Biofumigation – an alternative method to control late blight in organic potato production?

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Key words: *Brassicaceae*, cover crop, glucosinolate, isothiocyanate, *Phytophthora infestans*, *Solanum tuberosum*

Abstract

To control late blight in organic potato production, copper fungicides are currently used. Due to the problematic aspects of copper fungicides, it is necessary to develop alternative methods to control Phytophthora infestans. In this context the use of cover crops and particularly the biofumigation method are discussed, too. Because there is barely literature about the effectivity of biofumgiation in organic potato production, the method was evaluated with laboratory experiments and a field trial in 2012. Brassicaceae plant tissue inhibited the hyphal growth of P. infestans in vitro significantly. However, in the one year field experiment no positive biofumigation effects could be observed concerning late blight infestation and potato tuber yields. Based on the missing biofumigation effects in the field and considering P. infestans to be no mainly soil-borne pathogen, the potential of biofumigation concerning late blight in organic potato production seems currently to be limited.

Introduction

Late blight is probably one of the most important problems concerning organic potato production in Germany. Therefore copper fungicides are currently used by organic farmers to control *Phytophthora infestans (MONT.) DE BARY*, the phytopathogen causing late blight. Due to problematic aspects of copper fungicides, like accumulation in soil and negative effects on non-target organism, it is necessary to develop alternative methods to control late blight in organic potato cultivation. In this context cover crops and particularly biofumigation are discussed as a possible method against *P. infestans* by practice. Thereby *Brassicaceae* with high contents of glucosinolates are incorporated into the soil to support the development of isothiocyanates (ITC), which are toxic to several phytopathogens (Morra and Kirkegaard 2002). Because there is barely literature about the usability and effectivity of biofumigation in organic potato production, the method of biofumigation with different *Brassicaceae* compared with one *Fabaceae* was evaluated with laboratory experiments and a field trial in Southern Germany.

Material and methods

Laboratory experiments

In vitro laboratory tests were used to get first information about the sensitiveness of *P. infestans* to different plant materials (*Brassica juncea*, *Raphanus sativus*, *Brassica rapa*, *Sinapsis alba*, *Vicia sativa*: three experiments) and to allyl isothiocyanate (AITC: one experiment). Petri dishes with V8 agar medium were inoculated with *P. infestans* isolate. After turning upside down, chopped plant material (2.5 g fresh matter) or AITC in methanol (3 µl total) was added to the lids. There was no contact between the Agar and the plant material or AITC. Airtight sealed Petri dishes were incubated in the dark at 17 °C. To the control dishes nothing or only methanol (3 µl) was added. All treatments were replicated three times. The diameter of the radial growth was measured and the relative area under the disease progress curve (relative AUDPC) calculated.

Biofumigation field trial

To test the biofumigation method in the open, a field trial was conducted on an organic farm with intensive potato cultivation in Southern Germany, 25 km northwest of Munich in the year 2012 (average annual temperature 8.5 °C, average precipitation 928 mm). The soil was humic sandy loam and the previous crop was rye. A split-plot design was chosen with the factors cover crop (*B. juncea*, *R. sativus*, *B. rapa*, *V. villosa*) and incorporation time (autumn, spring). All cover crops were seeded in August 2011 and shredded and incorporated in October 2011 (autumn) or April 2012 (spring). Potatoes were planted in April 2012 with 41700 tubers ha^{-1}. Potato growth, *P. infestans* progress (AUDPC) and potato tuber fresh matter (FM) yields were determined.

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Data analysis

All data were analysed using the R Project 3.0.2 (R Core Team 2013) with analyses of variance (ANOVA), split-plot ANOVA and linear models. Tukey's honest significant difference test (Tukey's HSD) was used to identify significant differences. As significance level always $p < 0.05$ was chosen.

Results

Laboratory experiments

Regarding all three laboratory experiments, plant material of the four *Brassicaceae* inhibited the hyphal growth of *P. infestans* on agar significantly. The relative AUDPC according to different plant material is provided by Figure 1 a). Only the *Fabaceae V. sativa* with 0.24 relative AUDPC had no significant effect compared to the control with 0.29. The broadest inhibition showed *S. alba* with 0.07 and *B. juncea* with 0.08 relative AUDPC. The growth inhibition of different amounts of AITC is provided by Figure 1 b). Thereby 0.03 µmol AITC did not inhibit the growth significantly, but 0.3 µmol AITC with 0.25, 3 µmol and 30 µmol both with 0.06 relative AUDPC inhibited *P. infestans* significantly compared to the control with 0.34 relative AUDPC.

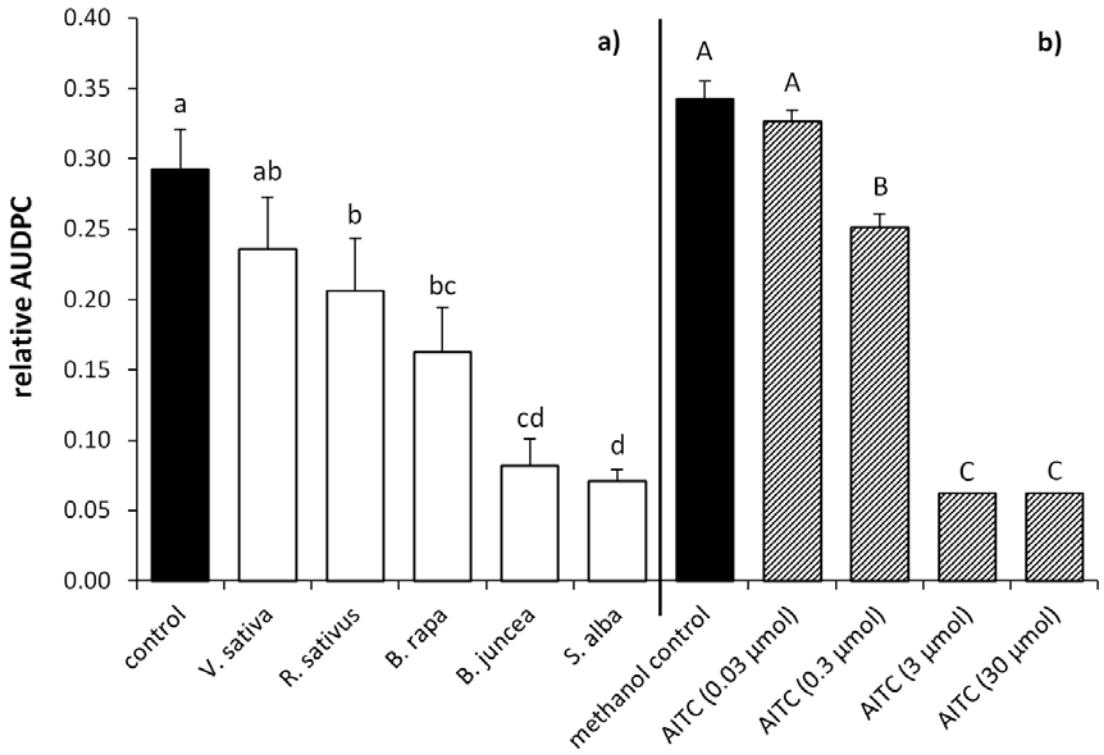

Figure 1. *P. infestans* hyphal growth inhibition. Plant material: 2.5 g fresh matter, three experiments. AITC (Allyl isothiocyanate): one experiment. Mean values, error bars: standard error of the mean, Tukey's HSD ($p < 0.05$), different letters imply significant differences.

Biofumigation field trial

An overview of the tuber yields and the AUDPC of all eight cover crop and incorporation time combinations is provided by Figure 2. There were no significant differences concerning tuber yields and AUDPC. Split-plot ANOVA stated that neither the factor cover crop nor the factor incorporation time or any interaction had a significant effect to *P. infestans* (mean AUDPC 2282) or fresh matter tuber yields (mean 21.8 t FM ha^{-1}). Incorporation time autumn had slightly higher tuber yields than incorporation time spring, but not significant. AUDPC tended to be smaller with incorporation time autumn in the case of the three *Brassicaceae*, however in the case of *V. villosa* AUDPC tended to be higher. Regarding all single plot values, with higher *P. infestans* infestation i.e. bigger AUDPC the tuber yields were decreasing significantly according to linear regression ($b = - 0.006$, $p < 0.01$).

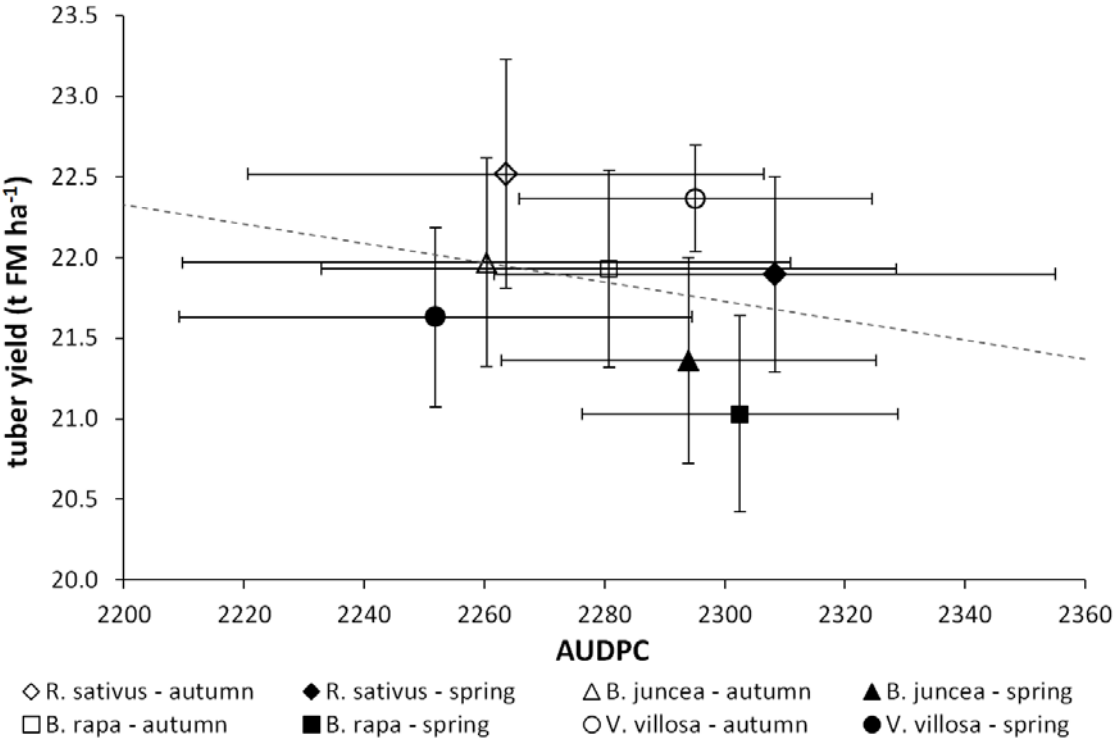

Figure 2. Potato tuber yield and AUDPC. Mean values, error bars: standard error of the mean, no significant differences, ---: linear regression with all single plot values (b= - 0.006, p < 0.01).

Discussion

First it seems like a gap between the in vitro laboratory results and the field trial results. Contrary to the *P. infestans* growth inhibition caused by *Brassicaceae* in the laboratory, there were no significant effects in the field trial. All four *Brassicaceae*, especially *S. alba* and *B. juncea* contained volatile ingredients which inhibited the hyphal growth of *P. infestans* similar to AITC in the in vitro experiments. AITC is a derivative of Sinigrin, the main glucosinolate of *B. juncea* (JKI 2010). But strictly speaking the laboratory experiments can only give hints to the inhibition of the hyphal growth. No conclusion for other development stages like zoospores and oospores are possible. Additionally the plant material is close to *P. infestans*, consequently the volatile ingredients can take effect. In contrary the cover crops in the field are seeded in autumn and incorporated to the soil in autumn or spring before potato planting. Therefore biofumigation can only harm soil-borne phytopathogens. But *P. infestans* mainly overwinters with latent infected seed tubers (Zellner et al. 2011) even though there are hints concerning the formation and existence of oospores in the soil (Andersson et al. 1998). The presented results are based on a one year field experiment with an early and intensive *P. infestans* disease. Maybe therefore rather moderate cover crop and biofumigation effects could not be observed. Furthermore factors like incorporation method and environmental conditions influence the effectiveness of the biofumigation method. Also other studies (JKI 2010) with different field crops showed that biofumigation is not always an effective and practical suitable method to control phytopathogens under middle European conditions.

Conclusions

According to the in vitro laboratory experiments *Brassicaceae* have the potential to inhibit the hyphal growth of *P. infestans*. But in an one year field experiment it was not possible to observe the anti phytopathogen effects of biofumigation under field conditions. The results did not show an effect of cover crop or incorporation time on potato health and yields. Considering *P. infestans* to be no mainly soil-borne phytopathogen, the potential of biofumigation concerning late blight in organic potato production seems currently to be limited. The field trials will be continued to get more reliable results, additional cover crops and further potato phytopathogens like *Rhizoctonia solani* will be considered.

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