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# Timing the application of fungicides to control potato early blight (*Alternaria solani*) in multi-location field trials in Denmark

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**SUMMARY**

Field experiments were carried-out at three locations in Denmark (i.e. Flakkebjerg, Sunds and Billund) in order to evaluate different spray strategies to control potato early blight. The treatments evaluated in the experiments were: (1) untreated, (2) a standard application in which fungicide application started at row closure, (3) starting fungicide application at the onset of first symptoms (First Symptoms), (4) starting fungicide application at 14 days after onset of first symptoms (Late Application), (5) fungicide application according to the maturity of the potato (Maturity-Based Model), (6) Modified TOMCAST, in which first spray was done at 330 physiologic days (Pdays) and subsequent spray was done according TOMCAST Disease Severity Value (DSV) threshold, and (7) TOMCAST + Maturity-based model, in which we combined the TOMCAST DSV and Maturity-Based Model. In general, our results showed that starting spraying from onset of symptoms could provide sufficient early blight control comparable to standard practice without any yield penalties. Starting application of fungicide later in the season resulted in lower disease control. The Modified-TOMCAST, Maturity-Based Model and TOMCAST + Maturity-based models controlled early blight effectively in all the experimental locations. In general, our results showed that low area under disease progress curve (AUDPC) values were associated with the fungicide treatments compared to the untreated. However, fungicide applications which started at 14 days after first symptoms resulted in lower disease control compared to the standard and other fungicide treatments. Starting application at the onset of symptoms resulted in low AUDPC blight control comparable to the standard treatment.

The decision support models showed a potential for optimizing the control of early blight by better targeting fungicide applications.

**KEYWORDS**

Early blight, Decision Support System, Control strategies, Maturity-based models, TOMCAST model, Physiologic age.

## INTRODUCTION

Early blight, caused by *Alternaria solani*, has become an important disease in recent years in Denmark. The disease is mainly seen in the starch potatoes in August to September and can cause substantial yield losses of 7-20% annually.

Currently, none of the potato varieties being grown in Denmark is completely resistant to early blight (Abuley et al., 2017); thus, fungicide application is widely used to control early blight in Denmark (Abuley and Nielsen, 2017).

There has been a lot of discussion in Denmark about how to control the disease. One of the common control practices is to spray at a 14-day interval three to four times with difenoconazole or pyraclostrobin + boscalid. Because of the high prevalence of fungicide resistant F129L mutants, azoxystrobin is only used in maximum one application. However, there is no agreement on when to start the first spraying. Thus, our first objective was to determine the best time to start fungicide application to control early blight.

Recently, we published some Decision Support System models (DSS) (i.e. TOMCAST and Maturity-based models) to control early blight (Abuley and Nielsen, 2017). However, these trials were conducted at one location (Flakkebjerg). The second objective of this study was, therefore, to evaluate these models at different locations. Should the models perform well in multi-location field trials in Denmark, it would be made available to the farmers for the control of early blight.

## MATERIALS & METHODS

*General aspects of the experiment*

In co-operation with the Danish Advisory Service (SEGES), we conducted field experiments at Flakkebjerg Research Centre (AU), Sunds and Billund (SEGES) in the 2016 growing season. The experiment at Flakkebjerg Research Centre (Western Zealand) was artificially inoculated on 29$^{th}$ June with barley kernels infested with *A. solani* as described previously (Abuley et al., 2017). The experiments at Sunds and Billund were situated in farmers' fields in Western Jutland, which is the main potato-growing region in Denmark. The experiments in Sunds and Billund were not artificially inoculated with *A. solani.*

The experiment was laid out as a randomized complete block design (RCBD) with four replications at all experimental locations. The plot size was 7 m x 3.75 m in all experimental locations. The potato variety Kuras was used at all experimental plots. Kuras is a late maturing variety that covers more than 50% of the area with starch potatoes in Denmark. The variety, even though is susceptible to early blight, is known to develop early blight slowly (i.e. slow blighting type resistance) (Abuley et al., 2017).

The treatments investigated were as follows:

1. Untreated
2. Standard (4x Signum WG). Here full dose (i.e. 0.25 kg/ha) of the fungicide Signum WG (pyraclostrobin+boscalid) starting from row closure at 14-day intervals.
3. First Symptoms (4x Signum WG). In this treatment, full dose of Signum WG was applied four times in the season starting from the onset of early blight lesions at 14 days intervals.
4. Late Application (4x Signum WG). Fungicide application (full dose) was started 14 days after first symptoms were observed.

5. Maturity-Based Model. This treatment recommended fungicide application according to the age-dependent susceptibility of the potato plant (Abuley and Nielsen, 2017).
6. Modified-TOMCAST model. In this treatment, first fungicide treatment occurred after 330 physiologic age/days (P-days), and subsequent sprays followed the accumulation of 20 TOMCAST DSV. Full dose of Signum WG was applied whenever fungicide application is required like described in Abuley and Nielsen (2017).
7. TOMCAST + Maturity-Based model. In this treatment, we combined the TOMCAST and the Maturity-based models as described in Abuley and Nielsen (2017).

*Weather data and model implementation*

Hourly readings of temperature, relative humidity and leaf wetness were taken from the nearest weather station. The physiologic age of the potatoes was determined from 50% emergence using the physiologic age equation described by Sands et al. (1979). The leaf wetness data and temperature during the hours of leaf wetness were used to run the TOMCAST model as described in Abuley and Nielsen (2017).

*Disease assessment and statistical analyses*

At each experimental location, we assessed the percentage covered by early blight on each plot on a weekly basis. The assessment data were used to calculate the area under the disease progress curve (AUDPC) according to Shaner and Finney (1977) to compare the treatments. The starch yield was assessed for each treatment as described in Abuley and Nielsen (2017).

The disease (AUDPC) and yield (hkg starch/hectare) were statistically analyzed by using ANOVA in R statistical software (R Core Team, 2016).

## RESULTS & DISCUSSION

The AUDPC values were significantly different between the treatments ($p<0.001$). In general, the fungicide treatments had low levels of early blight compared to the untreated (Figure 1), which suggests that fungicide application is important to control early blight.

It is apparent from Figure 1 that fungicide application according to the Modified-TOMCAST model resulted in the lowest AUDPC values at all three locations. There was a clear indication that starting fungicide application 14 days after first symptoms resulted in lower disease control and significantly higher AUDPC compared to starting at row closure or from the onset of the disease (Figure 1). The conclusion from this observation that for effective early blight control fungicide application should start at the onset of first symptoms. Previous reports (e.g. Campo-Arana, 2007; Abuley and Nielsen 2017) have also found that effective control comparable to a standard application can be achieved when fungicide application starts from first symptoms.

The use of physiologic age to time the application of fungicide instead of first symptoms was also effective in our models. Previous reports have shown that the time of first symptoms is dependent on the physiologic age of the potato plant (Pschiedt and Stevenson, 1988). The physiologic age model is a simple model driven only by temperature; thus, it can be a good alternative to scouting for first symptoms. In these field trials, all the weather-based models (i.e. Modified-TOMCAST, Maturity-Based Model and TOMCAST + Maturity-Based Model) were based on the physiologic age of the potato as determined by the temperature-based physiologic model.

Spraying fungicides according to the Maturity-based model reduced early blight attack significantly at all locations. We observed sufficient early blight suppression when we combined TOMCAST and Maturity-Based model (Figure 1). In general, the models provided appreciable levels of fungicide use than the standard application.

Even though we saw significant differences in the AUDPC values of the treatments, the starch yields were not statistically different at Sunds and Billund (Figure 2). In Flakkebjerg, however, the Modified-TOMCAST, Maturity-based model and TOMCAST+Maturity-Based models resulted in the highest starch yields, which were statistically different from the starch yield in the untreated plots (Figure 2).

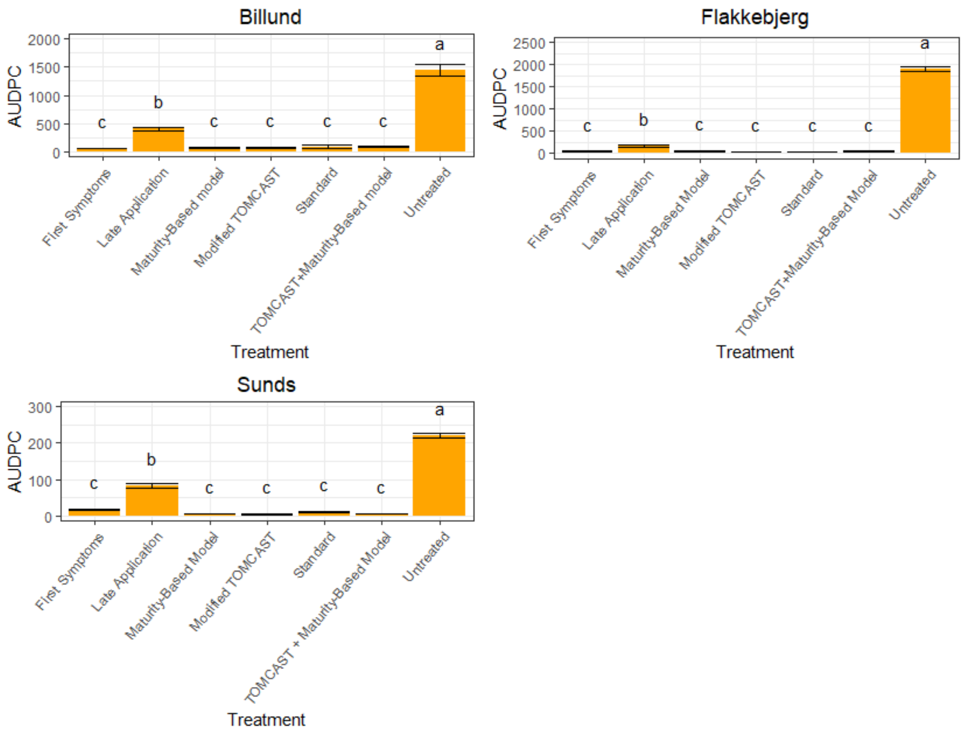


***Figure 1.*** *The area under disease progress curve (AUDPC) as function of fungicide application at the three experimental location (Flakkebjerg, Sunds and Billund). The bars represent the mean values of four replicates. Bars followed by the same letters are not significantly different and vice versa (α=0.05, Tukey honest significance difference). See text for explanation of treatments.*


***Figure 2.*** *Starch yield (hkg/ha) for the trials at the three experimental locations (Flakkebjerg, Sunds and Billund). Means followed by the same letter within a column are not significantly different (α=0.05, Tukey's Honest significant differences). See text for explanation of treatments.*

## CONCLUSION

These experiments showed that the initial spray in the control of early blight can start at the onset of symptoms and still provide sufficient early blight control compared to the non-treated control plots without any yield reduction. Delaying the application of fungicide to i.e. 14 days after onset of symptoms resulted in weaker disease control. The Modified-TOMCAST, Maturity-based and TOMCAST + Maturity-based models controlled early blight effectively at all the experimental locations. The models show a potential for optimizing control of early blight by better targeting fungicide applications. The trials will be continued in 2017.

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