Efficacy of Selected Fungicides and Biofungicides for Control of Internal Discoloration of Horseradish Roots, 2005

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Introduction

Internal root discoloration, caused by *Verticillium dahliae*, *V. longisporum,* and *Fusarium solani*, continues to be the most serious threat to horseradish production in Illinois and other horseradish growing areas. This study was conducted to evaluate the effectiveness of two fungicides and three biofungicides for control of internal discoloration of horseradish roots.

Materials and Methods

A field trial was conducted at a commercial field near Collinsville, Illinois. The field had history of internal discoloration of horseradish root. Three horseradish cultivars, 15K, D25-E2, and 1573 were used in this study. Roots of all three cultivars were from a horseradish field in 2004 with no visual symptom of the discoloration complex or any other root diseases. Roots (0.4- to 0.5-inch in diameter) were selected, washed with tap water, and cut into 6-inch segments (sets). Two fungicides (Maxim 4FS, Maxim Potato WP) and three biofungicides (Serenade MAX, SoilGard 12G, G-41/ABM 127) (Table 1) were applied onto the sets on 9 May. Untreated control sets were included.

Set-treatment with fungicide Maxim 4FS. One hundred milliliters (100 ml) tap water was poured into a 2-gallon zip-lock plastic bag and 0.1 ml of the fungicide Maxim 4FS was added to water in the bag and mixed. Twenty horseradish sets were placed in the bag and shaken for 2 min to coat the sets with Maxim 4FS. Treated sets were dried in an exhaust hood.

Set-treatment with fungicide Maxim Potato (WP). One hundred milliliter (100 ml) of tap water was poured into a 2-gallon zip-lock plastic bag and 5 g of the fungicide Maxim Potato (WP) was added to water in the bag and mixed thoroughly. Twenty horseradish sets were placed in the bag and shaken for 2 min to coat the sets with Maxim potato. Treated sets were dried in an exhaust hood.

Set-treatment with biofungicides. Three biofungicides, Serenade MAX (*Bacillus subtilis*), SoilGard 12G (*Trichoderma virens* GL-12), and G-41/ABM 127 (*Trichoderma virens* G-41) (Table 1) were used. The sets were dipped in tap water, and then placed in 2-gallon zip-lock plastic bag containing the biofungicide. The bag was gently shaken for 30 seconds. The sets were thoroughly covered with the biofungicide. Treated sets were dried in an exhaust hood.

Field was plowed prior to planting and the sets were planted on 11 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 (10 plants per row). The plots were arranged in a split-plot design, cultivar being as the main plot and treatments as sub-plots. The treatments (Table 3) were randomly arranged in each plot. Each treatment was replicated three times.

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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 site, are presented. Precipitation was 4 days (0.71 in.), 4 days (2.21 in.), 5 days (3.94 in.), 7 days (2.11 in.), 6 days (5.69 in.), and 0 day (0.00 in.) during 11-31 May, June, July, August, September, and 1-11 October, respectively. Average monthly high and low temperatures (EF) were 78/54, 88/64, 88/66, 88/67, 84/59, and 73/51 during 11-31 May, June, July, August, September, and 1-11 October, respectively.

Number of plants in each plot was recorded on 10 June, 8 July, 26 August, 23 September, and 11 October. Plants were harvested on 11 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). Each root was sectioned at 1/3 (upper section) and 2/3 (lower section) of the length from the top and severity of discoloration was assessed at the cross sections. Also, two lateral roots of each main root were sectioned in the middle and incidence and severity of discoloration were assessed at the cross section.

Results and Discussion

Due to the dryer environmental conditions than normal, emergence of plants from soil was delay by more than two weeks. But, plants grew well after emergence. There was no adverse effect of any of the fungicides and biofungicides used in this study on either set germination or plant growth.

In all three cultivars, root discoloration originated in vascular area, then expanded inwards and outwards. This pattern of symptom development was expected as *Verticillium* and *Fusarium* species invade horseradish plants through vascular system. Overall, disease incidence and severity in main roots in cultivar 15K were significantly lower than those of cultivars D-25-E2 and 1573 (Table 2). Similarly, disease incidence and severity in main roots of cultivar D25-E-2 were significantly lower than those of cultivars 1573. Also, number of harvested roots from plots of 15K was significantly higher than number of roots harvest from plots of other two cultivars (Table 2). Disease incidence and severity of internal discoloration of roots of plants treated with either fungicides (Maxim 4FS, Maxim Potato WP) or biofungicides (Serenade MAX, SoilGard 12 G, G-41) were significantly lower than those of untreated control plants (Table 3).

There was no significant correlation between incidence of internal discoloration in main roots and lateral roots. There was none or negligible other root diseases in the plots. Therefore, no data are presented on hallow root, root rot, or any other root related diseases.

Conclusions. Among three cultivars used in this study, cultivar 15K was the least susceptible to internal discoloration of root. Application of both of the fungicides (Maxim 4 FS, Maxim Potato WP) and all three biofungicides (Serenade MAX, SoilGard 12 G, G-41/ABM 127) reduced incidence and severity of internal discoloration of horseradish root significantly. Similar results were obtained in 2003 and 2004. The results of this experiment and the results of trials conducted in 2003 and 2004 are very promising for control of internal discoloration of

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horseradish root by using any of the treatments described in this study. However, the most important consideration is that, in order to achieve effective control of internal discoloration of horseradish roots, **the sets for planting must be pathogen-free**. 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 biofungicides tested for control of internal discoloration of horseradish roots in 2005.

Material used			**Manufacturer**	**Rate (product)**	**Treatment**
Trade name	**Agent**	**Active ingredient**			
Maxim 4FS	Fungicide	Fludioxonil	Syngenta, Inc.	1 ml/L	Soaking[y]
Maxim Potato WP	Fungicide	Fludioxonil	Syngenta, Inc.	50 g/L	Slurry[y]
Serenade MAX	Bacterium	*Bacillus subtilis*	AgraQuest, Inc	Set-cover	Slurry[z]
SoilGard 12G	Fungus	*Trichoderma virens* GL-12	Certis USAL.L.C.	Set-cover	Slurry[z]
G-41/ABM 127	Fungus	*Trichoderma virens* G-41	Biowork, Inc.	Set-cover	Slurry[z]

[y] Fungicide was added to water in a plastic bag, the sets placed in the bag, and shaken for 2 min.
[z] The sets were dipped in water and shaken with the agent in a plastic bag.

Table 2. Incidence and severity of internal discoloration of horseradish roots in three cultivars used in the field trial in 2005.

Cultivar	**Root discoloration (%)**								**Plants per plot (no)**	
	Main root				**Lateral root**					
	Upper[y]		**Lower[y]**		**Root 1**		**Root 2**		**Emer-ged**	**Har-vested**
	Incidence	**Severity**	**Incidence**	**Severity**	**Incidence**	**Severity**	**Incidence**	**Severity**		
15K	15.56 c[z]	2.07 b	14.4 c	1.78 c	3.7 b	0.44 b	4.1 a	0.57 a	15.22 a	15.17 a
D25-E2	34.4 b	2.94 b	34.1 b	2.85 b	13.33 a	1.06 a	6.7 a	0.67 a	13.05 b	12.83 b
1573	54.1 a	5.22 a	54.1 a	4.46 a	11.9 a	0.79 ab	7.4 a	0.50 a	13.00 b	13.00 b
LSD$_{(P=0.05)}$	***7.6***	***1.05***	***7.6***	***0.93***	***4.9***	***0.48***	***NS***	***NS***	***0.63***	***0.63***

[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.
[z] Mean of 45 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=0.05).

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Table 3. Effects of set-treatment with the fungicides and biofungicides on internal discoloration of horseradish roots in 2005.

Cultivar	Treatment	Root discoloration (%)								Plants per plot (no)	
		Main root				Lateral root					
		Upper[w]		Lower[w]		Root 1		Root 2			
		Incid[x]	Sev[y]	Incid[x]	Sev[y]	Incid[x]	Sev[y]	Incid[x]	Sev[y]	Emerged	Harvested
15K	Maxim 4FS	13.3 bc[z]	1.67 bc	13.3 bc	1.22 bc	2.2 b	0.11 a	0.0 b	0.00 b	17.00 a	17.00 a
	Maxim Potato WP	2.2 c	0.44 c	4.4 c	0.78 bc	0.0 b	0.00 a	0.0 b	0.00 b	12.67 c	12.67 c
	Serenade MAX	4.4 c	0.56 c	4.4 c	0.56 c	4.4 ab	0.22 a	4.4 ab	0.22 b	15.00 b	14.67 b
	SoilGard 12G	8.9 c	0.44 c	8.9 c	0.44 c	0.0 b	0.00 a	0.0 b	0.00 b	17.00 a	17.00 a
	G-41/ ABM 127	24.4 b	3.22 b	24.4 ab	2.89 ab	11.1 a	1.22 a	8.9 a	0.78 b	14.33 b	14.33 b
	Control	40.0 a	6.11 a	31.1 a	4.78 a	4.4 ab	1.11 a	11.1 a	2.44 a	15.33 b	15.33 b
	LSD$_{(P=0.05)}$	***14.2***	***2.52***	***14.1***	***2.25***	***7.8***	***NS***	***8.1***	***1.41***	***1.03***	***1.02***
D25-E2	Maxim 4FS	28.9 bc	2.00 bc	28.9 bc	2.00 bc	20.0 ab	1.11 b	13.3 ab	0.89 b	11.33 c	10.33 c
	Maxim Potato WP	17.8 c	1.22 c	15.6 c	1.00 c	8.9 bc	0.56 b	6.7 bc	0.33 b	14.64 a	14.64 a
	Serenade MAX	15.6 c	1.00 c	15.6 c	1.00 c	8.9 bc	0.56 b	0.0 c	0.00 b	8.67 d	8.33 d a
	SoilGard 12G	26.7 bc	1.56 c	26.7 bc	1.56 bc	2.2 c	0.11 b	0.0 c	0.00 b	14.98 a	14.98 a
	G-41/ ABM 127	40.0 b	3.56 b	40.0 b	3.44 b	8.9 bc	0.78 b	0.0 c	0.00 b	13.33 b	13.33 b
	Control	77.8 a	8.33 a	77.8 a	8.11 a	31.1 a	3.22 a	20.0 a	2.78 a	15.33 a	15.33 a
	LSD$_{(P=0.05)}$	***17.9***	***1.91***	***17.8***	***1.90***	***13.7***	***1.22***	***9.9***	***1.32***	***0.94***	***0.94***
1573	Maxim 4FS	42.2 c	3.44 c	42.2 c	2.78 c	11.1 b	0.67 ab	6.7 ab	0.67 ab	14.67 b	14.67 b
	Maxim Potato WP	53.3 bc	4.33 bc	53.3 bc	4.00 bc	4.4 b	0.44 b	2.2 b	0.22 ab	13.0 c	13.0 c
	Serenade MAX	68.9 ab	6.78 b	68.9 ab	5.89 b	13.3 ab	1.00 ab	13.3 a	0.89 a	6.33 d	6.33 d
	SoilGard 12G	51.1 bc	3.56 c	51.1 bc	3.33 c	13.3 ab	0.78 ab	6.7 ab	0.33 ab	17.00 a	17.00 a
	G-41/ ABM 127	33.3 c	2.67 c	33.3 c	2.00 c	4.4 b	0.22 b	0.0 b	0.00 b	13.0 c	13.0 c
	Control	75.6 a	10.56 a	75.6 a	8.78 a	24.4 a	1.67 a	15.6 a	0.89 a	14.00 bc	14.00 bc
	LSD$_{(P=0.05)}$	***20.0***	***2.69***	***20.0***	***2.17***	***13.3***	***1.00***	***10.7***	***0.780***	***1.47***	***1.47***

[w] 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] Incid = incidence (percentage of roots affected).

[y] Sev = severity (percentage root area affected).

[z] Mean of 45 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*=0.05).