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Development of *Rhizoctonia solani on* Stems, Stolons and Tubers of Potatoes I. Effect of Inoculum Source

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Abstract *Rhizoctonia solani* may affect potato growth, yield and grade through lesions on stems and stolons and through development of black scurf on daughter tubers. *R. solani* inoculum can be found on seed potatoes and in the soil, although the relative importance of each inoculum source is unknown. Field studies at Parma and Aberdeen, Idaho, were conducted in 2004 and 2005 to evaluate the importance of each source of inoculum on the subsequent development of this disease. Seed of cultivars Ranger Russet (2004) and Russet Burbank (2005) was washed and sorted into three (2004) and two (2005) levels of black scurf. Prior to planting, the plots were inoculated with *R. solani* cultures mixed with vermiculite at low, medium and high rates. Each level of seed inoculum was planted at each level of soil inoculum. Significantly greater levels of disease on stems and stolons was consistently found on plants grown from high inoculum seed compared to low inoculum seed. However, significant effects of soil inoculum level on stem and stolon disease were rarely seen. In contrast, both seed and soil inoculum level influenced the development of black scurf on daughter tubers. The largest response to soil inoculum level was seen when seed inoculum was low.

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Resumen *Rhizoctonia solani* puede afectar el crecimiento de la papa, el rendimiento y calidad a través de lesiones en tallos y estolones y por el desarrollo de costras negras en los tubérculos producidos. El inoculo de *R. solani* se puede encontrar en tubérculo semilla y en el suelo, aunque se desconoce la relativa importancia de cada fuente de inoculo. Durante 2004 y 2005 se condujeron estudios de campo en Parma y Aberdeen, Idaho, para evaluar la importancia de cada fuente de inoculo en el desarrollo subsecuente de esta enfermedad. A semilla de los cultivares Ranger Russet (2004) y Russet Burbank (2005) se les lavó y agrupó en tres (2004) y dos (2005) niveles de costra negra. Antes de plantar, los lotes se inocularon con cultivos de *R. solani* mezclados con vermiculita a niveles bajo, medio y alto. Cada nivel de inoculo a la semilla se plantó en cada uno de los niveles de inoculo al suelo. Se encontraron consistentemente niveles significativamente mayores de enfermedad en tallos y estolones de plantas que crecieron en altos niveles de inoculo en la semilla comparados con los de niveles bajos. No obstante, raramente se vieron los efectos significativos de los niveles de inoculo en el suelo sobre la enfermedad en tallo y estolón. En contraste, ambos niveles de inoculo en semilla y suelo, influenciaron el desarrollo de la costra negra en los tubérculos generados. La mayor respuesta al nivel de inoculo en el suelo se observó cuando el nivel de inoculo a la semilla era bajo.

Keywords Rhizoctonia solani · Inoculum source · Black scurf

Introduction

Rhizoctonia solani Kuhn infects all below ground portions of the potato plant (stems, stolons, roots and tubers). Lesions develop on these tissues and, when severe, cause

girdling of sprouts, stems and stolons and reduce stem number, tuber set and root mass (Rich 1983). Sprout girdling may result in delayed emergence and delayed tuber bulking (Banville 1989, Carling et al. 1989; Hide et al. 1989). As stolons are pruned and tuber set is reduced, there are fewer tubers per plant to act as sinks for products of photosynthesis. This can lead to uneven tuber growth, thereby increasing yields of off-grade tubers (Simons and Gilligan 1997). The fungus may also form brown to black sclerotia on the surfaces of mature tubers, a symptom that is commonly referred to as black scurf. It has been suggested that the most economically damaging aspect of this disease is not due to yield loss; rather, money is lost due to a shift in the tuber size profile and loss of quality due to black scurf, particularly for fresh market potatoes (Strand 2006).

Infested soil and/or infected seed tubers provide inoculum for disease development. However, previous research has not identified the most significant source of inoculum. Some studies have shown that seed inoculum is more important in disease development (Banville 1989; Davis 1977; Hide et al. 1973; VanEmden 1965); while other studies have shown that soil inoculum is more important (James and McKenzie 1972; Sanford 1937). Additional research has concluded that total inoculum load from all sources is important to disease development and the relative importance of each source cannot be separated out (Bolkan et al. 1974; Frank and Leach 1980; Tsror and Perentz-Alon 2005). Frank and Leach (1980) theorized that seed-borne inoculum might be more important in the early stages of plant development because as sprouts emerge from the tuber the pathogen is located where immediate infection can occur. In contrast, as stolons grow through the soil and away from the seed piece inoculum, the inoculum in soil may become the primary source of infection of the stolon tips. Their theory supports the idea of seed-borne inoculum being the most important source of stem infection, with soil-borne inoculum playing a companion role in stolon infection.

While acknowledging that both inoculum sources can contribute to *R. solani* infection, one of the sources, either seed or soil, is likely to be a more significant source of inoculum. The objective of this study was to evaluate the importance of seed-borne versus soil-borne inoculum on the subsequent development of *R. solani* in the potato growing regions of Southern Idaho.

Materials and Methods

2004 Growing Season

Field trials were conducted at two locations, Parma and Aberdeen, Idaho. In Parma, the trial was conducted on a Greenleaf silt loam soil with a pH of 7.8 and 1.7% organic matter. The Aberdeen soil type was a Declo loam with a pH of 8.1 and 1.3% organic matter. Both locations were spring fumigated with Telone C-35 (63% dichloropropene + 35% chloropicrin), at 187 L product ha^{-1}, in an attempt to reduce the level of soil borne *R. solani* to a negligible level. This fumigant was chosen because chloropicrin has shown very strong fungicidal activity (Duniway 2002). The Parma site was fumigated on 23 March and the Aberdeen site on 7 April.

Soil inoculum was prepared by growing an isolate of *R. solani* recovered from a potato stem lesion on potato dextrose agar (PDA) in 160 mm diameter petri plates. One hundred sixty *R. solani* cultures containing agar and mycelia fragments were blended with 4000 ml of water into a slurry and mixed with 22 L of vermiculite to create the soil inoculum.

Soil was inoculated 1 to 3 days prior to planting by pulling a 150 mm wide shovel through the center of the pre-made potato rows where the seed pieces would be planted. This left a furrow 100 to150 mm deep where 0, 16 and 32 ml of inoculum per seed piece was placed and covered by hand for the low, medium and high rates, respectively.

Soil moisture at both locations was less than desired because of a very dry spring. The available soil moisture (ASM) at the site of inoculation was 20–30% in Parma and 40–60% ASM in Aberdeen.

Ranger Russet seed was washed and sorted into three inoculum levels by amount of black scurf (visible *R. solani* sclerotia) present on the surface of the tuber in late November of 2003, before the eyes sprouted. The targeted divisions of seed inoculum included low (seed with no visible sclerotia), medium (10% to 15% of the tuber surface covered with sclerotia—mean of 12%), and high (>16% of the tuber surface with sclerotia—mean of 18%) levels. The low inoculum seed was treated in a 1.85% formaldehyde dip for 2 min to kill any unseen mycelial fragments associated with the eyes of the tuber (Carling et al. 1989). The whole seed tubers were hand cut into 70 g seed pieces 1 week prior to planting in rows 0.914 m apart with 25 cm between plants. Planting dates were 14 April in Parma and 5 May in Aberdeen. Plots were four rows wide and 7.6 m long arranged in a complete randomized block design (RCBD) with four replications.

Whole plant samples were taken from the center plot rows 45 and 60 days after planting (DAP). Five consecutive plants were excavated and evaluated for stem and stolon disease levels. *Rhizoctonia* stem canker disease severity was visually rated as an average of all stems from each plant using the following scale:

0 = No disease
1 = Less than 10% of stem area covered with lesions

2 = 10–25% of stem area covered with lesions
3 = 26–50% of stem area covered with lesions
4 = Stem girdled with lesions

Stolon disease severity was also visually rated as an average of all stolons from each plant and utilized a similar scale:

0 = No disease
1 = 1 or 2 stolons with lesions
2 = 1 or 2 stolons girdled
3 = 3 stolons girdled
4 = 4 or more stolons girdled

A disease index (DI) for both stems and stolons was calculated by the following formula.

$$DI = \frac{(n_1 \times 1) + (n_2 \times 2) + (n_3 \times 3) + (n_4 \times 4)}{Y \times 4} \times 100$$

Where n_x = number of stems or stolons in the x severity class and Y = total number of stems or stolons

The maximum DI would be 100 if all of the stems or stolons were girdled.

Six soil core samples, 25 mm diameter by 305 mm deep, were collected from the middle of each plot in Parma on 14 July in an effort to determine the level of *Rhizoctonia* soil inoculum in each treatment. These samples were analyzed by plating soil pellets on prochloraz amended Ko and Hora's media according to the method of Castro et al. (1988).

Tubers from the center two rows of each plot were harvested on 12 October in Parma and 20 October in Aberdeen. Ninety days after harvest, 30 randomly selected tubers per plot were visually rated after hand-washing to estimate the amount of tuber surface covered with black scurf, using the following scale:

0 No visible black scurf
1 1 to 5% covered
2 6 to 10% covered
3 11 to 25% covered
4 26 to 50% covered
5 51 to 75% covered
6 76 – 100% covered

The black scurf index was calculated as an average score of all tubers evaluated, therefore the maximum disease index if all tubers were more than 75% covered with black scurf would be 6.0.

2005 Growing Season

This trial was planted in Parma only and was fumigated on 30 November 2004, with Telone C-17 (81% dichloropropene + 17% chloropicrin) at 374 L of product per ha^{-1}. This rate provided the same amount of chloropicrin as the Telone C-35 treatment used in the 2004 experiments. The soil type was a Greenleaf silt loam with a pH of 8.5 and 1.2% organic matter.

The protocol for preparation and culture of the inoculum was the same as in 2004 with some noted differences. Non-replicated greenhouse work conducted in the winter of 2004–2005 suggested that inoculum levels needed to be higher than what was added to the soil in 2004 to better detect differences in disease among soil inoculum treatments. The rates of inoculum were adjusted to 0, 30 and 90 ml per seed piece for the low, medium and high rates, respectively. Samples of the slurry were examined and mycelial fragments were counted using a hemocytometer. Inoculum densities of approximately 6.0×10^4 and 1.8×10^5 mycelial fragments per seed piece were added with 30 and 90 ml of inoculum.

Soil moisture conditions at the time of inoculation were also too dry in 2004, so changes in the inoculation procedure were made. A fertilizer-banding machine was used to inoculate plots. This method did not disturb the potato row as much as the 2004 method, thereby reducing soil moisture loss. The inoculum was banded behind an injection shank at 150–200 mm deep into soil with >75% ASM. Inoculation took place 25 March and potato seed pieces were planted on 1 April.

The same seed inoculum sorting procedure used in 2004 was followed with the following exceptions. Russet Burbank seed was used instead of Ranger Russet. Only 2 levels of seed inoculum, low (seed with no visible sclerotia) and high (10 to 15% of the tuber surface covered with sclerotia—mean of 12%) were planted because the medium level in 2004 performed similarly to the high level.

The experimental design was changed from the RCBD used in 2004 to a split-split plot design with four replications, with level of soil inoculum as the main plot, and the level of seed inoculum as the sub-plot.

Whole plant samples were again taken 45 and 60 DAP and the same disease evaluation procedures as in 2004 were used. Tubers in the center two rows of each plot were harvested on 7 September and then visually rated for black scurf after storage using the same scale as in 2004.

Statistical Analysis

Data from 2004 and 2005 were analyzed separately using the analysis of variance procedure in the SAS program (SAS Institute 2004). Treatment means for main effects and interactions were separated by Fischer's Least Significant Difference test when the analysis of variance indicated significance at the $p<0.05$ level.

Results

2004 Growing Season

Stem Disease Index

Plants grown from seed with medium to high levels of *R. solani* inoculum had a significantly higher stem disease index compared to low inoculum seed in Aberdeen at both 45 and 60 DAP (Table 1). The stem disease rating of the medium seed inoculum level was also significantly less than the high inoculum level at 45 DAP, but not at 60 DAP. Seed inoculum level had no effect on stem disease index in Parma at either 45 or 60 DAP (Table 2).

Plants grown in soil with the high level of inoculum had significantly higher stem disease index than low to medium soil inoculum in Aberdeen at 60 DAP (Table 1). However, soil inoculum level did not significantly affect stem disease ratings on either evaluation date at Parma (Table 2). The only significant interaction between seed and soil inoculum was on stem disease ratings in Aberdeen at 60 DAP (Table 1). Low and medium inoculum seed showed a large response to soil inoculum level, while the high seed inoculum level was less affected by soil inoculum level (Fig. 1).

Stolon Disease Index

Stolon disease index was significantly higher at medium and high seed inoculum levels compared to low inoculum at Aberdeen on both evaluation dates (Table 1). This was also true in Parma at 45 DAP, but not at 60 DAP (Table 2).

Soil inoculum only affected stolon disease index at 45 DAP in Aberdeen, with high inoculum level having a higher disease index than medium or low soil inoculum (Table 1). Soil inoculum level had no impact on stolon disease index on either evaluation date at Parma (Table 2). There were also no significant interactions between seed and soil inoculum on stolon disease index ratings.

Black Scurf

Black scurf disease index and the percentage of non-infected tubers (black scurf free) were significantly affected by both seed and soil inoculum in Aberdeen, but not at

Table 1 The effect of seed and soil-borne inoculum level on *R. solani* stem and stolon disease index (DI) ratings of Ranger Russet potatoes at 45 and 60 days after planting (DAP) at Aberdeen, ID in 2004

Main effects	45 DAP		60 DAP	
	Stem DI	Stolon DI	Stem DI	Stolon DI
Seed				
Low	25.7 C[a]	9.5 B	28.5 B	6.7 B
Medium	35.9 B	15.0 A	39.3 A	11.9 A
High	43.1 A	18.7 A	40.9 A	13.3 A
LSD (0.05)	5.8	4.0	6.6	3.5
Soil				
Low	29.5	10.5 B	30.3 B	9.3
Medium	36.2	13.5 B	33.3 B	10.3
High	39.0	19.2 A	45.0 A	12.2
LSD (0.05)	NS	4.0	6.6	NS
	P values ($P > F$)			
Seed	<0.0001	<0.0001	0.0005	0.0007
Soil	0.0054	0.0002	<0.0001	0.2637
Seed*Soil	0.3958	0.5646	0.0469	0.6949

[a] Main effect means with different letters are significantly different at the $p<0.05$ level

Table 2 The effect of seed and soil-borne inoculum level on *R. solani* stem and stolon disease index (DI) ratings of Ranger Russet potatoes at 45 and 60 days after planting (DAP) at Parma, ID in 2004

Main effects	45 DAP		60 DAP	
	Stem DI	Stolon DI	Stem DI	Stolon DI
Seed				
Low	47.3	13.3 B[a]	48.4	39.4
Medium	51.7	18.7 A	53.8	47.6
High	52.3	18.1 A	51.1	45.9
LSD (0.05)	NS	3.7	NS	NS
Soil				
Low	48.5	15.9	45.9	39.6
Medium	49.0	15.1	52.0	44.9
High	57.0	19.2	55.4	48.4
LSD (0.05)	NS	NS	NS	NS
	P values ($P > F$)			
Seed	0.3923	0.0096	0.4010	0.1230
Soil	0.3864	0.0893	0.0547	0.1208
Seed*Soil	0.2111	0.1768	0.4170	0.3400

[a] Main effect means with different letters are significantly different at the $p<0.05$ level

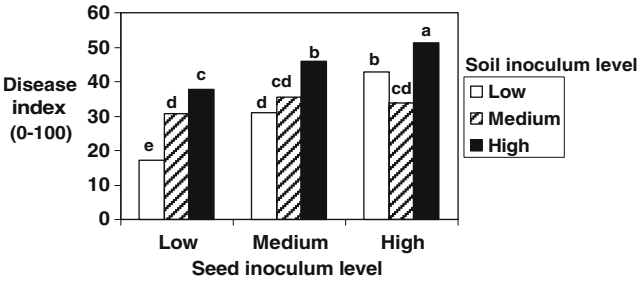

Fig. 1 The effect of seed and soil inoculum level on *R. solani* stem disease index ratings of Ranger Russet potatoes 60 days after planting at Aberdeen, ID in 2004. *Letters* indicate mean separations by Fischer's Protected LSD at $P<0.05$ level

Parma (Table 3). At Aberdeen, daughter tubers from the high inoculum seed treatment had higher disease index and fewer non-infected tubers than those from low inoculum seed. Likewise, daughter tubers from the medium and high soil inoculum treatments had higher black scurf disease index and fewer non-infected tubers than those from low inoculum soil.

There was a significant interaction between seed and soil inoculum for black scurf ratings and percentage of non-infected tubers at Aberdeen (Table 3). Black scurf ratings of daughter tubers from the low seed inoculum treatment showed a large response to soil inoculum level, while tubers from the medium and high inoculum seed treatments were less affected by soil inoculum level (Fig. 2). Results for the percentage of non-infected tubers were very similar to those for black scurf ratings (Fig. 3).

Soil Inoculum Assay

Soil cores assayed for *R. solani* inoculum levels at midseason by plating on selective media did not provide usable information due to contamination with non-rhizoctonia fungal contaminants (data not shown).

2005 Growing Season

Stem Disease Index

Seed inoculum level had a significant effect on stem disease index on both sampling dates, with plants from high inoculum seed having higher disease index than low inoculum (Table 4). In contrast, soil inoculum level did not significantly affect stem disease index on either evaluation date, and there were no significant seed inoculum by soil inoculum interactions.

Stolon Disease Index

Seed inoculum had no effect on stolon disease index at 45 DAP, while at 60 DAP plants grown from high inoculum seed had significantly higher stolon disease index than plants from low inoculum seed (Table 4). Soil inoculum did not affect stolon disease index on either evaluation date. There was a significant seed and soil inoculum interaction on stolon disease ratings at 60 DAP (Table 4). The combination of high seed inoculum with high soil inoculum produced higher stolon disease index than all other treatments (Fig. 4).

Black Scurf

Both seed and soil inoculum levels significantly affected black scurf index and percentage of non-infected tubers (Table 5). Daughter tubers from the high inoculum seed treatment had higher disease index and fewer non-infected tubers than those from low inoculum seed. Likewise, daughter tubers from the high soil inoculum treatment had higher black scurf disease index and fewer non-infected tubers than those from medium and low inoculum soil.

There was also a significant interaction between the level of seed inoculum and the level of soil inoculum (Table 5). Black scurf ratings of daughter tubers from the low seed inoculum treatment showed a large response to soil inoculum level, while tubers from the high inoculum seed

Table 3 The effect of seed and soil-borne inoculum level on *R. solani* black scurf disease index rating and percentage non-infected tubers (black scurf free) of Ranger Russet potatoes at Aberdeen and Parma, ID in 2004

Main effects	Aberdeen		Parma	
	Disease index	% Non-infected tubers	Disease index	% Non-infected tubers
Seed				
Low	0.4 C[a]	75.6 A	0.8	44.1
Medium	0.6 B	63.4 B	0.6	50.8
High	0.7 A	58.5 B	0.7	45.3
LSD (0.05)	0.1	6.1	NS	NS
Soil				
Low	0.4 B	75.6 A	0.6	53.3
Medium	0.6 A	61.5 B	0.7	44.7
High	0.6 A	60.3 B	0.8	42.2
LSD (0.05)	0.1	6.1	NS	NS
	P values ($P > F$)			
Seed	<0.0001	<0.0001	0.1067	0.3291
Soil	<0.0001	<0.0001	0.0844	0.0570
Seed*Soil	0.0158	0.0303	0.7057	0.5008

[a] Main effect means with different letters are significantly different at the $p<0.05$ level

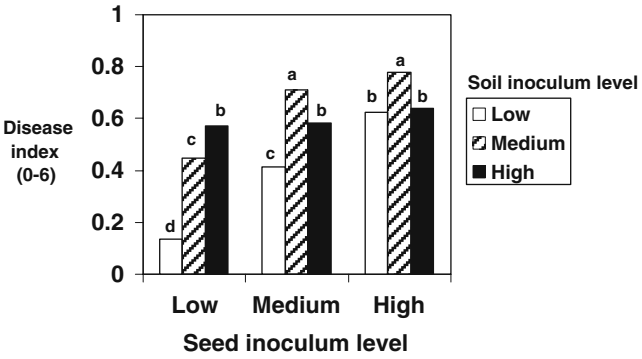

Fig. 2 The effect of seed and soil inoculum level on black scurf disease index ratings of Ranger Russet tubers from Aberdeen, ID in 2004. *Letters* indicate mean separations by Fischer's Protected LSD at $P<0.05$ level

treatments were less affected by soil inoculum level (Fig. 5).

Discussion

High levels of *R. solani* inoculum on seed (greater than 12% of surface covered with sclerotia) was associated with a significantly higher incidence and severity of disease on stems and stolons compared to clean seed (no visible sclerotia) in 8 of the 12 evaluations in this study. In 2004, these effects were more pronounced in Aberdeen than in Parma. In Parma the potato seed was planted into very dry soil and irrigated prior to emergence, which may have increased disease pressure, making it difficult to detect significant differences among treatments. Soil moisture was higher at planting in Aberdeen in 2004 and Parma in 2005, where the effects of seed inoculum level on disease development were consistently seen. These results would agree with Brenchley and Wilcox (1979) who reported that stem canker was more prevalent in dry soils.

The importance of seed-borne inoculum in determining the severity of *Rhizoctonia* stem canker has previously been reported (Hide and Cayley 1982; Platt 1989; Sanford 1937; Small 1943). Our results indicate that seed inoculum levels of 12% of the tuber surface covered with black scurf are enough to consistently increase disease incidence and severity. Simons and Gilligan (1997) also found a similar relationship between seed inoculum level and the incidence of stem canker. In contrast, other authors have reported no influence of seed tuber inoculum levels of less than 15% to

Table 4 The effect of seed and soil-borne inoculum level on *R. solani* stem and stolon disease index ratings Russet Burbank potatoes at 45 and 60 days after planting (DAP) at Parma, ID in 2005

Main Effects	45 DAP		60 DAP	
	Stem DI	Stolon DI	Stem DI	Stolon DI
Seed				
Low	22.5 A[a]	2.9	28.2 A	15.1 A
High	26.8 B	2.6	35.4 B	20.2 B
LSD (0.05)	4.2	NS	4.8	3.9
Soil				
Low	24.8	1.6	32.5	17.6
Medium	23.6	3.8	27.4	15.8
High	25.5	2.8	35.3	19.4
LSD (0.05)	NS	NS	NS	NS
	P values ($P > F$)			
Seed	0.0439	0.7291	0.0032	0.0017
Soil	0.9174	0.1146	0.0518	0.2922
Seed*Soil	0.2102	0.9335	0.2867	0.0218

[a] Main effect means with different letters are significantly different at the $p<0.05$ level

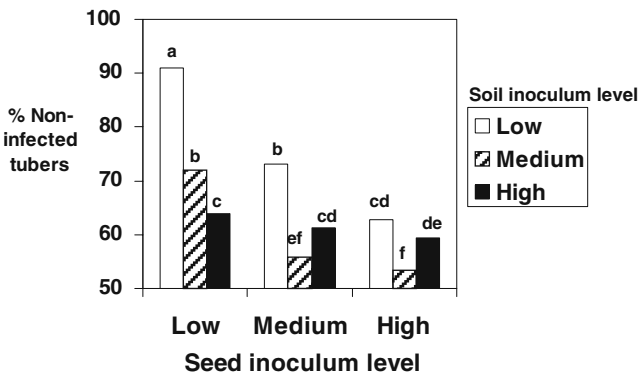

Fig. 3 The effect of seed and soil inoculum level on the percentage of non-infected (black scurf free) Ranger Russet tubers at Aberdeen, ID in 2004. *Letters* indicate mean separations by Fischer's Protected LSD at $P<0.05$ level

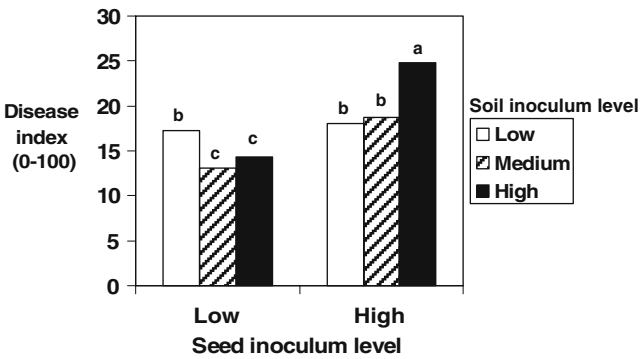

Fig. 4 The effect of seed and soil inoculum level on *R. solani* stolon disease index ratings of Russet Burbank 60 days after planting at Parma, ID in 2005. *Letters* indicate mean separations by Fischer's Protected LSD at $P<0.05$ level

Table 5 The effect of seed and soil-borne *R. solani* inoculum level on black scurf disease index ratings and percent of non-infected tubers (black scurf free) of Russet Burbank potatoes at Parma, ID in 2005

Main effects	Disease index	% Non-infected tubers
Seed		
Low	0.2 B[a]	79.8 A
High	0.5 A	62.1 B
LSD (0.05)	0.1	7.4
Soil		
Low	0.3 B	83.0 A
Medium	0.3 B	74.2 A
High	0.5 A	62.1 B
LSD (0.05)	0.1	9.0
	P values ($P > F$)	
Seed	<0.0001	0.0009
Soil	<0.0001	0.0002
Seed*Soil	0.0053	0.4438

[a] Main effect means with different letters are significantly different at the $p<0.05$ level

20% on disease development (Gudmestad et al. 1979, James and McKenzie 1972).

Research on the effects of *R. solani* inoculum on stolon canker is limited compared to that on stem canker. Effects on stolons are usually reported as effects on tuber number and yield, not as severity of disease. High seed inoculum levels were associated with high stolon disease severity in both years of our study, which could increase the number of stolons that are completely girdled. Atkinson (2005) reported that increased stolon infection was occasionally related to a reduction in tuber numbers.

The effects of soil-borne *R. solani* inoculum on disease development have not been as well studied as seed-borne inoculum. Visually quantifying black scurf levels on a seed tuber is much easier than conducting a soil assay and counting *R. solani* colonies on a selective media, which may explain why fewer studies have been conducted on soil-borne inoculum. Our attempts to quantify the level of *R. solani* in soil following inoculation proved unsuccessful. However, we did find that our soil inoculation technique consistently affected black scurf incidence on daughter tubers at both locations. In contrast, our results indicated that soil inoculum only occasionally played a significant role in stem and stolon disease incidence. Previous studies have shown that disease incidence increases with increasing soil inoculum level and potato cropping frequency (Banville 1989; Hide and Read 1991; Gilligan et al. 1996). Gilligan et al. (1996) showed that when following a susceptible rotation crop 70% to 80% of potato plants could become infected from soil-borne inoculum. Leach et al. (1993) reported that differences in soil inoculum level as small as 2 propagules per 100 g soil were enough to explain differences in stem disease ratings between moldboard and chisel plow treatments.

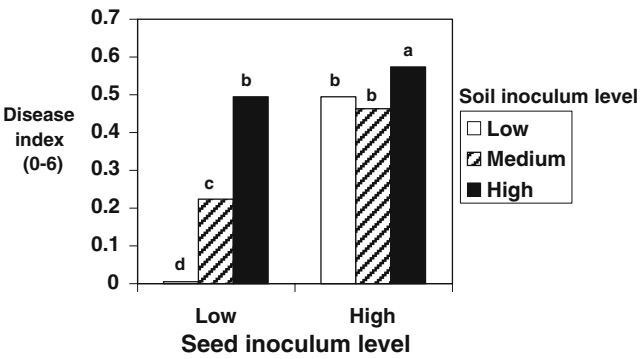

Fig. 5 The effect of seed and soil inoculum level on black scurf disease index ratings of Russet Burbank tubers at Parma, ID in 2005. *Letters* indicate mean separations by Fischer's Protected LSD at $P<0.05$ level

It has been noted that Rhizoctonia disease severity is a function of host susceptibility, inoculum level, and climate and that the effects of this pathogen on potato are inconsistent (Platt 1989). Gilligan et al. (1996) also noted a high degree of variability in results between 2 years of study. This idea of factors other than inoculum playing key roles in disease development helps explain the differences observed in the present study between locations as well as differences between years. However, the fact that high seed inoculum level was consistently linked to an increase in stem and stolon disease incidence and severity in this trial, while soil-borne inoculum was not, demonstrates the primary importance of seed-borne inoculum on the development of these stages of the disease in southern Idaho.

In contrast, both seed and soil-borne inoculum appeared to play a role in the incidence and severity of black scurf on daughter tubers. Our results showed that the largest response to soil inoculum level was seen when seed inoculum was low. Previous research has shown that level of seed inoculum is closely related to the level of black scurf on progeny tubers (Banville 1989). Tsror and Perentz-Alon (2005) found that inoculum from either seed or soil increased the severity of black scurf. They reported that the effect of seed and soil inoculum was additive, indicating that total inoculum load is important.

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