Chemical and Cultural Controls for Moss, *Bryum argenteum* on Putting Greens

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Summary: In two trials conducted at Friendly Hills Country Club, Whittier, CA, a variety of herbicides, fungicides, surfactants, algaecides and fertilizers were tested for their ability to decrease infestations of *Bryum argenteum* (silver thread moss) on a heavily moss infested poa/bent putting green. Key findings include:

- Moss was positively identified as *Bryum argenteum* on the basis of leaf cell architecture (upper leaves with rhomboid-hexagonal cells) and the silvery-white color of the plants. A blue-green algae was consistently found in association with the moss.
- The most effective treatments contained chlorothalonil (Daconil 2787 and Daconil Ultrex) or quaternary ammonia (RD-20), with up to 80% moss control achieved by the end of the 3 month trial. No phytotoxicity was observed with these treatments. The efficacy of these products may be related to their algaecidal activity.
- Treatments which injured turfgrass (Lesco Iron Plus fertilizer, Ronstar 2G and Dimension) resulted in an overall increase in moss by the end of the study. Although these treatments initially injured the moss plants, lack of competition of from injured turf appeared to allow the moss to expand its invasion into areas of thinning and/or damaged turf.
- Some treatments which were reported to control moss at other locations (Ferrous sulfate, Ultra Dawn, Subdue 2E mixtures) had no effect on moss populations in this trial. This may be due to the fact that all treatments were made using broadcast applications (2 - 4 gallons spray solution/1000 sq ft), rather than spot treatments. In a follow up trial investigating the use of Ultra Dawn applied as a spot treatment, drench-type applications (4 oz/gallon UltraDawn, applied in 80 gallons spray solution/1000 sq ft) were found to be extremely effective for control of moss.
- If moss infestations are heavy, gradual removal of moss, as was observed using chlorothalonil or quaternary ammonia, is the most desirable strategy, since it avoids the appearance of large areas of dead or dying moss. However, if moss infestations are light, spot treatments with products that rapidly kill the moss may be the most effective strategy.

STUDY 1: Low volume, broadcast applications

Materials and Methods

Location: Research plots were located on a combination poa/bentgrass green at Friendly Hills Country Club, Whittier, CA. This location was selected based on a severe infestation of moss on the green.

Experimental design and application: Plots measuring 5 feet by 10 feet were replicated three times in a randomized design. Sprayable treatments were applied with a CO_2 backpack sprayer equipped with 8008 VS flat fan nozzles and delivering 3.4 gallons of water per 1000 square feet, with 28 psi at the boom (accomplished by making two passes across the plot area). Calibration of each nozzle was confirmed prior to application to be within 5% of the desired nozzle flow rate. Boom height was 17 inches above the ground. The spray swath was 5 feet. Speed was 3 mph. Spray bottles were agitated by shaking 10 times prior to charging with compressed CO_2. Spray lines were purged with CO_2 and then water prior to changing treatments. Granular products were applied with a Gandy drop spreader, which formed a 33 inch swath. Gandy settings of 33 and 14 were used to deliver Lesco Iron Plus and Ronstar 2G, respectively. The accuracy of calibration was confirmed to be within 5% of the desired rate by conducting 3 passes of 15 linear feet each at the specified settings, collecting the product in question and weighing it. Ronstar 2G treatments were watered in with 1/10 inch water following application. To accomplish this selective irrigation, the designated plots were sprayed with 15.75 liters water each, delivered through the backpack sprayer described above. A flow meter was used to monitor the total volume of water applied to each plot.

Treatments: Treatments and application dates are listed in Table 1 below. Applications were initiated on 5/26/98.

Evaluations: Percent moss infestations were determined visually on 5/11, 6/22, 7/10 and 8/17/98. Percent moss control was then determined by comparing the moss infestation levels in each plot, on each evaluation date, against the pre-treatment moss infestation levels on 5/11/98. Percent control data was calculated using the equation below.

$$\textbf{\textit{\% moss control}} = \frac{\textit{\% moss pre-application - \% moss post-application}}{\textit{\% moss pre-application}}$$

Data was subjected to analysis of variance, and treatment means separated using Fisher's LSD, where $P<0.10$. For analysis of variance, percent moss control data was transformed to the arcsine (square root) of the proportion

Results

Moss was positively identified as *Bryum argenteum* on the basis of leaf cell architecture (upper leaves with rhomboid-hexagonal cells) and the silvery-white color of the plants (Figure 1, Figure 6). This species of moss has been identified on golf course greens throughout the United States. An unidentified blue-green algae was consistently found in association with the moss (Figure 2). This algae may contribute in some way to the competitive ability of the moss, but this remains to be determined.

Figure 1. Close-up of turf infested with the moss, *Bryum argenteum.*

Figure 2. Close-up of the same area shown in Figure 1, following incubation in the dark for 12 hours. During the dark period, blue-green algae present at the base of the moss plants migrated to the top of the moss and turf plants in search of light. This blue-green algae was found in all samples of *Bryum argenteum* examined.

The most effective treatments contained chlorothalonil (Daconil 2787 and Daconil Ultrex) or quaternary ammonia (RD-20), with up to 80% moss control achieved by the end of the 3 month trial. The control achieved was gradual, with no obvious signs of dead or dying moss in plots treated with these products. This is a positive attribute, especially in a situation where moss populations are heavy, as it avoids the development of large patches of browning, dying moss. Although the mode of action is not understood, it is possible that chlorothalonil and quaternary ammonia interfered with moss growth and competitiveness by injuring the blue-green algae that was seen in association with the moss. Whatever the mechanism, application of these products appears to have allowed the turf to compete more effectively with the moss. No phytotoxicity was observed with these treatments.

Although several treatments resulted in visual injury to moss (Lesco Iron Plus fertilizer, Ronstar 2G and Dimension), these treatments also injured the turf. As a result, there was an overall increase in moss in plots treated with these products. It appears that the damaged turf was unable to compete effectively with the moss, thus allowing the moss to expand its invasion into areas of thinning and/or damaged turf.

Some treatments which were reported to control moss at other locations (Ferrous sulfate, Ultra Dawn, Subdue 2E mixtures) had no effect on moss populations in this trial. This may be due to the fact that all treatments were made using broadcast applications (2 - 4 gallons spray solution/1000 sq ft), rather than spot (drench) treatments. The use of

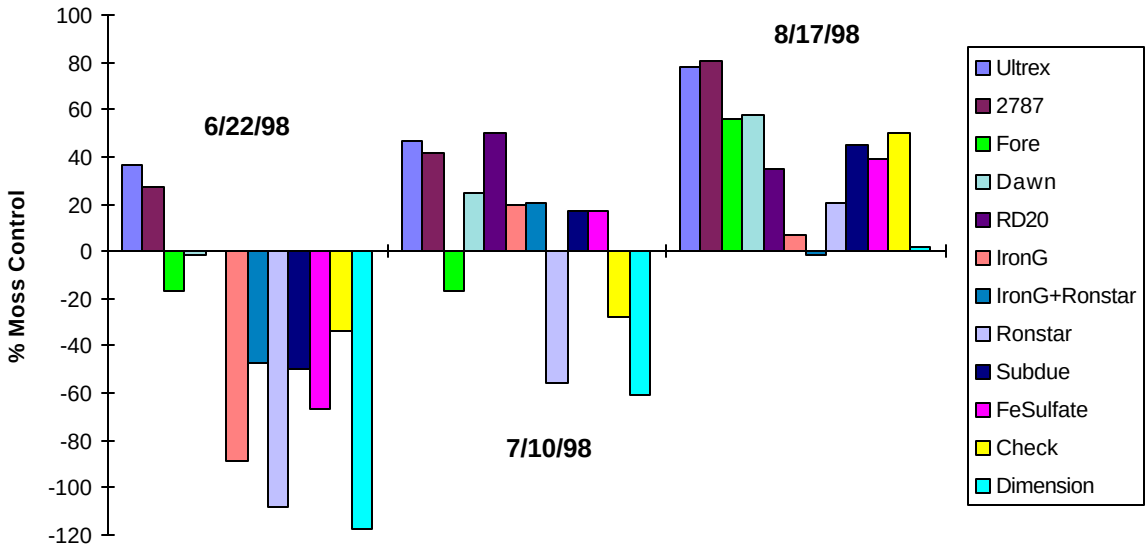
drench applications of Ultra Dawn is reported in Study 2 (see below).

If moss infestations are heavy, gradual removal of moss, as was observed using chlorothalonil or quaternary ammonia, is the most desirable strategy, since it avoids the appearance of large areas of dead or dying moss. However, if moss infestations are light, spot treatments (see below) with products that rapidly kill the moss may be the most effective strategy.

Table 1. Moss Control on a Poa annua/Bentgrass Green. Friendly Hills Country Club, Whittier, CA. Treatments in green shaded boxes performed significantly better than the non-treated check, while treatments in the red shaded boxes performed significantly worse than the non-treated check (Fisher's LSD, P<0.10). For analysis of variance, percent moss control data was transformed to the arcsine (square root of the proportion).

				PERCENT MOSS CONTROL			
Treatment	**Active Ingredient**	**Application Dates**	**Rate/ 1000 sq ft**	**6/22/98**	**7/10/98**	**8/17/98**	**Mean % Control (average of 3 ratings)**
Daconil Ultrex	chlorothalonil	5/26, 6/8, 6/22	7.3 oz	36.5 c	46.4 c	77.9 de	53.6 d
Daconil 2787	chlorothalonil	5/26, 6/8, 6/22	11.0 oz	27.2 c	41.3 c	80.9 e	49.8 d
Fore Flo	mancozeb	5/26, 6/8, 6/22	12.0 oz	-16.7 bc	-16.7 abc	55.8 cde	7.5 bcd
Ultra Dawn	anionic and non-ionic surfactants	5/26, 6/8, 6/22	4.0 oz	-1.6 bc	25 bc	57.4 cde	26.9 cd
RD-20	quaternary ammonia	5/26, 6/8, 6/22	1.6 oz	0.0 bc	50.0 c	35.0 abc	28.3 cd
Lesco Iron Plus (0-0-0, 18% iron)		5/26, 6/22	14.3 lb	-88.9 ab	19.4 bc	7.2 ab	-20.8 abc
Lesco Iron Plus + Ronstar 2G	oxadiazon	5/26, 6/22	14.3 lb + 1.7 lb	-47.4 abc	20.3 bc	-1.3 a	-9.5 abcd
Ronstar 2G	oxadiazon	5/26, 6/22	1.7 lb	-107.9 a	-55.6 a	20.5 abc	-47.7 ab
Subdue 2E + Lesco Spreader Sticker + Lesco Wet	metalaxyl	5/26, 6/22	2.0 + 1.3 + 1.3 oz	-49.6 abc	16.8 bc	45.1 bcde	4.1 abcd
Iron Sulfate	iron sulfate	5/26, 6/8, 6/22	5 oz	-66.7 ab	16.7 bc	38.9 abcd	-3.7 abcd
Check				-33.3 abc	-27.5 ab	50 cde	-3.6 abcd
Dimension EC	dithiopyr	5/26, 6/22	1.5 oz	-117.2 a	-61.1 a	2.2 a	-58.7 a

Figure 3. Moss Control on Three Different Evaluation Dates (6/22, 7/10 and 8/17/98). Friendly Hills Country Club, Whittier, CA



STUDY 2: High volume, drench applications

Materials and Methods

Location: Research plots were located on a combination poa/bentgrass green at Friendly Hills Country Club, Whittier, CA. This location was selected based on a severe infestation of moss on the green.

Experimental design and application: Non-replicated plots were circles, 0.545 square feet in area (diameter = 10 inches), that were placed in areas of heavy moss infestation. Plots were treated by placing a plastic cylinder (10 inches in diameter, 1.5 feet high) on the plot area, and spraying the area with a Delavan HC4 70-degree hollow cone nozzle. To accomplish this, an inverted spray header was used (R and D Sprayers, Opelousas, LA) and the total volume present in the pint sized spray bottles was applied in each plot. The CO_2 sprayer delivered 60 psi.

Treatments: Plots were treated once, on June 8, 1998. The treatments are listed below in Table 2.

Evaluations: Evaluations were conducted on three dates: 6/22/98 (2 weeks after application), 7/10/98 (4.5 weeks after application) and 8/17/98 (10 weeks after application). Percent moss control was evaluated visually. Turf quality was rated on a 0 – 9 scale, with 0 = worst possible turf and 9 = best possible turf.

Results: This study was designed to determine the efficacy of UltraDawn dishwashing liquid for control of moss, and to determine at which rates and which application volumes the best results (high moss control, low turf damage) would be achieved. Our results demonstrate (Table 2) that application volume has a very important effect on the performance of this product. High volumes of application (more than 80 gallons / 1000 square feet) provided the best control, with the least amount of turf damage. At these volumes, the turf is treated in a drench fashion, as opposed to the very light, almost invisible spray coverage that is typically seen with broadcast applications. At lower application volumes (less than 40 gallons/1000 square feet) almost no moss control was observed. The levels of control observed, especially at the 80 and 160 gallon/1000 square foot volumes, were excellent, especially when the residual control is considered; with only one application on June 8, 1998, 100% control was still observed 10 weeks later, on August 17, 1998 (Figure 5)

The rate of UltraDawn used is also important, especially from the standpoint of avoiding damage to turf. Rates above 4 oz/gallon spray solution resulted in some damage to turfgrass (Figure 6), and are not necessary to achieve optimal moss control.

Based on these results, drench applications of UltraDawn (4 oz/gallon spray solution) applied at application volumes of 80 gallons/1000 square feet, provided excellent control of moss. Levels of control reached 100%, with continued good control for 10 weeks or more after application. However, some damage to turf was observed. To avoid turf damage, it is possible that lower rates of UltraDawn (1-2 oz/gallon), applied more frequently (every 3-4 weeks) would be more effective.

NOTE: UltraDawn dishwashing liquid is not registered for use on turf for pest control. For this reason, a California Department of Pesticide Regulation Research Authorization (#805082) was issued to allow this product to be tested experimentally.

Table 2. Moss Control on a Poa annua/Bentgrass Green. Friendly Hills Country Club, Whittier, CA.
Treatments which resulted in good moss control, with minimal damage to turf are noted in green shaded boxes.

			6/22/98		7/10/98		8/17/98	
Trt #	**UltraDawn rate/gallon**	**Volume/ 1000 sq ft**	**% moss control**	**Turf quality**	**% moss control**	**Turf quality**	**% moss control**	**Turf quality**
1	UltraDawn 4 oz	10 ga	0	6	0	6	0	6
2	UltraDawn 4 oz	20 ga	5	6	5	6	10	6
3	UltraDawn 4 oz	40 ga	75	5	50	5.5	75	6
4	UltraDawn 4 oz	80 ga	80	5	100	5	100	6
5	UltraDawn 4 oz	160 ga	80	5.5	100	5	100	6
6	UltraDawn 1 oz	10 ga	0	6	0	6	0	6
7	UltraDawn 2 oz	10 ga	0	6	30	5.5	0	6
8	UltraDawn 8 oz	10 ga	20	5.5	30	5.5	0	6
9	UltraDawn 16 oz	10 ga	20	5	30	5.5	10	6
10	UltraDawn 32 oz	10 ga	80	4	30	5.5	80	6
11	No treatment		0	6	0	6	0	6

Figure 4. Test area following application of UltraDawn dishwashing detergent. June 8, 1998. Each circle represents one of eleven treatments tested in this study. The varying intensities of color in each circle reflect the spray volume used, with higher volumes producing darker green circles. Note also the heavy moss infestation (gray or silvery patches) occurring within and around the plot area.

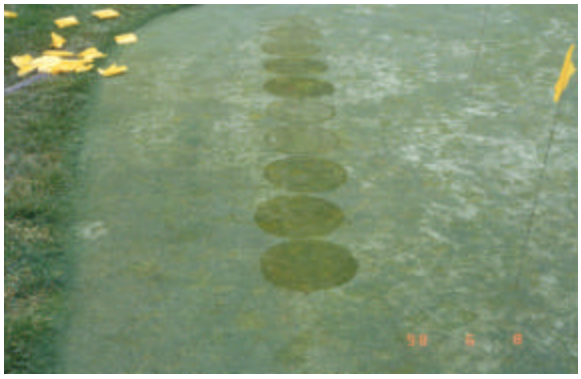


Figure 5. Efficacy of UltraDawn dishwashing liquid (4 oz/gallon) when delivered at three different spray volumes: 40 gallons (treatment 3), 80 gallons (treatment 4) and 160 gallons (treatment 5) per 1000 square feet. Photo taken 8/17/98. Note the complete lack of moss in treatments 4 and 5, 10 weeks after treatment.

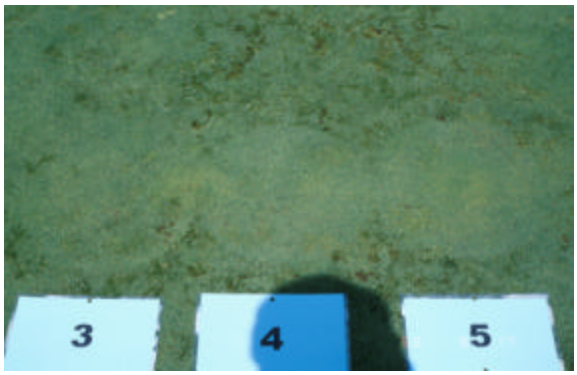


Figure 6. Phytotoxicity when high rates of UltraDawn dishwashing liquid (16 and 32 oz/gallon) are used. Although these rates controlled moss, significant damage to turf was noted on 6/22/98 (2 weeks after treatment). Turf eventually recovered from this damage, however.