Evaluation of a Fungicide Application as Influenced by Spray Nozzles for Rhizoctonia Blight Management in Cool-Season Turfgrass Lawns[1]

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Abstract

Increased utilization of tall fescue (*Schedonorus arundinaceus* [Schreb.] Dumort) in residential lawns is due to enhanced drought tolerance and minimal problems with insect pests. Rhizoctonia blight (*Rhizoctonia solani* Kühn) or "brown patch", however, is a persistent disease of tall fescue lawns during summer months. The objective of this research was to evaluate a new fungicide [Mural 0.45WG active ingredients (a.i.'s: azoxystrobin and benzovindiflupyr)] for Rhizoctonia blight control in tall fescue as influenced by spray nozzle type. The fungicide was applied once to tall fescue in Ohio (OH) and Pennsylvania (PA), in both preventive and curative field trials. Three different spray nozzles were used to produce different spray droplet sizes (TurfJet 1/4TTJO4 = extremely coarse; Air Induction 8004 = very coarse; and XR TeeJet 8008 = coarse). Disease control and turfgrass quality were evaluated for a 63-day period after application. The fungicide, when applied using spray nozzles that produced either coarse or very coarse droplets, provided $\geq$42 days of preventive and curative disease control at both sites. Overall, better turfgrass quality was related to better disease control also at both sites. This offers value for turfgrass industry professionals as well as allowing for reductions in drift and non-target environmental problems.

Species used in this study: tall fescue, *Schedonorus arundinaceus* (Schreb.) Dumort.

Chemicals used in the study: Mural 0.45WG (active ingredients a.i.'s: azoxystrobin and benzovindiflupyr).

Index words: brown patch, tall fescue, turfgrass, turfgrass disease, spray droplet size.

Significance to the Horticulture Industry

Residential (i.e. home) lawns represent an environment that is beneficial to soil quality, water filtration, mental health, and surface cooling amongst other ecosystem services on a daily basis. Turfgrass comprises a vast majority of these lawns, and if managed in a responsible and sustainable manner, these spaces can have a positive impact on both the environment and society. In an attempt to reduce maintenance requirements and inputs, breeding of more sustainable turfgrass species has led to the development of turfgrass cultivars with lower requirements for water and nitrogen. These advances are not a complete solution, however, because plant disease-causing fungal pathogens continue to persist, especially within current global climate conditions. Rhizoctonia blight (*Rhizoctonia solani* Kühn) is a major disease of tall fescue [*Schedonorus arundinaceus* (Schreb.) Dumort] lawns. A single targeted fungicide application for preventive or curative Rhizoctonia blight management in tall fescue lawns would be a sustainable way to reduce and optimize resource inputs. A liquid fungicide application can be delivered effectively through spray nozzles that produce a flat-fan spray pattern of coarse to extremely coarse droplet sizes. Also, the potential for spray drift can be significantly reduced with air induction spray nozzles that produce a very coarse droplet size.

Introduction

Tall fescue [*Schedonorus arundinaceus* (Schreb.) Dumort, formerly *Festuca arundinacea*] has become a very popular turfgrass species for lawns in the Mid-Atlantic and Mid-West regions of the USA, particularly since the commercialization of turf-type tall fescue cultivars (Funk et al. 1981, Samples et al. 2009, Watkins and Meyer 2004). Tall fescue is a cool-season grass with a bunch-type or tillering growth habit (Landschoot 2016). Forage-type tall fescues have a very coarse or wide leaf blade; however, turf-type tall fescues have a narrow or smaller width leaf blade similar to Kentucky bluegrass (*Poa pratensis* L.) and are more visually appealing for lawns and more functional for sports fields (Turgeon and Kaminski 2019).

In the northern hemisphere, typical summer environmental conditions of high air and soil temperatures and high humidity facilitate the occurrence of Rhizoctonia blight (*Rhizoctonia solani* Kühn), which is a common and severe foliar disease of tall fescue lawns (Fidanza et al. 1996, Latin 2008). Lawn care companies often rely on cultural practices in an attempt to manage Rhizoctonia blight in tall fescue lawns (Watschke et al. 2013). Both preventive and curative fungicide programs can be an effective management strategy for Rhizoctonia blight in turfgrass maintained on golf courses and sports fields; however, fungicide use is limited for lawns (Turgeon and Kaminski 2019). This is due to multiple possible factors, such as homeowners not valuing the need for the application and having concerns around the non-target effects of fungicide application, as well as the lack of

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Table 1. Spray droplet classification for agricultural pesticide applications.

Spray droplet dize classification[z]	VMD range[y]	Example of various degrees of atomization		Relative size	
	— μ —		— μ —		— μ —
Extremely Fine	<61	Fog	≤25	point of needle	25
Very Fine	61-105	Fine Mist	20-100	human hair	100
Fine	106-235	Fine Drizzle	100-250	sewing thread	150
Medium	236-340	Heavy Drizzle	250-500	toothbrush bristle	300
Coarse	341-403	Light Rain	500-800	staple	550
Very Coarse	404-502	Heavy Rain	800-1000	paper clip	850
Extremely Coarse	503-665	Thunderstorm Rain	1000-4000	#2 pencil lead	2000
Ultra Coarse	>665				

[z]Classification system developed by the American Society of Agricultural and Biological Engineers (https://www.asabe.org), listed as ASABE S572.1, as the standard method to measure and interpret droplet quality from spray nozzles.

consistent revenue generation for lawn care companies from the management of the disease. This limitation may be a deterrent to the introduction of tall fescue into more lawns, which would lead to overall benefits in reduced irrigation and pesticide inputs (Fidanza 2023).

Recent advances with pesticide application technology have focused on spray nozzles (i.e., spray tips) designed to improve delivery of foliar applied fungicides (Fidanza et al. 2009a, 2009b, Kaminski and Fidanza 2009, Nangle et al. 2021), and reduce spray drift to non-target sites (Grella et al. 2020, Kalsing et al. 2018). The nozzle orifice is designed to produce spray solution droplets in various sizes depending on the nozzle type (ASABE 2009, Lake 1977). A larger spray droplet translates to poorer coverage (i.e., less droplets per unit area of the intended plant canopy target) but better at drift reduction as compared to smaller spray droplets that have better coverage (i.e., more droplets per unit area) but more prone to drift off target (ASABE 2009, Creech et al. 2015, Stainier et al. 2006).

All spray nozzles produce a range of droplet sizes within their spray pattern; however, droplet size is based on volume mean diameter (VMD). The VMD represents 50% of the total spray volume comprised of droplets within diameters larger than the median value, and 50% smaller than the median value (ASABE 2009, Mathews 1992). Spray droplet sizes are determined from VMD and range from very fine to ultra coarse (Table 1). Therefore, spray droplet size listed for a nozzle is based on the manufacturer's laboratory analysis and specification for the various nozzle types at various application pressures (ASABE 2009, Creech et al. 2015).

Many lawn care companies now use ride-on sprayers/spreaders for product applications to lawns and landscapes (Nagro 2019). This motorized equipment facilitates the delivery of dry (i.e., granular) and liquid (i.e., spray) products quickly, uniformly, and efficiently. Because these machines are small and easy to drive and maneuver, it is now operationally possible and economically feasible for lawncare operators to easily apply both granular and liquid products (i.e., pesticides, fertilizers, biostimulants) to lawns and landscape properties (Patton et al. 2013). These machines typically have a 57 L (15 gal) capacity spray tank for liquid products, and a rotary spreader capacity for up to 23 kg (50 lb) of fertilizer.

These ride-on sprayers/spreaders for lawncare maintenance represent an opportunity to effectively delivery a single fungicide application for managing Rhizoctonia blight in tall fescue lawns. As the turfgrass maintenance industry moves toward improving efficacy with liquid product applications, an optimized and sustainable approach to managing this turfgrass disease is needed. Currently, the lawncare industry does not have a clear consensus as to what specific spray nozzle type should be utilized for ride-on sprayers/spreaders (Patton et al., 2013). Therefore, the objective of this research was to evaluate preventive and curative Rhizoctonia blight control or management in tall fescue lawns from the delivery of a single liquid fungicide application as influenced by spray nozzle type.

Materials and Methods

Field experiments or trials on tall fescue were conducted concurrently in Ohio and Pennsylvania. At both locations, treatments consisted of Mural 0.45WG fungicide (Syngenta Professional Solutions; Greensboro, NC) applied via three different spray nozzles and an untreated control, for a total of four treatments. The fungicide product label application rate is listed as 0.50 $L \cdot ha^{-1}$ (0.16 fl $oz \cdot 1000\ ft^{-2}$). Mural 0.45WG is formulated as a water dispersible granule and contains 30% azoxystrobin (FRAC code 11) and 15% benzovindiflupyr (FRAC code 7) (https://www.frac.info). The three spray nozzles were: TurfJet 1/4TTJO4 (TJ; spray droplet size = extremely coarse), Air Induction 8004 (AI; spray droplet size = very coarse), and XR TeeJet 8008 (XR; spray droplet size = coarse), all from TeeJet Technologies (200 W. North Ave., Glendale Heights, IL 60139) (Nangle et al. 2021). Of note, all three nozzles produce a flat-fan spray pattern.

Ohio – Preventive field trial. The preventive field trial was conducted at The Ohio State University Agricultural Technical Institute (Wooster, OH) on a three-year-old stand of turf-type tall fescue blend ('Avenger II' + 'Titanium 2LS' + 'Raptor III' + 'Hemi' + 'Inferno'). The soil rootzone texture was a loam with pH of 6.7 and 3.8% organic matter. Rhizoctonia blight has been frequently observed on this site during the summer months when environmental conditions favor poor air movement and high relative humidity.

The site typically was mowed one to two times per week at a height of 7 cm (2.75 in) with no collection of clippings. In comparison to many residential lawns in the Midwest USA when mowed by homeowners, this is considered a recommended mowing height for tall fescue and a higher height-of-cut may be even more beneficial (Samples et al. 2009). The site was fertilized with granular 25N-0P_2O_5-10K_2O (The Andersons Company; Maumee, OH) at 32 kg·N ha^{-1} (0.6 lb N·1000 ft^{-2}) with each application on 15 April, 10 May, and 25 June 2021.

Individual plot size was 1.8 × 1.8 m (6 × 6 ft) and treatments were arranged in a randomized complete block design with four replications. All treatments were applied using a CO_2-powered backpack sprayer at an operating pressure of 271 kPa (40 psi) delivered in 814 L water-carrier·ha^{-1} (2 gal·1000 ft^{-2}). All treatments were applied on 24 Jun 2021 prior to any development of disease symptoms and data were collected weekly throughout the duration of the field trial.

Ohio - Curative field trial. The curative field trial also was conducted at The Ohio State University Agricultural Technical Institute (Wooster, OH), in close proximity to the preventive field trial and on the same turf-type tall fescue blend where the pathogen had been previously observed. The soil rootzone texture also was a loam with pH of 6.8 and 3.4% organic matter. This site also has a history of Rhizoctonia blight activity during the summer months.

The site also was mowed one to two times per week at a height of 7 cm (2.75 in) with no collection of clippings. The site also was fertilized with granular 25N-0P_2O_5-10K_2O (The Andersons Company; Maumee, OH) at 32 kg·N ha^{-1} (0.6 lb N·1000 ft^{-2}) with each application on 15 April, 10 May, and 25 June 2021.

Individual plot size also was 1.8 × 1.8 m (6 × 6 ft) and treatments were arranged in a randomized complete block design with four replications. All treatments were applied on 20 July 2021 using a CO_2-powered backpack sprayer at an operating pressure of 271 kPa (40 psi) delivered in 814 L water-carrier·ha^{-1} (2 gal·1000 ft^{-2}). Data were collected weekly throughout the duration of the field trial.

Pennsylvania - Preventive field trial. The preventive field trial was conducted at the Center for the Agricultural Sciences and a Sustainable Environment (Berks Campus, Pennsylvania State University; Reading, PA) on a mature stand of a turf-type tall fescue blend ('Barmesh RTF' + 'Barvado' + 'Barrobusto'). The soil was a soil loam with a pH of 7.1, and 3.2% organic matter. This site has a history of naturally occurring Rhizoctonia blight often observed during high air temperature and relative humidity periods in the summer months.

From early spring through late fall 2021, the site was mowed once per week with a rotary mower to a height of 7.6 cm (3.0 in), and clippings typically not removed. This height-of-cut and mowing practice is common among turfgrass industry practitioners in the Mid-Atlantic USA region (Landschoot, 2016). This site was fertilized in late March 2021 with 44 kg·N ha^{-1} (0.9 lb N·1000 ft^{-2}) from granular 12N-0P_2O_5-0K_2O formulated with an herbicide (active ingredient = dithiopyr) for preemergence crabgrass (*Digitaria* sp.) control. The site was fertilized again in late May 2021 with 44 kg·N ha^{-1} (0.9 lb N·1000 ft^{-2}) from granular 28N-0P_2O_5-3K_2O formulated with herbicides (a.i.'s = 2,4-D and mecoprop) for postemergence broadleaf weed control. No further fertilizer, herbicide, or other pesticides were applied to this site for the duration of the field trial.

Individual plot size was 0.9 × 1.8 m (3 × 6 ft). All treatments were arranged as a randomized complete block design with four replications. All treatments were applied from a CO_2-powered backpack sprayer, calibrated to deliver 407 L·water carrier ha^{-1} (1 gal·1000 ft^{-2} at 241kPa (35 psi) for all three spray nozzles. All treatments were applied once on 23 June 2021 prior to the visual appearance of Rhizoctonia blight symptoms within the turfgrass sward.

Pennsylvania - Curative field trial. The curative field trial was conducted in Lancaster, PA, on an established residential lawn that consisted of a turf-type tall fescue with unknown cultivars. The soil was a soil loam with a pH of 6.7, and 4.4% organic matter. This site also has a history of naturally occurring Rhizoctonia blight often observed during the summer months.

From early spring through late fall 2021, the site was mowed once per week with a rotary mower to a height of 8.9 cm (3.5 in) , and clippings typically not removed. This site was fertilized in early March 2021 with 34 kg·N ha^{-1} (0.7 lb N·1000 ft^{-2}) from granular 12N-0P_2O_5-4K_2O formulated with a herbicide (active ingredient = dithiopyr) for preemergence crabgrass (*Digitaria* sp.) control, and fertilized again in mid-May 2021 with 34 kg·N ha^{-1} (0.7 lb N·1000 ft^{-2}) from granular 29N-0P_2O_5-3K_2O formulated with herbicides (a.i.'s = 2,4-D and mecoprop) for postemergence broadleaf weed control

Individual plot size was 0.9 × 1.8 m (3 × 6 ft), and all treatments were arranged as a randomized complete block design with four replications. All treatments also were applied from a CO_2-powered backpack sprayer, calibrated to deliver 407 L·water carrier ha^{-1} (1 gal water carrier·1000 ft^{-2}) at 241 kPa (35 psi) for all three spray nozzles. All treatments were applied once on 28 Jun 2021 because severe Rhizoctonia blight was first observed at this site on 23 June 2021.

Data collection and analysis. For both Ohio and Pennsylvania locations and for both preventive and curative field trials, individual plots were visually evaluated for Rhizoctonia blight on a 0 to 100% scale, where 0% = no foliar disease symptoms present, and 100% = entire plot area blighted or affected. Turfgrass quality was visually assessed on a 1 to 9 scale, where 9 = best visual color, density, and uniformity, 5 = minimum acceptable quality, and 1 = worst quality. The area under disease progress curve (AUDPC) index was calculated using the formula AUDPC = $[(y_i + y_{i+1})/2]\ [(t_{i+1})-t_i]$, where i = l, 2, 3…$n$–l, y_i is the amount of disease (percent plot area blighted), and t_i is the time of the i^{th} rating (Campbell and Madden 1980). The area under the turfgrass quality curve (AUTQC) index was calculated with the same formula but utilized turfgrass quality ratings. All data were subjected to analysis of variance using Agricultural Research Management software (GDM Solutions; Brookings, SD). Treatment means were compared using Fisher's protected least significant difference test at $p \leq 0.05$ (Mead et al. 2003).

Table 2. One preventive application of Mural 0.45WG fungicide (azoxystrobin and benzovindiflupyr) applied on a tall fescue (*Schedonorus arundinaceus*) lawn for Rhizoctonia blight (*Rhizoctonia solani*) management.

Nozzle and droplet size[z]	0		7		14		21		28		35		42		49		63		AUDPC[w]	
Ohio																				
	Days after treatment[y] — % plot area blighted[x]																			
TurfJet 1/4TTJO4 ….EC	0	a	<1	a	0	b	0	b	0	b	0	a	0	b	4	a	61	a	464	b
Air Induction 8004 ...VC	0	a	<1	a	<1	b	0	b	0	b	<1	a	<1	b	5	a	67	a	551	b
XR TeeJet 8008 ……..C	0	a	1	a	0	b	0	b	0	b	<1	a	0	b	2	a	51	a	404	b
Untreated	0	a	2	a	3	a	7	a	16	a	3	a	4	a	4	a	72	a	792	a
Pennsylvania																				
	Days after treatment[y] — % plot area blighted[x]																			
TurfJet 1/4TTJO4 ….EC	0	a	0	a	0	b	3	b	0	b	5	b	5	b	13	b	36	a	438	b
Air Induction 8004 ...VC	0	a	0	a	0	b	0	b	0	b	3	b	3	b	6	c	19	b	174	c
XR TeeJet 8008 ……..C	0	a	0	a	0	b	0	b	0	b	4	b	4	b	8	bc	18	b	201	c
Untreated	0	a	0	a	3	a	9	a	10	a	15	a	11	a	20	a	42	a	723	a

[z]Mural 0.45WG fungicide applied at 0.16 oz product·1000 ft^2 (488.24 $kg \cdot ha^{-1}$) in one gal water-carrier·1000 ft^2 (407 $L \cdot ha^{-1}$); spray nozzle type (all nozzles produced a flat-fan spray pattern), and spray droplet size of volume mean diameter: EC = extremely coarse (501-650 μm), VC = very coarse (401-500 μm), and C = coarse (326-400 μm).

[y]Days after treatment, Ohio: day 0 (treatments applied) = 24 June 2021; day 63 = 26 August 2021.

[y]Days after treatment, Pennsylvania: day 0 (treatments applied) = 23 June 2021; day 63 = 25 August 2021.

[x]Percent plot area affected from Rhizoctonia blight on a 0 to 100% scale; means of four replications followed by the same letter are not significantly different at $p \leq 0.05$ according to Fisher's protected least significance difference test.

[w]AUDPC = area under disease progress curve from day 0 through day 63; means of four replications followed by the same letter are not significantly different at $p \leq 0.05$ according to Fisher's protected least significance difference test.

Results and Discussion

Ohio - Preventive field trial - Rhizoctonia blight. The preventive fungicide treatments were applied on 24 June 2021, and Rhizoctonia blight foliar symptoms first appeared in untreated plots by 7 DAT on 1 July 2021. Rhizoctonia blight infection was considered low to moderate in untreated plots from 7 DAT through 49 DAT, and severe by 63 DAT (Table 2). All fungicide-treated plots had significantly less disease versus untreated plots from 14 to 42 DAT. All fungicide-treated plots had ≤ 1% plot area blighted from 0 to 42 DAT, and ≤ 5% plot area blighted at 49 DAT. Hence, the fungicide provided excellent preventive suppression or control of Rhizoctonia blight regardless of spray nozzles (i.e., spray droplet sizes). Plots treated preventively with the fungicide as delivered from all three spray nozzles (i.e., XR = coarse, AI = very coarse, or TJ = extremely coarse spray droplet sizes) had ≤ 5% plot area blighted from 0 to 49 DAT. By 63 DAT, disease dramatically increased in all plots in a severe resurgence, and no statistical differences were detected among all treatments (data not shown).

The AUDPC calculated a statistically similar lower index (i.e., best disease control) with the fungicide delivered from all three spray nozzles (Table 2). All fungicide-treated plots had significantly lower AUDPC values versus untreated plots. Therefore, all three spray nozzles and their respective spray droplet sizes facilitated optimum delivery of the fungicide and disease control at 0 to 49 DAT.

Ohio - Preventive field trial – Turfgrass quality. All fungicide-treated plots had significantly better turfgrass quality versus untreated plots at 14 to 42 DAT, and no turfgrass quality differences were observed among all fungicide-treated plots on six of nine rating dates (Table 3). At 28 DAT, turfgrass quality was acceptable but significantly lower in plots treated with the fungicide from the extremely coarse spray nozzle versus plots treated with the fungicide from the very coarse spray nozzle, and this trend continued at 35 and 42 DAT. By 63 DAT, turfgrass quality in all plots was considered marginally acceptable (i.e., ≤ 5) due to the appearance of severe foliar disease symptoms.

The AUTQC index revealed that all fungicide-treated plots had significantly better turfgrass quality versus untreated plots (Table 3). Although turfgrass quality differences among fungicide-treated plots were observed on three rating dates, the AUTQC index indicated that no significant differences were detected among all fungicide-treated plots. Therefore, spray nozzles (i.e., spray droplet sizes) did not have an overall influence or impact on turfgrass quality in this field trial.

Ohio – Curative field trial - Rhizoctonia blight. The curative fungicide treatments were applied on 20 Jul 2021, and Rhizoctonia blight activity was considered low to moderate as indicated by a range of 14 to 18% plot area blighted. In untreated plots, Rhizoctonia blight activity declined from 14 to 42 DAT, but resurged severely by 63 DAT (Table 4). At 14 to 42 DAT, plots treated with the fungicide applied from all three spray nozzles had ≤ 1%

Table 3. Turfgrass quality from one preventive application of Mural 0.45WG fungicide (Azoxystrobin and Benzovindiflupyr) applied on a tall fescue (*Schedonorus arundinaceus*) lawn for Rhizoctonia blight (*Rhizoctonia solani*) management.

Ohio																				
	Days after treatment[y]																			
Nozzle and droplet size[z]	0		7		14		21		28		35		42		49		63		AUTQC[w]	
	Turfgrass quality[x]																			
TurfJet 1/4TTJO4 ….EC	7.1	a	6.6	a	7.0	a	7.0	a	7.1	b	7.3	a	7.5	a	6.8	a	5.4	a	431	a
Air Induction 8004 ...VC	7.4	a	7.1	a	7.0	a	6.8	a	7.5	a	6.9	b	7.0	b	6.4	a	5.5	a	427	a
XR TeeJet 8008 ……..C	7.4	a	6.8	a	7.0	a	7.0	a	7.3	ab	7.4	a	7.1	ab	6.6	a	5.9	a	434	a
Untreated	7.3	a	6.6	a	6.5	b	6.4	b	6.8	c	6.5	c	6.5	c	6.5	a	5.1	a	411	b
Pennsylvania																				
	Days after treatment[y]																			
Nozzle and droplet dize[z]	0		7		14		21		28		35		42		49		63		AUTQC[w]	
	Turfgrass quality[x]																			
TurfJet 1/4TTJO4 ….EC	9.5	a	9.8	a	9.3	a	8.4	b	9.0	a	8.0	a	8.1	a	6.0	a	4.3	b	488	b
Air Induction 8004 ...VC	9.0	a	9.6	a	9.9	a	9.9	a	9.3	a	8.4	a	8.6	a	7.3	a	5.5	a	532	a
XR TeeJet 8008 ……..C	9.8	a	9.6	a	9.7	a	9.3	a	9.3	a	8.3	a	8.4	a	6.3	a	5.3	a	515	a
Untreated	9.8	a	8.3	a	7.5	b	7.9	c	7.9	b	6.0	b	6.3	b	4.8	b	3.3	c	397	c

[z]Mural 0.45WG fungicide applied at 0.16 oz product·1000 ft^2 (488.24 $kg \cdot ha^{-1}$) in one gal water-carrier·1000 ft^2 (407 $L \cdot ha^{-1}$); spray nozzle type (all nozzles produced a flat-fan spray pattern), and spray droplet size of volume mean diameter: EC = extremely coarse (501-650 µm), VC = very coarse (401-500 µm), and C = coarse (326-400 µm).

[y]Days after treatment, Ohio: day 0 (treatments applied) = 24 June 2021; day 63 = 26 August 2021.

[y]Days after treatment, Pennsylvania: day 0 (treatments applied) = 23 June 2021; day 63 = 25 August 2021.

[x]Turfgrass quality on a 1-9 scale (9 = best visual color, density, uniformity, and 1 = worse quality); means of four replications followed by the same letter are not significantly different at $p \leq 0.05$ according to Fisher's protected least significance difference test.

[w]AUTQC = area under turfgrass quality curve from day 0 through day 63; means of four replications followed by the same letter are not significantly different at $p \leq 0.05$ according to Fisher's protected least significance difference test.

disease present, thus indicating excellent curative suppression or control of Rhizoctonia blight. At 63 DAT, plots treated with the fungicide applied from all three spray nozzles had ≤ 4% plot area blighted, while untreated plots had 50% plot area blighted.

The AUDPC calculated a significantly lower index (i.e., best disease control) in plots treated with the fungicide applied from all three spray nozzles versus untreated plots (Table 4). Also, all fungicide-treated plots had a similar AUDPC index, thus indicating that all three spray nozzles delivered the fungicide effectively to provide an acceptable level of disease control.

Ohio – Curative field trial – Turfgrass quality. Throughout the duration of this field trial, all plots had acceptable turfgrass quality on all rating dates (Table 5). All fungicide-treated and untreated plots had similar turfgrass quality at 0 to 21 DAT, and at 42 DAT. All fungicide-treated plots had significantly better turfgrass quality versus untreated plots at 28 to 35 DAT, and at 49 to 63 DAT. Only at 63 DAT did plots treated with the fungicide using coarse droplets have statistically better turfgrass quality compared to applications using extremely coarse droplets.

The AUTQC index showed that all fungicide-treated plots had significantly better turfgrass quality versus untreated plots (Table 5). The AUTQC index also showed that turfgrass quality was similar among all fungicide-treated plots. Thus, spray droplet size did not influence turfgrass quality among all fungicide-treated plots. While some disease was evident, it was not considered severe enough to impact overall turf quality.

Pennsylvania - Preventive field trial - Rhizoctonia blight. The preventive fungicide treatments were applied on 23 June 2021, and visual foliar symptoms of Rhizoctonia blight first appeared in untreated plots by 14 DAT on 7 July 2021. Rhizoctonia blight was considered moderate to severe based on disease persistence in untreated plots from 14 DAT through 63 DAT. All fungicide-treated plots had significantly less disease versus untreated plots from 0 to 49 DAT (Table 2). All fungicide-treated plots had ≤ 3% plot area blighted at 28 DAT, and ≤ 5% plot area blighted at 35 to 42 DAT. Therefore, the fungicide provided excellent preventive suppression or control of Rhizoctonia blight regardless of spray nozzle (i.e., spray droplet size). By 49 and 63 DAT, disease increased in fungicide-treated plots, but significantly more blighting was observed in fungicide-treated plots delivered through extremely coarse spray nozzle versus very coarse or coarse spray nozzles. Thus, plots treated preventively with the fungicide as delivered from all three spray nozzles (i.e., coarse, very coarse, or extremely coarse spray droplet sizes) had ≤ 5% plot area blighted from 0 to 42 DAT.

The AUDPC revealed a significantly lower index (i.e., best disease control) with the fungicide delivered from coarse or very coarse spray nozzles versus extremely coarse (Table 3). All three spray droplet sizes facilitated

Table 4. One curative application of Mural 0.45WG fungicide (azoxystrobin and benzovindiflupyr) applied on a tall fescue (*Schedonorus arundinaceus*) lawn for Rhizoctonia blight (*Rhizoctonia solani*) management.

Ohio												
	Days after treatment[y]											
Nozzle and droplet size[z]	**0**		**14**		**28**		**42**		**63**		**AUDPC**[w]	
	% plot area blighted[x]											
TurfJet 1/4TTJO4 ….EC	15	a	<1	b	<1	b	0	b	4	b	269	b
Air Induction 8004 ...VC	14	a	0	b	0	b	0	b	4	b	203	b
XR TeeJet 8008 ….….C	18	a	<1	b	0	b	0	b	3	b	218	b
Untreated	16	a	4	a	5	a	4	a	50	a	634	a

Pennsylvania																				
	Days after treatment[y]																			
Nozzle and droplet size[z]	**0**		**7**		**14**		**21**		**28**		**35**		**42**		**49**		**63**		**AUDPC**[w]	
	% plot area blighted[x]																			
TurfJet 1/4TTJO4 ….EC	53	a	0	a	6	b	23	b	11	b	11	b	10	b	13	b	15	a	525	b
Air Induction 8004 ...VC	45	a	0	a	0	b	0	b	0	b	0	b	0	b	4	b	2	b	44	c
XR TeeJet 8008 ….….C	41	a	0	a	0	b	0	b	0	b	0	b	0	b	5	b	3	b	52	c
Untreated	51	a	71	a	66	a	54	a	48	a	55	a	44	a	54	a	81	a	2472	a

[z]Mural 0.45WG fungicide applied at 0.16 oz product·1000 ft^2 (488.24 $kg \cdot ha^{-1}$) in one gal water-carrier·1000 ft^2 (407 $L \cdot ha^{-1}$); spray nozzle type (all nozzles produced a flat-fan spray pattern), and spray droplet size of volume mean diameter: EC = extremely coarse (501-650 µm), VC = very coarse (401-500 µm), and C = coarse (326-400 µm).

[y]Days after treatment, Ohio: day 0 (treatments applied) = 20 July 2021; day 63 = 21 September 2021.

[y]Days after treatment, Pennsylvania: day 0 (treatments applied) = 28 June 2021; day 63 = 30 August 2021.

[x]Percent plot area affected from Rhizoctonia blight on a 0 to 100% scale; means of four replications followed by the same letter are not significantly different at $p \leq 0.05$ according to Fisher's protected least significance difference test.

[w]AUDPC = area under disease progress curve from day 0 through day 63; means of four replications followed by the same letter are not significantly different at $p \leq 0.05$ according to Fisher's protected least significance difference test.

optimum delivery of the fungicide at 0 to 42 DAT, but significantly less disease was observed with coarse to very coarse spray droplets at 49 to 63 DAT versus extremely coarse spray droplets. All fungicide-treated plots, however, had significantly lower AUDPC values versus untreated plots.

Pennsylvania - Preventive field trial – Turfgrass quality. All fungicide-treated plots had significantly better turfgrass quality versus untreated plots at 0 to 49 DAT, and no turfgrass quality differences were observed among fungicide-treated plots except on 21 DAT (Table 3). At 21 DAT, turfgrass quality was acceptable but significantly lower in plots treated with the fungicide from the extremely coarse spray nozzle versus plots treated with the fungicide from either the coarse or very coarse spray nozzles. By 63 DAT, turfgrass quality in all plots was considered unacceptable (i.e., ≤ 5) due to the appearance of moderate to severe foliar disease symptoms.

The AUTQC index indicated that all fungicide-treated plots had significantly better turfgrass quality versus untreated plots (Table 3). The AUTQC index also indicated that plots treated with the fungicide delivered from coarse or very coarse spray nozzles had better turfgrass quality versus the plots treated with the fungicide delivered from the extremely coarse spray nozzle. Thus, plots treated with the fungicide applied from coarse or very coarse spray nozzles had better turfgrass quality by 63 DAT versus plots treated with the fungicide applied from the extremely coarse nozzle. Of note, lower turfgrass quality ratings were attributed to the visual presence and evidence of foliar Rhizoctonia blight symptoms.

Pennsylvania – Curative field trial - Rhizoctonia blight. The curative fungicide treatments were applied on 28 June 2021. Visual foliar disease symptoms ranged from 41 to 53% plot area blighted, and therefore this site was considered very severe for Rhizoctonia blight. In untreated plots, diseased remained active and very severe throughout the duration of this field trial (Table 4). At 7 to 42 DAT, plots treated with the fungicide applied from coarse or very coarse spray nozzles had 0% disease present, thus indicating excellent curative suppression or control of Rhizoctonia blight. Plots treated with the fungicide applied from the extremely coarse spray nozzle initially had 0% disease at 7 DAT, however disease level increased to 6% plot area blighted at 14 DAT, 23% at 21 DAT, then a range of 10 to 11% through 42 DAT. At 49 and 63 DAT, plots treated with the fungicide applied from coarse or very coarse spray nozzles had ≤ 5% plot area blighted, while plots treated with the fungicide applied from the extremely coarse nozzle had 13 to 15% plot area blighted.

The AUDPC revealed a significantly lowest index (i.e., best disease control) in plots treated with the fungicide applied from coarse or very coarse spray nozzles versus the extremely coarse nozzle (Table 5) . Of note, all fungicide-treated plots had a significantly lower AUDPC index versus untreated plots. However, for a curative fungicide appli-

Table 5. Turfgrass quality from one curative application of Mural 0.45WG fungicide (Azoxystrobin and Benzovindiflupyr) applied on a tall fescue (*Schedonorus arundinaceus*) lawn for Rhizoctonia blight (*Rhizoctonia solani*) management.

Ohio

Nozzle and droplet size[z]	Days after treatment[y] 0		7		14		21		28		35		42		49		63		AUTQC[w]	
	Turfgrass quality[x]																			
TurfJet 1/4TTJO4 ….EC	7.3	a	6.8	a	6.5	a	6.6	a	6.6	a	7.3	a	7.1	a	7.1	a	6.8	b	434	a
Air Induction 8004 ...VC	7.4	a	6.8	a	6.4	a	6.5	a	6.5	a	7.1	a	7.1	a	7.0	a	7.0	ab	431	a
XR TeeJet 8008 ……..C	7.4	a	6.6	a	6.1	a	6.5	a	6.8	a	7.0	a	7.0	a	7.1	a	7.3	a	427	a
Untreated	7.3	a	6.6	a	6.5	a	6.4	a	6.1	b	6.5	b	6.5	a	6.5	b	6.1	c	411	b

Pennsylvania

Nozzle and droplet size[z]	Days after treatment[y] 0		7		14		21		28		35		42		49		63		AUTQC[w]	
	Turfgrass quality[x]																			
TurfJet 1/4TTJO4 ….EC	2.3	ab	7.3	a	6.9	b	5.3	b	6.6	b	6.9	b	7.2	a	7.1	a	6.1	a	402	b
Air Induction 8004 ...VC	3.8	a	7.6	a	8.5	a	8.6	a	8.5	a	8.5	ab	8.6	a	6.4	a	7.9	a	488	a
XR TeeJet 8008 ……..C	3.0	ab	7.5	a	8.3	ab	8.4	a	8.5	a	8.8	a	8.6	a	6.7	a	6.8	a	477	a
Untreated	1.5	b	1.2	b	1.8	c	3.8	c	4.0	c	3.0	c	4.5	b	3.5	b	1.5	b	185	c

[z]Mural 0.45WG fungicide applied at 0.16 oz product·1000 ft^2 (488.24 $kg{\cdot}ha^{-1}$) in one gal water-carrier·1000 ft^2 (407 $L{\cdot}ha^{-1}$); spray nozzle type (all nozzles produced a flat-fan spray pattern), and spray droplet size of volume mean diameter: EC = extremely coarse (501-650 µm), VC = very coarse (401-500 µm), and C = coarse (326-400 µm).

[y]Days after treatment, Ohio: day 0 (treatments applied) = 20 July 2021; day 63 = 21 September 2021.

[y]Days after treatment, Pennsylvania: day 0 (treatments applied) = 28 June 2021; day 63 = 30 August 2021.

[x]Turfgrass quality on a 1-9 scale (9 = best visual color, density, uniformity, and 1 = worse quality); means of four replications followed by the same letter are not significantly different at $p \leq 0.05$ according to Fisher's protected least significance difference test.

[w]AUTQC = area under turfgrass quality curve from day 0 through day 63; means of four replications followed by the same letter are not significantly different at $p \leq 0.05$ according to Fisher's protected least significance difference test.

cation, the better or optimum Rhizoctonia blight suppression or control would be achieved by delivering the fungicide through coarse or very coarse spray nozzles and not an extremely coarse spray nozzle.

Pennsylvania – Curative field trial – Turfgrass quality. At 0 DAT, turfgrass quality was unacceptable in all plots with ratings of ≤ 3.8 (Table 5). Turfgrass quality in untreated plots remained unacceptable throughout the duration of the field trial, with ratings ranging from 1.2 to 4.5 at 7 to 63 DAT. All fungicide-treated plots, however, had acceptable turfgrass quality at 7 to 63 DAT with ratings ranging from 5.3 to 8.8. All fungicide-treated plots had statistically better turfgrass quality ratings versus untreated plots at 7 to 63 DAT. Among all fungicide-treated plots at 7 to 63 DAT, an overall observed trend was better turfgrass quality in plots treated with the fungicide delivered from coarse to very coarse droplet sizes versus extremely coarse droplet size.

The AUTQC index also indicated that all fungicide-treated plots had significantly better turfgrass quality versus untreated plots (Table 5). The AUTQC index also indicated that plots treated with the fungicide delivered from coarse or very coarse spray nozzles provided better turfgrass quality versus the plots treated with the fungicide delivered from the extremely coarse spray nozzle. Thus, plots treated with the fungicide applied from coarse or very coarse spray nozzles (i.e., coarse to very coarse spray droplets) had better turfgrass quality by 63 DAT versus plots treated with the fungicide applied from the extremely coarse nozzle. Of note, lower turfgrass quality ratings were attributed to the visual presence and evidence of foliar Rhizoctonia blight symptoms.

In conclusion, at the Ohio location, the fungicide applied preventively through any of the spray nozzles that deliver coarse to extremely coarse spray droplet sizes provided up to 42 days of Rhizoctonia blight suppression or control under low disease activity and pressure. For a single curative fungicide application to active Rhizoctonia blight, delivery from spray nozzles that produce coarse to extremely coarse spray droplet sizes provide up to 63 days of disease control under low to moderate pressure.

At the Pennsylvania location, the fungicide applied preventively through any of the spray nozzles that deliver coarse to extremely coarse spray droplet sizes provided up to 42 days of Rhizoctonia blight suppression or control under moderate to severe disease conditions. For a single curative fungicide application to active Rhizoctonia blight, delivery from spray nozzles that produce coarse to very coarse spray droplet sizes also can facilitate up to 42 days of disease control.

The perceived benefit of utilizing a particular spray nozzle to produce larger spray droplets for the delivery of a preventive or curative fungicide application would be to reduce any potential for spray drift and subsequent reduced efficacy. Larger spray droplets have been shown to provide improved efficacy with herbicides (Carroll 2017) but not with fungicides in a turfgrass disease management programs. The other benefit of larger spray droplets is the reduction in drift (Al Heidary et al. 2014) and in urban landscapes where space is restricted this is an important consideration. This offers an ability to reduce potential concerns about non-target plant injury and also allay environmental concerns that might exist.

Overall, the observations and data indicate that a properly timed, single preventive or curative fungicide application could consistently provide up to 49 days (~7 weeks) of Rhizoctonia blight suppression when delivered from spray nozzles that produce a flat-fan spray pattern of coarse to very coarse droplet sizes. Future research is needed to evaluate the fungicide delivered at low water-carrier volume [for example 102 to 204 $L{\cdot}ha^{-1}$ (0.25-to-0.5-gal water·1000 ft^2)] from ride-on machines for disease control in tall fescue lawns.

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