Effects of Selected Biocontrol Agents and a Fungicide on Internal Discoloration of Horseradish Roots

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Introduction

Internal discoloration of horseradish is disease complex caused by *Verticillium dahliae* and *V. longisporum,* and *Fusarium* species. At present, there is no method available to provide adequate control of this disease. The objective of this study was to evaluate the effectiveness of selected fungicides and biocontrol agents on controlling the internal discoloration of horseradish roots.

Materials and Methods

A field trial was conducted at a commercial field near Collinsville, Illinois. The field had a long history of internal discoloration of horseradish root. Two horseradish cultivars, 1573 and K-15, were used in this study. Cultivar 1573 is a susceptible horseradish to internal root discoloration, and K-15 is a tissue culture-generated cultivar. The roots used in this study had no visual symptoms of the discoloration complex. Roots (0.4- to 0.5-inch in diameter) were selected, washed with tap water, and cut into 6-inch segments (sets). One fungicide and four biocontrol agents (Table 1) were applied onto the sets on 17 May. Untreated control sets were included.

***Set-treatment with fungicide*.** Two liters of tap water was poured into a 2-gallon zip-lock plastic bag and 0.2 ml of fungicide Maxim 4FS was added to water in the bag and mixed. The sets were added to the bag and shaken for 5 min. Treated sets were drained and dried in an exhaust hood.

***Set-treatment with biocontrol agents*.** Four biological agents (Table 1) were used. The sets were dipped in tap water, and then placed in 2-gallon zip-lock plastic bag containing the biological agent. The bag was gently shaken for 30 seconds. The sets were thoroughly covered with the agent. Treated sets were dried in the exhaust hood.

Field was plowed on 19 May, and the sets were planted on 20 May. Sets were planted 24-inch apart within the rows spaced 36-inch apart. Each plot consisted of two 20-foot rows. A total of 20 sets were planted in each plot. The plots were arranged in a split-plot design, cultivar being as the main plot and treatments as sub-plots. The treatments were randomly arranged in each plot. Each treatment was replicated three times.

During the season, weeds were controlled by cultivation and hand weeding. The field was not irrigated. Precipitation and temperature in the field were not recorded. Therefore, the data from the Belleville weather station, the nearest weather station to the experimental field, are presented. Precipitation was 10 days (5.68 in.) in May, 7 days (1.54 in.) in June, 6 days (3.44 in.) in July, 8 days (3.12 in.) in August, 8 days (3.12 in.) in September, 14 days (4.88 in.) in October, and 9

days (0.96 in.) in November. Average monthly high and low temperatures (EF) were 72/51 in May, 85/63 in June, 89/68 in July, 85/66 in August, 82/56 in September, 63/44 in October, and 52/33 in November.

Number of plants in each plot was recorded on 10 June, 8 July, 7 August, 14 September, and 6 November. Plants were harvested on 6 November using a potato digger. Harvested roots were washed, weighed, and evaluated for internal discoloration. Fifteen roots from each plot were evaluated for the incidence (the presence of disease) and severity (percentage of root area affected) of internal discoloration and hallow root. Each root was sectioned at 1/3 (upper section) and 2/3 (lower section) of the length from the top. Severity of discoloration in the vascular, core, and cortex areas was rated as percent area discolored in the cross section.

Results and Discussion

In cultivar 1573, the incidence of vascular discoloration (peppered root) ranged from 40% (Soil Gard) to 80% (control) in lower cross sections (Table 2). Similar results were obtained from upper sections of roots. Severity of peppered root ranged from 2.98% (Soil Gard) to 6.04 % (Maxim). The highest incidence of core discoloration was 26.7% in the roots from maxim treatment. Less than 3% of the roots from other plots exhibited core discoloration. Cortex discoloration was observed only in the roots from control plots. The highest incidence of root hallow was 6.7%. QRD-283 was phytotoxic to set germination. In treatments other than QRD-283, the number of plants emerged from the soil and survived throughout the season averaged from 15.7 (78.5%) to 19.3 (96.5%) per plot, and were not significantly different from each other (Table 2). Average weight of individual roots in the plots ranged form1.00 to 1.32 pounds.

There was not a considerable root discoloration in cultivar K-15. The highest incidence of discoloration was 6.7, 8.9, and 6.7% in vascular, core, and cortex areas, respectively. QRD-238 also was phytotoxic to germination of K-15 sets. In treatments other than QRD-283, the number of plants harvested ranged from 14.7 (73.5%) to 18.3 (91.5%) per plot. The weight of individual roots in the plots averaged from 1.80 to 2.06 pounds.

Conclusions. QRD-238 was phytotoxic to germination of roots. In 2002, Maxim 4FS was less effective on controlling root discoloration than it was in 2001. Soil Gard, G-41, and QRD-137 appeared to be effective against root discoloration complex of horseradish; similar results were obtained with Soil Gard, G-41, and QRD-137 treatments in 2001. In addition to five treatments reported here, there was another fungicide treatment with Apron-Maxim, which was found very phytotoxic to germination of sets, thus the related data was not reported.

The incidence of root discoloration in cultivar K-15 was significantly lower than that of cultivar 1573. Also, the yield of cultivar K-15 was significantly higher than that of cultivar 1573. The reasons for better performance of cultivar K-15 than cultivar 1573 could be: (i) cultivar K-15 may be resistant to pathogens causing root discoloration in horseradish; and/or (ii) planted sets of cultivar K15 were pathogen-free, as they were generated from tissue culture and increased at Dixon Spring; white the planted sets of cultivar 1573 may had been infected without exhibiting visual symptoms, which is common in horseradish roots. Further investigations are needed to

determine the effectiveness of the biological agents on reducing the incidence and severity of internal discoloration of horseradish roots.

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Table 1. Fungicide and biocontrol agents tested for control of internal discoloration of horseradish roots in 2002.

Material used		Manufacturer	Rate (product)	Treatment
Trade name	Agent			
Maxim 4FS	Fungicide	Syngenta	0.1 ml/L	Soaking*
SoilGard 12G	Fungus	Certis	Set-cover	Slurry**
G-41	Fungus	Biowork	Set-cover	Slurry
QRD-137	Bacterium	AgraQuest	Set-cover	Slurry
QRD-137	Bacterium	AgraQuest	Set-cover	Slurry
Untreated control	—	—	—	—

* Fungicide was added to water in a plastic bag, the sets placed in the bag, and shaken for 5 min.
** The sets were dipped in water and shaken with the agent in a plastic bag.

Table 2. Effects of set-treatment with the fungicide and biological agents on internal discoloration of horseradish roots and yield.

Cultivar	Treatment	Root discoloration												Hallow root				Plants in plot (no)	Root weight (lb/plant)
		Peppered root [z]				Core discoloration				Cortex discoloration									
		Upper [y]		Lower [y]		Upper		Lower		Upper		Lower		Upper		Lower			
		Inc [x]	Sev [x]	Inc	Sev	Inc	Sev	Inc	Sev	Inc	Sev	Inc	Sev	Inc	Sev	Inc	Sev		
1573	Maxim 4FS	60.0 ab [w]	6.04 a	60.0 abc	6.04 a	17.8 a	1.11 a	26.7 a	1.89 a	0.0	0.0	0.0	0.00	0.0 b	0.00 b	0.0 b	0.00 b	18.3 ab	1.05 ab
	Soil Gard 12 G	37.8 c	3.27 b	40.0 c	2.98 b	0.0 b	0.00 b	0.00 b	0.00 b	0.0	0.0	0.0	0.00	0.0 b	0.00 b	0.0 b	0.00 b	16.7 ab	1.00 ab
	G-41	48.9 bc	4.38 ab	48.9 bc	4.38 ab	2.2 b	0.11 b	2.22 b	0.11 b	0.0	0.0	0.0	0.0 0	4.4 a	0.22 a	6.7 a	0.55 a	15.7 ab	1.32 a
	QRD-137	48.9 bc	4.78 ab	51.1 bc	5.42 a	0.0 b	0.00 b	0.00 c	0.00 b	0.0	0.0	0.0	0.00	0.0 b	0.00 b	2.2 ab	0.04 b	19.3 a	1.02 ab
	QRD-283	66.7 ab	4.33 ab	60.0 abc	4.31 ab	0.0 b	0.00 b	0.00 b	0.00 b	0.0	0.0	0.0	0.00	0.0 b	0.00 b	0.0 b	0.00 b	11.3 b	0.76 b
	Control	77.8 a	5.16 ab	80.0 a	5.82 a	2.2 b	0.11 b	2.22 b	0.11 b	0.0	0.0	2.2	0.11	2.2 ab	0.11 ab	0.0 b	0.00 b	18.0 ab	1.05 ab
	LSD	***20.1***	***2.33***	***20.1***	***2.49***	***7.5***	***0.47***	***8.3***	***0.61***	***NS***	***NS***	***NS***	***NS***	***4.3***	***0.22***	***5.0***	***0.37***	***7.5***	***0.46***
K-15	Maxim 4FS	0.0 b	0.0 b	0.0	0.0	2.2 b	1.11 ab	0.0	0.0	0.0 b	0.0 b	0.0	0.00	11.1 a	3.33 a	2.2	0.22	18.0 a	1.80 a
	Soil Gard 12 G	0.0 b	0.0 b	0.0	0.0	0.0 b	0.00 b	0.0	0.0	2.2 ab	0.44 b	2.2	0.11	6.7 ab	0.78 ab	2.2	0.67	18.0 a	2.06 a
	G-41	0.0 b	0.0 b	0.0	0.0	0.0 b	0.00 b	0.0	0.0	0.0 b	0.0 b	0.0	0.00	6.7 ab	0.67 ab	0.0	0.00	15.0 a	2.00 a
	QRD-137	0.0 b	0.0 b	0.0	0.0	8.9 a	1.78 a	0.0	0.0	0.0 b	0.0 b	2.2	0.44	0.0 b	0.00 b	0.0	0.00	14.7 a	1.96 a
	QRD-283	6.7 a	0.33 a	0.0	0.0	0.0 b	0.00 b	0.0	0.0	6.7 a	1.56 a	0.0	0.00	4.4 ab	1.56 ab	0.0	0.00	5.3 b	1.74 a
	Control	0.0 b	0.0 b	0.0	0.0	4.4 ab	0.78 ab	0.0	0.0	2.2 ab	0.22 b	2.2	0.67	4.4 ab	1.56 ab	0.0	0.00	18.3 a	1.81 a
	LSD	***4.3***	***0.21***	***NS***	***NS***	***6.5***	***1.77***	***NS***	***NS***	***5.6***	***1.27***	***NS***	***NS***	***9.5***	***2.77***	***NS***	***NS***	***4.8***	***0.40***

[z] Discoloration of vascular area.

[y] Upper= upper section of root, sectioned at 1/3 of the root from the top; Lower=lower section of root, sectioned at 2/3 of the root from the top.

[x] Inc = incidence, percent roots affected; Sev = severity, percent area affected.

[w] Average of 75 plants (15 plant/plot). Values within each column of each cultivar with a letter in common are not significantly different from each other (Fisher's LSD).