Validation of the BlightManager DSS for the control late blight and early blight

Isaac Kwesi Abuley & Jens Grønbech Hansen

Introduction

Late blight, caused by *Phytophthora infestans*, and early blight, caused by *Alternaria solani*, are two important diseases in potatoes in Denmark. The management of these diseases is heavily reliant on prophylactic fungicides. The recent statistics from the Danish Ministry for Environment show that fungicide usage, contributes about 70% of the total treatment frequency index (16.2) in potatoes (Miljøstyrelsen 2021). This usage of fungicide is unsustainable for social, economic, and environmental reasons, and thus reducing the fungicide usage in potatoes is critical. There is a need to improve the existing decision support systems by inclusion of precision agriculture and by analysing the potential of resistant cultivars to reduce the need for disease control with fungicides. These questions were analysed in the GUDP funded project called BlightManager.

We have previously explained the different components of the BlightManager DSS (Abuley and Hansen 2020; Abuley and Hansen 2021), thus we will only give a brief overview of the DSS. The BlightManager DSS integrates late blight and early blight model calculatins as well as disease surveillance information using the BlightTracker APP for recording of attacks of both late bligt and early blight and a GIS dashboard for visualization of disease recordings at field level. The Late blight models calculates the weather based risk of sporulation and infection and the surveillance system indicates the proximity of active late blight and early blight. The survellance system is based on an extensive network of advisors and other stakeholders in the potato industry and our well-established Blight Tracker APP for timely reporting of disease outbreaks. The total system is used to advise when, with what and how much to apply fungicide. The early blight model consists of two sub-models: TOMCAST, which estimates the favorability of the weather to early blight attack; and the physiological age model, which estimates the plant age. The physiological age sub-model is relevant to timing the first spray as well as the dosage at a given age.

Our models have traditionally been used with weather data from the Danish Meteorological Institute (DMI), but not all areas in Denmark are well covered with DMI weather station. Thus, to obtain a field-specific forecast, we were also interested in testing our models with in-field weather stations. To this extent, we tested the in-field weather stations from FieldSense.

Overview of the experiment

The improved BligtManager DSS was validated in field experiments at three locations in Denmark (Arnborg, Dronninglund and Flakkebjerg). The varieties in the trials were Folva (Medium-maturing ware potato) and Saprodi (late-maturing, starch potato). The potato variety Allstar (late maturing and starch variety) was used for the early blight experiment. The experiment set-up was a randomized block design with four replicates in all experimental sites. Except for the location Flakkebjerg, late blight infections were established naturally. At Flakkebjerg Folva spreader rows were inoculated on 4 July with a sporangial suspension (1000 sporangia per ml) in the late blight experiment. The early blight experiment was inoculated on 22 June 2021 by placing 110g of autoclaved barley grains infested with *A. solani* between the rows. All standard agronomic practice for healthy potato production was performed at all experimental sites. The treatments in the experiments were as follows:

Late blight

1. Untreated: no use of fungicides for late blight control.
2. Routine: Weekly application of Ranman Top (0.5 l/ha). This treatment represented the standard control for late blight.
3. Skimmelstyring (BM-old): fungicide application was according to the previous version of the Blightmanager DSS called Skimmelystyring. See Abuley and Hansen (2020) for details of this model.
4. BlightManager model with variable spraying interval and variable dosage (BM-dynamic). This treatment followed the BlightManager model, in which fungicide is sprayed only when infection pressure and infection risk are at least 10 and 93, respectively (Abuley and Hansen 2020; Abuley and Hansen 2021).
5. Blight manager with fixed dosage (full dosage) but variable application intervals. We tested this model with an in-field weather station from Fieldsense (BM-FS) or the nearest DMI weather station (BM-DMI).

Early blight

1. Untreated: no use of fungicides for early blight control.
2. Standard. This treatment represented control of early blight and involved the application of 0.4l/ha Narita, starting from 7 weeks after emergence.
3. TOMCAST model with either DMI (TOMCAST-DMI) or in-field weather data from fieldsense (TOMCAST-FS). Here, fungicide application followed the TOMCAST model as described by Abuley and Hansen (2020). However, we only used full dosage whenever the model recommended fungicide application.

Disease and yield assessment

Late blight and early blight severity per plot were assessed weekly from the onset of attack in the late blight and early blight experiments, respectively. The disease severity assessment data were used to calculate the area under the disease progress curve (AUDPC) with the mid-point method (Shaner and Finney 1977) and the efficacy (i.e. the percentage of disease control relative to the untreated) was calculated as described by Abuley and Nielsen (2017). Tubers were harvested from the two middle rows (15.75m^2 at Flakkebjerg and 15m^2 at Arnborg and Dronninglund) for tuber yield assessment. The starch yield was calculated for the starch variety, but not for the ware variety Folva. As a consequence, for the late blight experiments, we only focus on the tuber yield to allow for a similar analysis for the two varieties used in the study. Moreover, similar conclusions would be reached for Saprodi with either tuber or starch yield. The yield increase relative to the untreated was calculated as Abuley and Nielsen (2017). We used the yield increase and efficacy for further comparisons of the treatments.

Statistical analyses

All data handling and analysis were done in R language and environment for programming and statistical computing (hereafter R) (R Core Team 2020). The pooled efficacy and yield increase from the three locations were analysed with a gaussian linear model ("lm" function in R) and the effect of treatment ($\alpha = 0.05$) was determined via analysis of variance (ANOVA). We calculated the effect size (unstandardized) as the difference between the mean of the models and routine (late blight)/standard (early blight) treatment and the 95% bootstrapped confidence interval (CI) of the effect sizes was calculated. The bootstrapped CIs were determined by bootstrapping with antithetic simulations (replicates = 1000) with the "boot" function and estimating the percentile CI with the"boot.ci" function (Canty and Ripley 2021).

Results and discussions

Late blight

Infection pressure

The estimated infection pressure varied between the experimental sites, regardless of the source of weather data (Figure 1), suggesting a different epidemiological consequence on the varieties depending on the experimental location and thus the need to tailor control strategies to local blight conditions. The estimated infection pressures also varied according to the source of weather data. This was particularly evident at Arnborg, where the FS showed a linear increase in infection pressures compared to the undulating pattern exhibited by the DMI (Figure 1). Generally, the infection pressure was higher in September than in the other months.

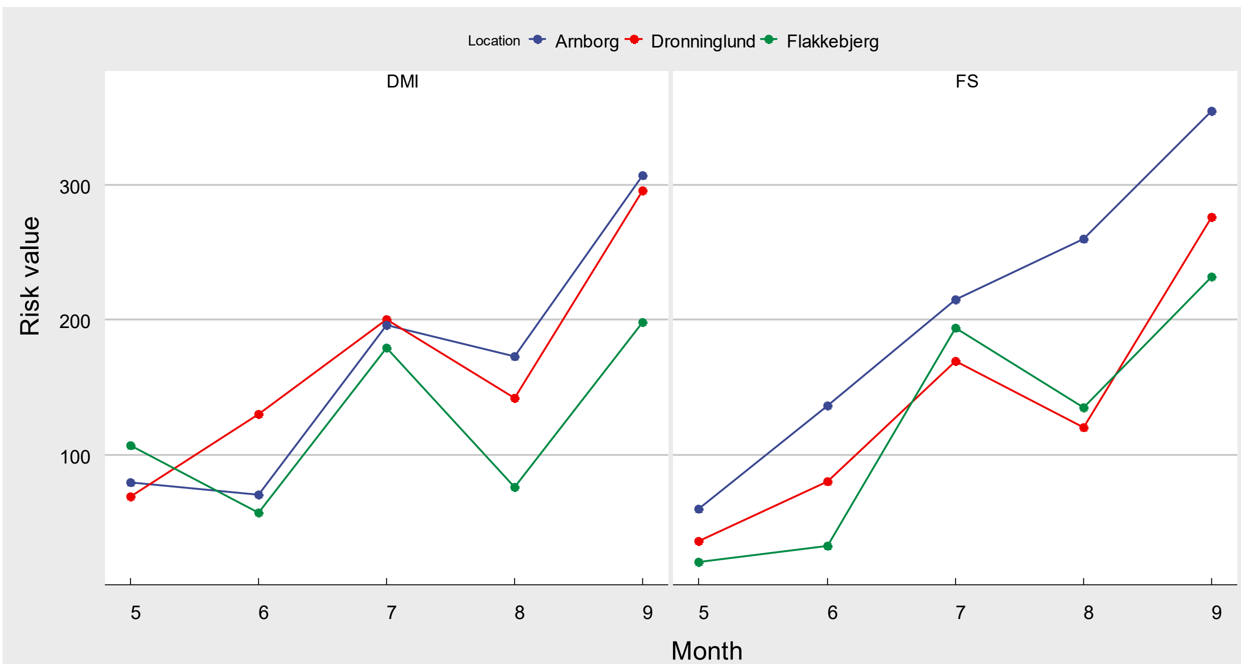

Figure 1. Monthly infection risk at Arnborg, Dronninglund and Flakkebjerg with in-field weather data from Fieldsense (FS) or nearest station operated by DMI.

Disease development

Late blight developed rapidly and reached >95% on the varieties in the untreated plots (Figure 2). Fungicide application suppressed late blight attacks below 10% on the varieties at all locations, except at Arnborg, where late blight severity exceeded 70% in the fungicide treatments (Figure 2). We believe, the infection pressure, which was higher in Arnborg than Flakkebjerg and Dronninglund might partly explain the higher disease level at Arnborg (Figures 1 & 2). Proxanil, a curactive fungicide, was used at Dronninglund and Flakkebjerg but not Arnborg. Therefore, the omission Proxanil, which could have ensured a better disease control during the active stages of the disease, at Arnborg might also account for the higher disease levels at Arnbog compared to the other locations.

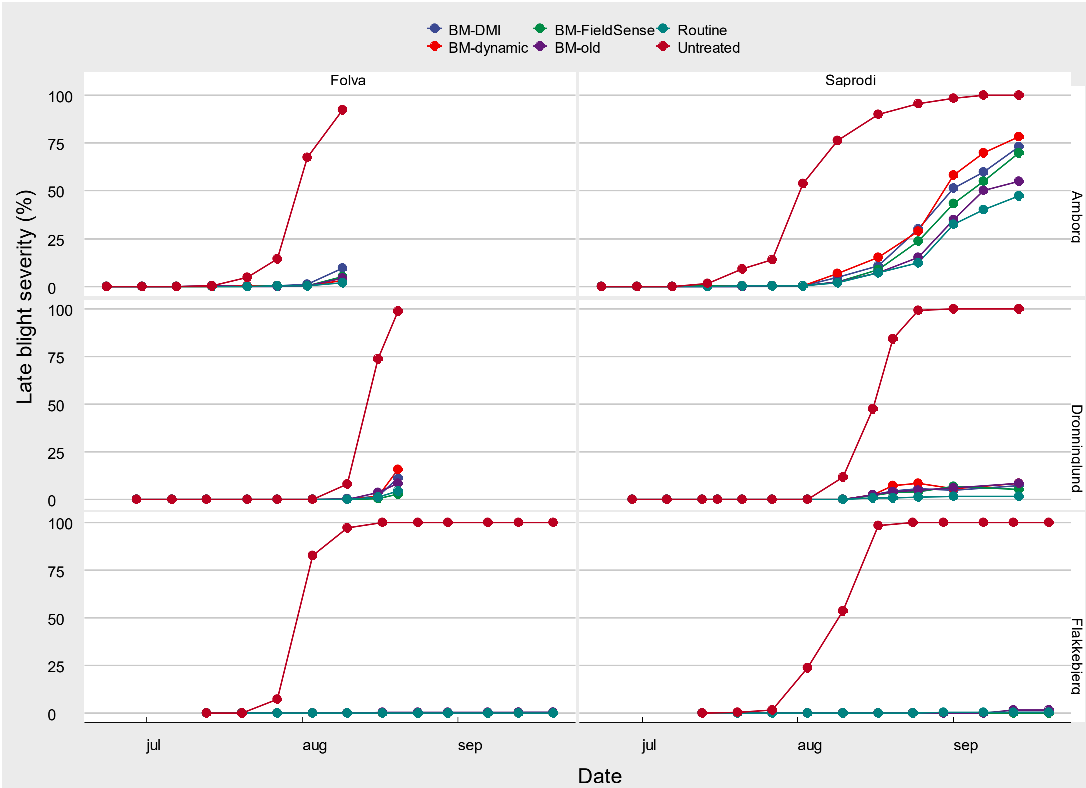

Figure 2. Disease development during the season on the potato varieties Folva and Saprodi in the different treatments.

Fungicide reduction

The results of fungicide reduction showed an average savings of 17-30% (Saprodi) and 12-31% (Folva) (Figure 3). The BM-dynamic model saved the highest amount of fungicides (~30%) on both Saprodi and Folva.

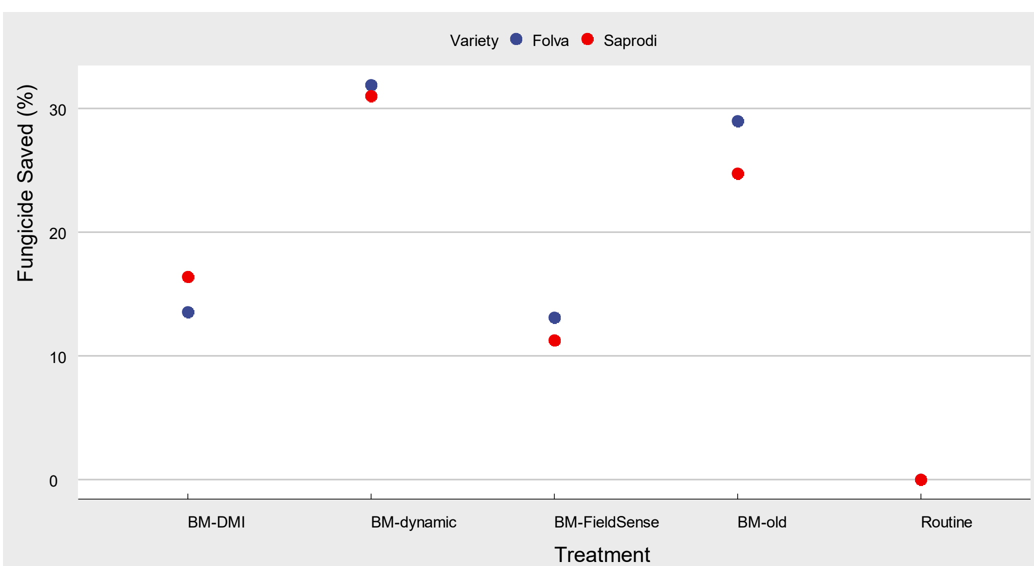

Figure 3. Fungicide saved relative to the routine (standard) treatment.

Efficacy and yield increase

The efficacy of treatments was higher in Folva (>95%) than in Saprodi (<95) (Figure 4). The BM-FS had the highest efficacy in both Folva and Saprodi (Figure 4). The yield increase ranged between 15-22% (Folva) and 30-35% Saprodi (Figure 4). The treatments had a strongly insignificant effect on yield increases (p>0.1) The differences between the routine treatment and models were not statistically significant as their CIs overlapped with the null effect (Figure 4). The statistical analyses showed that fungicide treatment had an insignificant effect (p>0.2) on efficacy and yield in both Saprodi and Folva. The pairwise comparison also confirmed this, as CIs of the effect size between the models and Routine treatment overlapped with the null effect (Figure 4). This suggests there is no significant loss of yield and disease control for using the models to control late blight.

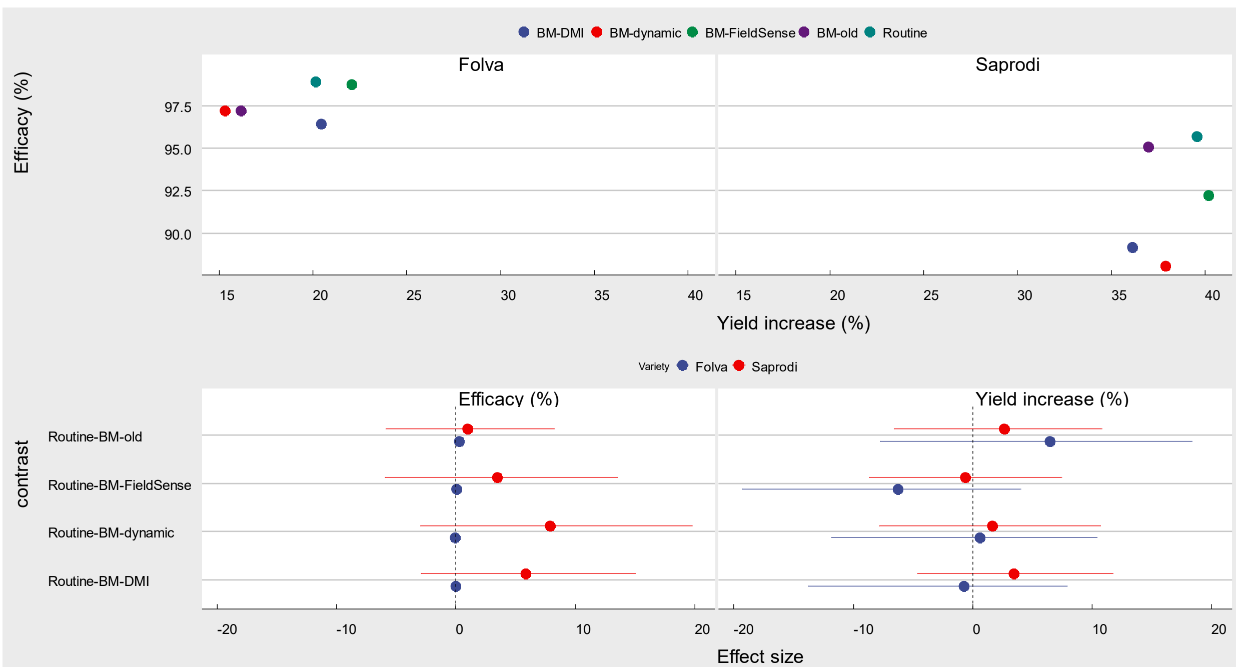

Figure 4. Upper panel: Efficacy and yield increase of the treatments relative to the untreated; Lower panel: The effect sizes (difference) and their associated confidence intervals (horizontal bars) between the routine and late blight models for recommending fungicide application. Effect sizes with confidence intervals that include or overlap with a null effect (dashed black line) are not statistically different and vice versa.

Early blight

The severity of early blight was low in the experiments at Arnborg and Dronninglund compared to Flakkebjerg (Figure 5). At Flakkebjerg, the development of early blight remained slow until the beginning of September (Figure 5).

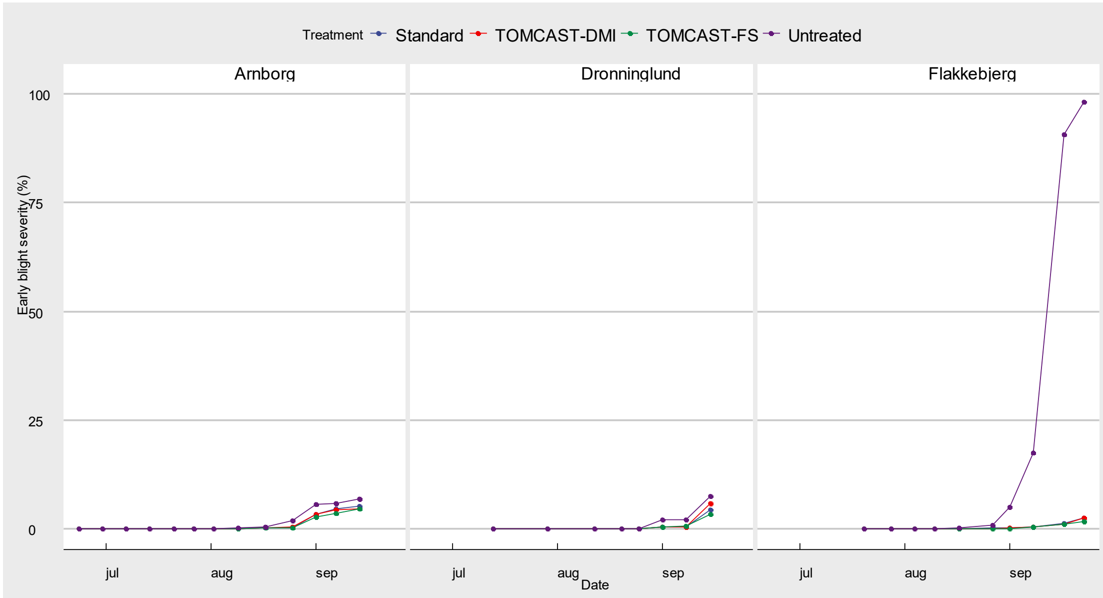

Figure 5. Development of early blight during the season at Arnborg, Dronninglund and Flakkebjerg.

Fungicide saved

The TOMCAST models saved fungicide usage by about 20-30% fungicide relative to the standard treatment (Figure 6). The TOMCAST-DMI model resulted in the most fungicide savings (Figure 6).

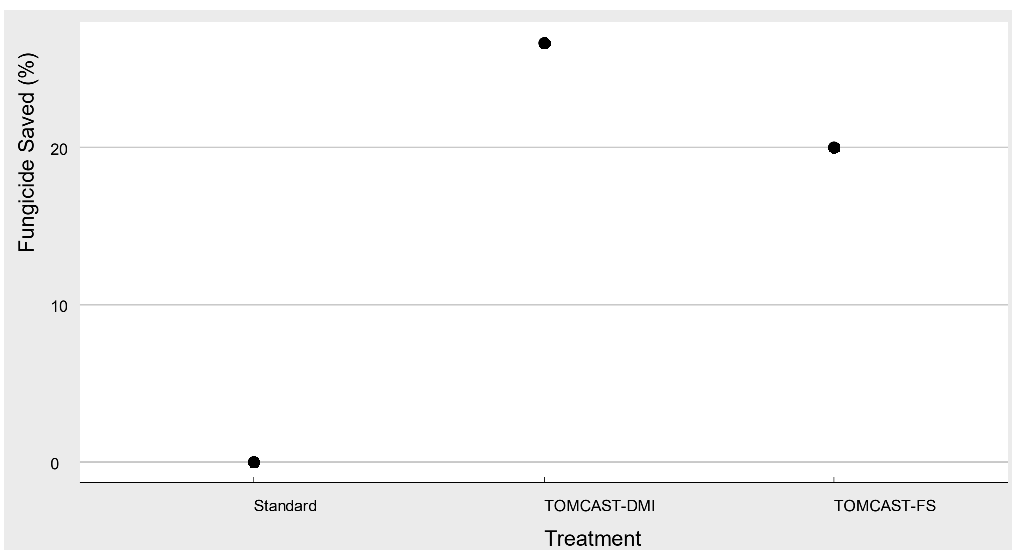

Figure 6. Fungicide saved relative to the routine (standard) treatment

Efficacy and yield increase

The efficacy of the fungicide treatments in the early blight experiment (Figure 7) was markedly lower compared to what we observed in late blight (Figure 4). This was mainly due to the low disease development in the early blight experiments. Accordingly, the treatments had no significant effect on efficacy (p= 0.26). Similarly, the yield increase was below 5% and was not significantly affected by the treatments (p=0.7). The pairwise comparisons between the routine and the early blight models also showed overlapping CIs with the null effect for both efficacy and yield increase, suggesting no significant loss of efficacy or yield for using the models.

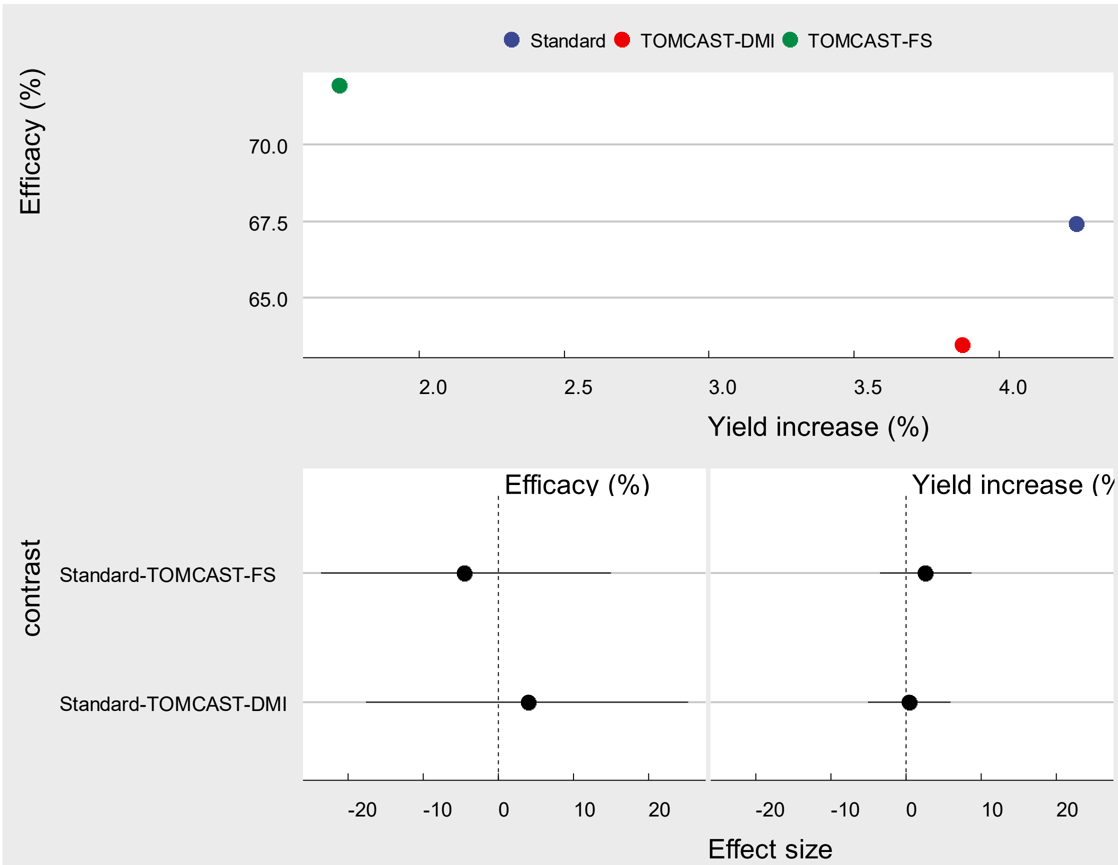

Figure 7. Upper panel: Efficacy and yield increase of the treatments relative to the untreated; Lower panel: The effect sizes (difference) and their associated confidence intervals (horizontal bars) between the routine and late blight models for recommending fungicide application. Effect sizes with confidence intervals that include or overlap with a null effect (dashed black line) are not statistically different and vice versa.

Concluding remarks

We have shown significant fungicide savings (~30%) by using BlightManager for managing late blight and early blight without compromising on efficacy or yield. Indeed, this is remarkable as we seek to minimise the usage of fungicides in the potato production. However, we need to do more to reach the 50% target of the "Farm-to-Fork" strategy. Admittedly, using DSSs is relevant for saving fungicides, but we can achieve further fungicide savings (~60%) if we shift to very resistant potato varieties as we showed in our previous publication (Abuley and Hansen, 2020) and replace some fungicides with environmentally benign products (e.g., biological control agents).

References

Abuley, I. K., and Nielsen, B. J. 2017. Evaluation of models to control potato early blight (Alternaria solani) in Denmark. Crop Protection 102:118-128.

Abuley, I. K., and Hansen, H. H. 2020. Control of late blight (Phytophthora infestans) and early blight (Alternaria solani) in potatoes. Pages 98-98 in: Applied crop protection 2019

vol. DCA rapport, no. 167,. T. H. LN Jørgensen, IK Abuley, SK Mathiassen, PK Jensen, HS Kristjansen & P Hartvig (eds),, ed. Aarhus Universitet - DCA - Nationalt Center for Fødevarer og Jordbrug, Slagelse.

Abuley, I. K., and Hansen, J. G. 2021. Controlling late blight in susceptible and resistant potato cultivars with BlightManager. Pages 96-96 in: Applied Crop Protection 2020, vol. No. 187. L. N. Jørgensen, T. M. Heick, I. K. Abuley, P. K. Jensen, K. H. Saltoft and A. Hansen, eds. Aarhus Universitet - DCA - Nationalt Center for Fødevarer og Jordbrug, Tjele.

Canty, A., and Ripley, B. 2021. boot: Bootstrap R (S-Plus) Functions. . R package version 1.3-26.

Miljøstyrelsen. 2021. Behandlingshyppighed og pesticidbelastning baseret på salg og forbrug. Miløstyrelsen.

R Core Team. 2020. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Shaner, G., and Finney, R. E. 1977. The Effect of Nitrogen Fertilization on the Expression of Slow-Mildewing Resistance in Knox Wheat. Phytopathology 77:1051.