Effects of Lightweight Rolling, Sand Topdressing, and Insecticide on the Rhodesgrass Mealybug (Hemiptera: Pseudococcidae) on Golf Course Putting Greens[1]

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Abstract Rhodesgrass mealybug, *Antonina graminis* Maskell (Hemiptera: Pseudococcidae), is an important pest on golf course putting greens. *Antonina graminis* feeding causes extensive yellowing and browning that causes turfgrass mortality. Lightweight rolling and sand topdressing are standard cultural practices on the golf course; however, it is unclear whether they can reduce *A. graminis* densities and provide additional suppression when combined with insecticide. Thus, the objectives of the study were to determine the effects of (a) lightweight rolling and sand topdressing and (b) combining these practices with a systemic insecticide, thiamethoxam, on *A. graminis* densities on golf course putting greens. In 2021 and 2022, experiments were conducted in a split-plot design where lightweight rolling was the main plot treatment and sand topdressing, insecticide, sand topdressing + insecticide, and nontreated were subplot treatments. The numbers of *A. graminis* were not significantly affected by rolling treatment in the 2021 and 2022 experiments. Similarly, the sand topdressing alone had no significant effect on the *A. graminis* densities on the putting greens. The numbers of *A. graminis* were significantly lower for the insecticide (thiamethoxam) and combination of sand topdressing + insecticide treatment than for the nontreated subplot.

Key Words lightweight rolling, sand topdressing, thiamethoxam, *Antonina graminis*

Rhodesgrass mealybug, *Antonina graminis* (Mask.) (Hemiptera: Pseudococcidae), is an important pest of golf course putting greens in subtropical regions of the United States (Chada and Wood 1960). The golf course turf, ranging from Myrtle Beach, SC, along the coast, throughout Florida, and Texas along the Gulf of Mexico, and westward into California (GGE 2010, NGF 2019), are vulnerable to *A. graminis* infestation and feeding damage. *Antonina graminis* was first observed causing damage on the golf course in 1949 at Houston Country Club (Henry 1950), followed by other courses in Florida and Louisiana in the early 1950s (Ferguson 1953, 1954; Lawrence 1952; Sander 1953; Watson 1953). *Antonina graminis* damage to golf courses has been reported worldwide, especially in Australia, Israel, and Korea (Berlinger and Barak 1981, Brimblecombe 1968, Gyu-Yul and Kim 1994). *Antonina graminis* can attack more than 100 species of grasses (Poaceae) but prefers turfgrass on the putting greens (Reinhert et al. 2009, 2010). In the southern United States, golf is played year-round, as the climate remains warm during the winter. Golf enthusiasts travel

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from courses in northern states to courses in the southern states. However, these courses are susceptible to *A. graminis* infestations and affect the playability of golf. On the putting greens, severe *A. graminis* feeding causes yellowing and browning of turfgrass, and the affected turfgrass may die within weeks. These damage symptoms affect the aesthetics and playability of golf.

Antonina graminis females are 2- to 3-mm-long insects. They are parthenogenetic, with each female capable of producing 150–300 eggs (Chada and Wood 1960). The eggs hatch within the female, and crawlers are born live (Joseph and Hudson 2019). Crawlers are the only mobile stage of *A. graminis*. They settle on the nodes under the leaf sheath close to the soil and molt through two sessile nymphal stages before molting into adults. It can take about 50–60 d for a female *A. graminis* to reach reproductive maturity. Adult longevity is up to 100 d (Chada and Wood 1960).

Putting greens are highly maintained golf course areas for aesthetics and performance. Many cultural practices are routinely administered to achieve aesthetic and performance goals. The turfgrass on the putting greens is mowed multiple times each week and maintained at $\sim$2.3 mm height, sometimes for the entire year. Lightweight rolling improves smooth ball roll on the putting green surfaces. The lightweight rollers are designed for putting green surfaces, typically weighing less than 500 kg and exerting 24 to 50 kPa ground pressure (Turgeon and Kaminski 2019). To prevent excessive shoot growth, which could later build up as thick thatch deposition, a 0.5- to 1-mm thin layer of sand is topdressed on the putting greens and incorporated into the thatch layer to maintain firmness and uniform soil structure. The putting greens are also irrigated as needed to prevent turfgrass desiccation. Fertilizers and plant growth regulators are regularly applied to promote turfgrass growth, and pesticides are prophylactically applied to prevent pathogen, insect, and weed pest attacks. Although all these cultural practices are available to golf superintendents, not all practices are adopted because of economic constraints.

Cultural control is an important tactic within integrated pest management principles, where the production or cultural practices are modified to reduce the incidence or abundance of pests or their damage (Flint 2012). Previous observations showed that vertical mowing reduced *A. graminis* densities on the putting green surfaces (Ferguson 1954). Modern putting green management techniques encourage frequent sand topdressing and lightweight rolling in addition to routine mowing operations. These practices enhance the firmness and smoothness of the putting green surfaces for improved playability. Little is known whether frequent lightweight rolling and sand topdressing would reduce *A. graminis* densities on the putting green surface. The assumption was that the angular edges of the sand grains applied as topdressing and the rolling would abrasively exert additional pressure on females and enhance *A. graminis* mortality. In addition, it is unclear whether these cultural practices combined with effective insecticide can provide additional *A. graminis* control on the putting greens. Previously, systemic insecticides, especially thiamethoxam and flupyradifurone, have shown promise in reducing *A. graminis* densities (Joseph et al. 2021). Thus, the objectives of the study were to determine the effects of (a) lightweight rolling and sand topdressing and (b) combining these practices with insecticide on *A. graminis* densities on golf course putting greens.

Materials and Methods

Study site, general methods, insects. In 2021 and 2022, the experiments were conducted on the putting greens at the Columbus State University Key Golf Studio in Columbus, GA. Two separate putting greens 15 m apart were selected for the study. In 2015, the putting greens were constructed in the golf facility on the basis of the U.S. Golf Association's construction guidelines (USGA 2018) using sand and sphagnum peat mix (85:15). The turfgrass on the putting greens was 'TifEagle' bermudagrass [*Cynodon dactylon* CL. (Pers) × *C. transvaalensis* (Burtt-Davy)]. The entire putting greens were naturally infested with *A. graminis* before the trials. From March to November 2021 and 2022, the putting greens were mowed using a walk-behind mower (TORO® Greensmaster 1000, Bloomington, MN) with a bench height of 2.3 mm. The putting greens received nitrogen fertilizer weekly as liquid urea at 3.36 kg/ha per year. The plant growth regulator trinexapac-ethyl (11.3%) at 30–59 mL/ha (Primo Maxx®, Syngenta, Basil, Switzerland) was applied weekly depending on the growth rate of turfgrass. Preventative fungicides such as chlorothalonil (Manicure 6FL, Lesco, Cleveland, OH) at 9.5 L/ha and penthiopyrad (Velista, Syngenta) at 1.53 kg/ha were applied when disease pressure was high. In the spring, foramsulfuron (Revolver®, Bayer Environmental Science [Envu Environmental Science], Cary, NC) was applied at 0.7 L/ha to suppress grassy weeds. No insecticides were applied previously on the putting greens before the start of the experiments. In addition, except for mowing, all mechanical practices, such as aerification, vertical mowing, rolling, and sand topdressing, were suspended on the selected putting greens.

Experimental design. The treatments were arranged in a split-plot design where lightweight rolling was the main plot treatment and sand topdressing, insecticide, a combination of sand topdressing and insecticide, and nontreated were subplot treatments. The treatments were replicated four times. The individual plots measured 1.5 m × 1 m. The experiments were initiated on 31 August 2021 and 5 August 2022, as *A. graminis* populations increased through the summer. The rolling treatment was conducted using a TruTurf RB48 golf greens roller (TruTurf, Gold Coast, Australia) 1.2 m wide and weighing 321 kg (plus 84 kg of the operator) and exerting 24 kPa of ground pressure. The rolling treatment was conducted six times each week of the experiment, where one rolling each was performed on Mondays and Wednesdays and two rollings each on Fridays and Saturdays. For the sand topdressing treatment, 1.25 kg of 45-mesh, 0.35-mm, subangular silica sand (Covia Holdings Corp., Junction City, GA) was added thrice to each designated plot at 0, 14, and 28 d postinitiation of the experiment. The sand was applied by hand and incorporated with a 61-cm-wide Palmyra bristled push broom (Grainger®, Lake Forest, IL) from both directions. For the insecticide treatment, thiamethoxam (Meridian® 25WG, Syngenta) was applied once at 224 g/ha using a CO_2-powered sprayer with a TeeJet® flat fan nozzle (XR11008). The water volume used for the application was 813 L/ha at 219.9 kPa.

Evaluation. In 2021 and 2022, three turfgrass plugs were collected from each plot using a 1.9-cm stainless steel soil core probe (soil probe portion: 53.3 cm length × 1.91 cm diameter, SiteOne® Landscape Supply, Roswell, GA). The plug samples were collected in plastic bags, transported to the laboratory, and stored at 10°C for ~2 d. The samples were examined for *A. graminis* individuals under a dissecting microscope (AmScope, Irvine, CA) at 10× magnification. Individual *A. graminis* were examined for viability by piercing with a needle. Live *A. graminis* exuded a reddish-brown-colored fluid, whereas dead ones exuded yellow-colored fluid or none. In 2021, the sampling for *A. graminis* was conducted at 0, 7, 15, 21, 31, 39, and 45 d postinitiation of the experiment, whereas in 2022, the sampling was conducted at 0, 7, 14, 21, 28, and 35 d postinitiation of the experiment. The sampling dates were 31 August 2021; 7, 15, and 22 September 2021; 1, 9, and 15 October 2021; 5, 12, 19, and 26 August 2022; and 2 and 9 September 2022.

Statistical analyses. All statistical analyses were conducted using SAS software (SAS Institute 2016). The data sets were log-transformed (ln[x+2]) after checking the normality of residuals using the PROC UNIVARIATE procedure in SAS. To determine the effects of the main plot, subplot, and their interaction for *A. graminis* density, a two-way analysis of variance (ANOVA) was conducted using the PROC MIXED procedure in SAS. The fixed effects were the main plot (rolling) and subplot (topdressing, insecticide, topdressing + insecticide, and nontreated) treatments. The random effects were the replication and replication × main plot treatment. The sample date was included in the model as a repeated measure. To understand further, one-way ANOVA was conducted by sampling date on *A. graminis* density data using the PROC MIXED procedure in SAS. The fixed effects were main plot (rolling) and subplot (topdressing, insecticide, topdressing + insecticide, and nontreated). The random effects were the replication and replication × main plot treatment. The least-square means for the main plot and subplot treatments were separated using the Tukey–Kramer ($P < 0.05$) test in SAS. Means and standard errors of the main plot and subplot treatments were calculated using the PROC MEANS procedure in SAS.

Results and Discussion

In 2021 and 2022, there were no significant differences between rolling versus nonrolling treatments for *A. graminis* densities (Table 1; Fig. 1), suggesting that the lightweight rolling failed to reduce *A. graminis* densities on the putting greens. The lightweight roller is primarily used on putting greens to smooth the turfgrass putting surface without causing soil compaction. Despite multiple rollings of lightweight rolling at 24 kPa, it did not exert enough ground pressure to crush the *A. graminis* densities physically. This is the first study examining the use of a lightweight roller to reduce arthropod pests on putting green surfaces. However, a previous study showed that the severity of anthracnose and dollar spot was reduced after lightweight rolling (Inguagiato et al. 2009). The current study was not conducted beyond 6 weeks. It is unclear if prolonged rolling and sand topdressing treatments would reduce *A. graminis* densities in the longer term.

The subplot treatments were significantly different for *A. graminis* densities (Table 1). However, the interaction between main plot and subplot treatments was not significantly different for *A. graminis* densities (Table 1). Because there were significant effects for the subplot treatments, one-way ANOVA was conducted by sampling dates. In 2021, there were no significant differences for *A. graminis* densities among subplot treatments at 0 and 7 d postinitial treatment. At 15, 21, 31, and 39 d postinitial treatment, significantly lower numbers of *A. graminis* were observed for the insecticide and insecticide + topdressing treatments than for the topdressing alone and nontreated areas (Table 1; Fig. 2A). There were no significant differences between insecticide and insecticide + topdressing treatments for these sampling

Table 1. Effects of main plot (rolling) and subplot (insecticide, topdressing, topdressing + insecticide, and nontreated) on *Antonina graminis* densities on golf course putting greens in 2021 and 2022.

	2021				2022			
Treatment	**Posttreatment Intervals (d)[c]**	***F***	**df**	***P***	**Posttreatment Intervals (d)[c]**	***F***	**df**	***P***
	Combined				Combined			
Main plot[a]		1.9	1, 3	0.261		1.8	1, 3	0.268
Subplot[b]		14.1	3, 210	<0.001		8.6	3, 178	<0.001
Main plot × subplot		0.6	3, 210	0.618		0.7	3, 178	0.530
	0				0			
Main plot		0.0	1, 3	0.932		1.9	1, 3	0.254
Subplot		0.1	3, 18	0.955		0.5	3, 18	0.723
Main plot × subplot		1.2	3, 18	0.344		0.3	3, 18	0.814
	7				7			
Main plot		0.9	1, 3	0.420		0.4	1, 3	0.597
Subplot		1.9	3, 18	0.158		0.1	3, 18	0.933
Main plot × subplot		0.4	3, 18	0.755		1.0	3, 18	0.412
	15				14			
Main plot		1.0	1, 3	0.384		3.1	1, 3	0.175

Table 1. Continued.

	2021				2022			
Treatment	**Posttreatment Intervals (d)[c]**	***F***	**df**	***P***	**Posttreatment Intervals (d)[c]**	***F***	**df**	***P***
Subplot		16.6	3, 18	<0.001		3.1	3, 18	0.053
Main plot × subplot		0.6	3, 18	0.640		0.2	3, 18	0.913
	21				21			
Main plot		0.7	1, 3	0.461		4.1	1, 3	0.137
Subplot		28.19	3, 18	<0.001		9.4	3, 18	0.001
Main plot × subplot		0.73	3, 18	0.550		2.3	3, 18	0.115
	31				28			
Main plot		1.3	1, 3	0.335		2.5	1, 3	0.215
Subplot		23.7	3, 18	<0.001		8.4	3, 18	0.001
Main plot × subplot		1.3	3, 18	0.298		2.1	3, 18	0.141
	39				35			
Main plot		2.9	1, 3	0.187		0.0	1, 3	0.920
Subplot		18.0	3, 18	<0.001		3.8	3, 18	0.028
Main plot × subplot		1.5	3, 18	0.260		0.3	3, 18	0.860
	45							
Main plot		0.2	1, 3	0.656		—	—	—

Table 1. Continued.

Treatment	2021				2022			
	Posttreatment Intervals (d)[c]	*F*	df	*P*	Posttreatment Intervals (d)[c]	*F*	df	*P*
Subplot		15.9	3, 18	<0.001		—	—	—
Main plot × subplot		1.1	3, 18	0.369		—	—	—

[a] Main plot treatments were rolled and nonrolled.
[b] Subplot treatments were insecticide only, top dressing only, top dressing + insecticide, and nontreated.
[c] Sampling was conducted on 31 August 2021; 7, 15, and 22 September 2021; 1, 9, and 15 October 2021; 5, 12, 19, and 26 August 2022; and 2 and 9 September 2022.

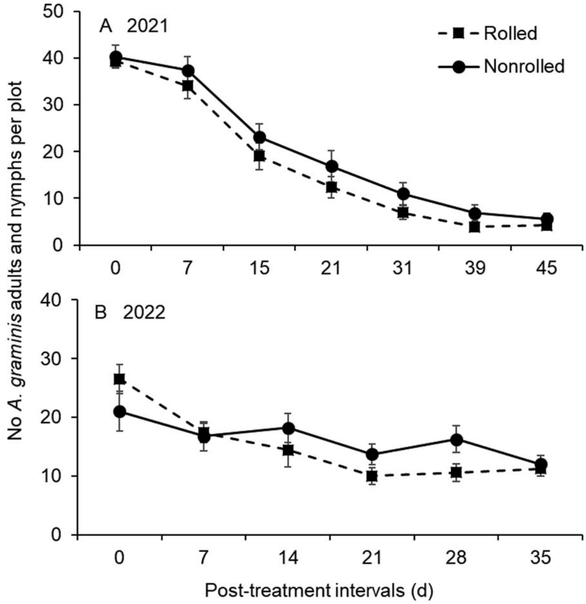

Fig. 1. Mean (±SE) numbers of *Antonina graminis* densities collected from main plot (rolling) treatment on golf course putting greens at various sampling dates after the initial application of treatments in 2021 and 2022. No letters or symbols are provided at each sampling date as treatment effects were not significantly different at $\alpha = 0.05$.

dates (Fig. 2A). At 45 d, the numbers of *A. graminis* were significantly lower for the insecticide and insecticide + topdressing treatments than for the topdressing treatment (Table 1; Fig. 2A).

In 2022, there were no significant differences for *A. graminis* densities among subplot treatments at 0, 7, and 14 d after initial treatment (Table 1; Fig. 2B). At 21 d, the numbers of *A. graminis* were significantly lower for the insecticide + topdressing treatment than for the nontreated area (Table 1; Fig. 2B). At 28 d, *A. graminis* densities were significantly lower for the insecticide and insecticide + topdressing treatments than for the topdressing only and nontreated subplots (Table 1; Fig. 2B). There were no significant differences between insecticide and insecticide + topdressing treatments for these sampling dates (Fig. 2B). At 35 d, the numbers of *A. graminis* were significantly lower for the insecticide treatment than for the topdressing and nontreated areas (Table 1; Fig. 2B). Although sand topdressing firmed up the turfgrass canopy (R.M.W. pers. comm.), the topdressing application did not reduce *A. graminis* densities on the putting greens. Some studies have shown that initiating sand topdressing on the putting green surface increased the incidence of disease outbreaks as the sand created more wounds on the turfgrass blades. However, after repeated applications, sand topdressing improved turfgrass quality and reduced disease severity (Inguagiato et al. 2012). In the current study, a single application of thiamethoxam effectively reduced *A. graminis* densities within 4 weeks, which is consistent with the previous study (Joseph et al. 2019).

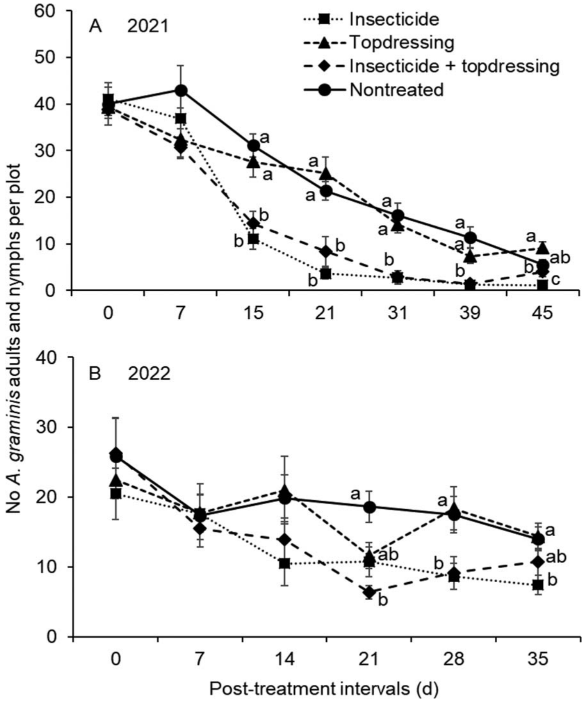

Fig. 2. Mean (± SE) numbers of *Antonina graminis* densities collected from subplot (insecticide, topdressing, topdressing + insecticide, and nontreated) treatments on golf course putting greens at various sampling dates after the initial application of treatments in 2021 and 2022. Same letters with sampling dates indicate no significant differences among treatments (Tukey–Kramer test, $\alpha = 0.05$). No letters are provided for sampling dates when none of the treatments significantly differed at $\alpha = 0.05$.

In summary, cultural practices, such as lightweight rolling and sand topdressing, were ineffective in reducing *A. graminis* densities on putting greens. These practices were only administered for a short period in the current study, and an extended application of these cultural tactics may produce suppression of *A. graminis* densities, which warrants further investigation. Developing sustainable management tactics for *A. graminis* on putting greens, in conjunction with compatible, reduced-risk insecticides, should be further evaluated along with other strategies, such as biological control. Only chemical control strategies effectively reduced *A. graminis* densities (Joseph et al. 2019) despite the active biological control agents on the putting greens (R.M.W. pers. obs.). Previous studies showed that enhanced use of nitrogen fertilizer can improve the turfgrass quality and mitigate the damage to a certain extent (R.M.W., unpubl. data); however, insecticidal suppression of *A. graminis* densities is critical for the long-term management of *A. graminis* populations on golf course putting greens.

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