Fungicide and Biocontrol Agents for Control of Internal Discoloration of Horseradish Roots

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Introduction

Internal root discoloration, caused by *Verticillium dahliae*, *V. longisporum*, and *Fusarium solani*, is a serious threat to horseradish production in Illinois and other horseradish growing areas. At present, there is no method available to provide adequate control of this disease. The study was conducted to evaluate the effectiveness of a fungicide and three biocontrol agents for control of internal discoloration of horseradish roots.

Materials and Methods

Two field trials were conducted at two separate commercial fields near Collinsville, Illinois. Both fields had history of internal discoloration of horseradish root. Three horseradish cultivars, K-15, D25-E2, and 1573 were used in this study. Roots of cultivars 15K and D25-E2 were produced at Dixon Springs from the plants generated in tissue culture. Roosts of cultivar 1573 were produced a field in Decatur, IL, with no history of internal discoloration of horseradish root. The roots 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 three biocontrol agents (Table 1) were applied onto the sets on 1 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 placed in the bag and shaken for 5 min. Treated sets were drained and dried in an exhaust hood.

Set-treatment with biocontrol agents. Three biocontrol agents, SoilGard 12G (*Gliocladium virens*), G-41 (*Gliocladium virens*), and QRD-137 (*Bacillus subtilis*) (Table 1) were used. The sets were dipped in tap water, and then placed in 2-gallon zip-lock plastic bag containing the biocontrol agent. The bag was gently shaken for 30 seconds. The sets were thoroughly covered with the agent. Treated sets were dried in an exhaust hood.

Fields were plowed on 1 May, and the sets were planted on 3 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. All three cultivars were included in the trial in one field, but only cultivar 15K was included in the trial in the second field.

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 12 days (4.78 in.), 9 days (8.29 in.), 3 days (1.93 in.), 7 days (4.19 in.), 9 days (5.03 in.), and 9 days (2.18 in.) in May, June, July, August, September, and October, respectively. Average monthly high and low temperatures (EF) were 76/55, 82/60, 90/67, 90/66, 80/54, and 73/46 in May, June, July, August, September, and October, respectively.

Number of plants in each plot was recorded on 20 June, 22 August, and 10 October. Plants in both fields were harvested on 24 October using a potato digger. Harvested roots were washed, weighed, and evaluated for internal discoloration. Fifteen roots from each plot were evaluated for the incidence (percentage of roots discolored) 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 core, vascular, and cortex areas was rated in the cross section.

Results and Discussion

Internal discoloration developed in roots of all tree cultivars. Discoloration of vascular tissues and adjacent areas to vascular tissues was more prevalent than discoloration of core and cortex areas (Tables 2 and 3). All three pathogens, *V. dahliae, V. longisporum,* and *F. solani*, are soil-borne fungi and invade horseradish roots through vascular system.

Overall, severity of internal discoloration of horseradish roots in 2003 was low. The incidence of discoloration of vascular tissue in untreated plants was significantly higher than those of treated plants, either with fungicide or biocontrol agents (Tables 2 and 3). In untreated plants, discoloration of vascular tissue in the upper sections of roots was higher than that of the lower sections of roots.

The highest incidence of hallow root was 8.9%. Occurrence of hallow symptoms in roots and internal discoloration of roots were not related. There was no significant difference in number of plants in the plots. Root weight of plants in the plots varied, but no definite conclusion could be derived about the effects of treatments on root yield.

Conclusions

- Control of international discoloration of horseradish root is achievable.

- Fungicide Maxim 4FS and biocontrol agents SoilGard, G-41, and QRD-137 suppress growth of *V. dahliae, V. longisporum,* and *F. solani* and protect horseradish roots against these pathogens. There is no adverse effect of either the fungicide or the biocontrol agents on set germination and plant growth.

- It is believed that the biocontrol agents, SoilGard, G-41, and QRD-137, provide longer protection to horseradish roots than fungicide Maxim 4 FS.

- In order to achieve control of internal discoloration of horseradish roots, **it is essential to plant pathogen-free sets**. Pathogen-free sets can be produced from plants generated in tissue culture and propagated in the field with no history of horseradish production. Also, the sets may be cleaned from the pathogens by reliable treatments (e.g., heat treatment), which need to be worked out.

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Table 1. Fungicide and biocontrol agents tested for control of internal discoloration of horseradish roots in 2003.

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
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 biocontrol agents on internal discoloration of horseradish roots and yield, field 1.

Cultivar	Treatment	Root discoloration												Hallow root				Plants in plot (no)	Root weight (lb/plant)
		Core discoloration				Vascular discoloration				Cortex discoloration									
		Upper[x]		Lower[x]		Upper		Lower		Upper		Lower		Upper		Lower			
		Inc[y]	Sev[y]	Inc	Sev	Inc	Sev	Inc	Sev	Inc	Sev	Inc	Sev	Inc	Sev	Inc	Sev		
15K	Maxim 4FS	0.0	0.00	0.0	0.00	15.6 b[z]	0.82 b	2.2 b	0.11 b	4.4 ab	0.71	4.4	0.78	4.4	0.51	4.4	0.29	18.0	1.53 a
	SoilGard 12G	4.4	0.71	6.1	0.87	22.2 b	1.24 b	13.3 b	0.45b	11.1ab	1.00	9.3	1.07	0.0	0.00	0.0	0.00	17.0	1.25 c
	G-41	2.2	0.44	2.2	0.02	6.7 c	0.44 b	4.4 b	0.24 b	2.2 b	0.04	6.7	0.67	4.4	0.56	2.2	0.67	18.3	1.26 c
	QRD-137	4.4	0.67	0.0	0.00	15.6 b	0.57 b	6.7 b	0.16 b	15.6 a	0.98	6.5	0.51	0.0	0.00	0.0	0.00	18.0	1.35 b
	Control	0.0	0.00	2.2	0.11	46.7 a	3.73 b	26.7 a	1.29 a	8.9 ab	1.44	6.7	1.58	2.2	0.11	2.2	1.11	18.7	1.41 b
	LSD	***NS***	***NS***	***NS***	***NS***	***16.2***	***1.91***	***12.4***	***0.83***	***11.5***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***0.08***
D25-E2	Maxim 4FS	0.0 b	0.00	0.0	0.00	31.1 b	3.11 ab	26.7 b	2.58 ab	0.0	0.00	0.0	0.00	0.0	0.00	2.2 b	0.44 ab	19.7	2.21 b
	SoilGard 12G	0.0 b	0.00	2.2	0.22	20.0 b	1.20 b	15.6 b	0.87 b	0.0	0.00	0.0	0.00	0.0	0.00	8.9 a	1.67 a	19.7	2.30 a
	G-41	0.0 b	0.00	2.2	0.44	35.6 b	2.98 ab	28.9 b	2.33 ab	0.0	0.00	0.0	0.00	0.0	0.00	2.2 b	0.44 ab	19.7	2.13 bc
	QRD-137	2.2 ab	0.22	4.4	0.44	20.0 b	2.69 ab	22.2 b	2.76 ab	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00 b	18.7	2.11 c
	Control	6.7 a	0.40	6.7	0.31	64.4 a	4.96 a	48.9 a	4.62 a	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00 b	19.6	2.19 bc
	LSD	***5.4***	***NS***	***NS***	***NS***	***18.7***	***2.52***	***18.4***	***2.68***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***0.06***	***1.42***	***NS***	***0.09***
1573	Maxim 4FS	4.4	0.22	2.2	0.07	11.1 b	0.53	8.9 b	0.42	2.2	0.11ab	2.2	0.07	2.2	0.44	2.2	0.44	19.7	1.46 ab
	SoilGard 12G	2.2	0.11	0.0	0.00	4.4 b	0.18	8.9 b	0.27	0.0	0.00 b	0.0	0.00	0.0	0.00	0.0	0.00	18.7	1.67 a
	G-41	6.7	0.20	2.2	0.02	15.6 b	1.05	11.1 b	0.78	0.0	0.00 b	0.0	0.00	0.0	0.00	0.0	0.00	19.0	1.41 c
	QRD-137	6.7	0.33	3.2	0.07	11.1 b	0.47	11.1 b	0.50	0.0	0.00 b	0.0	0.00	0.0	0.00	0.0	0.00	18.3	1.41 c
	Control	0.0	0.00	6.7	0.16	48.9 a	1.67	28.9 a	0.82	6.7	0.36 a	0.0	0.00	0.0	0.00	0.0	0.00	19.3	1.52 b
	LSD	***NS***	***NS***	***NS***	***NS***	***14.8***	***1.06***	***14.1***	***NS***	***5.4***	***0.34***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***0.08***

[x] 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.

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

[z] Mean of 75 plants (15 plants/plot). Values within each column of each cultivar with a letter in common are not significantly different from each other according to Fisher's protected LSD (*P*=05).

Table 3. Effects of set-treatment with the fungicide and biocontrol agents on internal discoloration of horseradish roots and yield, field 2.

Cultivar	Treatment	Root discoloration												Hallow root				Plants in plot (no)	Root weight (lb/plant)
		Core discoloration				Vascular discoloration				Cortex discoloration									
		Upper[x]		Lower[x]		Upper		Lower		Upper		Lower		Upper		Lower			
		Inc[y]	Sev[y]	Inc	Sev	Inc	Sev	Inc	Sev	Inc	Sev	Inc	Sev	Inc	Sev	Inc	Sev		
15K	Maxim 4FS	8.9 ab[z]	0.27	4.4	0.09	11.1 b	0.33 b	4.4 b	0.24 b	2.2	0.22	0.0	0.00	0.0	0.00	0.0	0.00	—	1.71 b
	SoilGard 12G	4.4 ab	0.44	2.2	0.44	8.9 b	0.31 b	6.7 b	0.16 b	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	—	1.55 c
	G-41	0.0 b	0.00	4.4	0.29	2.2 b	0.02 b	4.4 b	0.18 b	2.2	0.07	0.0	0.00	0.0	0.00	0.0	0.00	—	1.89 a
	QRD-137	2.2 ab	0.22	0.0	0.00	2.2 b	0.07 b	4.4 b	0.13 b	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	—	1.82 ab
	Control	11.1 a	1.29	2.2	0.07	62.2 a	2.44 a	35.6 a	1.31 a	2.2	0.07	0.0	0.00	0.0	0.00	0.0	0.00	—	1.45 c
	LSD	***9.3***	***0.97***	***NS***	***NS***	***12.7***	***0.59***	***12.2***	***0.56***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	—	***0.13***

[x] 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.

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

[z] Mean of 75 plants (15 plants/plot). Values within each column of each cultivar with a letter in common are not significantly different from each other according to Fisher's protected LSD (*P*=05).