Different herbicide responses by moss species in creeping bentgrass greens

Two herbicides produced different reactions in three species of mosses.

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Moss encroachment on creeping bentgrass (*Agrostis stolonifera* L.) putting greens is a growing problem (2,4,6,7,8,9,11). The increase in infestation has been attributed to greater demand for a more competitive playing surface, reduced fertility and restriction of mercury-based pesticides (2,8). *Bryum argenteum* (Hedw.), known as silvery-thread moss, is a common species found on creeping bentgrass putting greens; however, other species such as *B. lisae* De Not., *Amblystegium trichopodium* (Schultz) Hartm. and *Brachythecium* species B.S.G., have also been identified (6). Research conducted at the University of Tennessee identified *Entodon seductrix* and *A. serpens* along with *B. argenteum* on creeping bentgrass putting greens located in eastern Tennessee. These three species are visually very different and can be identified taxonomically.

Identification of three moss species

Bryum argenteum can be identified visually by its white to pale green/silver appearance. The silver color is due to the absence of chlorophyll in the upper leaf cells (3). *Bryum* species are perennial mosses and have a leaf habit that is sparse near the soil surface but gradually increases in leaf denseness toward the top of the plant (3). The plants have a reddish stem base that is forked because of the formation of sex organs. This forked stem is located just below the inflorescence. *Bryum argenteum* species of moss also have well-developed cilia that contain short protruding appendages located within the spore case or capsule. Cilia are subtle threadlike structures that alternate with segments of rough teethlike appendages formed from basal tissue in a circular pattern located within the capsule (3).

Amblystegium serpens has a green to yellow appearance and is not as compact as *B. argenteum*. It has a creeping growth habit and can be found on numerous surfaces such as tree trunks, rotten wood, rocks and soil (3). *Amblystegium* species can be identified by their asymmetrical branched stems, which may be creeping or rising (3). *Amblystegium serpens* contains slender, straight leaf veins referred to as *costa*. It is a small species of moss and contains short firm cells. Leaves are generally erect and are less than 1 millimeter long (3).

Entodon seductrix is a green to yellowish brown species, and like *Amblystegium* species, it can be found on rotten wood sites and at the bases of trees (3). *Entodon* species have a creeping growth habit that ranges from a flat mat to loose tufts. The leaves are crowded on the stems and are appressed (3). Stems vary from round to a flat oval shape and contain a double costa as compared to the single costa associated with *A. serpens*. *Entodon seductrix* also can be identified by the red seta (or stalk) that supports the narrow cylindrical capsules (3).

Materials and methods

Quicksilver (carfentrazone, FMC Corp.) and Junction (mancozeb, SePro Corp.) are labeled to control *Bryum argenteum* (Hedw.) in creeping

bentgrass (*Agrostis stolonifera* L.) greens (5,10). No research, however, has investigated control of *Entodon seductrix* and *Amblystegium serpens*, two other moss species found in creeping bentgrass greens. Therefore, research was conducted to evaluate the control of all three moss species by Quicksilver and Junction. Quicksilver (3.35 and 6.7 fluid ounces product/acre [0.24 and 0.49 liter/hectare]) and Junction (2 and 4 ounces product/1,000 square feet [0.6 and 1.2 grams/square meter]) were applied singly (0 days after initial treatment) and sequentially (0 and 14 days after initial treatment) to greenhouse-grown plugs of the three moss species.

Moss species were evaluated visually on a scale of 0% (no moss control, no burned tissue) to 100% (total moss control, total burned tissue) at 14, 21 and 28 days after initial treatment. Visual color was the main component for these ratings.

Different responses to herbicides

Quicksilver

Quicksilver controlled *Bryum argenteum* more effectively than it controlled *Entodon seductrix* and *Amblystegium serpens*. Sequential applications of Quicksilver were more effective than single applications for controlling all three moss species (Table 1). Quicksilver was most effective at controlling *B. argenteum* but achieved less than 17% control of both *A. serpens* and *E. seductrix* throughout the entire study. When Quicksilver was applied sequentially at 3.35 fluid ounces/acre (0.24 liter/hectare), control of *B. argenteum* was evaluated at 78% at 21 days after initial treatment; and sequential applications at 6.7 fluid ounces/acre (0.49 liter/hectare) produced 86% control of *B. argenteum* at 21 days after initial treatment. However, at 28 days after initial treatment, visual control was reduced to 33% for the 3.35-ounce (0.24-liter/hectare) rate and 39% for the 6.7-ounce (0.49-liter/hectare) rate.

Similar regrowth and recovery was observed with the initial Quicksilver applications. At 14 days after initial treatment, all Quicksilver treatments showed 26%-36% control of *B. argenteum*. Single applications of Quicksilver decreased visually evaluated control from 26% at 14 days after initial treatment to 18% for the 3.35-ounce (0.24-liter/hectare) rate and 19% for the 6.7-ounce (0.49-liter/hectare) rate at 28 days after initial treatment. At 21 days after initial treatment, sequential Quicksilver applications at 6.7 fluid

% moss control

			Amblystegium serpens			*Bryum argenteum*			*Entodon seductrix*		
			Days after initial treatment								
Treatment	Rate[†]	Timing DAIT[‡]	14	21	28	14	21	28	14	21	28
	fluid ounces/acre		% moss control (SE)								
Quicksilver	3.35	0	6 (2.2)	1 (0.8)	7 (4)	26 (12.6)	24 (13.6)	18 (12.5)	3 (1.9)	6 (3.9)	14 (8.1)
Quicksilver	6.67	0	14 (7.1)	6 (3.1)	1 (0.6)	26 (9.7)	22 (13.9)	19 (12.5)	6 (3.2)	5 (2.3)	8 (4.4)
Quicksilver	3.35	0 fb 14	9 (3.6)	6 (2.2)	9 (5)	31 (9.9)	78 (6.6)	33 (13.5)	6 (1.8)	4 (1.8)	14 (5.6)
Quicksilver	6.67	0 fb 14	14 (7.2)	17 (3.1)	14 (3.9)	36 (8.7)	86 (4.6)	39 (11.7)	1 (0.8)	5 (2.5)	15 (8.0)
	ounces/ 1,000 square feet										
Junction	2	0	6 (4.3)	1 (0.6)	1 (0.6)	10 (8.0)	11 (7.7)	8 (6.8)	2 (1.9)	0 (0)	2 (1.3)
Junction	4	0	11 (7.1)	1 (0.6)	1 (0.6)	7 (4.9)	8 (7.4)	8 (7.4)	4 (2.6)	0 (0)	1 (0.6)
Junction	2	0 fb 14	5 (2.5)	0 (0)	0 (0)	3 (2.5)	18 (8.3)	11 (7.0)	2 (1.3)	3 (2.1)	4 (1.6)
Junction	4	0 fb 14	4 (2.6)	1 (0.6)	1 (0.8)	8 (7.4)	14 (7.5)	4 (3.7)	3 (1.6)	1 (1.3)	7 (4.2)
LSD			13	4	8	23	26	25	6	5	11

Abbreviations: DAIT, days after initial treatment; fb, followed by; SE, standard error.

[†]3.35 fluid ounces/acre = 0.24 liter/hectare; 6.67 fluid ounces/acre = 0.49 liter/hectare; 2 ounces/acre = 0.6 grams/square meter; 4 ounces/acre = 1.2 grams/square meter.

[‡]Treatments were applied at 0 and 14 days after initial treatment.

[§]Visual control was rated on a scale of 0 (no control) to 100 (complete moss control).

Table 1. *Amblystegium serpens*, *Bryum argenteum* and *Entodon seductrix* visual control with single and sequential applications of Quicksilver and Junction.

Bryum argenteum **Photos by S. McElroy**

Amblystegium serpens

ounces/acre (0.49 liter/hectare) showed 17% control of *A. serpens*.

None of the treatments achieved more than 15% control of *E. seductrix* at any time. A previous report that was not peer-reviewed indicated that multiple applications of Quicksilver are required to continually suppress and eventually control *B. argenteum* (1).

In our research, regrowth was observed with single applications from 14 to 28 days after initial treatment. We believe that recovery occurred when only the surface moss tissue was burned, allowing the residual unburned tissue to sustain regrowth. Because moss species lack a true vascular system (3), the translocation of systemic pesticides does not progress (12). Quicksilver did not achieve greater than 86% control of any of the moss species, and regrowth was observed in *B. argenteum*.

Junction

Junction did not adequately control any of the three moss species (Table 1). At 21 days after initial treatment, Junction applied at 2 ounces/1,000 square feet (0.6 gram/square meter) achieved 18% control of *B. argenteum* and applied at 4 ounces/1,000 square feet (1.2 grams/square meter) achieved 14% control. Junction did not control *A. serpens* or *E. seductrix* at any rate or timing.

Summary

Quicksilver controlled *Bryum argenteum* more successfully than it controlled *Amblystegium serpens* and *Entodon seductrix*. Quicksilver controlled all three moss species more effectively than Junction, which caused only minimal injury at every rate tested.

Sequential applications of Quicksilver are required to reduce moss regrowth, and sequential Quicksilver applications applied at 6.7 ounces/acre (0.49 liter/hectare) were the most effective treatments for all three moss species.

Single applications of Quicksilver can potentially increase growth rates of *B. argenteum*. Quicksilver applications made to *A. serpens* and *E. seductrix* stabilized growth rates, but they did not decrease populations. Regrowth was observed with all treatments. Diversity in moss species could potentially be attributed to erratic Quicksilver efficacy and was most evident with *E. seductrix*.

Multiple applications of Quicksilver accompanied with cultural practices should be the focus of future research concerning moss infestation on putting greens.

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Entodon seductrix

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GCM

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The research says

→ Quicksilver was most effective at controlling *Bryum argenteum*.

→ Junction caused only minimal injury to any of the moss species tested.

→ Sequential Quicksilver applications at 6.7 ounces/acre were the most effective treatments for all three moss species.

→ Regrowth was observed with all treatments.