Baysal-Gurel and Kabir, J Plant Pathol Microbiol 2018, 9:9
DOI: 10.4172/2157-7471.1000451

Journal of
Plant Pathology & Microbiology
ISSN: 2157-7471

Research Article Open Access

Comparative Performance of Fungicides and Biocontrol Products in Suppression of *Rhizoctonia* Root Rot in Viburnum

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Abstract

Rhizoctonia root rot disease is one of the destructive diseases of woody ornamentals with a wide host range. In this study the efficacy of biocontrol products and fungicides against *Rhizoctonia* root rot of *Viburnum odoratissimum* was assessed in a separate greenhouse and field experiments. Treatments used in both experiments were RootShield *PLUS*+, MBI110, SoilGard, IT-5103, TerraClean 5.0+TerraGrow program, Mural, Empress Intrinsic and Paegant Intrinsic. Pots/plots were inoculated with *Rhizoctonia solani* agar slurry. Non-treated, non-inoculated and inoculated pots/plots served as controls. In both greenhouse and field experiments, all the treatments significantly reduced *Rhizoctonia* root rot severity. The treatments most effective in reducing *Rhizoctonia* root rot severity were Mural, Empress Intrinsic, Paegant Intrinsic and TerraClean 5.0+TerraGrow program in both greenhouse and field experiments compared to the other treatments and non-treated, inoculated control. Phytotoxicity and defoliation were not observed in any of the viburnum plants. This study will help nursery producers make proper management decisions by using recommended fungicides and biocontrol products of this study in a rotation or alone to manage *Rhizoctonia* root rot diseases of viburnum.

Keywords: Soilborne diseases; Nursery production; *Rhizoctonia solani;* Fungicides; Biocontrol products

Introduction

Soilborne diseases are considered one of the major limitations to field grown nursery production of woody ornamentals, particularly for propagation systems- field or container [1]. Soilborne pathogens (*Rhizoctonia* spp., *Phytophthora* spp., *Sclerotinia* spp., *Pythium* spp., *Verticillium* spp., and *Fusarium* spp.) cause approximately 50% to 75% economic losses of the possible yield for many crops [2,3]. At the southern region integrated pest management meeting in 2009, all nursery producers and other representatives were considered to rate root rot disease as one of the most important concern in the United States southern region ornamental nursery productions [4]. *Rhizoctonia solani* is one of the most important soilborne plant pathogens in nursery productions with a wide host range [5]. *R. solani* attacks about 360 genera of ornamentals in the United States [6]. *R. solani* spread very quickly among huge number of ornamental plant varieties which can reduce the quantity and quality in the ornamental productions [7]. Most of the time comparing to mature plants young seedlings is more susceptible to *Rhizoctonia* root rot disease [7,8]. Woody ornamental nursery producers are heavily relying on conventional fungicides and pesticides to control soilborne diseases, insects and pests [9-11]. Disease and pest management are considering as one of the most important expenses in nursery production. In 2012, the total expenditure of pesticides in the United States agricultural sector was $8.9 billion [12]. The total expenditure of conventional pesticides was $1.4 billion. In 2012, worldwide total pesticide expenditure was about $55.92 billion [12]. In lots of cases, repeated application of fungicides resulted in control failures due to fungicide resistance development [13]. Because of the rising threat of fungicide resistance in plant pathogens and also major environmental concerns, in recent years researchers are focusing on finding out different alternatives of using chemical pesticides for managing soilborne plant pathogens [14]. Several techniques and approaches are being sought to the reduction of fewer usages of conventional fungicides, using comparatively fewer toxic materials and introducing alternatives such as biological fungicides or biorational products in the nursery crop productions. As throughout the whole world several isolates of *R. solani* have been documented as fungicides insensitive, so it is really important to find out new biocontrol products and less harmful synthetic chemical formulas to control this soilborne pathogens in ornamental productions [15-22]. Nowadays, nursery producers are more concerned to reduce the pesticide usage in their production management system. However, nursery producers are sceptical using new practices in their productions until that practices are properly tested. Cost effective and reliable compounds compared to available chemical compounds need to be evaluated to adopt new approaches. Only limited number of research studies was done on woody ornamental plant production. Therefore more research studies are necessary with new fungicides and biocontrol products to determine their effectiveness in nursery production. This study focused on the evaluation of different chemical and biocontrol products for the control of *Rhizoctonia* root rot (caused by *R. solani)* with different application methods and intervals in woody ornamentals in greenhouse and field conditions. The rationale of this work is to present efficacy test results for *Rhizoctonia* root rot management to help nursery producers to make proper management decisions about fungicides and biocontrol products to use in their woody ornamental production.

Materials and Methods

Fungal culture

Rhizoctonia solani cultures were obtained from the culture collection in the laboratory of Dr. Fulya Baysal-Gurel at Tennessee State University. *R. solani* cultures were maintained on potato dextrose agar (PDA) medium.

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Received September 10, 2018; **Accepted** September 25, 2018; **Published** September 30, 2018

Citation: Baysal-Gurel F, Kabir N (2018) Comparative Performance of Fungicides and Biocontrol Products in Suppression of *Rhizoctonia* Root Rot in Viburnum. J Plant Pathol Microbiol 9: 451. doi: 10.4172/2157-7471.1000451

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Rhizoctonia solani inoculum preparation

Seven-day old *R. solani* culture was chopped and placed into a sterilized beaker with 1L sterilized distilled water (1 petri dish/1L) and then homogenized with blender mixer (Hamilton Beach hand blender, Model number 59785R) to prepare slurry of *R. solani* [23].

Greenhouse experimental design and condition

The experiments were conducted at the Tennessee State University Otis L. Floyd Nursery Research Center in McMinnville, TN. Uniform viburnum (*Viburnum odoratissimum*) rooted cuttings (Liner source Inc, Eustis, FL) were potted in no. 1 nursery containers (Morton's Horticultural Products, Inc) in Morton's #2 Grow Mix. Four single-plant replications per treatment (Table 1) were arranged in a completely randomized design in a greenhouse. Each plant was top dressed in 10 g of 18-6-8 Nutricote controlled-release fertilizer (Arysta Life Science America Inc., New York, NY, USA). Viburnum plants were watered with overhead irrigation two times per day for 2 minutes per irrigation cycle. Pots were inoculated with slurry of *R. solani* (7-day old cultures on PDA were homogenized) at a rate of 100 ml/0.1 m^2. Non-treated, non-inoculated and inoculated pots served as controls. Treatment Terra Clean 5.0 was drenched into the potting mix 24 h prior to transplanting in dedicated pots (265 liters of mixed solution/92.9 m^2). Dedicated rooted cuttings were dipped in TerraGrow at 0.8 g/L rate prior to planting and then received a potting mix drench of TerraGrow at 0.3 g/L after planting. The other treatments except IT-5103 were applied as drenches starting after transplanting. All treatments were applied according to label directions at the recommended labelled rates (Table 1). Greenhouse study was conducted twice between 22 March and 14 August 2017. Average greenhouse maximum temperatures for 22-30 March, April, May, June, July, and August 1-14, 2017 were 26.67°C, 31.67°C, 28.89°C, 32.33°C, 30.94°C, and 31.56°C; average minimum temperatures were 16.67°C, 20°C, 17.78°C, 17.17°C, 19.78°C, and 19.22°C, respectively.

Field study experimental design and condition

Experiments were conducted in 2016 and 2017 at the Tennessee State University Otis L. Floyd Nursery Research Center in McMinnville, TN in a field plot with Waynesboro loam soil. The field was cultivated and leveled. Plots were measured and marked in a randomized complete block design with four replications per treatment (Table 1). Plots were drench-inoculated with slurry of *R. solani* (7-day old cultures on PDA were homogenized) at a rate of 100 ml/0.1 m^2. Non- treated, non-inoculated and inoculated plots served as controls. Viburnum (*V. odoratissimum*) rooted cuttings (Liner source Inc, Eustis, FL) were transplanted in field plots on 28 July 2016 and 8 August 2017. Each plot consisted of 5 plants spaced 60.0 cm apart with 2.0 m between rows. Plants were fertilized with 10 g of 18-6-8 Nutricote controlled-release fertilizer. Plants were watered as needed using a drip irrigation system. Herbicide (Finale, 31.3 ml/L) was applied as spot treatment for weed control in the field. TerraClean 5.0 was drenched into the soil 24 hr prior to transplanting in dedicated plots (265 liter of mixed solution/92.9 m^2). Dedicated rooted cuttings were dipped in TerraGrow at 0.8 g/L rate prior to planting and then received a soil drench of TerraGrow at 0.3 g/L after planting. The other treatments except IT-5103 were applied as soil drenches starting after transplanting. In 2016, average maximum temperatures for 28-30 June, July, August, September, October, and 1-10 November were 22.28°C, 27.5°C, 30.83°C, 31.11°C, 29.33°C and 27.56°C; average minimum temperatures were 8.22°C, 14.22°C, 18.78°C, 20.83°C, 17.89°C and 15.22°C; and total rainfall amounts were 4.57, 2.46, 5.36, 7.92, 3.86 and 4.19 cm, respectively. In 2017, average maximum temperatures for 8-31 August, September, October and 1-20 November were 29.87°C, 28.32°C, 23.19°C and 17.52°C; average minimum temperatures were 18.41°C, 14.52°C, 9.57°C and 6.53°C; and total rainfall amounts were 11.30, 12.60, 12.24 and 10.08 cm, respectively.

Product	Types	Rate	Active ingredient	Manufacturer	Interval
Empress Intrinsic 23.8SC	Fungicide	0.23 ml/L	Pyraclostrobin	BASF Corporation	3 weeks
IT-5103 WP	Biocontrol product	2.0 g/ plant	*Trichoderma* spp.	Italpollina Inc.	Once
MBI110	Biocontrol product	1.0 % (v/v)	*Bacillus amyloliquefaciens*	Marrone Bio Innovations, Inc.	1 week
Mural 45WG	Fungicide	0.22 g/L	Azoxystrobin + benzovindiflupyr	Syngenta International AG	3 weeks
Pageant Intrinsic 38WG	Fungicide	1.35 g/L	Boscalid + pyraclostrobin	BASF Corporation	3 weeks
RootShield *PLUS*+ WP	Biocontrol product	0.60 g/L	*T. harzianum* Rifai strain T-22, *T. virens* strain G-41	Bioworks Inc.	8 weeks
SoilGard	Biocontrol product	2.40 g/L	*Gliocladium virens* strain GL-21	Certis USA LLC.	Once
TerraClean 5.0 and TerraGrow	Fungicide and Biocontrol product	0.2% (v/v) and 0.75 g/L 0.30 g/L 0.07 g/L	Hydrogen dioxide + peroxyacetic acid and *Bacillus* spp. and *T. harzianum*	BioSafe Systems LLC.	3 weeks

Table 1: List of fungicides and biocontrol products, rates, active ingredients, manufacturers and intervals.

Data collection

Viburnum plants were evaluated for disease severity three months after first application of treatments. Root rot was assessed using a scale of 0% to 100% roots affected. Physiological data such as whole plant and root fresh weights, plant height and width were recorded at the end of each experiment for analysing.

Statistical analysis

Analyses of variance of all the data sets were performed using the general linear model procedure with SAS statistical software (SAS Institute Inc., Cary, NC) and means was separated using Turkey test.

Results

Evaluation of biocontrol products and fungicides for the control of *Rhizoctonia* root rot of viburnum in greenhouse condition

Rhizoctonia root rot disease pressure was moderate to high in the first experiment with non-treated control plants showing 59.88% disease severity (Table 2). All the treatments significantly reduced *Rhizoctonia* root rot severity compared to the non-treated inoculated control except RootShield *PLUS*+, MBI110 and Soil Gard (Table 2). The treatments most effective in reducing *Rhizoctonia* root rot severity were Mural, Empress Intrinsic, Pageant Intrinsic, TerraClean 5.0+TerraGrow program and IT-5103. There were no significant differences among plant fresh and root weights, plant height and width between treated and non-treated plants. Phytotoxicity and defoliation were not observed in any of the viburnum plants. *Rhizoctonia* root rot disease pressure was also moderate to high in the second experiment with non-

treated control plants showing 61.50% disease severity (Table 3). All of the treatments significantly reduced *Rhizoctonia* root rot severity compared to the non-treated inoculated control. The most effective treatments in reducing *Rhizoctonia* root rot severity were Empress Intrinsic, Mural, Pageant Intrinsic, TerraClean 5.0+TerraGrow program, IT-5103 and MBI110. There were no significant differences in plant fresh and root weights, plant height and width between treated and non-treated plants. Phytotoxicity and defoliation were also not observed in any of the viburnum plants.

Evaluation of biocontrol products and fungicides for the control of *Rhizoctonia* root rot of viburnum in field condition

Rhizoctonia root rot disease pressure was high reaching 63.30% in the 2016 experiment (Table 4). All of the treatments significantly reduced *Rhizoctonia* root rot severity in viburnum plants compared to the non-treated inoculated control. Plots treated with Mural, Empress Intrinsic, Paegant Intrinsic and Terraclean+TrerraGrow program had significantly less *Rhizoctonia* root rot than the other treatments. Paegant Intrinsic, Mural, Terraclean+TrerraGrow program and Empress Intrinsic treatments significantly increased plant fresh weight and root weight compared to the non-treated inoculated control. Mural, Empress Intrinsic, Paegant Intrinsic, RootShield *PLUS*$^+$ WP and Terraclean+TrerraGrow program significantly increased the plant height compared to the non-treated inoculated control. Pageant Intrinsic significantly increased the plant width compared to the non-treated inoculated control. Phytotoxicity and defoliation were not observed in any of the viburnum plants.

In 2017 field experiment, *Rhizoctonia* root rot disease pressure was high in viburnum plants showing 66.38% (Table 5). All of the treatments significantly reduced *Rhizoctonia* root rot severity compared to the non-treated, inoculated control. There were no significant differences on *Rhizoctonia* root rot severity between plants treated with Mural, Empress Intrinsic, Pageant Intrinsic and non-treated, non-inoculated control. There were no significant differences in plant fresh weight, root weight and plant height between treated and non-treated plants. Biocontrol products IT-5103, SoilGard, RootShield *PLUS*$^+$ WP, and MBI110 significantly increased plant width compared to the non-treated, inoculated control. Phytotoxicity and defoliation were not observed in any of the viburnum plants.

Discussion

Soilborne plant pathogens cause significant economic losses in nursery productions. *R. solani* is one of the important soilborne

Treatment and rate	*Rhizoctonia* root rot severity (%)[y]	Plant fresh weight (g)	Root weight (g)	Plant height (cm)	Plant width (cm)
RootShield *PLUS*$^+$ WP 0.60 g/L	38.00 ab[x]	89.63 a	31.88 a	18.41 a	20.80 a
MBI110 1%	25.50 ab	84.13 a	30.50 a	16.79 a	19.53 a
SoilGard 2.40 g/L	31.75 ab	73.25 a	29.38 a	17.93 a	25.09 a
IT-5103 WP 2 g/plant	19.25 b	73.38 a	26.88 a	17.31 a	22.37 a
TerraClean 5.0 0.2% (v/v) TerraGrow 0.75 g/L TerraGrow 0.30 g/L TerraGrow 0.07 g/L	19.25 b	84.38 a	27.75 a	18.25 a	21.59 a
Mural 45WG 0.22 g/L	9.88 b	84.13 a	28.13 a	18.11 a	23.82 a
Empress Intrinsic 23.8SC 0.23 ml/L	16.13 b	84.25 a	27.75 a	13.66 a	21.11 a
Pageant Intrinsic 38WG 1.35 g/L	22.38 b	86.75 a	32.00 a	14.30 a	26.04 a
Non-treated, inoculated control	59.88 a	78.63 a	28.50 a	13.33 a	18.34 a
Non-treated, non-inoculated control	9.88 b	82.88 a	32.63 a	15.71 a	26.83 a
p-value	0.0010	0.2472	0.1352	0.2139	0.2373

[y]Disease severity was based on percentage of roots affected.
[x]Values are the means of four replicates; treatments followed by the same letter within a column are not significantly different at $p \leq 0.05$.

Table 2: Greenhouse experiment 1: Effects of biocontrol products and fungicides on severity of *Rhizoctonia* root rot disease on viburnum.

Treatment and rate	*Rhizoctonia* root rot severity (%)[y]	Plant fresh weight (g)	Root weight (g)	Plant height (cm)	Plant width (cm)
RootShield *PLUS*$^+$ WP 0.60 g/L	31.75 b[x]	82.50 a	30.75 a	19.50 a	26.13 ab
MBI110 1%	22.25 bc	92.50 a	34.13 a	25.13 a	25.50 ab
SoilGard 2.40 g/L	32.00 b	74.50 a	24.00 a	23.75 a	27.38 ab
IT-5103 WP 2 g/plant	24.75 bc	98.88 a	36.00 a	26.38 a	31.81 a
TerraClean 5.0 0.2% (v/v) TerraGrow 0.75 g/L TerraGrow 0.30 g/L TerraGrow 0.07 g/L	13.75 bc	99.25 a	33.38 a	19.00 a	29.44 ab
Mural 45WG 0.22 g/L	13.75 bc	88.75 a	30.75 a	24.00 a	28.06 ab
Empress Intrinsic 23.8SC 0.23 ml/L	11.75 c	83.63 a	31.25 a	23.63 a	24.00 ab
Pageant Intrinsic 38WG 1.35 g/L	14.00 bc	85.63 a	30.25 a	26.50 a	28.88 ab
Non-treated, inoculated control	61.50 a	74.25 a	25.75 a	14.50 a	28.75 ab
Non-treated, non-inoculated control	7.75 c	78.25 a	39.88 a	20.13 a	12.25 b
p-value	< 0.0001	0.1231	0.1807	0.4465	0.1015

[y]Disease severity was based on percentage of roots affected.
[x]Values are the means of four replicates; treatments followed by the same letter within a column are not significantly different at $p \leq 0.05$.

Table 3: Greenhouse experiment 2: Effects of biocontrol products and fungicides on severity of *Rhizoctonia* root rot disease on viburnum.

Treatment and rate	Application dates[z]	*Rhizoctonia* root rot severity (%)	Plant fresh weight (g)	Root weight (g)	Plant height (cm)	Plant width (cm)
RootShield *PLUS*+ WP 0.60 g/L	2,10	26.5 c[x]	26.4 c	15.70 abc	19.90 a	13.90 bc
MBI110 1%	2-14	28.4 c	24.90 c	15.30 abc	16.50 bc	12.80 c
SoilGard 2.40 g/L	2	24.3 c	28.30 bc	15.9 abc	18.70 abc	14.40 abc
IT-5103 WP 2 g/plant	2,5,8,11,14	37.7 b	25.70 c	14.80 bc	18.40 abc	13.80 bc
TerraClean 5.0 0.2% (v/v) TerraGrow 0.75 g/L TerraGrow 0.30 g/L TerraGrow 0.07 g/L	1 2 2 5,8,11,14	13.9 d	37.50 ab	22.90 ab	19.70 ab	15.90 abc
Mural 45WG 0.22 g/L	2,5,8,11,14	5.9 de	38.30 ab	25.50 a	21.50 a	15.60 abc
Empress Intrinsic 23.8SC 0.23 ml/L	2,5,8,11,14	6.7 de	37.70 ab	23.40 ab	19.90 a	14.50 abc
Pageant Intrinsic 38WG 1.35 g/L	2,5,8,11,14	13.6 d	40.60 a	24.90 ab	20.30 a	17.60 a
Non-treated, inoculated control	--	63.3 a	18.70 c	10.4 c	15.70 c	13.40 c
Non-treated, non-inoculated control	--	3.7 e	42.10 a	22.10 ab	21.60 a	16.90 ab
p-value	--	≤ 0.0001	0.0008	0.0643	0.0799	0.0150

[z]Application dates: 1=27 Jul; 2=28 Jul; 3=4 Aug; 4=11 Aug; 5=18 Aug; 6=25 Aug; 7=11 Sep; 8=8 Sep; 9=15 Sep; 10=22 Sep; 11=29 Sep; 12=6 Oct; 13=13 Oct; 14=20 Oct.
[y]Disease severity rating was based on percentage root affected.
[x]Values are the means of four block replication; treatments followed by the same letter within a column are not significantly different at $p \leq 0.0799$.

Table 4: Field experiment 1: Effects of biocontrol products and fungicides on severity of *Rhizoctonia* root rot disease on viburnum, 2016.

Treatment and rate	Application dates[z]	*Rhizoctonia* root rot severity (%)[y]	Plant fresh weight (g)	Root weight (g)	Plant height (cm)	Plant width (cm)
RootShield *PLUS*+ WP 0.60 g/L	2,10	26.19 bcd[x]	30.75 a	12.75 a	30.19 a	28.47 bc
MBI110 1%	2-14	25.94 bcd	28.56 a	10.91 a	32.50 a	27.25 bcd
SoilGard 2.40 g/L	2	28.56 bcd	28.59 a	11.66 a	28.00 a	28.58 bc
IT-5103 WP 2 g/plant	2,5,8,11,14	36.13 b	29.88 a	14.22 a	27.00 a	33.00 b
TerraClean 5.0 0.2% (v/v) TerraGrow 0.75 g/L TerraGrow 0.30 g/L TerraGrow 0.07 g/L	1 2 2 5,8,11,14	18.56 cde	23.41 a	9.72 a	26.88 a	20.98 de
Mural 45WG 0.22 g/L	2,5,8,11,14	9.94 ef	29.81 a	12.34 a	28.81 a	19.88 e
EmpressIntrinsic 23.8SC 0.23 ml/L	2,5,8,11,14	11.25 ef	34.03 a	11.97 a	30.50 a	22.64 cde
Pageant Intrinsic 38WG 1.35 g/L	2,5,8,11,14	16.44 def	28.97 a	13.03 a	28.69 a	22.70 cde
Non-treated, inoculated control	--	66.38 a	23.38 a	9.84 a	23.44 a	18.67 e
Non-treated, non-inoculated control	--	7.63 f	29.72 a	12.09 a	29.75 a	44.88 a
p-value	--	< .0001	0.5445	0.7071	0.1052	< .0001

[z]Application dates: 1=7 Aug; 2=8 Aug; 3=15 Aug; 4=22 Aug; 5=29 Aug; 6=5 Sep; 7=12 Sep; 8=19 Sep; 9=26 sep; 10=3 Oct; 11=10 Oct; 12=17 Oct; 13=24 Oct; 14=31 Oct.
[y]Disease severity was based on percentage of roots affected.
[x]Values are the means of four block replicates; treatments followed by the same letter within a column are not significantly different at $p \leq 0.05$.

Table 5: Field experiment 2: Effects of biocontrol products and fungicides on severity of *Rhizoctonia* root rot disease on viburnum, 2017.`

pathogen with a broad host range in both non-cultivated and cultivated crops including woody ornamentals. This soilborne plant pathogen is responsible to damage ornamental plant cuttings which lead to main economic losses in the production of woody ornamental nurseries. Soilborne diseases are often difficult to control and cannot be managed solely using crop rotations, improved disease-resistant varieties. The application of fungicides and bio control products are also important management tools for soilborne disease management in sustainable field grown nursery production systems [24]. Nursery grown ornamental crop producers heavily rely on conventional fungicides and pesticides to control soilborne diseases, insects and pests [9-11]. The following fungicides azoxystrobin, pyraclostrobin, prothioconazole and tebuconazole are mostly used to manage soilborne diseases caused by *R. solani* [25-28]. In this study we have evaluated three synthetic fungicides pyraclostrobin (Empress Intrinsic), azoxystrobin+benzovindiflupyr (Mural) and boscalid+pyraclostrobin (Pageant Intrinsic) to *Rhizoctonia* root rot disease on Viburnum plants in both greenhouse and filed conditions. All three fungicides significantly reduced *Rhizoctonia* root rot disease on Viburnum plants compared to the other treatments and non-treated, inoculated control. Alternative products, which are safer for nursery producers and environmentally friendly, would be an important addition to nursery production systems. Biopesticides are normally less toxic and harmful to non-target microorganisms, which can decompose very quickly, compare to conventional pesticides [29]. Use of biopesticides is increasing in crop production and are considering as alternative to control soilborne fungal diseases in woody ornamental nursery production system. This interest is increasing due to concerns about the human and environment safety and developing plant pathogens resistance to different chemical formulas. Several microorganisms such as *Bacillus* spp., *Pseudomonas* spp., and *Trichoderma* spp. have been studied and identified as effective biocontrol agents against *R. solani* [30-33]. In this study we evaluated biocontrol agents *Trichoderma* spp. (IT-5103), *Bacillus amyloliquefaciens* (MBI110), *T. harzianum* Rifai strain T-22 and *T. virens* strain G-41 (RootShield *PLUS*+), *Gliocladium virens* strain GL-21 (SoilGard), and hydrogen dioxide+peroxyacetic acid and *Bacillus* spp.+*T. harzianum* application program (TerraClean 5.0 and TerraGrow program) against *R. solani* in greenhouse and field

conditions. Tested biocontrol products are fairly new and registered as pesticides by U.S. Environmental Protection Agency and also commercially available to control *Rhizoctonia* root rot diseases in ornamental productions. From this study, the results showed that all biocontrol products significantly or numerically reduced *Rhizoctonia* root rot severity in viburnum plants compared to the non-treated inoculated control in both greenhouse and field conditions and the reduction on *Rhizoctonia* root rot more apparent in greenhouse condition. The application program of fungicide (hydrogen dioxide+peroxyacetic acid-TerraClean 5.0) and biocontrol product (*Bacillus* spp.+*T. harzianum*-TerraGrow) were effective against *Rhizoctonia* root rot disease in field condition compared to the other biocontrol products alone. Phytotoxicity is another most important factor when selecting the synthetic fungicides and biocontrol agents. In this study fungicides and biocontrol products as well as fungicide and biocontrol product application program did not cause any crop safety issues in any of the viburnum plants in both greenhouse and field experiments. The results from greenhouse and field studies support the previous reports which indicated that biopesticides could be incorporated in nursery disease management system and also it can reduce the usage and dependence on conventional fungicides [34].

Conclusion

An integrated disease management approach should be used to control *Rhizoctonia* root rot disease in greenhouse and field conditions. Results of both greenhouse and field experiments indicated that fungicides such as Mural, Pageant Intrinsic, and Empress Intrinsic provide control of *Rhizoctonia* root rot disease of viburnum. Nursery producers could also benefit from using biocontrol products alone or in a rotation program of the fungicides typically drenched to control *Rhizoctonia* root rot in viburnum.

Acknowledgements

We thank Prabha Liyanapathiranage and Terri Simmons for their assistance with this project. We thank BASF, Bioworks, Marrone Bio Innovations, Syngenta, Certis, and Italpollina for fungicide donations. This work was supported by the National Institute of Food and Agriculture (NIFA), United States Department of Agriculture (USDA) Evans-Allen grant, under award numbers TENX-1520-CCOCP and TENX-S-1053.

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