Evaluation of Fungicides and Biofungicides for Control of Internal Discoloration of Horseradish Roots - 2004

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Introduction

Internal root discoloration, caused by *Verticillium dahliae*, *V. longisporum,* and *Fusarium solani*, is the most 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 two fungicides and three biofungicides 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, 15-K, D25-E2, and 1573 were used in this study. Roots of all three cultivars were from our experimental plots in 2003 and had no visual symptoms 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) (Table 1) were applied onto the sets on 4 May. Untreated control sets were included.

Set-treatment with fungicide Maxim 4FS. Two liters of tap water was poured into a 2-gallon zip-lock plastic bag and 0.2 ml of the 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 fungicide Maxim Potato (WP). One hundred milliliter 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 5 min. Treated sets were drained and dried in an exhaust hood.

Set-treatment with biofungicides. Three biofungicides, Serenade MAX (*Bacillus subtilis* QST 713), SoilGard 12G (*Gliocladium virens* GL-12), and G-41 (*Gliocladium 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.

Fields were plowed on 4 May, and the sets were planted on 6 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 1) were randomly arranged in each plot. Each treatment was replicated three times. One trial was established in a field that planted for sweet corn in 2003 and horseradish in 2004. The other trial was established in a field that planted for horseradish in 2003 and field corn in 2004. The experimental site in the second field was completely surrounded with field corn.

During the season, weeds were controlled by cultivation and hand weeding. The fields were not irrigated. Precipitation and temperature in the fields were not recorded. Therefore, the data from the Belleville weather station, the nearest weather station to the experimental fields, are presented. Precipitation was 12 days (8.72 in.), 10 days (2.81 in.), 8 days (6.57 in.), and 7 days (5.21 in.) in May, June, July, and August, respectively. Average monthly high and low temperatures (EF) were 80/60, 85/63, 86/67, and 84/59 in May, June, July, and August, respectively.

Number of plants in each plot was recorded on 8 June, 24 July, 12 August, 16 September, and 1 October. Plants in the first field were harvested on 1 October, and plants in the second field were harvested on 16 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, a lateral root of each main root was sectioned in the middle and incidence and severity of discoloration were assessed at the cross section.

Results and Discussion

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. Percentage of disease incidence and severity of internal discoloration of roots of plants treated with either fungicides (Maxim 4FS, Maxim Potato WP) or biopesticides (Serenade MAX, SoilGard 12 G, G-41) were significantly lower than those of untreated control plants (Table 2).

Almost all of the sets planted gave rise to plants that grew well during the season, indicating that there was no adverse effect of any of the fungicides and biofungicides used in this study on either set germination or plant growth. But, few plants in some plots were lost to brittle root disease, caused by the beet leaf hopper-transmitted *Spiroplasma citri*, during July-September. Incidence of internal discoloration of roots in some plot received treatments was higher than those of other treated plots. This was likely due to late-season plant infection with *Spiroplasma citri*, which did not kill the plants but interacted with root invading microorganisms, thus discoloring internal tissues of roots, similar to the internal root discoloration caused by *Verticillium* and *Fusarium* species.

There was no significant correlation between incidence or severity of internal discoloration in mail roots and lateral roots. Root yield of cultivar D25-E2 was significantly higher than those from cultivars 15-K and 1753.

Since incidence of brittle root infection of plants in the second field was too high, and interpretation of the results was to too difficult, we decided to only present the result of from the first field harvested on 1 October.

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. Both of the fungicides (Maxim 4 FS, Maxim Potato WP) and all three biofungicides (Serenade MAX, SoilGard 12 G, G-41) effectively controlled internal discoloration of horseradish root, caused by *V. dahliae*, *V. longisporum*, and *F. solani*, in 2004. Similar results were obtained in 2003. The results of this experiment and the results of experiments conducted in 2003 are very promising for control of internal discoloration of 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. Additional investigations are needed to further evaluate the efficacy of these fungicides and biofungicides on controlling this devastating disease and support registration of the Maxim Potato (WP) and biofungicides for use on horseradish.

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Table 1. Fungicide and biofungicides tested for control of internal discoloration of horseradish roots in 2004.

Material used			**Manufacturer**	**Rate (product)**	**Treatment**
Trade name	**Agent**	**Active ingredient**			
Maxim 4FS	Fungicide	Fludioxonil	Syngenta, Inc.	0.1 ml/L	Soaking*
Maxim Potato WP	Fungicide	Fludioxonil	Syngenta, Inc.	50 g/L	Slurry*
Serenade MAX	Bacterium	*Bacillus subtilis* QST 713	AgraQuest, Inc	Set-cover	Slurry**
SoilGard 12G	Fungus	*Gliocladium virens* GL-12	Certis USAL.L.C.	Set-cover	Slurry**
G-41	Fungus	*Gliocladium virens* G-41	Biowork, Inc.	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 fungicides and biofungicides on internal discoloration of horseradish roots and yield in 2004.

Cul-tivar	Treatment	Root discoloration (%)						Plants per plot (no)		Root weight (lb/plant)
		Main root				Lateral root				
		Upper*		Lower*						
		Incidence	Severity	Incidence	Severity	Incidence	Severity	Emer-ged	Harves-ted	
15-K	Maxim 4FS	22.2 bc**	0.84 c	13.3 c	0.58 c	0.0 b	0.0 b	18.33 b	18.33 b	0.77 bc
	Maxim Potato WP	8.9 cd	0.36 c	8.9 c	0.31 c	2.2 b	0.11 b	17.33 c	16.67 c	0.71 d
	Serenade MAX	33.3 b	1.93 b	37.8 b	2.27 b	15.6 a	1.73 a	19.00 a	19.00 a	1.16 a
	SoilGard 12G	2.2 d	0.07 c	2.2 c	0.07 c	0.0 b	0.0 b	18.00 b	18.00 b	0.81 b
	G-41	0.0 d	0.00 c	2.2 c	0.07 c	0.0 b	0.0 b	18.33 b	18.33 b	0.72 cd
	Control	66.7 a	3.84 a	71.1 a	4.51 a	2.2 b	0.07 b	17.33 c	17.00	0.82 b
	LSD$_{(P=0.05)}$	***14.5***	***0.92***	***14.1***	***0.96***	***7.2***	***0.84***	***0.44***	***0.50***	***0.05***
D25-E2	Maxim 4FS	6.7 c	0.62 c	8.9 c	0.47 c	0.00 b	0.00 b	19.67 a	19.67 a	1.29 cd
	Maxim Potato WP	26.7 b	2.13 b	24.4 b	1.71 b	6.7 a	0.73 a	18.67 b	18.67 b	1.41 a
	Serenade MAX	2.2 c	0.11 c	4.4 c	0.18 c	0.00 b	0.00 b	19.33 a	19.33 a	1.39 ab
	SoilGard 12G	2.2 c	0.11 c	2.2 c	0.11 c	0.00 b	0.00 b	19.67 a	19.67 a	1.33 bc
	G-41	6.7 c	0.40 c	8.9 c	0.51 c	0.00 b	0.00 b	18.33 b	18.33 b	1.23 d
	Control	53.3 a	4.24 a	55.5 a	4.31 a	4.4 ab	0.29 ab	19.67 a	19.67 a	1.30 c
	LSD$_{(P=0.05)}$	***13.4***	***1.24***	***13.9***	***1.11***	***5.5***	***0.62***	***0.42***	***0.42***	***0.07***
1573	Maxim 4FS	37.8 bc	3.89 ab	48.9 b	4.29 ab	17.8 a	1.62 a	18.67 bc	16.67 bc	1.05 ab
	Maxim Potato WP	28.9 c	2.11 bc	37.8 b	2.31 b	4.4 bc	0.33 bc	19.33 a	19.00 a	0.92 c
	Serenade MAX	4.4 d	0.13 c	6.7 c	0.24 c	0.0 c	0.00 c	19.00 ab	15.67 cd	0.87 c
	SoilGard 12G	26.7 c	2.18 bc	37.8 b	2.44 b	11.1 abc	0.89 abc	19.33 a	16.33 c	1.02 b
	G-41	48.9 b	2.98 b	51.1 b	3.78 b	17.8 a	1.22 ab	18.33 c	17.67 b	1.11 a
	Control	71.1 a	5.29 a	80.0 a	6.02 a	15.6 ab	1.44 ab	19.33 a	15.00 d	0.90 c
	LSD$_{(P=0.05)}$	***18.2***	***2.18***	***18.7***	***2.03***	***12.9***	***1.13***	***0.39***	***1.15***	***0.06***

* 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.

**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).