Effect of suppressive composts and initial seed tuber infection on *Rhizoctonia Solani* in organic potato production

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Abstract

The suppressive effects of green yard composts to control *R. solani* in potatoes and the effect of initial infection of the seed tubers were tested in field trials under organic management at the University Kassel (Germany) in the years 2006-08 and at two farm sites in northern Germany in 2008. Compost directly applied at the seed tuber area at 5 t DM ha^{-1}, significantly reduced the infestation of harvested potatoes with black scurf and tuber malformations and plus dry core tubers by an average of 33% and 41%, respectively while marketable yields and tuber numbers were increased by 5 to 25%. The rate of initial black scurf infection of the seed tubers also affected tuber number, health and quality significantly. Compared to healthy seed tubers initial black scurf sclerotia infestation of 2-5 and >10 % of tuber surface lead in untreated plots to a decrease in marketable yields by 14-19 and 44-66 %, a increase of black scurf severity by 8-40 and 34-86 % and also increased amount of malformed and dry core tubers by 32-57 and 109-214 %.

Keywords: *Rhizoctonia solani,* organic potatoes, compost, initial seed tuber infection**.**

Introduction

As the *Rhizoctonia* pathogen is as well soil as seed tuber borne the primary means to reduce black scurf in potatoes are the use of healthy seed tubers and field hygiene. *Rhizoctonia*-infested seed tubers are of importance in disseminating the disease and adding to the pool of soil-borne inoculum (Jeger et al., 1996). While conventional seed tubers are usually treated with fungicides, in organic systems until now there exist no reliable measures for the control of seed borne inoculum. Especially the production of organic certified healthy seed tubers poses serious problems. Since the use of organic seed potatoes has become compulsory in organic potato production black scurf is increasing in importance. To reduce soil borne infection it is important to ensure good soil conditions with a high microbial activity with a high antagonistic potential. Soil organic matter greatly increases soil microbial activity and diversity which, in turn, are related to soil and seed borne disease suppression (Lumdsen et al., 1983; Fließbach & Mäder, 2000). Such organic matter could be supplied by high quality suppressive biogenic waste composts. Suppressiveness of composts is closely related to colonisation by disease suppressive micro-organisms during curing e.g. *Bacillus spp., Enterobacte spp., Flavobacterium balustinum 299, Pseudomonas spp*., and other bacterial genera and *Streptomyces spp*. as well as fungal species including *Penicillium spp, Gliocladium virens,* several *Trichoderma spp*. and others (Chung & Hoitink, 1990; Hoitink et al., 1996). Compost application leads to sustained increase in microbial activity and the establishment of microbial populations with antagonistic features (Hoitink & Boehm 1999) and promising results have been obtained with suppressive composts against several soil-borne pathogens. Tsror et al. (2001) and Lootsma (1997) already demonstrated that it might be possible to control R. solani with composts in practice. However, we have shown that good effects are generally dependent on the amount of applied compost material (Bruns & Schüler 2002). To reduce the total amount of compost needed, our study aimed at testing if the targeted application of limited amounts of compost near the seed tubers can reduce the total amount needed.

In this study, we conducted three field trials to test the effects of targeted compost application within the row during planting of potatoes on plant and tuber infection with *R. solani*. The following questions were addressed in this study: (i.) is it possible to achieve disease control with compost applications of only 5 t DM * ha^{-1} in field grown potatoes and can this be enhanced by application technology? (ii.) How effective are composts when used with tubers varying in initial black scurf infestation?

Materials and methods

Two-factorial field trials were performed as split-plot design with four replications (at the experimental farm of University of Kassel in Witzenhausen on a silty loam with 74 soil points (according to the German system scale 0-100) in the years 2006-2008. In 2008 the trial was conducted additionally at two On-Farm fields in Northern Germany, in Barnstedt on a sandy soil (25 soil points) and Sudwalde on a sandy loam soil (50 soil points).

Factor A: <u>Compost application vs. contol</u>. In all years, a 5 month old compost made of organic househould waste-/ yard waste (60/40), composted according to the requirements in EEC regulation No 2092/91 (Annex II) was used. Control plots without compost received an N,P,K –nutrient-equivalent to the household/yard waste compost nutrient load (Table 1). Composts were applied at 5t DM ha^{-1}, directly to the seed tuber area by using a modified fertiliser application machine (Universal Kastenstreuer, UKS 150, Rauch, Sinzheim

Table 1. Properties of composts used in the field trials

	2006	2007	2008
DM (%)	68.97	79.12	70.19
NO3-N mg * kg TM^{-1}	392.01	433.02	387.55
NH4-N mg * kg TM^{-1}	97.96	107.18	88.8
pH	7.65	7.65	7.73
P mg *kg DM^{-1}	2060	1700	1811
K mg *kg DM^{-1}	14400	12000	13578
N t (%)	1.81	1.71	1.48
C t (%)	20.97	17.69	20.43
C / N	11.57 :1	10.34 :1	13.82 :1

<u>Factor B: Infection severity of seed tubers.</u> Seed tubers (variety Nicola same seed source in the respective years) naturally infested with black scurf were planted of three infection severities ≤1%, 2-5% and high infection > 10% (not in 2008) of the seed tuber surface area.

Assessments

All assessments of symptoms of *Rhizoctonia solani* were performed according to the EPPO – standard PP 1/32 (2) (EPPO, 2000). Tuber symptoms were assessed on 100 marketable tubers per plot. Black scurf severity was assessed as mean percentage infestation of tuber surface. Percent incidence of tubers with dry core and malformations were also recorded. Marketable yield consisted of tubers of marketable size without malformations and dry core and with black scurf infestation of less than 15 %.

Data analysis

Statistical analysis was based on the SPSS GLM procedure (version 13). All data of *R. solani* symptoms were calculated in percentage values and arc sine transformed before analysing. The Kolmogorov-Smirnov test was conducted to analyse the normal distribution. Data were analysed by using fixed effect models per compost treatment, initial seed tuber infection and harvest date. Due to the split plot design the interaction between replication and compost treatment was used as random effect. The Bonferroni - Holm Test was conducted to separate means with a confidence level of 95 %.

Results and discussion

Both, initial infection and compost amendments significantly affected final infection levels of harvested tubers in all years and in 2008 at all sites (Tab. 2 and 3). Compost directly applied at the seed tuber area at 5 t*DM ha^{-1}, reduced the infestation of harvested potatoes with black scurf by a mean of 2 % or relatively by 33 % and the rate of tubers with deformations and dry core by 7.8% (relatively -41 %), on average, at final harvest (Tab. 2). Application of the household/yard waste compost increased marketable yields between 2.4 and 6.1 % t*ha^{-1} (average of + 4.1 t*ha^{-1} or + 20% (Tab. 3). Marketable yields were mainly increased, due to increased tuber numbers (+ 3.94*m$^{2\ -1}$) and less tubers with malformations and dry core symptoms (Tab. 2 and 3).

In terms of farmers' income this would mean an increase of the proceeds of up to 2000 /ha. Preliminary data on microbial activity indicate that the main impact of compost application is in the phase of potato emergence till end of flowering (Schulte-Geldermann et.al.2008). Probably, there is also a strong interaction between quality of organic matter of the composts and soil microbial life. However, these measurements were just on quantities and not on qualitative microbial activity; therefore it is not clear if the reduction of *R. solani* was caused by specific antagonism or due to the higher microbial activity. Nevertheless, the results confirm several studies that documented the suppressive effect of high quality compost amendments against soil borne diseases like *Rhizoctonia, Pythium* and *Fusarium* in potting mixtures and under field conditions (Hoitink & Fahy, 1986; Termorshuizen et al., 2006; Hoitink et al., 1996; Bruns & Schüler, 2002; Tsror et al., 2001). However, compost application amount in organic agriculture is limited at 5t DM ha^{-1} year^{-1} and the studies reporting successes in suppressive effects relatively high amounts of compost were used. By that reason effectiveness of compost application placements targeted close to the seed tubers was compared with broadcast application in 2006 (data not shown). The targeted application (ridge) of compost was considerably superior in reduction of *R. solani* symptoms especially in the amount of tuber malformations (Schulte-Geldermann, 2008). Therefore, there is a need to develop a targeted application system to achieve reliable control of *R. solani* with the limited compost amount of 5t DM ha^{-1}.

Table 2. Impact of initial seed tuber infection and compost treatment on the R.solani symptoms black scurf infestation , dry core and malformed tubers of harvest tuber in three consecutive years (2006-2008) at the research station Eichenberg and at two On-Farm sites in Northern Germany (Barnstedt and Sudwalde) in 2008

Year	Site / soil type	Initial seed tuber infection	Mean black scurf infestation (% of tuber surface)			Dry core and malformations (% of tubers)		
			Compost	Control	*P • 0.05*	Compost	Control	*P • 0.05*
2006	Eichenberg / silty loam	•1 %	3.36	5.95	*a*	7.75	15.75	*a*
		2 -5 %	5.8	8.51	*b*	14.75	20.75	*b*
		> 10%	6.57	10.43	*b*	14.75	32.25	*b*
		P • 0.05	*a*	*b*		*a*	*b*	
2007	Eichenberg / silty loam	•1 %	1.4	2.72	*a*	5.74	9.86	*a*
		2 -5 %	2.61	3.82	*b*	9.36	13.57	*a*
		> 10%	3.28	5.05	*c*	13.79	20.47	*b*
		P • 0.05	*a*	*b*		*a*	*b*	
2008	Barnstedt / sandy	•1 %	0.93	2.28	*a*	5.27	10.48	*a*
		2 -5 %	4.38	5.63	*b*	10.46	19.27	*b*
		P • 0.05	*a*	*b*		*a*	*b*	
	Sudwalde / sandy loam	•1 %	5.70	7.60	*a*	13.82	21.06	*a*
		2 -5 %	7.11	9.85	*b*	18.77	26.73	*b*
		P • 0.05	*a*	*b*		*a*	*b*	
	Eichenberg / silty loam	•1 %	1.37	3.13	*a*	5.71	14.58	*a*
		2 -5 %	5.16	6.59	*b*	11.24	19.73	*b*
		P • 0.05	*a*	*b*		*a*	*b*	

*** Different letters indicate significant differences: vertically between different initial seed tuber infection severities and horizontally between compost treatment and control, respectively.**

The effect of initial seed tuber infection on yield and disease was clearly demonstrated in our trials. Compared to relatively healthy seed tubers (≤1 % infestation of tuber surface) initial black scurf sclerotia infestation of 2-5 and >10 % of tuber surface in untreated plots lead to a decrease in marketable yields by 14-19 and 44-66 % as well as tuber numbers by 3-14 and 7-24% , an increase of black scurf severity by 8-40 and 34-86 %, respectively. Also the amount of malformed and dry core affected tubers was increased by 32-57 and 109-214 %, respectively.

Similar results of the impact of seed tuber health were also investigated by Karalus et al. (2003) underlines the importance of using healthy seed tubers particularly in organic potato production because of the lack of reliable control measures of seed borne inoculum. Especially the production of organic certified healthy seed tubers poses serious problems. Since the use of organic seed potatoes has become compulsory in organic potato production black scurf is increasing in importance.

In 2008 the On-Farm site Sudwalde showed significant higher *R. solani* infection levels than the two other sites. This was mainly due to due to waterlogging and a high amount of fresh straw residues at that site, most probably releasing high concentrations of free nutrients (glucose) which represses enzymes produced by *Trichoderma spp*. required for parasitism and eradication of sclerotia of plant pathogens such as *R. solani* (Nelson et al, 1983, Hoitink and Boehm, 1999)

Table 3. Impact of initial seed tuber infection and compost treatment on the marketable yield (30-60mm, - black scurf >15% , - malformed and dry core tubers) and tuber number per area (m2) of harvest tuber in three consecutive years (2006-2008) at the research station Eichenberg and at two On-Farm sites in Northern Germany (Barnstedt and Sudwalde) in 2008

Year	Site / soil type	Initial seed tuber infection	Marketable yield ($t*ha^{-1}$)			Tuber no.*m^{-2}		
			Compost	Control	*P • 0.05*	Compost	Control	*P • 0.05*
2006	Eichenberg / silty loam	•1 %	25.26	21.55	*a*	56.86	51.93	*a*
		2 -5 %	22.72	18.59	*b*	54.64	49.99	*b*
		> 10%	20.34	14.33	*c*	51.64	48.08	*c*
		P • 0.05	*a*	*b*		*a*	*b*	
2007	Eichenberg / silty loam	•1 %	20.88	16.8	*a*	40.60	36.61	*a*
		2 -5 %	16.45	14.05	*b*	35.57	31.51	*b*
		> 10%	13.94	11.44	*c*	30.72	27.87	*c*
		P • 0.05	*a*	*b*		*a*	*b*	
2008	Barnstedt / sandy	•1 %	28.38	25.85	*a*	53.41	49.33	*a*
		2 -5 %	25.94	21.44	*b*	51.45	47.18	*b*
		P • 0.05	*a*	*b*		*a*	*b*	
	Sudwalde / sandy loam	•1 %	31.02	25.13	*a*	60.74 a	53.44 b	
		2 -5 %	25.97	20.51	*b*	53.42 b	51.39 c	
		P • 0.05	*a*	*b*				
	Eichenberg / silty loam	•1 %	31.36	27.32	*a*	53.90	51.92	*a*
		2 -5 %	26.67	21.86	*b*	49.67	46.14	*b*
		P • 0.05	*a*	*b*		*a*	*b*	

* Different letters indicate significant differences: vertically between different initial seed tuber infection severities and horizontally between compost treatment and control, respectively.

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