Presentation

Analysis of correlation between soil moisture and late blight occurrence

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SUMMARY

During a 3-year project the relation between soil moisture and first appearance of *Phytophthora infestans* was characterised. The aim was to integrate a soil moisture module in the prediction model SIMBLIGHT1 (Kleinhenz *et al.* 2007), which calculates the first appearance of *P. infestans* in potato fields.

Potato tubers, which are infected with *P. infestans*, are able to release sporangia and zoospores in the ambient soil, when temperature and soil moisture are optimal for the fungus. Soil-borne infections can increase the risk of an early appearance of *P. infestans* in field (Adler 2000; Bäßler 2005). In a field trial inoculated potato tubers were buried next to healthy tubers. In this way the possibility for soil-borne infections of healthy potato plants were tested. Additionally monitoring data of first occurrence of late blight in Germany of the years 2006 to 2010 were analysed taking into account the influence of soil moisture.

The results showed that no explicit correlation between soil moisture and an early appearance of *P. infestans* could be detected.

KEYWORDS

Phytophthora infestans, soil moisture, zoospore infections, latent infected tubers, SIMBLIGHT1

INTRODUCTION

The prediction model SIMBLIGHT1 (Kleinhenz *et al.* 2007), which calculates the first appearance of *Phytophthora infestans* in potato fields, was developed by ZEPP (Central Institution for Decision Support Systems in Crop Protection) and is used by the GCPS (Governmental Crop Protection Services) in Germany. SIMBLIGHT1 calculates a higher risk for an early outbreak of *P. infestans* if there had been a four day long period of totally water saturated soil between planting and 7 days after emergence.

Former studies showed, that a correlation between high soil moisture after planting and early occurrence of *P. infestans* can be assumed. Adler (2000) found out, that latent infected potato tubers became more important on primary infections of late blight because of modern storages. In her opinion this fact leads to an earlier outbreak of sprout infections in years with wet springs. She called for focusing on soil-borne infections between planting and emergence.

Similar postulations were brought up by Bäßler (2005). In his experiments on the influence of

soil type and soil moisture on primary infections he recommended a soil module for prediction models, to describe the correlation between soil type, soil moisture and latent infected sprouts. The main aspects of his experiments showed an increase of latent infections of sprouts according to the duration of irrigation and the heaviness of soil. He postulated to specify the influence of soil physical parameters. Boyd (1980) argued that primary infections are caused from contaminated soil to leaves and not from soil-borne infected sprouts. His experiments produced more infected potato plants on the flat 3 % and 5.3 % respectively than on ridges were he had less than 1 % infected sprouts.
The aim of this study was to specify the relation between soil characteristics and first appearance of *P. infestans* to integrate a soil moisture module in SIMBLIGHT1.

HYPOTHESES

In this study the influence of soil moisture on the first occurrence of late blight was investigated. Therefore the analyses were focused on the incubation period of *P. infestans*. In field trials soil-borne infections from infected tubers to healthy sprouts were taken into account.
Potato tubers, which are infected with *P. infestans*, are able to release sporangia and zoospores in the ambient soil, when temperature and soil moisture are optimal for the fungus (Zan 1962; Lacey 1967; Sato 1980; Adler 2000; Porter 2005).
As described in literature sporangia formation of *Phytophthora spp*. requires damp soil around 150 hPa (Macdonald and Duniway 1978). This soil moisture is characterised by the interval of field capacity. At field capacity the soil moisture tension is between 60 and 300 hPa.
After spores formation on the surface of an infected tuber indirect germination is required, because only zoospores have the possibility to be transported by soil water through soil pores (Porter *et al.* 2005). As written by Macdonald and Duniway (1978) for indirect germination of *Phytophthora spp*. a water potential from up to 25 hPa is required. In addition zoospore movement through soil pores is only possible when soil moisture is above field capacity, which means soil saturation is required.
Therefore it seems that in years with high soil moisture on the fields, the possibility for movements of zoospores exists. This process increases the risk of an early appearance of *P. infestans* in field. The effect of soil moisture on potato tuber infections due to *P. infestans* was assessed in a field experiment.

MATERIAL AND METHODS

Field trials 2010 and 2011

Based on the hypotheses a field trial was carried out in 2010 and 2011 (Figure 1). Inoculated potato tubers were buried next to healthy tubers in a field. The trial was surrounded by a crop not susceptible to *P. infestans* and in a potato free growing area to avoid *P. infestans* infections from outside the trial plot.
During planting contact between the inoculated and the healthy tubers was avoided. Additionally sensors for the measurement of soil moisture and soil temperature were installed. Afterwards the potato field was divided into three plots. Each plot consisted of 10 rows with a length of 4 meters planted with potatoes. Inoculated tubers were not buried near the borders of each plot to avoid infections between the plots. The three plots were irrigated for a different amount of days and at different times respectively; one was without irrigation, one with irrigation before emergence and one with irrigation after emergence. Additionally the half of each plot was covered with a foil to reduce the effects of precipitation. In the irrigated plots 20 litres of water per square meter were given every day.
The assessment of visual late blight symptoms was done twice a week after emergence. 20 sprouts per plot from the plants of the formerly healthy tubers were sampled at BBCH 65. They were used for

PCR-detection (Keil 2007; Judelson and Tolley 2000) of latent infections with *P. infestans*.

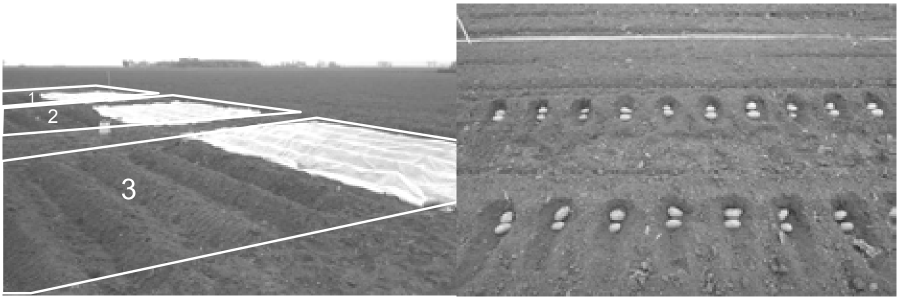

Figure 1: Design of field trial (left) and planting of the inoculated tubers next to the healthy tubers (right)

Figure 2 shows the dates of the field experiments in 2010 and 2011. The planting date was in both years in the middle of April. In 2010 the irrigation was reduced from the scheduled four days to two and one day respectively, because of continuous precipitation. In 2010 the sprouts for PCR-detection were sampled at the end of June and in 2011 at the beginning of June.

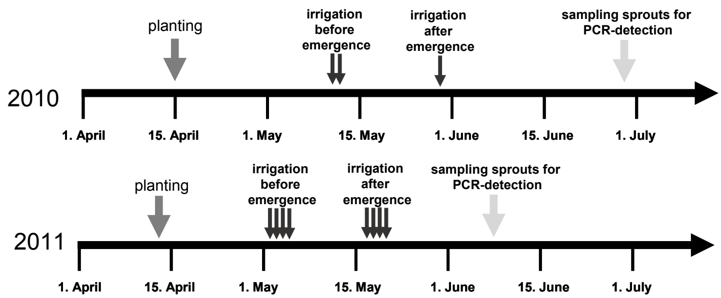

Figure 2: Dates of the field trials in 2010 and 2011

Analyses of monitoring data

To determine the influence of soil moisture on the date of the first occurrence of late blight in field, analyses with late blight monitoring data from Germany of the years 2006 to 2010 were done. Within this monitoring the parameters crop prevalence (high/low) and soil moisture (high/low) were assessed. Analyses concerning the variability of first late blight occurrences were carried out according to four groups

- low soil moisture and low crop prevalence (1)
- low soil moisture and high crop prevalence (2)
- high soil moisture and low crop prevalence (3)
- high soil moisture and high crop prevalence (4)

In total an amount of 510 data sets were split into the four different groups. Statistical differences between the four groups and significant differences respectively were tested by Tukey-test with a confidence interval of 95 %.

RESULTS

Field trial 2010

The irrigation led to a different amount of days above field capacity in the different plots. In Figure 3 the number of days above field capacity between planting and 7 days after emergence is shown. This is the relevant period for the influence of soil moisture in the prediction model SIMBLIGHT1. In addition Figure 3 shows the number of days above field capacity in the total period until the sampling of the sprouts for PCR-detection. On a second vertical axis the percentage of latent infected sprouts of the 20 samples is shown.

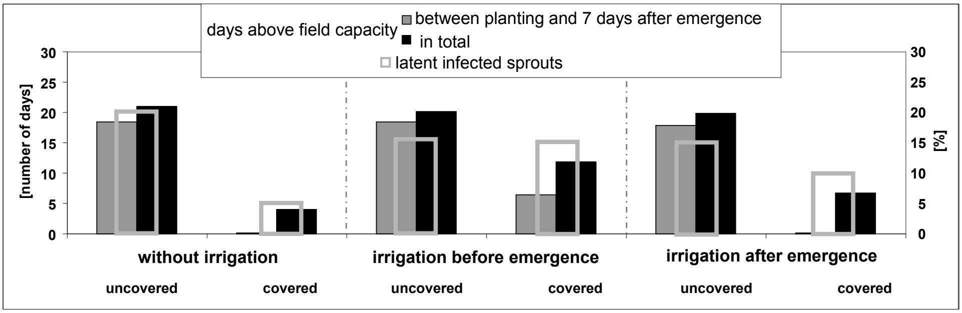

Figure 3: Number of days above field capacity between planting and 7 days after emergence, number of days above field capacity in the total period of the experiment and percentage of latent infected sprouts per plot in 2010

The correlation of the number of days above field capacity between planting and 7 days after emergence with the percentage of latent infected sprouts showed that both parameters are positively correlated (Figure 4). The coefficient of determination is about 0.67. The coefficient of determination is even better, if the percentage of latent infected sprouts was correlated with the number of days above field capacity between planting and the sampling of the sprouts (Figure 5). Until harvesting at the beginning of August no visual late blight symptoms in any plot could be observed.

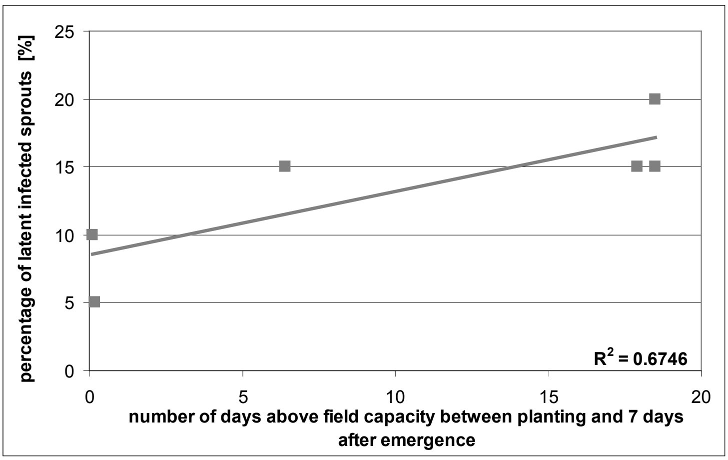

Figure 4: Correlation of the values number of days above field capacity between planting and 7 days after emergence and percentage of latent infected sprouts in each plot

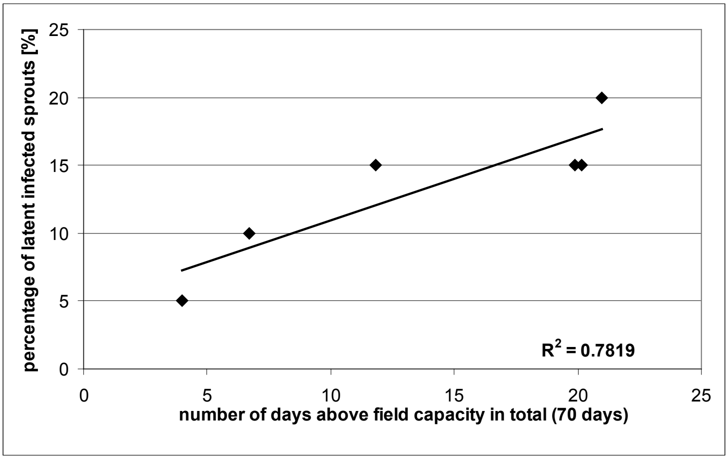

Figure 5: Correlation of the values number of days above field capacity in total and percentage of latent infected sprouts in each plot

Field trial 2011

Figure 6 shows the number of days above field capacity between planting and 7 days after emergence, the number of days above field capacity until the sampling of the sprouts for PCR-detection and the percentage of latent infected sprouts per plot. In 2011 there had been a clearly lower amount of days above field capacity because of very warm and dry weather conditions. The days above field capacity were only due to irrigation in this year. Out of the 120 sampled sprouts for PCR-detection of *P. infestans* only one showed a positive result. For this reason no statistical analysis could be done. Also in 2011 no visual late blight symptoms until harvesting were found.

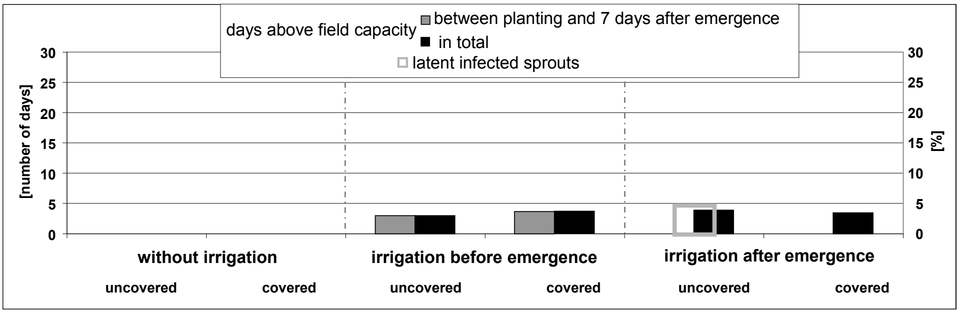

Figure 6: Number of days above field capacity between planting and 7 days after emergence, number of days above field capacity in the total period of the experiment and percentage of latent infected sprouts per plot in 2011

Analyses of monitoring data

The box plots in Figure 7 show the variability of the date of first late blight occurrence in field in the years 2006 to 2010 within the four defined groups. It can be seen that, expect the fourth group, the variability of the whiskers has a nearly identical range. The average of the date of first occurrence lies within 7 days.

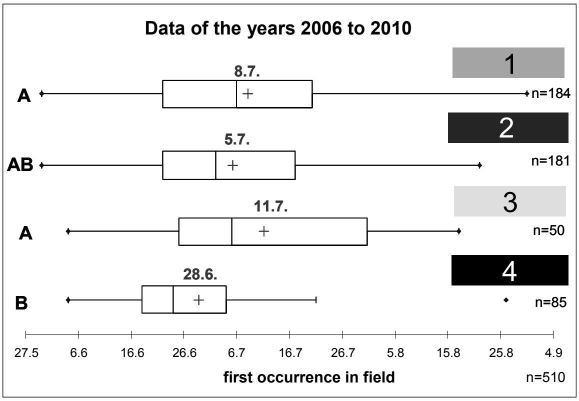

Figure 7: Box plots of the variability of the date of first late blight occurrence in field in the years 2006 to 2010 within the four defined groups (low soil moisture and low crop prevalence (1), low soil moisture and high crop prevalence (2), high soil moisture and low crop prevalence (3) and high soil moisture and high crop prevalence (4)) and significant different groups as a result of Tukey-test (confidence interval of 95 %)

In Tukey-test the influence of crop prevalence and soil moisture on the date of first occurrence of *P. infestans* in field was determined. For that purpose each of the four groups was tested versus another to find out significant differences between the groups. To find out significant differences depending on soil moisture, the different groups of soil moisture within the same group of crop prevalence had to be tested. The result was that no significant differences in the date of the first occurrence of late blight relating to soil moisture could be found. Significant differences only occurred under the influence of crop prevalence.

Contrast			Significance
1	versus	3	no
2	versus	4	no
3	versus	4	yes
3	versus	2	no
1	versus	4	yes
1	versus	2	no

Figure 8: Results of the significant differences out of Tukey-test concerning the four different groups (low soil moisture and low crop prevalence (1), low soil moisture and high crop prevalence (2), high soil moisture and low crop prevalence (3) and high soil moisture and high crop prevalence (4))

DISCUSSION

Out of the results no explicit correlation between soil moisture and the appearance of *P. infestans* in field could be found. A correlation between high soil moisture and latent infected sprouts could be detected in the field trial in 2010. Despite a high percentage of latent infections from up to 20 %, no visual symptoms of *P. infestans* occurred until harvesting. This is one reason why it is difficult to transfer results based on latent infections to practical field results.

In the field trial in 2011 no correlation between days above field capacity and infected sprouts could be found. One reason could be the dry weather conditions in spring, which could have led to unfavourable conditions for sporangia formation on the tubers surface. Whereas in 2010 all the required processes for a soil borne infection were given, in 2011 caused by the warm and dry weather no conditions for sporangia formation were reached. One possibility for the missing infections of the plants from the healthy tubers could be that there had been no sporangia for zoospore release at the time of irrigation.

A correlation between high soil moisture and the date of the first late blight occurrence in field could not be found neither in the analysis of the monitoring data nor in the field trials. Instead a correlation between high crop prevalence and the date of first late blight occurrence could be found. Out of this results it could be possible that the effect of soil moisture on the date of the first occurrence of late blight is low. Analyses which led to a high effect of soil moisture on the first occurrence of *P. infestans* are often related to latent infections and not to visual symptoms in field. The correlation between soil moisture and latent infections could be proved in field in 2010. The results suggest that latent infections are not correlated to an earlier outbreak of late blight. The outbreak of *P. infestans* in field must be related to other suitable conditions for the fungus. It is possible that high soil moisture could lead to an intense distribution of zoospores in the soil and in relation to this to a high percentage of latent infections. But statistical analyses revealed that high soil moisture has no influence on the date of the first occurrence of late blight in the field.

CONCLUSIONS

Out of the results no explicit correlation between soil moisture and an early appearance of *P. infestans* could be found. High soil moisture could lead to an intense distribution of zoospores in soil resulting in a high percentage of latent infections, but high soil moisture has no influence on the date of first occurrence of late blight in the field. For this reason the integration of a soil moisture module in model SIMBLIGHT1 predicting first occurrence of late blight has no practical use.

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