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**IR-4 Environmental Horticulture Program
Thielaviopsis Efficacy: A Literature Review**

Thielaviopsis basicola

**Authors: Ely Vea and Cristi Palmer
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Susan Bierbrunner**

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Abstract

From 2003 to 2017, numerous products representing 23 active ingredients were evaluated in greenhouse trials as soil drench against *Thielaviopsis basicola* causing black root rot on ornamentals (Table1). Although there were insufficient data for definitive conclusions, two new experimentals (BAS 750 - mefenftrifluconazole) and A20808C showed promising efficacy comparable to the standards. Several products that are not yet labeled for *Thielaviopsis basicola* also showed promising efficacy in single trials. These include Empress Intrinsic (pyraclostrobin), Endorse/Veranda O (polyoxin D), Mural (azoxystrobin + benzovindiflupyr), Tournay (metconazole) and Vital (potassium phosphite). The experimentals A19649B and Pyraziflumid SC (pyraziflumid) provided poor efficacy in single trials. The established standards 3336 and Terraguard generally provided excellent efficacy.

Introduction

In 2018, IR-4 initiated a high priority project to determine efficacy of several fungicides on non-Oomycete root rot pathogens, including *Thielaviopsis* species, and obtain data supporting current and future registrations on ornamentals. We reviewed available ornamental trials published in Biological & Cultural Tests, Fungicide & Nematicide Tests and Plant Disease Management Reports to check efficacy of experimental and registered fungicides on *Thielaviopsis* species. This report is a brief summary of available data from ornamental trial reports. The source of report is included under each data table. Data from IR-4 project trials will be added when received from researchers.

Materials and Methods

From 2003 to 2017, numerous products representing 23 active ingredients were evaluated in the greenhouse as soil drench to control black root rot (*Thielaviopsis basicola*). Twelve trials were conducted on pansy, petunia and vinca. Treatments were generally applied as soil drench either a few days before or immediately after *Thielaviopsis* inoculation, and reapplied biweekly. Researchers used a minimum of four replications. Disease severity and incidence were recorded at various intervals after initial application. Phytotoxicity or lack of it was generally noted in the reports. Six researchers were involved in the testing (Appendix 1).

Products were supplied to researchers by their respective manufacturers.

For IR-4 testing, the following protocol was used: 18-005. Please visit <https://www.ir4project.org/about-environmental-horticulture/ehc-registration-support-research/env-hort-researcher-resources/> to view and download these protocols.

Table 1. List of Products and Rates Tested on Environmental Horticulture Plants from 2003 to 2017.

Active Ingredient(s)	Products	Manufacturer	Rate(s) Tested		# Trials
A19649B	A19649B	Syngenta	Drench	13 fl oz	1
A20808C	A20808C	Syngenta	Drench	27 fl oz	1
Azoxystrobin	Heritage	Syngenta	Drench	0.9 oz per 100 gal	1
Azoxystrobin + benzovindiflupyr	Mural 45WG	Syngenta	Drench	3 oz per 100 gal	1

Active Ingredient(s)	Products	Manufacturer	Rate(s) Tested	# Trials	
Cyazofamid	Cyazofamid 400SC	ISK	Drench	1.5 fl oz	1
			Drench	3 fl oz	1
Didecyl dimethyl ammonium chloride	KleenGrow	Pace	Drench	6 + 14 fl oz per 100 gal	1
Dipotassium phosphonate + dipotassium phosphate	Biophos 43L	Agrisel	Drench	25.6 fl oz per 100 gal	1
			Drench	64 fl oz per 100 gal	1
			Drench	128 fl oz per 100 gal	1
Etridiazole + thiophanate-methyl	Banrot WP	Scotts	Drench	6 oz per 100 gal	1
			Drench	8 oz per 100 gal	1
Fludioxonil	Medallion	Syngenta	Drench	1 oz per 100 gal	1
			Drench	2 oz per 100 gal	4
Fludioxonil + mefenoxam	Hurricane	Syngenta	Drench	0.75 oz per 100 gal	1
Fluxapyroxad + Pyraclostrobin	BAS 703, Orkestra	BASF	Drench	4 fl oz per 100 gal	2
			Drench	6 fl oz per 100 gal	2
			Drench	8 fl oz per 100 gal	3
			Drench	10 fl oz per 100 gal	1
			Drench	13 fl oz per 100 gal	1
<i>Gliocladium catenulatum</i> strain J1446	Prestop 37WP	AgBio	Drench	27 oz per 100 gal	1
Mefentrifluconazole	BAS 750	BASF	Drench	1.8 fl oz per 100 gal	2
			Drench	2.4 fl oz per 100 gal	2
			Drench	3.0 fl oz per 100 gal	2
Metconazole	Tourney 50WDG	Valent	Drench	4 oz per 100 gal	1
Pentachloronitrobenzene (PCNB)	Terraclor 75WP	Chemtura	Drench	4 oz per 100 gal	1
Polyoxin D	Endorse 11.3D	Arysta	Drench	4 oz per 100 gal	1
			Drench	8 oz per 100 gal	1
	Veranda O WDG	OHP	Drench	0.25 lb per 100 gal	1
			Drench	0.50 lb per 100 gal	1
Potassium phosphite	Vital 4L	Luxembourg	Drench	32 fl oz per 100 gal	1
			Drench	64 fl oz per 100 gal	1
Pyraclostrobin	Empress Intrinsic SC	BASF	Drench	3 fl oz per 100 gal	2
			Drench	23.8 fl oz per 100 gal	1
Pyraziflumid	Pyraziflumid 20SC	Nichino	Drench	1.69 fl oz per 100 gal	1
			Drench	3.38 fl oz per 100 gal	1
			Drench	6.76 fl oz per 100 gal	1
<i>Streptomyces griseoviridis</i> strain K61	Mycostop 11G	Verdera	Drench	0.18 oz per 100 gal	1
Thiophanate methyl	3336 50WP	Cleary	Drench	4 oz per 100 gal	1
			Drench	8 oz per 100 gal	1
			Drench	16 oz per 100 gal	3
	3336 SC	Nisso	Drench	24 fl oz per 100 gal	1
			Drench	16 oz per 100 gal	1
	Topsin-M WSB	OHP 6672 F	OHP	Drench	12 oz per 100 gal
Triflumizole	Terraguard 50W	Chemtura	Drench	14.5 fl oz per 100 gal	1
			Drench	4 oz per 100 gal	2
	Terraguard SC	Chemtura	Drench	6 fl oz per 100 gal	1
			Drench	8 fl oz per 100 gal	1
Drench	24 fl oz per 100 gal	1			

Active Ingredient(s)	Products	Manufacturer	Rate(s) Tested		# Trials
			Rate(s) Tested		
Triticonazole	Trinity	BASF	Drench	2 fl oz per 100 gal	1
				6 fl oz per 100 gal	1

Results

Comparative Efficacy on *Thielaviopsis basicola*

In 2003, Hausbeck conducted a trial to determine efficacy of several fungicides applied as drench to control black root rot (*Thielaviopsis basicola*) on vinca (*Catharanthus roseus*). Plant roots were dipped into a spore solution and planted into a soilless medium on May 5; treatments were applied on May 9 and 23. Banrot 40WP and 3336 50WP completely prevented plant death from a severe disease pressure (Table 2). Terraclor and Terraguard were less effective.

Table 2. * Efficacy on Black Root Rot (*Thielaviopsis basicola*) on Vinca (*Catharanthus roseus*) ‘Rose Cooler’, Hausbeck, MI, 2003.

Treatment	Rate Per 100 Gal	Plant Health Rating ^x			Plant Death (%)	
		5/23	5/30	6/6	5/30	6/6
3336 50WP (thiophanate-methyl)	4.0 oz	1.2 ab	1.5 a	1.3 ab	0.0 a	0.0 a
Banrot 40WP (etrizazole + thiophanate-methyl)	8.0 oz	1.0 a	1.5 a	1.2 ab	0.0 a	0.0 a
Terraclor 75WP (PCNB)	4.0 oz	3.2 bcd	3.8 bc	3.3 b-e	50.0 ab	50.0 ab
Terraguard 50W (triflumizole)	4.0 oz	1.8 abc	2.7 ab	2.2 abc	16.7 ab	16.7 ab
Untreated uninoculated	-	1.5 ab	1.0 a	1.0 a	0.0 a	0.0 a
Untreated inoculated	-	3.8 d	4.7 bc	4.5 de	66.7 b	83.3 b

* Not an IR-4 Experiment: F&N Tests Vol 59:OT016.

^x Rated on a scale of 1-5, where 1=healthy, 5=dead. Means followed by same letter do not differ significantly based on Tukey’s Studentized Range test, $P=0.05$.

In 2003, Benson conducted a trial to determine efficacy of several fungicides applied as drench to control black root rot (*Thielaviopsis basicola*) on pansy (*Viola x wittrockiana*). Initially, Mycostop (0.07 oz/cu yd) and Prestop (10 oz/cu yd) were incorporated into the container mix prior to transplanting, and the other products were drenched at 100 ml per 6-cell pack on Jan 3, 5 days before inoculating plants. All materials were re-applied as drenches on Feb 11 and Mar 5 for a total of three applications (30-day schedule). Disease pressure was severe in both controls. After 75 days, the non -inoculated control had become heavily infected by splash dispersal of inoculum from overhead watering. Biophos at the highest rate, Vital at the two highest rates and 3336 WP significantly reduced black root rot and increased plant weights, while Prestop and Mycostop were ineffective (Table 3). No phytotoxicity was observed from any treatment.

Table 3. * Efficacy on Black Root Rot (*Thielaviopsis basicola*) on Pansy (*Viola x wittrockiana*) ‘Delta Tapestry’, Benson, NC, 2003.

Treatment	Rate Per 100 Gal	Root Rating ^x	Top Wt (g)
3336 50WP (thiophanate-methyl)	8 oz	2.3 c	11.9 a
Biophos 43L (dipotassium phosphonate + dipotassium phosphate)	25.6 fl oz	2.7 bc	8.8 bc
	64 fl oz	2.5 c	9.4 b
	128 fl oz	2.5 c	10.4 ab
Mycostop 11G (<i>Streptomyces</i> strain K61)	0.18 oz	3.6 a	4.7 e
Prestop 37WP (<i>Gliocladium catenulatum</i> strain J1446)	27 oz	3.6 a	4.5 e
Vital 4L (potassium phosphite)	32 fl oz	2.2 c	8.4 bc
	64 fl oz	2.1 c	9.6 ab
Untreated uninoculated	-	3.1 ab	4.8 de
Untreated inoculated	-	3.1 ab	7.0 cd

* Not an IR-4 Experiment: F&N Tests Vol 59:OT024.

^x Rated on a scale of 1-5, where 1= healthy, no black root rot, 2= lesions of black root rot on some roots, 3= root rot severe, 50% of root system diseased, 4= root rot very severe, 75% or more of root system diseased, and 5 = plant dead, few roots and all diseased. Means followed by same letter do not differ significantly based on Waller-Duncan k ratio, k=100, P=0.05.

In 2005, Hausbeck conducted a trial to determine efficacy of several fungicides applied as drench to control black root rot (*Thielaviopsis basicola*) on pansy (*Viola x wittrockiana*). Treatments were applied on May 5 to plants that were inoculated the same day. Endorse at the high rate (8 oz), Medallion and Cleary’s 3336 provided excellent control, comparable to the untreated uninoculated Check on plant health and death caused by a severe disease pressure (Table 4). Heritage was less effective, while Cyazofamid was ineffective. No phytotoxicity was observed from any treatment.

Table 4. * Efficacy on Black Root Rot (*Thielaviopsis basicola*) on Pansy (*Viola x wittrockiana*) ‘Purple’, Hausbeck, MI, 2005.

Treatment	Rate Per 100 Gal	Plant Health Rating ^x				Plant Death (%)	
		5/16	5/23	5/31	6/6	5/31	6/6
3336 50WP (thiophanate-methyl)	16 oz	1.0 a	1.4 a	1.5 a	1.5 a	12.5 a	12.5 a
Cyazofamid 400SC	1.5 fl oz	2.3 b	3.4 c	3.9 bc	4.8 b	12.5 a	75.0 b
	3 fl oz	2.7 b	3.9 c	4.4 c	5.0 b	37.5 a	100.0 b
Endorse 11.3DF (polyoxin D)	4 oz	1.0 a	1.0 a	1.4 a	1.6 a	0.0 a	14.3 a
	8 oz	1.0 a	1.0 a	1.0 a	1.1 a	0.0 a	0.0 a
Heritage 50WG (azoxystrobin)	0.9 oz	1.3 a	2.5 b	3.1 b	4.6 b	12.5 a	62.5 b
Medallion 50WP (fludioxonil)	2 oz	1.0 a	1.1 a	1.5 a	2.0 a	0.0 a	0.0 a
Untreated uninoculated	-	1.0 a	1.0 a	1.0 a	1.0 a	0.0 a	0.0 a
Untreated inoculated	-	2.4 b	3.3 c	4.3 c	5.0 b	25.0a	100.0 b

* Not an IR-4 Experiment: F&N Tests Vol 61:OT020.

^x Rated on a scale of 1-5, where 1=healthy, 5=dead. Means followed by same letter do not differ significantly based on Student-Newman-Keuls test, P=0.05.

In 2005, Warfield conducted a trial to determine efficacy of several fungicides applied as drench to control black root rot (*Thielaviopsis basicola*) on pansy (*Viola x wittrockiana*). Treatments were applied on Apr 6 to plants that were inoculated on Mar 31; a second application occurred at dates shown in Table

5. The standard 3336 50WP provided excellent control, comparable to the untreated uninoculated Check on root rot rating caused by a severe disease pressure (Table 5). Banrot and Terraguard were also effective, while Medallion was ineffective.

Table 5. * Efficacy on Black Root Rot (*Thielaviopsis basicola*) on Pansy (*Viola x wittrockiana*) ‘Delta Violet with Face’, Warfield, NC, 2005.

Treatment	Rate Per 100 Gal	Applic. Dates	Health Rating ^x	Root Rating ^y	Top Wt (g)
3336 50WP (thiophanate-methyl)	16 oz	4/6, 4/27	1.9 c	1.3 d	0.61 b
Banrot 40WP (etrizazole + thiophanate-methyl)	6 oz	4/6, 5/4	1.9 c	2.5 c	0.52 bc
Medallion 50WSP (fludioxonil)	2 oz	4/6, 4/27,	3.8 b	4.7 ab	0.10 d
Terraguard 50W (triflumizole)	4 oz	4/6, 4/20	2.5 c	2.8 c	0.37 c
Untreated uninoculated	-	-	1.0 d	1.5 d	0.90 a
Untreated inoculated	-	-	4.9 a ^x	5.0 a	0.04 d

* Not an IR-4 Experiment: F&N Tests Vol 61:OT002. Not all products tested included in table.

^x Rated on a scale of 1-5, where 1= healthy plant, dark green leaves, three or more flowers or buds, 2= dark green leaves, branching, height reduction, one or more flowers, 3=no branching, height reduction, one or more flowers, 4= severely stunted, moderate chlorosis, one bud or flower present, 5= severe stunting, severe chlorosis, no flowers. Means followed by same letter do not differ significantly based on Waller-Duncan k ratio, t-test, k=100, P=0.05.

^y Rated on a scale of 1-5, where 1=healthy white roots filled pot, 2= white roots with a few brown roots, roots filled pot, 3= mostly white roots, roots only partially filled pot, lesions of black root rot on some roots, 4= root rot severe, 66% or more of root system with lesions of black root rot, 5= severely infected roots, roots failed to grow beyond plug.

In 2010, Steddom conducted a trial to determine efficacy of several fungicides applied as drench to control black root rot (*Thielaviopsis basicola*) on pansy (*Viola x wittrockiana*). Treatments were applied when the plugs were watered in, within 4 hours after infestation. Trinity 2SC was applied on Apr 14 and May 5. All other fungicides were applied on Apr 14, Apr 28 and May 12. Veranda O at the high rate and both Hurricane treatments reduced foliar disease symptoms from a severe disease pressure (Table 6). However, the high rate of Veranda O was the only treatment that significantly reduced the severity of both foliar and root symptoms. The consistent differences between the uninoculated Check and any of the fungicide treatments from May 7 and beyond illustrate the importance of sanitation in management of this disease, with chemicals being used prophylactically. No phytotoxicity was observed from any treatment.

Table 6. * Efficacy on Black Root Rot (*Thielaviopsis basicola*) on Pansy (*Viola x wittrockiana*) ‘Matrix Sunrise’, Steddom, TX, 2010.

Treatment	Rate Per 100 Gal	Visual Disease Rating			
		Apr 30 ^x	May 7 ^x	May 14 ^x	May 19 ^w
3336 WP (thiophanate-methyl)	16.0 oz	1.3 a	2.7 abc	3.3 a-d	3.3 abc
Hurricane (fludioxonil + mefenoxam)	0.75 oz	0.040 d	0.88 de	2.7 d	3.3 bc
KleenGrow + KleenGrow ^z (didecyl dimethyl ammonium chloride)	6 + 13 fl oz	1.2 ab	2.5 abc	3.3 a-d	4.0 a
Medallion (fludioxonil)	1.0 oz	1.1 ab	2.5 abc	3.1 bcd	3.3 abc
	2.0 oz	1.3 a	2.5 abc	3.4 abc	3.6 abc
Trinity 2SC (triticonazole)	2.0 fl oz	1.3 a	3.0 ab	3.3 a-d	3.3 abc
	6.0 fl oz	1.3 a	3.3 a	4.0 a	3.7 ab
Veranda O WDG (polyoxin D)	0.25 lb	0.42 bcd	2.5 abc	3.4 abc	3.6 abc
	0.5 lb	0.93 abc	2.1 bc	2.9 cd	2.9 c
Untreated uninoculated	-	0.10 d ^x	0.63 e	1.6 e	0.40 d
Untreated inoculated	-	1.0 ab	2.4 abc	3.7 ab	3.8 ab

* Not an IR-4 Experiment: Plant Disease Management Reports Vol 5:OT010. Not all products tested included in table.

^x Visual assessment of foliage based on a 0-5 scale where 0= healthy, 3= chlorosis and stunting with plant unmarketable, and 5=plant nearly dead. Means followed by same letter do not differ significantly based on Fisher’s Protected LSD test, P=0.05.

^y Visual assessment of the whole plant based on a 0-5 scale where 0=a large, healthy plant with no root discoloration, 3=a moderately stunted plant with discolored roots, and 5=a plant that is severely stunted with the majority of roots with black streaking.

^z Initial application at low rate followed by the high rate for subsequent applications.

In 2014, Beckerman conducted a trial to determine efficacy of several fungicides applied as drench to control black root rot (*Thielaviopsis basicola*) on pansy (*Viola x wittrockiana*). Fungicides were applied on day 0, week three, and week six. On day 2, roots were rinsed, suspended in a *Thielaviopsis* spore suspension (6.4×10^8 spores/ml) for 10 seconds, and then re-potted. BAS 703 (4 fl oz) had healthier roots compared to the positive control and BAS 703 (6 fl oz). The results of this study suggest that the low rate of BAS 703 (4 fl oz) effectively controls black root rot with little to no phytotoxicity (Table 7). However, higher rates of BAS 703 (6 and 8 fl oz) and Empress Intrinsic (3 fl oz) are phytotoxic to pansies and consequently allowed pathogen entry, resulting in lowered plant quality and root health.

Table 7. * Efficacy on Black Root Rot (*Thielaviopsis basicola*) on Pansy (*Viola x wittrockiana*) ‘Delta Premium Purple Medley’, Beckerman, IN, 2014.

Treatment	Rate Per 100 Gal	Week 6		Week 8		Week 10		
		Plant Health ^x	Phyto ^y	Plant Health	Phyto	Plant Health	Phyto	Root Rating ^z
BAS 703 (pyraclostrobin + fluxapyroxad)	4 fl oz	4.2 a	0.6 ab	4.3 a	0.5 a	4.7 a	0.5 a	0.7 ab
	6 fl oz	2.7 a	1.3 a	2.3 a	1.6 a	3.2 a	1.5 a	2.3 a
	8 fl oz	2.0 a	1.7 a	2.2 a	1.6 a	2.0 a	1.7 a	2.0 ab
Empress Intrinsic (pyraclostrobin)	3 fl oz	2.2 a	1.3 a	2.3 a	1.1 a	2.3 a	1.2 a	1.5 ab
Untreated uninoculated	-	4.8 a	0.0 b	4.8 a	0.0 a	4.8 a	0.0 a	0.0 b
Untreated inoculated	-	2.8 a	0.0 b	3.0 a	0.0 a	2.8 a	0.0 a	2.2 a

* Not an IR-4 Experiment: Plant Disease Management Reports Vol 12: OT018.

^x Rated on a scale of 0-5, where 5= healthy, dark green leaves, 4= <10% leaf wilt or discoloration, 3= partly stunted, 30% leaf wilt discoloration, 2= severely stunted, >50% leaf wilt discoloration, 1= severely stunted, >90% leaf wilt or discoloration, 0= dead. Means followed by same letter do not differ significantly based on Tukey-Kramer HSD test, $P=0.05$.

^y Rated on a scale of 0-3, where 0= no symptoms, 1= partial stunting and <10% leaf burn, 2= partial stunting and 50% leaf burn, 3=severely stunted and >75% leaf burn.

^z Rated on a scale of 0-4, where 0= healthy all white roots, no sign of pathogen infection, 1= mostly white and few brown roots, no sign of pathogen, 2= mostly brown, no signs of pathogen, 3= mostly brown with signs of pathogen mycelia, 4= mostly dead with signs of pathogen mycelia.

In 2014, Hausbeck conducted a trial to determine efficacy of several fungicides applied as drench to control black root rot (*Thielaviopsis basicola*) on petunia (*Petunia x hybrida*). Plants were inoculated on Aug 27, treatments were applied on Aug 27 and Sep 10. Disease pressure was severe with 50% of the untreated inoculated control plants dead by the final rating date (Table 8). Empress and the industry standards Medallion and Terraguard provided adequate control of the pathogen and resulted in plant health ratings statistically similar to the uninoculated Check by the final rating date. BAS 703 was not effective and resulted in plant health ratings statistically similar to the untreated inoculated control. Veinal chlorosis was observed on all plants treated with BAS 703; however, this symptom could not be associated exclusively with phytotoxicity, it could have been a symptom of injury from the pathogen, or a combination of both.

Table 8. * Efficacy on Black Root Rot (*Thielaviopsis basicola*) on Petunia (*Petunia x hybrida*) ‘Madness Yellow’, Hausbeck, MI, 2014.

Treatment	Rate Per 100 Gal	Plant Health Rating ^x			Plant Death (%)	
		Sep 8	Sep 19	Oct 1	Sep 19	Oct 1
BAS 703 01F (pyraclostrobin + fluxapyroxad)	4 fl oz	2.2 cd	2.3 bc	3.0 b	0.0 a	0.0 a
	6 fl oz	2.2 cd	2.2 bc	2.8 b	0.0 a	0.0 a
	8 fl oz	2.3 d	2.7 c	3.8 b	16.7 a	50.0 b
Empress SC (pyraclostrobin)	3 fl oz	1.5 ab	1.0 a	1.2 a	0.0 a	0.0 a
Medallion 50WP (fludioxonil)	2 oz	1.7 bc	1.3 ab	1.5 a	0.0 a	0.0 a
Terraguard SC (triflumizole)	8 fl oz	1.8 bcd	1.0 a	1.2 a	0.0 a	0.0 a
Untreated uninoculated	-	1.0 a	1.0 a	1.0 a	0.0 a	0.0 a
Untreated inoculated	-	2.3 d	3.0 c	3.2 b	16.7 a	50.0 b

* Not an IR-4 Experiment: Plant Disease Management Reports Vol 9:OT013.

^x Rated on a scale of 1-5, where 1=healthy, 2=chlorosis/stunting, 3=minor wilting, 4=moderate/severe wilting, 5=plant death. Means followed by same letter do not differ significantly based on Fisher's LSD test, $P=0.05$.

In 2015, Beckerman conducted a trial to determine efficacy of several fungicides applied as drench to control black root rot (*Thielaviopsis basicola*) on pansy (*Viola x wittrockiana*). Treatments were applied on Mar 23, and inoculations occurred on Mar 24. All products were re-applied on Apr 6 and 20 for a total of three applications. Disease pressure was moderate and plant health decreased over time with the untreated, inoculated control plants showing chlorosis and stunting by the end of the trial period and the untreated, uninoculated control having consistently high visual plant health (Table 9). Plants treated with lowest rate of BAS 70306 (8.0 fl oz) and Topsin-M displayed significantly high plant health throughout the trial. Plants treated with higher rates of BASF 70306 (10.0 and 13.0 fl oz) had lower plant health, and slight symptoms of phytotoxicity at the end of the trial.

In 2016, Beckerman conducted a trial to determine efficacy of several fungicides applied as drench to control black root rot (*Thielaviopsis basicola*) on pansy (*Viola x wittrockiana*). Treatments were applied on Jun 28, and inoculations occurred on Jun 29. All products were re-applied on Jul 28. Disease pressure was moderate to high and increased over time with the untreated, inoculated Check plants showing chlorosis, stunting and/or death by the end of the trial period (Table 10). BAS 750 at 2.4 and 3.0 fl oz rates, along with Topsin-M and Terraguard, provided excellent disease control. All fungicides reduced the presence of fungal signs in the root tissue. Terraguard caused some phytotoxicity in the form of leaf distortion.

Table 9. * Efficacy on Black Root Rot (*Thielaviopsis basicola*) on Pansy (*Viola x wittrockiana*) ‘Sorbet Series’, Beckerman, IN, 2015.

Treatment	Rate Per 100 Gal	April 21			May 5		May 19		
		Plant Health ^x	Phyto ^y	Root Rating ^z	Plant Health	Phyto	Plant Health	Phyto	Root Rating
BAS 70306 (pyraclostrobin + fluxapyroxad)	8 fl oz	4.3 a	0.6 a	0.2 a	4.5 a	0.6 ab	4.5 a	0.8 bc	0.5 c
	10 fl oz	4.5 a	0.5 a	0.3 a	4.0 ab	1.6 a	3.0 bc	1.8 a	1.8 b
	13 fl oz	4.1 a	0.5 a	0.5 a	4.1 ab	0.5 ab	3.8 ab	1.5 ab	2.0 b
Topsin-M WP ((thiophanate-methyl))	12 oz	4.3 a	0.3 a	0.5 a	4.5 a	0.5 ab	4.1 a	0.6 bc	1.8 b
Untreated uninoculated	-	4.6 a	0.0 a	0.6 a	4.6 a	0.0 b	4.6 a	0.0 c	0.5 c
Untreated inoculated	-	4.1 a	0.0 a	0.5 a	3.6 b	0.0 b	2.8 c	0.0 c	2.6 a

* Not an IR-4 Experiment: Plant Disease Management Reports Vol 12: OT017.

^x Rated on a scale of 0-5, where 1= severely stunted >90% leaf wilting or discoloration; 2= Severely stunted, >50% leaf wilting or discoloration; 3= Partly stunted, 30% leaf wilting or discoloration; 4= <10% leaf wilting or discoloration; 5= Healthy dark green leaves. Means followed by same letter do not differ significantly based on Fisher’s Protected LSD test, $P=0.05$.

^y Rated on a scale of 0-3, where 0= no symptoms, 1= partial stunting and <10% leaf burn, 2= partial stunting and 50% leaf burn, 3=severely stunted and >75% leaf burn.

^z Rated on a scale of 0-4, where 0=healthy, white root with no sign of pathogen; 1= mostly white root, some browning; 2= mostly brown roots without signs of pathogen; 3= brown roots with limited pathogen signs; 4= mostly dead with pathogen signs.

Table 10. * Efficacy on Black Root Rot (*Thielaviopsis basicola*) on Pansy (*Viola x wittrockiana*) ‘Mixed Blue’, Beckerman, IN, 2016.

Treatment	Rate Per 100 Gal	May 17		May 24		May 31		
		Percent Symptom Development ^x	Phyto ^y	Percent Symptom Development	Phyto	Percent Symptom Development	Phyto	Percent Root Infection ^z
BAS 750 (mefentrifluconazole)	1.8 fl oz	10.8 a	1.1	25.8 a	1.2	13.3 b	1.2	41.7 ab
	2.4 fl oz	4.2 a	1.0	4.2 b	1.0	10.8 b	1.0	33.3 b
	3.0 fl oz	1.7 a	1.0	3.3 b	1.0	14.2 b	1.0	15.8 b
Terraguard SC (triflumizole)	24 fl oz	8.3 a	1.0	13.3 ab	1.5	8.3 b	1.7	24.2 b
Untreated inoculated	-	10.8 a	1.0	25.8 a	1.0	33.3 a ^w	1.0	66.7 a

* Not an IR-4 Experiment: Plant Disease Management Reports Vol 12: OT019.

^x Above ground symptom development was assessed by percent of replicate exhibiting chlorosis, necrosis or stunting. Means followed by same letter do not differ significantly based on Tukey-Kramer HSD test, $P=0.05$.

^y Rated on a scale of 1-5, where 1= no symptoms; 2= slight stunting and 1-20% leaf yellowing; 3= partial stunting and 20-40% leaf yellowing; 4= severely stunted and 40-60% leaf yellowing; 5= 80-100% stunting and/or chlorosis.

^z Rated on a scale of 0-4, where 0= healthy, white root with no sign of pathogen; 1= mostly white root, some browning; 2= mostly brown roots without signs of pathogen; 3= brown roots with limited pathogen signs; 4= mostly dead with pathogen signs.

In 2016, Beckerman conducted a trial to determine efficacy of several fungicides applied as drench to control black root rot (*Thielaviopsis basicola*) on vinca (*Catharanthus roseus*). Treatments were applied on Jun 28, and inoculations occurred on Jun 29. All products were re-applied as drenches on Jul 28. Disease pressure was moderate to high and increased over time with the untreated, inoculated Check plants showing chlorosis, stunting and/or death by the end of the trial period (Table 11). BAS 750 at 2.4 and 3.0 fl oz rates, along with Topsin-M and Terraguard, provided excellent disease control. All fungicides reduced the presence of fungal signs in the root tissue. Terraguard caused some phytotoxicity in the form of leaf distortion.

Table 11. * Efficacy on Black Root Rot (*Thielaviopsis basicola*) on Vinca (*Catharanthus roseus*) ‘Mediterranean Mixed’, Beckerman, IN, 2016.

Treatment	Rate Per 100 Gal	Disease Severity ^x				Root Rating ^y
		Jul 20	Jul 28	Aug 2	Aug 14	
BAS 750 (mefentrifluconazole)	1.8 fl oz	4.66 a	4.33 a	4.33 a	4.33 ab	1.33 b
	2.4 fl oz	4.17 a	4.33 a	4.17 a	3.58 ab	0.50 b
	3.0 fl oz	3.58 ab	3.42 ab	3.50 ab	3.00 ab	0.50 b
Terraguard SC (triflumizole)	6 fl oz	3.75 a	3.67 ab	3.67 ab	3.08 ab	0.83 b
Topsin-M WSB (thiophanate-methyl)	12 oz	4.0 a	3.67 ab	3.50 ab	4.83 a	0.17 b
Untreated inoculated	-	4.33 a	3.50 ab	2.50 b	2.17 b	3.33 a

* Not an IR-4 Experiment: Plant Disease Management Reports Vol 12:OT015.

^x Rated on a scale of 1-5, where 5= healthy; 4= minor chlorosis; 3= moderate chlorosis/stunting; 2= severe chlorosis/wilting; 1= plant dead. Means followed by same letter do not differ significantly based on Tukey-Kramer HSD test, $P=0.05$.

^y Rated on a scale of 0-4, where 0= healthy, white root with no sign of pathogen; 1= mostly white root, some browning; 2= mostly brown roots without signs of pathogen; 3= brown roots with limited pathogen signs; 4= mostly dead with pathogen signs.

In 2016, Hausbeck conducted a trial to determine efficacy of several fungicides applied as drench to control black root rot (*Thielaviopsis basicola*) on pansy (*Viola x wittrockiana*). Treatments were applied on Apr 25 to plants that were inoculated the same day. Select fungicides were reapplied at a 10 or 14-day interval as indicated in Table 12. Disease pressure was severe in this trial with 83.0% of the untreated inoculated control plants dead and an average plant health rating of 4.8 by 16 May. The industry standard OHP 6672 F was highly efficacious with treated plants showing no symptoms of *T. basicola* infection. Pyraziflumid and Empress Intrinsic were ineffective. Plants treated with Tourney 50WDG were stunted compared to the uninoculated Checks, however, more research is needed to determine if this stunting was a result of pathogen infection or phytotoxicity from the fungicide. No phytotoxicity was observed from any treatment.

Table 12. * Efficacy on Black Root Rot (*Thielaviopsis basicola*) on Pansy (*Viola x wittrockiana*) ‘Northern Lights’, Hausbeck, MI, 2016.

Treatment and application interval	Rate Per 100 Gal	Plant Health Rating ^x				Plant Death (%)			
		May 2	May 5	May 10	May 16	May 2	May 5	May 10	May 16
Empress Intrinsic SC (pyraclostrobin) <i>14-day</i>	3.0 fl oz	1.2 a	2.7 b	4.2 b	4.8 c	0.0	0.0	17.0	83.0 b
OHP 6672 F (thiophanate-methyl) <i>14-day</i>	14.5 fl oz	1.0 a	1.0 a	1.0 a	1.0 a	0.0	0.0	0.0	0.0 a
Pyraziflumid 20SC (pyraziflumid) <i>10-day</i>	1.69 fl oz	2.0 b	3.7 c	4.3 bc	5.0 c	0.0	33.0	67.0	100.0 b
	3.38 fl oz	2.5 c	4.3 c	4.8 c	4.8 c	0.0	33.0	83.0	83.0 b
	6.76 fl oz	2.2 bc	4.2 c	4.7 bc	4.8 c	0.0	17.0	67.0	83.0 b
Tourney 50WDG (metconazole) <i>one application</i>	4.0 oz	1.2 a	1.3 a	1.3 a	2.2 b	0.0	0.0	0.0	0.0 a
Uninoculated Control		1.0 a	1.0 a	1.0 a	1.0 a	0.0	0.0	0.0	0.0 a
Inoculated Control		2.2 bc	3.7 c	4.3 bc	4.8 c	0.0	17.0	33.0	83.0 b

* Not an IR-4 Experiment: Plant Disease Management Reports Vol 11:OT031.

^x Rated on a scale of 1-5, where 1=healthy, 2=chlorosis/stunting, 3=minor wilting, 4=moderate/severe wilting, 5=plant death. Means followed by same letter do not differ significantly based on Fisher LSD test, *P*=0.05.

In 2017, Hand conducted a trial to determine efficacy of several fungicides applied as drench to control black root rot (*Thielaviopsis basicola*) on petunia (*Petunia x hybrida*). Treatments were applied on Jan 17, and inoculations occurred on Jan 19. Disease pressure was moderate in this trial and increased progressively over time with untreated, inoculated control plants showing moderate to severe chlorosis and stunting by the end of the trial period (Table 13). A20808C, Medallion and Mural provided excellent control, 3336 was less effective, while A19649B was ineffective. A19649B caused bleaching on leaves of plants treated within one-week post application.

Table 13. * Efficacy on Black Root Rot (*Thielaviopsis basicola*) on Petunia (*Petunia x hybrida*) ‘Madness Yellow’, Hand, OH, 2017.

Treatment	Rate Per 100 Gal	Disease Severity ^x			
		Jan 26	Feb 2	Feb 9	Feb 16
A19649B SC (A19649B)	13 fl oz	2.16 a	2.87 a	3.00 ab	3.20 a
A20808C SC (A20808C)	27 fl oz	1.61 bc	1.58 cd	1.75 c	1.88 c
Cleary’s 3336 SC (thiophanate-methyl)	24 fl oz	2.04 ab	2.29 ab	2.41 bc	2.41 bc
Medallion 50WG (fludioxonil)	2 oz	1.58 bc	1.79 bc	1.87 c	1.95 c
Mural 45WG (azoxystrobin + benzovindiflupyr)	3 oz	1.45 cd	1.66 bc	1.79 c	1.83 c
Untreated uninoculated	-	1.00 d	1.00 d	1.00 d	1.00 d
Untreated inoculated	-	2.00 ab	2.79 a	3.12 a	3.29 a

* Not an IR-4 Experiment: Plant Disease Management Reports Vol 11:OT026. Not all treatments included in table.

^x Rated on a scale of 1-5, where 1=healthy; 2=minor chlorosis; 3=moderate chlorosis/stunting; 4=severe chlorosis/wilting; 5=plant dead. Means followed by same letter do not differ significantly based on Tukeys HSD test, $P=0.05$.

Efficacy Summary by Product/Active Ingredient

A brief efficacy summary for select products is given below, with a reminder that there are very limited data available to draw definitive conclusions for product efficacy on *Thielaviopsis basicola*. Products were selected based on interest in these products for testing in the 2018 Non-Oomycete Root Rot efficacy project, and on whether product is registered or not for this root rot species.

A19649B. This active ingredient provided poor efficacy on *Thielaviopsis basicola* in a pansy experiment.

A20808C. This active ingredient provided good efficacy on *Thielaviopsis basicola* in a pansy experiment.

Azoxystrobin. Heritage provided poor efficacy on *Thielaviopsis basicola* in a pansy experiment.

Azoxystrobin + benzovindiflupyr. Mural provided excellent efficacy on *Thielaviopsis basicola* in a petunia experiment.

Cyazofamid. Cyazofamid SC provided poor efficacy on *Thielaviopsis basicola* in a pansy experiment.

Didecyl dimethyl ammonium chloride. L KleenGrow provided poor efficacy on a severe *Thielaviopsis basicola* pressure in a pansy experiment; the standard 3336 also provided poor efficacy.

Fludioxonil. Medallion provided excellent efficacy on *Thielaviopsis basicola* in a petunia experiment, and poor and excellent in 2 pansy trials. In another pansy trial, poor efficacy on a severe *Thielaviopsis basicola* pressure was obtained; the standard 3336 also provided poor efficacy.

Fludioxonil+Mefenoxam. Hurricane provided mediocre efficacy, but better than the standard 3336, on a severe *Thielaviopsis basicola* pressure in a pansy experiment.

Fluxapyroxad + Pyraclostrobin. This active ingredient provided mixed efficacy (poor to excellent) on *Thielaviopsis basicola* in 3 experiments on pansy and petunia. The lower rates (4-8 fl oz) looked more efficacious, while higher rates might be phytotoxic.

Gliocladium catenulatum strain J1446. Prestop WP provided poor efficacy on *Thielaviopsis basicola* in a pansy experiment.

Mefentrifluconazole. BAS 750 provided excellent efficacy on *Thielaviopsis basicola* in 2 pansy and vinca experiments.

Metconazole. provided good efficacy on *Thielaviopsis basicola* in a pansy experiment.

Polyoxin D. Endorse provided excellent efficacy on *Thielaviopsis basicola* in a pansy experiment. In another trial, Veranda O provided mediocre efficacy on a severe *Thielaviopsis basicola* pressure, but it performed better than the standard 3336.

Potassium phosphite. Vital provided excellent efficacy on *Thielaviopsis basicola* in a pansy experiment.

Pyraclostrobin. Empress Intrinsic provided excellent efficacy on *Thielaviopsis basicola* in a petunia experiment, but mediocre efficacy in a pansy trial.

Pyraziflumid. Pyraziflumid SC provided poor efficacy on *Thielaviopsis basicola* in a pansy experiment.

Streptomyces griseoviridis strain K61. Mycostop G provided poor efficacy on *Thielaviopsis basicola* in a pansy experiment.

Thiophanate methyl. This active ingredient, used as a standard, generally provided excellent efficacy in 9 experiments on pansy, petunia and vinca.

Triflumizole. Terraguard, used as a standard generally provided excellent efficacy in 3 experiments on pansy and petunia.

Triticonazole. Trinity provided poor efficacy on a severe *Thielaviopsis basicola* pressure in a pansy experiment; the standard 3336 also provided poor efficacy.

Phytotoxicity

In 2014, plants treated with higher rates of BAS 703 (6 and 8 fl oz) and Empress Intrinsic (3 fl oz) were phytotoxic to pansies and consequently allowed pathogen entry, resulting in lowered plant quality and root health; in 2015, higher rates of BASF 703 (10.0 and 13.0 fl oz) had lower plant health, and slight symptoms of phytotoxicity at the end of the trial in another pansy trial. In a vinca trial, Terraguard caused some phytotoxicity in the form of leaf distortion. In a petunia trial, A19649B caused bleaching on leaves of plants within one-week post application.

Appendix 1: Contributing Researchers

Dr. Janna L. Beckerman	Purdue University Dept. of Botany and Plant Pathology West Lafayette, IN 47907 765-494-4628
Dr. Mike Benson (<i>retired</i>)	North Carolina State University Dept. of Plant Pathology 840 Method Rd. – Unit 3 Raleigh, NC 27695
Dr. Francesca Hand	Ohio State University Department of Plant Pathology 475C Kottman Hall Columbus, OH 43210
Dr. Mary Hausbeck	Michigan State University Department of Plant Pathology 140 Plant Pathology Building East Lansing, MI 48824
Dr. Karl Steddom (<i>past affiliate</i>)	Texas A & M University Texas AgriLife Extension Service Overton, TX 75684
Dr. Colleen Warfield	Ball Horticultural Company 622 Town Road West Chicago, IL 60185