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PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 290 projects at a cost of $25 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

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Evaluation of Newer Products for Selective Control of Moss on Creeping Bentgrass Greens

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SUMMARY

Chicago District Golf Association scientists continue to conduct research to evaluate new ways to reduce moss in putting greens without causing phytotoxic effects to bentgrass. Study treatments included baking soda, a herbicide (carfentrazone-ethyl; Quicksilver) and a fungicide (chlorothalonil; Daconil Ultrex). To date, the study's findings include:

- Multiple strategies can be used to suppress moss.
- No strategy was capable of eliminating moss.
- Moss strategies should be timed when moss is actively growing spring and fall, and may not be necessary midsummer.
- Baking soda spot applied twice in spring can effectively suppress moss all season.
- Chlorothalonil alone or in combination with other contact fungicides can suppress moss, but requires at least three sequential applications every 14 days.
- Spring and fall applications of Quicksilver at 6 oz/A (four total) can effectively suppress moss without adverse effects to bentgrass health.

Moss represents a diverse group of primitive plants. Of between four and five thousand forms that exist, silvery thread moss (*Bryum argenteum* Hedw.) continues to be a troublesome problem for putting greens across much of the United States because it interrupts surface aesthetics/smoothness (Image 1).

In Illinois, moss is difficult to remove once established. Increasingly, golf course superintendents report greater problems of moss encroachment on greens. The exact contributing factor(s) remain speculative. The EPA removal of mercury-based fungicides is one probable explanation since mercury is highly toxic to moss. However, today's cultural practices are also likely to blame whenever they reduce plant density which can allow moss to gain a foothold. For example, in Chicago moss is often found in quantity on ridges, knolls, and the perimeter clean-up lap--all common locations of scalping/thinning given today's low mowing heights.

A number of products can suppress moss to varying degrees and they range from metals, soaps, and salts, as well as certain fungicides. A new herbicide carfetrazone-ethyl is promising, but limited research on this product has been conducted. A consistent complaint is that moss control efforts can damage turfgrass by phytotoxicity. Additionally, minimal control may occur because recommended use rates and techniques vary widely. Therefore replicated research trials are invaluable to golf course superintendents who otherwise rely on observational information from peers.

For a second year, we conducted a USGA-sponsored research trial to evaluate new ways to reduce moss in putting greens without causing phytotoxic effects to bentgrass. Accordingly, the study treatments were narrowed in 2006 to include baking soda, a herbicide, and fungicides (Image 2). Additionally, a mixture of contact fungicides was added because some Chicago golf course superintendents use this strategy.

Image 1. Silvery thread moss interrupting the surface aesthetics/smoothness of bentgrass green at CDGA's 3-hole Sunshine Golf Course in Lemont, IL during April, 2006

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Image 2. Baking soda, a herbicide, and fungicide treatments of a moss study visible on the annual field day at CDGA's 3-hole Sunshine Golf Course in Lemont, IL during September, 2006. Moss is returning in Quicksilver herbicide treatments (center foreground).

Image 3. Randy Kane (right) and Chris Painter evaluate treatments to reduce moss of a bentgrass green at CDGA's 3-hole Sunshine Golf Course in Lemont, IL during July, 2006.

Materials and Methods

Treatments (Table 1) were evaluated on an established stand of 'L-93'/ 'G-2' (50:50) creeping bentgrass at CDGA's Sunshine Golf Course in Lemont, IL (Image 3). The turf was mowed to a height of 0.16 inches, irrigated as needed (no hand watering), and fertilized with 4 lb. N/1000 ft^2 annually. Beginning April 21 until October 4, applications were made at two-week intervals; sodium bicarbonate (Baking Soda; Arm and Hammer, Princeton, NJ) and two carfentrazone-ethyl (Quicksilver 21.3; FMC Corp., Philadelphia, PA) herbicide rates were applied on the first two dates. A third carfentrazone-ethyl treatment was applied both spring and fall at label rate; the first

Treatment by Group	Application Rate	Timing	Application Total
Untreated	N/A	N/A	--
Household product			
baking soda (spot applied)	6 oz per gallon	spring	2
Herbicide			
Quicksilver (1/2 label rate)	3 oz per Acre	spring	2
Quicksilver (spring)	6 oz per Acre	spring	2
Quicksilver (spring and fall)	6 oz per Acre	spring and fall	4
Fungicide			
Daconil Ultrex (half rate)	3.2 oz per 1000 ft^2	every 14 days	12
Daconil Ultrex	5 oz per 1000 ft^2	every 14 days	12
Daconil Ultrex + Fore + Spotrete	3.2 oz + 4 oz +5 oz per 1000 ft^2	every 14 days	12

Table 1. Products, rates, timing, and application total of selected treatments to suppress moss in a study in Lemont, IL during 2006

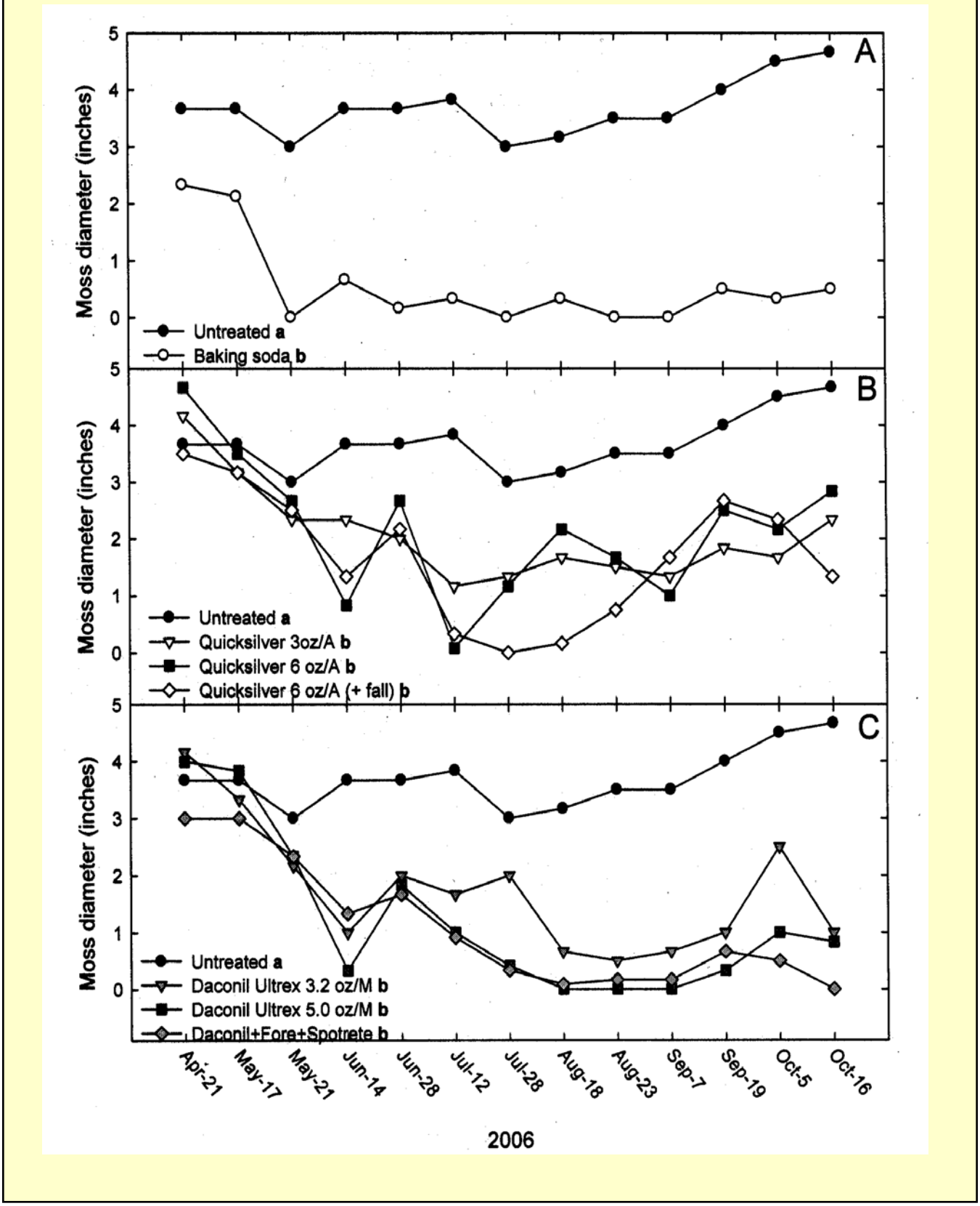

Figure 1. Ability of (A) baking soda, (B) carfentrazone herbicide, and (C) contact fungicides to reduce moss diameter on a putting green at Lemont, IL in 2006. Treatments are significantly different when legend labels are not followed by the same letter using Fisher's LSD of area under curve (AUC) values.

Image 4. A four-inch-diameter plug containing silvery thread moss was transferred to each plot of a study conducted on a bentgrass green at CDGA's 3-hole Sunshine Golf Course in Lemont, IL during April, 2006.

two and last two application dates. Contact fungicides used in the study were chlorothalonil (Daconil Ultrex 82.5 WDG; Syngenta Crop Protection Inc., Greensboro, NC), mancozeb (Fore 80 WP; Dow AgroSciences, Indianapolis, IN), and Thiram (Spotrete 75 WDG; Cleary Chemical Corp., Dayton, NJ).

All treatments except baking soda were applied with a CO_2-powered backpack sprayer with 8004 TeeJet nozzles at 35 psi in water equivalent to 2 gal. per 1000 ft^2. Baking soda solution was spot applied to uniformly wet individual moss colonies; a hand spray bottle was depressed three times (about 2 mL). Plots were not irrigated after application. Plots were 4 ft x 6 ft and arranged in a randomized complete block design with three replications.

At the start of the experiment, a 4-inch diameter cup-cutter was used to transfer moss to the center of each plot (Image 4), and the initial diameter of each moss colony was measured. Every two weeks preceding treatment application, moss diameter was measured and rated for health (0-4 scale; 4 = best). Visual quality (0-9 scale; 9 = best) was monitored for signs of phytotoxicity to bentgrass.

Image 6. Fall moss resurgence within untreated plots of the study area on a bentgrass green visible on the annual field day at CDGA's 3-hole Sunshine Golf Course in Lemont, IL during September, 2006.

Image 5. Fall moss resurgence is obvious as the green is mowed the morning of field day at CDGA's 3-hole Sunshine Golf Course in Lemont, IL during September, 2006.

Results

We found multiple strategies can be used to suppress moss. During the study period all treatments reduced moss diameter based on area under the curve analysis (Figure 1), and did not cause bentgrass phytotoxicity based on visual quality ratings (data not shown). Within date, analysis indicated that a single spring application of baking soda can effectively suppress moss of a green all season (Tables 2 and 3), but is more labor intensive because it is phytotoxic to bentgrass and requires spot application.

Treatment	Moss Diameter (inches)[a]						
	June 14	Aug. 10	Aug.23	Sept. 19	Sept.5	Oct.16	AUC[b]
Untreated	3.7 a	3.2 a	3.5 a	4.0 a	4.5 a	4.7 a	43 a
Baking Soda	0.7 c	0.3 cd	0.0 b	0.5 cd	0.3 b	0.5 b	7 b
Quicksilver 3 oz/A	2.3 ab	1.7 bc	1.5 ab	1.8 bcd	1.7 b	2.3 abc	24 b
Quicksilver 6 oz/A	0.8 bc	2.2 ab	1.7 ab	2.5 abc	2.2 b	2.8 ab	24 b
Quicksilver 6 oz/A (+fall)	1.3 bc	0.2 d	0.75 b	2.7 ab	2.3 ab	1.3 bc	20 b
Daconil Ultrex 3.2 oz/M	1.0 bc	0.7 cd	0.5 b	1.0 bcd	2.5 ab	1.0 bc	20 b
Daconil Ultrex 5 oz/M	0.3 c	0.0 d	0.0 b	0.3 d	1.0 b	0.8 bc	16 b
Daconil + Fore + Spotrete	1.3 bc	0.1 d	0.2 b	0.7 bcd	0.5 b	0.0 c	13 b

[a]means not followed by the same letter within the same column are significantly different (P = 0.05) by Fisher's LSD.

[b]Area under curve (AUC) value summarizes all 13 dates from April 21 to October 16.

Table 2. Dates (6 of 13 rated) when treatments reduced moss diameter in a study in Lemont, IL during 2006

Fungicides were capable of moss suppression on a majority of dates (Table 2), but required multiple applications (Table 1). In addition to cost considerations, Daconil Ultrex 82.5 WDG has a label limitation on greens of 88.5 pounds per acre per growing season (1) and was exceeded by fungicide treatments in this study. However, all fungicides reduced moss diameter by June 13 after three consecutive applications (Table 1), and thereafter a second or third sequence could be employed based on scouting and allow necessary compliance.

The herbicide Quicksilver has recently been labeled for moss control of bentgrass and is safe given 'Crenshaw' and 'Penncross' at green height (1). Similarly, we found Quicksilver was not phytotoxic to an 'L-93' / 'G-2' green. A spring and fall application of Quicksilver at 6 oz/A is rec-

Treatment	Moss Health[a]						
	July 28	Aug.10	Aug. 23 7	Sept. 7	Oct. 5	Oct. 16	AUC[b]
Untreated	3.7 a	3.3 a	3.7 a	3.6 a	4.0 a	3.7 a	33 a
Baking Soda	0.0 c	0.7 bc	0.0 c	0.0 c	1.0 c	1.0 cd	16 cd
Quicksilver 3 oz/A	1.7 bc	1.7 b	1.7 b	2.3 ab	2.3 abc	2.7 abc	25 ab
Quicksilver 6 oz/A	1.0 bc	1.7 b	1.0 bc	1.3 bc	1.7 bc	1.7 bcd	22 bc
Quicksilver 6 oz/A (+fall)	0.0 c	0.3 c	0.7 bc	1.3 bc	1.0 c	1.0 cd	19bcd
Daconil Ultrex 3.2 oz/M	2.0 ab	0.7 bc	0.3 bc	0.7 bc	3.3 ab	3.3 ab	21 bcd
Daconil Ultrex 5 oz/M	0.7 bc	0.0 c	0.0 c	0.0 c	1.3 c	1.3 cd	16 cd
Daconil + Fore + Spotrete	0.7 bc	0.3 c	0.3 bc	0.3 bc	1.0 c	0.0 d	14 d

[a]Rating is based on a 0-4 scale with 4 = best. Means not followed by the same letter within the same column are significantly different (P = 0.05) by Fisher's LSD.

[b]Area under curve (AUC) value summarizes all 13 dates from April 21 to October 16.

Table 3. Dates (6 of 13 rated) when treatments reduced moss health in a study in Lemont, IL during 2006

ommended given; i) half label rate was unable to reduce moss diameter by June (Table 1), ii) moss encroachment of Quicksilver plots occurred during September (Figure 1), and iii) Quicksilver applied during September at labeled rate reduced moss diameter by October 16 (Table 1). In Chicago, the second Quicksilver applications would likely be late August to early September. This would both avoid warm conditions (> 90 °F) that risk its phytotoxicity to bentgrass, and be early enough to suppress the observed moss growth surge at fall (Image 5 and 6).

In conclusion, no strategy was capable of eliminating moss on a green in this study. Moss control strategies should be timed during spring and fall when moss growth is at its peak. Although not demonstrated in this study, sequential fungicide applications can likely be discontinued at midsummer without sacrificing efficacy - a time when moss growth was static in this study (Figure 1).

Controlled studies may better elucidate environmental factors such as heat which likely influence moss encroachment of putting greens. Such information could be used to optimize moss suppression with fungicides and ensure label restrictions are met (e.g. Daconil Ultrex). Quicksilver at label rate (6.7 oz/M) needs to be evaluated for health effects on *Poa annua*, as well as the plethora of improved bentgrass cultivars now available. Demonstrated safety of Quicksilver at green height regardless of turf species/cultivar would facilitate greater acceptance of this new moss control strategy.

Acknowledgements

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