure 16).

Table 3. Trial plan for testing different fungicides against early blight (Alternaria solani). Kuras, 2017.

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Dithane: Dithane NT 2.0 kg/ha, A: Amistar 0.5 l/ha, S: Signum WG 0.25 kg/ha, NA: Narita 0.4 l/ha.

In trial 17554-2 (population of F129L type) spraying with 2 x Fungicide B or Signum WG (2 x 0.25 kg/ha) gave 99% control and 95% control, respectively. Spraying with 2 x Narita (0.4 l/ha) gave 71% control, while spraying with 2 x Dithane NT (2 kg/ha) or 2 x Amistar (0.5 l/ha) gave 37% and 36% control, respectively (Figure 16, right). In trial 17554-1 (sensitive population) there was a large variation. Due to the difference in disease development it is not directly possible to compare treatment by treatment between the two trials. However, a difference could be observed. In trial 17554-1 (sensitive population) spraying with 2 x Amistar gave 80% control of early blight (Figure 16, left), while in trial 17554-2 (F129L type) the control level was only 36% (Figure 16, right). In both trials 2 x Fungicide B gave 96-99% control of early blight.

In 2016 a similar trial was carried out at Flakkebjerg using the standard sensitive isolates (as in trial 17554-1). Spraying three times with Amistar (0.5 l/ha), Signum WG (0.25 kg/ha) or Vendetta (0.5 l/ha) had in this trial a high impact on early blight with overall 85-88% control. Spraying three times with Revus Top had a significantly lower effect (65% control). Dithane NT had, as expected, an effect of 47% control, which was significantly lower than the effect of the other products (Nielsen & Abuley, 2017).
Figure 16. % attack of early blight (*Alternaria solani*) and the development of the disease in plots inoculated on 5 July with “Old”, standard population from Flakkebjerg sensitive to azoxystrobin (trial 17554-1; Field N26, left) and “New” population with 6 isolates from Jutland, 2016 resistant to azoxystrobin; F129L-type (trial 17554-2; Field F7, right). Inoculation on 5 July. The different treatment numbers are explained in Table 3. Variety Kuras, Flakkebjerg 2017.

References