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Strategies to reduce primary *Phytophthora* infections in conventional and organic potato production

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SUMMARY

Early primary stem infections developing from infected seed tubers are the most important starting points for early and massive late blight epidemics. As revealed by PCR analyses, about 10% of the seed tubers are latently infested with *P. infestans*, and thus carry the inoculum of the pathogen. In conventional farming, primary infections can be effectively prevented by early foliar applications of systemic fungicides, ideally 1-2 weeks ahead of the first visible symptoms. Seed treatments with contact fungicides might be an additional way to reduce incidence of primary infections. In organic farming, postponing the onset of infection originating from infected seed tubers is even more important, but systemic fungicides are not available. Seed treatments and foliar treatments with copper and/ or alternative products can be part of a management strategy aiming at a retardation of disease onset and a reduction of leaf infections to minimize the deposition of sporangial inoculum on the soil surface and the potato crop.

KEYWORDS

disease management, inoculum, late blight, latent infection, *Phytophthora infestans*, seed tubers, stem infection

INTRODUCTION

Late blight caused by *Phytophthora infestans* is one of the most devastating diseases of potato. In general, there are two major pathways of how the pathogen will infect a given potato field to start a late blight epidemic: i) infection will start from outside the field as sporangial inoculum originating from diseased volunteer plants, from infected refuse tubers, or from an infected neighboring stand, and blown into the field by wind; ii) infection will start from within the field, with infected seed tubers being the main source of inoculum (Johnson, 2010; Zellner *et al.,* 2011; Wharton *et al.,* 2012). Starting from an infected seed tuber, the pathogen can take several different ways to infect a potato plant and start an epidemic. When soils are sufficiently wet, sporulation on tubers might occur, leading to an infection of developing stems, or neighboring plants and tubers via the soil. Furthermore, the pathogen can grow on or inside the stem up to a certain height, and cause symptoms on aboveground parts of the stem. All these pathways will eventually lead to primary *Phytophthora* stem infections from which – via sporulation and secondary leaf infections – disease spots will develop that soon will affect the whole field. Such primary infections usually will occur relatively early in the season, earlier than secondary infections via airborne sporangia, as the primary inoculum originates directly from the tuber, and the pathogen can establish on the tuber and in the soil for a certain time before and during sprouting. In particular, this will happen when weather conditions are suitable for the pathogen and for the development of disease (i.e. moist soils and temperatures above 10° C).

Previous studies based on PCR analyses have shown that an average of 10% of the European seed tubers are (latently) infected with *P. infestans* (Zellner *et al.*, 2011) and as such, potentially carry the inoculum into the fields. Even if only 1% of these produce plants with diseased sprouts (Powelson *et al.,* 2002), this would eventually result in approx. 40 disease spots per hectare (assuming a density of 40,000 plants/ha).

This study has investigated different ways to reduce the extent of these primary stem infections in both conventional and organic potato production by fungicide applications on the foliage or on the tuber. In both conventional and organic production modes, a timely and effective control of primary *Phytophthora* infections is crucial for any further disease management efforts and for the prevention of substantial yield and quality losses.

MATERIALS AND METHODS

Field tests

All field tests were carried out using a "double setting" technique of potato seed tubers (Keil *et al.,* 2010), with one healthy tuber and one artificially infected tuber planted on the same position in the field. The artificially infected tubers (cv. Désirée) were produced by injecting approx. 50-100 sporangia in about 50 µl H_2O into each tuber with a syringe several days before planting. These tubers served as a source of inoculum for the neighboring healthy tubers (cv. Agria), thus facilitating the development of early stem infections and at the same time ensuring the sprouting of at least one plant per planting position. In case of the tuber treatment tests, the healthy tuber received the fungicide seed dressing, while the infected tuber remained untreated. In case of the foliage treatment tests none of the two tubers was treated. All tests were set up in a completely randomized block design with four replications per treatment, plot size ca. 25 m^2, at two sites in southern Germany in 2011, or 2012.

Conventional farming

Foliar applications: The treatments applied to potato foliage in this test are listed in Table 1. Dosage and timing of application were according to standard recommendations and common practice. Extent of late blight and stem blight were recorded in July. Data presented here are those of the cultivar planted as a healthy tuber (cv. Agria).

Table 1. *Treatments applied in field test for the prevention of stem infection by foliar treatment, conventional farming*

treatment / product	active ingredient	dosage	fungicide mode of action
untreated control	-	-	-
Infinito	propamocarb + fluopicolide	1.5 l/ ha	systemic (propamocarb)
Ridomil Gold MZ	metalaxyl M + mancozeb	2.0 kg/ ha	systemic (metalaxyl M)
Proxanil Pack	propamocarb + cymoxanil	2.0 l/ ha	systemic (propamocarb)
Fantic M	benalaxyl M + mancozeb	2.5 kg/ ha	systemic (benalaxyl M)
Revus	mandipropamid	0.6 l/ ha	locally systemic/ translaminar

Tuber treatments: The treatments applied to potato seed tubers several days before planting in this test and their dosages are listed in Table 2. Seed dressings were applied using ULV spray nozzles on an automatic potato grader. Extent of late blight and stem blight were recorded in July. Foliage treatments during the season were made with contact fungicides only to avoid any influence by systemic products on primary stem symptoms. Data presented here are those of the cultivar planted as a healthy, treated tuber (cv. Agria).

Table 2. *Treatments applied in field test for the prevention of stem infection by tuber treatment, conventional farming*

treatment/ product	active ingredient	dosage	fungicide mode of action
untreated control	-	-	-
Cuprozin fl.	Cu hydroxide	16 ml per 100 ml H20 per 100 kg	contact
Zetanil M	mancozeb + cymoxanil	120 g per 200 ml H20 per 100 kg	locally systemic/ translaminar
Fantic M	benalaxyl M + mancozeb	100 g per 200 ml H20 per 100 kg	systemic (benalaxyl M)
Monceren	pencycuron + prothioconazole	60 ml per 100 ml H20 per 100 kg	[Rhizoctonia treatment]

Organic farming

Foliar applications: Field (and laboratory) tests with copper and various alternative substances for foliar applications are described in another paper by the same authors in this proceedings (Nechwatal & Zellner, 2013).

Tuber treatments: The treatments were applied to potato seed tubers either in autumn shortly after harvest (before storage at 5°C), or in spring several days before planting, using ULV spray nozzles on an automatic potato grader. The preparations and their dosages are listed in Table 3. Extent of late blight and stem blight were recorded during June and July. Data presented here are those of the cultivar planted as a healthy, treated tuber (cv. Agria).

Table 3. *Treatments applied in field test for the prevention of stem infection by tuber treatment, organic farming*

treatment/ product	dosage	application time
control	-	-
copper (Cuprozin fl.)	16 ml per 100 ml H20 per 100 kg	autumn 2011
Na phosphonate (test product)	40 ml + 160 ml H2O per 100 kg	autumn 2011
Bacillus subtilis (Serenade)	320 ml per 100 kg	autumn 2011
chitosan (ChitoPlant)	2 g in 200 ml H20 per 100 kg	spring 2012
copper (Cuprozin fl.)	16 ml per 100 ml H20 per 100 kg	spring 2012
Na phosphonate (test product)	40 ml + 160 ml H2O per 100 kg	spring 2012
Bacillus subtilis (Serenade)	320 ml per 100 kg	spring 2012

LABORATORY TESTS

In addition to the detached leaf tests described by Nechwatal & Zellner (2013) in this proceedings, laboratory tests were performed to test alternative substances for their ability to reduce tuber blight (brown rot) in artificially infested potato tubers. Tubers were infested by a short full immersion in a sporangial suspension (5 sporangia/ µl) and incubation at room temperature for 24 – 48 h to initialize the infection. This treatment was meant to mimic natural tuber infestation at the end of the season with sporangia being washed onto the tubers from infected foliage. After that, dried tubers were treated by spray application with various substances, as indicated in Table 6, at a rate of approx. 0.7 ml/ tuber. After 6-8 weeks at 15°C in the dark, number of tubers with brown rot symptoms and extent of the rot for each tuber was recorded. Up to 6 tests were performed with each product, with 10 or 30 tubers per treatment.

RESULTS

Field tests

Conventional farming

Foliar applications: The results of the foliar application test are shown in Table 4. The combination of the use of artificially inoculated tubers and favorable weather conditions in 2011 generally caused high rates of primary stem blight. All three systemic fungicides caused a significant reduction in stem blight incidence as compared to the control. The reduction achieved by the use of a non-systemic fungicides was not significant.

Table 4. *Field test for the prevention of stem infection by foliar treatment in conventional farming. Incidence of stem infection. Different letters indicate significant differences according to a squared ranks test for variances*

treatment/ product	incidence of stem infection (%)
control	63a
Infinito	21b
Ridomil Gold MZ	20b
Ranman Proxanil Pack	15b
Fantic M	24b
Revus	33ab

Tuber treatments: The results of the tuber treatment trial are shown in Table 5. Again, incidence of stem infection was comparably high in all variants, due to the use of artificially infected tubers and suitable weather conditions in 2011. In this test, stem infection could be significantly reduced by the two contact or locally acting fungicides. The systemic fungicide could not reduce the incidence of stem infection, just as the seed dressing active against *Rhizoctonia*.

Table 5. *Field test for the prevention of stem infection by tuber treatment in conventional farming. Incidence of stem infection. Different letters indicate significant differences according to a squared ranks test for variances*

treatment/ product	incidence of stem infection (%)
control	41a
Cuprozin fl.	14b
Zetanil M	13b
Fantic M	31ab
Monceren	38a

Organic farming

Foliar applications: see another paper by the authors in this proceedings (Nechwatal & Zellner, 2013).

Tuber treatments: A field tests was performed in 2012 to test the influence of several alternative substances for use in organic farming for their ability to reduce stem blight. Application was done in autumn or in spring. However, although artificially infected seed tubers were used, incidence of stem blight was low in these trials. This was most likely due to relatively dry weather conditions during spring 2012. Therefore, no data on the effect of the seed dressing on stem infections are available. However, when the (secondary) leaf infection data as of August 2012 were considered, an effect of all treatments on the degree of leaf infections could be observed in one stand, and an effect of the spring copper treatment in the other (data not shown).

LABORATORY TESTS

Several alternative, copper-free products and substances for potential use in organic farming were applied to artificially infected tubers to evaluate their effect on the establishment of tuber infections and their ability to prevent/ reduce the amount of brown rot. Some of the products/ preparations were able to clearly reduce the number of successfully infected tubers and the amount of brown rot developing on the tubes after 6-8 weeks (Table 6). These effects were no-significant in most cases, due to the high variability of the data. Clove oil and a commercial mustard preparation proved to be the most effective, and are planned to be included in field tests in 2013.

Table 6. *Incidence and severity of brown rot in artificially infested tubers after application of alternative seed treatments. Tests consisted of 10 or 30 tubers per treatment. * denotes significant differences from the control at p ≤ 0.05 (Dunnett's Multiple Comparison Test)*

treatment/ product	dosage	no. of tests	mean percentage of brown rot per tuber (relative to control)	mean no. of successfully infected tubers (relative to control)
control	-	6	100%	100%
garlic product (AMN BioVit)	1%	5	128%	105%
copper (Cuprozin fl.)	16%	6	112%	105%
Pythium oligandrum (Polyversum)	7%	6	111%	92%
Aureobasidium pullulans (BoniProtect)	1%	3	102%	105%
44°C water (heat treatment)	-	3	102%	74%
Bacillus subtilis (Serenade)	1%	5	101%	90%
Brassica juncea powder (non-commercial)	10%	1	95%	103%
chitosan (ChitoPlant)	0.1%	5	83%	82%
knotweed product (Regalia)	0.25%	3	81%	83%
Na phosphonate (test product)	1%	6	75%	75%
clove oil (non-commercial)	1%	6	68%	65%
mustard powder product (Tillecur)	20%	4	41%	49%*

DISCUSSION

Early primary stem infections originating from infected seed tubers are the most important starting point for early and massive late blight epidemics in both conventional and organic potato production (Powelson *et al.*, 2002; Johnson, 2010; Zellner *et al.,* 2011; Wharton *et al.,* 2012). In contrast to any secondary infections originating from airborne sporangial inoculum these occur earlier in the season, making them particularly significant for the further development of the disease on a field scale (Zellner *et al.*, 2011).

In conventional farming foliage treatments are meant to directly affect the pathogen before or during its development in/ on the newly growing stems, and thus to directly reduce stem infections. Our results show that primary stem infections can be effectively prevented by an early foliar application of a systemic fungicide. Systemic fungicides are taken up into the tissue being distributed in the plant, and thus can reduce the growth of the pathogen from within the plant. In contrast, non-systemic or only locally systemic fungicides are not able to achieve this effect, as they cannot reach the pathogen growing in the stem or infecting the stem from below the soil line. The first application of a systemic fungicide to prevent the initiation of an epidemic ideally takes place approximately 1-2 weeks ahead of the first visible symptoms to reach optimum efficiency. Such optimum timing for the beginning of the first application can be determined approximately, when considering the regional infection pressure, weather data, and disease incidence in neighboring high risk areas (like river plains, depressed areas or other moist sites).

Seed treatments might be an additional way to reduce incidence of primary infections in conventional potato farming. They are meant both to reduce the risk of infection of the developing sprouts and to affect sporulation on the infected tuber in the soil. This will also provide protection of neighboring tubers within the potato hill. Our test has shown that in this case, contact or locally systemic fungicides are effective against primary stem blight, most likely by acting against *Phytophthora* propagules located on the tuber surface and in the surrounding soil. Systemic fungicides, in contrast, are not active on the tuber surface, as they are translocated quickly upwards the plant within the growing stems, and are therefore not optimized for an effect on the tuber surface or the surrounding soil.

In organic potato production, early primary infections are a key factor for development and economic significance of late blight disease, as they determine the onset of an epidemic and thus, have a strong influence on potato yield at harvest. Therefore, the time when an infection and an epidemic starts is even more important for organic farmers. As systemic fungicides are not available, copper currently is the only fungicide able to control late blight in organic farming (in Germany and other countries). Foliar treatments in this production type are rather considered a method to postpone the onset of a *Phytophthora* epidemic and to minimize the extent of leaf infections than to prevent the occurrence of primary stem infections itself. This will also minimize the deposition of sporangial inoculum on the soil surface and on the potato crop, and as such will reduce the extent of (latent) infection in the harvested tubers – an important prerequisite for the production of disease free seed tuber material.

As in conventional farming, seed treatments with copper or alternative products also can be part of a management strategy for late blight in organic production (Benker *et al.*, 2006; Wharton *et al.*, 2012). The effect of a seed treatment on secondary leaf infection that was found in our field test could not be unambiguously proven to be an effect of the tuber treatments on the incidence of primary stem blight, due to weather conditions unsuitable for the development of this type of symptom. However, it might still be considered as a retardation effect, the mechanism for which remains unclear. The different treatments might have caused a reduction of sporulation on the tubers, causing a decrease of sporangia present in the soil, and a later onset of massive leaf infections. Lab tests have shown that several alternative substances might have the potential to provide protection against primary stem blight when applied as a seed dressing. Further field tests to be carried out will show whether they are also effective under field conditions.

In both conventional and organic potato farming, the use of both leaf fungicides and seed treatments (seed dressing) might be able to achieve a further reduction and/ or retardation of a late blight epidemic and thus, might help to better control the disease and its impact on potato yield. In organic production, this strategy might further reduce the copper input and help to produce disease free seed tubers.

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REFERENCES

Benker M., M. Zellner, S. Wagner, 2006. Neue Ansätze zur Optimierung der Kraut- und Knollenfäulebekämpfung im ökologischen Kartoffelanbau. Gesunde Pflanzen 58, 18-27.

Johnson, D.A., 2010. Transmission of *Phytophthora infestans* from infected potato seed tubers to emerged shoots. Plant Disease 94, 18-23.

Keil S.B., M. Benker, M. Zellner, 2010. Double setting of potato seed tubers as a new approach to research primary stem blight (*Phytophthora infestans* (Mont.) de Bary). American Journal of Potato Research 87, 27-31.

Lobato M.C., F.P. Olivieri, E.A. González Altamiranda, E.A. Wolski, G.R. Daleo, D.O. Caldiz, A.B. Andreu, 2008. Phosphite compounds reduce disease severity in potato seed tubers and foliage. European Journal of Plant Pathology 122, 349-358.

Nechwatal J., M. Zellner, 2013. Evaluation of leaf treatment products to control late blight in organic potato production. Proceedings of the 14th Euroblight workshop in Limassol, Cyprus 12-15 May, 2013.

Powelson, M.L., R. Ludy, H. Partipilo, D.A. Inglis, B. Gundersen, M. Derie, 2002. Seed borne late blight of potato. Plant Health Progress Online, doi:10.1094/PHP-2002-0129-01-HM.

Wharton, P.S., W.W. Kirk, R.L. Schafer, P. Tumbalam, 2012. Evaluation of biological seed treatments in combination with management practices for the control of seed-borne late blight in potato. Biological Control 63, 326-332.

Zellner M., S. Keil, M. Benker, 2011. Latent infection rate of potato seed tubers with *Phytophthora infestans* (Mont.) De Bary – an underestimated problem. Journal of Cultivated Plants 63, 13-16.