Re-examining fungicide synergism for dollar spot control

Synergistic fungicide combinations do not appear to be an effective strategy for controlling dollar spot on golf course turf.

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The discovery of fungicide mixtures that control dollar spot at very low rates would greatly benefit superintendents in the northeastern quadrant of the United States, where the disease is a serious, season-long threat, and where limiting dollar spot damage often constitutes the single greatest chemical expense. Several narratives reporting synergy among fungicide combinations for dollar spot control have sparked considerable interest among superintendents (2,3). After fielding numerous questions about synergistic mixtures at our annual field days, we conducted simple trials in our experimental turf plots to help demonstrate fungicide synergy for dollar spot control. Our attempts to show better-than-expected levels of control with prescribed fungicide mixtures were unsuccessful, leading us to conduct more-structured and more-detailed research on fungicide synergy. This report provides a brief review of synergism and a re-examination of the phenomenon as it applies to dollar spot control on golf turf.

What is synergism?

The concept of synergism among fungicide combinations holds that for certain mixtures, levels of disease control achieved with the mixture are greater than the sum of individual components (7). Theoretically, when fungicides interact synergistically, excellent disease control is achieved with reduced (fractional) rates of each component fungicide. More-pronounced synergistic effects reportedly occur with fungicides with different modes of action, although synergy also has been described between certain fungicides with a similar mode of action (5,8). Many of the investigations that address synergy in fungicide mixtures have been limited to laboratory studies with fungal pathogens in culture (6). However, some published studies demonstrate synergistic interactions between fungicides at the field level. Most involve diseases of fruits and vegetables, but one published scientific paper describes synergism in fungicide mixtures used to control pythium blight on perennial ryegrass (4).

Measuring synergistic effects

In order to demonstrate synergistic activity and to identify synergistic fungicide combinations, it must be established that the levels of control achieved by the combination are greater than the levels of control that would be expected from the sum of the individual components. Performance

Besides causing unsightly turf, dollar spot can have an adverse effect on ball lie. Photos by R. Latin

of fungicide combinations and individual components can be evaluated in experimental field plots. However, expected levels of control provided by the sum of individual components are, by definition, an approximation, and therefore can be determined only by calculation.

There are several different approaches to calculating expected effects of fungicide combinations, but most are appropriate only for laboratory studies. The Gowing method is a simple calculation to estimate additive effects of two compounds in a mixture (9). It has been used to identify synergistic interactions among herbicides and was applied similarly to identify synergistic fungicide combinations for turf disease control by Couch (3). An example demonstrating how the Gowing equation is used to calculate the expected effects for the sum of two components in a mixture is illustrated in the sidebar.

Experimental methods

Experiments were conducted over three years (2004, 2006 and 2007) and at two locations, the University of Georgia in Griffin and Purdue University in West Lafayette, Ind. In Georgia, research was conducted on a sward of Penncross creeping bentgrass (*Agrostis stolonifera*) growing in a sand-based root-zone mix and mowed at 0.20 inch (5 millimeters) three times per week. Plots measured 3.3 feet × 9.8 feet (1 meter × 3 meters) and were replicated four times. In Indiana, plots were Penn A-4 creeping bentgrass established on a sand-based root-zone mix and mowed at 0.16 inch (4 millimeters) six times per week. Plots measured 3.3 feet × 6.6 feet (1 meter × 2 meters) and had four replications. For both locations, irrigation was applied as needed, and nitrogen fertilizer was applied according to local specifications for maintaining creeping bentgrass greens.

The same experimental treatments were evaluated in both locations and included fractional rates of the reportedly synergistic compounds applied individually and as mixtures shown in Table 1. Five of the treatments are individual component fungicides applied at fractional (one-quarter strength) rates relative to a high label rate for dollar spot control. These include Banner Maxx (propiconazole) and other fungicides that were thought to react synergistically with Banner Maxx: Bayleton (triadimefon), Chipco 26GT (iprodione), Curalan (vinclozolin) and Daconil (chlorothalonil). The other four treatments are tank-mix combinations of Banner Maxx with the other component fungicides.

Treatments were applied at 21-day intervals, and disease progress (percentage of plots with dol-

Research experiments were carried out at Purdue University (shown) and at the University of Georgia's Griffin campus.

Gowing's equation

The formula used to calculate the expected levels of control attributed to the sum of individual components is given by Gowing's "test for additivity" as follows:

$$E_{xp} = X + [Y^* (100 - X)]/100,$$

where E_{xp} is the expected level of control given by the sum of components, and X and Y represent the percent control of the individual components observed in the field plots.

Consider an example where component X resulted in 80% control, and component Y resulted in 40% control. The expected level of control (E_{xp}) achieved by the sum of the two components is determined by substituting 80 for X and 40 for Y in the above equation, as demonstrated below.

$$E_{xp} = X + [Y . (100 - X)]/100$$
$$E_{xp} = 80 + [40 . (100 - 80)]/100$$
$$E_{xp} = 80 + [40 . 20]/100$$
$$E_{xp} = 80 + [800]/100$$
$$E_{xp} = 80 + 8$$
$$E_{xp} = 88.$$

Therefore, the expected control attributed to the sum of the two components is 88%. In order to demonstrate synergism, levels of control in plots where the fungicide combination was applied must be statistically greater than 88%. Researchers identify statistical differences so that they can have confidence (95% or greater) in their conclusions. If the actual or observed level of control is not statistically different from the expected, then the effects of the combination are considered additive. Furthermore, if actual levels of control are statistically less than expected, then the fungicide interaction is considered antagonistic. Antagonistic interactions are quite rare, although an antagonistic interaction was demonstrated between mancozeb and chloroneb applied for pythium blight control (4).

lar spot symptoms) was assessed visually at regular intervals throughout the course of the experiment. Dollar spot severity assessments were converted to percent disease control. The values for the individual fractional fungicide treatments were substituted into the Gowing equation to calculate expected control percentages for each fungicide combination. Observed and expected disease control percentages were compared to determine statistical significance.

Couch's synergistic fungicides

Treatment	Application rate* (product/1,000 square feet)
Banner Maxx	0.25 fluid ounce
Bayleton	0.25 ounce
Chipco 26GT	1.0 fluid ounce
Curalan	0.25 ounce
Daconil WeatherStik	1.0 fluid ounce
Banner Maxx + Bayleton	0.25 fluid ounce + 0.25 ounce
Banner Maxx + Chipco 26GT	0.25 fluid ounce + 1.0 fluid ounce
Banner Maxx + Curalan	0.25 fluid ounce + 0.25 ounce
Banner Maxx + Daconil WeatherStik	0.25 fluid ounce + 1.0 fluid ounce

*Fractional rates represent one-quarter concentration of the high label rate as suggested by Couch (3).

Table 1. Component fungicides and fungicide mixtures reported to act synergistically for control of dollar spot on creeping bentgrass.

Griffin, Ga., study site

Treatment†	Application rate (product/1,000 square feet)	May 24 % dollar spot control Observed	May 24 Expected‡	June 7 Observed	June 7 Expected	June 22 Observed	June 22 Expected
Banner Maxx	0.25 fluid ounce	75.0 a§		75.0 b		71.9 a	
Bayleton	0.25 ounce	87.5 a		75.0 b		56.3 b	
Chipco 26GT	1.0 fluid ounce	68.8 a		68.8 b		31.3 b	
Curalan	0.25 ounce	81.3 a		68.8 b		50.0 b	
Daconil WeatherStik	1.0 fluid ounce	50.1 a		25.0 c		25.0 b	
Banner Maxx + Bayleton	0.25 fluid ounce + 0.25 ounce	87.5 a	96.9*	87.5 a	91.8 NS//	81.3 a	91.0 NS
Banner Maxx + Chipco 26GT	0.25 + 1.0 fluid ounce	81.3 a	92.2*	87.5 a	90.6 NS	81.3 a	85.2 NS
Banner Maxx + Curalan	0.25 fluid ounce + 0.25 ounce	87.5 a	95.3*	93.8 a	89.9 NS	71.9 a	90.5 NS
Banner Maxx + Daconil WeatherStik	0.25 + 1.0 fluid ounce	75.0 a	87.5 NS	84.4 a	79.7 NS	78.1 a	94.1 NS

†Fungicides were applied on April 25, May 16 and June 6.
‡Expected values were calculated according to the Gowing equation (9).
§Values within columns with the same letter are not statistically different.
//Expected values followed by NS are not statistically different from observed values; values followed by * are significantly different.

Table 2. Assessment of synergism among fungicide mixtures for dollar spot control in 2006 at the site in Griffin, Ga.

Results and discussion

Our three-year study was published in 2008 (1); representative portions of the results are presented in Tables 2 and 3. In each table, disease control percentages for individual fungicide components and four component mixtures are given for three evaluation dates along with the calculated (expected) control percentages.

Statistical analysis of results showed that for each of the combinations there were few differences between observed and expected levels of disease control. In several cases, observed control percentages were numerically greater than expected (for example, Banner Maxx + Curalan and Banner Maxx + Daconil on June 7 in Table 2, and a few others in Table 3). However, the differences were not statistically different; that is, they could not be attributed to the effects of fungicide treatments with 95% confidence. Therefore, the fungicides interacted additively rather than synergistically.

Throughout all of our experiments, the four fungicide mixtures were assessed for synergistic effects on 23 evaluation dates. Of the 92 total statistical comparisons of observed vs. expected levels of control, observed levels of control exceeded expected levels only three times. In contrast, five comparisons showed that expected levels were significantly greater than observed levels of control (for example, Banner Maxx + Bayleton, Banner Maxx + Chipco 26GT, and Banner Maxx + Curalan on May 24, 2006, in Griffin, Ga., Table 2). No difference between observed and expected values was found for the other 84 comparisons.

West Lafayette, Ind., study site

Treatment†	Application rate (product/1,000 square feet)	May 30 Observed	May 30 Expected‡	% dollar spot control June 19 Observed	June 19 Expected	June 27 Observed	June 27 Expected
Banner Maxx	0.25 fluid ounce	46.8 a§		76.0 a		91.4 a	
Bayleton	0.25 ounce	63.5 a		94.7 a		97.2 a	
Chipco 26GT	1.0 fluid ounce	32.1 a		56.6 a		74.1 c	
Curalan	0.25 ounce	38.3 a		77.3 a		86.3 b	
Daconil WeatherStik	1.0 fluid ounce	20.5 a		75.2 a		80.1 c	
Banner Maxx + Bayleton	0.25 fluid ounce + 0.25 ounce	45.0 a	65.0 NS//	94.9 a	91.0 NS	98.6 a	99.2 NS
Banner Maxx + Chipco 26GT	0.25 + 1.0 fluid ounce	69.6 a	56.1 NS	84.4 a	85.2 NS	91.0 a	97.8 NS
Banner Maxx +Curalan	0.25 fluid ounce + 0.25 ounce	42.7 a	59.1 NS	83.5 a	90.5 NS	94.6 a	98.7 NS
Banner Maxx +Daconil WeatherStik	0.25 + 1.0 fluid ounce	57.5 a	54.2 NS	89.9 a	94.1 NS	96.4 a	98.5 NS

†Fungicides were applied on May 17, and June 1 and June 21.
‡Expected values were calculated according to the Gowing equation (9).
§Values within columns with the same letter are not statistically different.
//Expected values followed by NS are not statistically different from observed values.

Table 3. Assessment of synergism among fungicide mixtures for dollar spot control in 2006 at the site in West Lafayette, Ind.

Results of our comprehensive research failed to provide consistent and reproducible evidence of fungicide synergism for control of dollar spot using recommended products and application rates (3). We conclude that there is a low probability for superintendents to take advantage of fungicide synergism to control dollar spot using products and rates previously reported.

Why fungicide synergy seems to be more useful for managing crop pathogens than turf pathogens is subject to speculation. Mixtures of fungicides at fractional rates providing 80%-90% control are often adequate for reducing crop yield losses, but for tees, putting greens and fairways, nearly 100% control is required for maintaining high-quality playing surfaces. Therefore, it is likely that the very low damage thresholds for fine turf marginalize the practical value of synergy using fractional rates of effective fungicides. Although we were unable to demonstrate fungicide synergism with low rates for dollar spot control, we continue to recommend tank-mixes of fungicides at label rates. Fungicide combinations broaden the spectrum of diseases controlled and are part of a comprehensive anti-resistance strategy.

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The research says

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→ Theoretically, when fungicides interact synergistically, excellent disease control is achieved with reduced (fractional) rates of each component fungicide.

→ To demonstrate synergistic activity and to identify synergistic fungicide combinations, it must be established that the levels of control achieved by the combination are greater than the levels of control that would be expected from the sum of the individual components.

→ Of the 92 total statistical comparisons of observed vs. expected levels of control, observed levels of control exceeded expected levels only three times. In 84 comparisons, no differences were seen between observed and expected levels of control.

→ There is a low probability for superintendents to take advantage of fungicide synergism to control dollar spot using products and rates previously reported.