Hello WTA Members:

Part of the Wisconsin Turfgrass Association’s mission is to "Disseminate research findings to turfgrass professionals.” With the many challenges that 2020 has brought to all of us, the WTA Board of Directors recently voted to have four (December thru March) supplemental newsletters that will focus on the research that our own University of Wisconsin-Madison professors conducted this year.

We have access to some of the world's leading turfgrass researchers at the University of Wisconsin-Madison. In partnering with these researchers, the WTA will be sending these research publications to our membership. These publications will include a plethora of information about new and existing products, turfgrass management strategies and agronomics. Look for these publications in your inbox and on our website. Thank you for your continued support of the WTA and enjoy the continued education!

Cheers,

Brad DeBels

WTA President

Control of Anthracnose on Golf Course Fairways

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OBJECTIVES

To determine the efficacy of standard and experimental fungicides for control of foliar anthracnose caused by the fungus *Colletotrichum cereale.*

MATERIALS AND METHODS

This study was conducted at Yahara Hills Golf Course in Madison, WI. The site is a mixed stand of annual bluegrass (*Poa annua*) and creeping bentgrass (*Agrostis stolonifera*) maintained under fairway conditions. The individual plots measured 3 ft by 10 ft and were organized in a randomized complete block design with four replications. All treatments were applied using a CO_2-pressurized boom sprayer with two Teejet AI8004VS nozzles at a pressure of 40 psi. All pesticides were agitated by hand and applied at 1.5 gallons of water per 1000 ft^2. All treatments were initiated on June 1, 2020 and subsequent applications were made at 14- or 21-day intervals. Disease severity (percent plot area affected) and turfgrass quality (1-9, 9 being excellent, 6 acceptable, and 1 bare soil) were assessed every two weeks. Turf quality and disease severity were subjected to an analysis of variance and means were separated using Fisher's LSD (P = 0.05). Due to extensive drought and traffic damage that affected all treatments in the first two replications, only replications 3 and 4 were analyzed as part of these results. Results of the disease severity and turfgrass quality ratings can be found in table 1 and 2, respectively.

RESULTS AND DISCUSSION

Disease severity in the non-treated controls was high starting in early July through the end of August. Non-treated controls averaged around 40% disease on the last 3 rating dates. All fungicide treatments significantly reduced disease severity on Aug 24. All treatments provided acceptable turf quality on Aug 24. No phytotoxicity was observed with any treatments.

Table 1. Mean anthracnose severity per treatment on creeping bentgrass/annual bluegrass maintained at fairway height at Yahara Hills Golf Course in Madison, WI during 2020.

	Treatment	Application Rate	App Interval	App Dates[b]	Anthracnose Severity (%)[a]		
					Jul 28	Aug 11	Aug 24
1	Non-treated control				40.0 a	37.5 a	42.5 a
2	Navicon	0.85 fl oz/1000ft2	14 day	CEGIKM	7.5 a	2.5 a	0.0 b
3	Insignia Civitas One	0.7 fl oz/1000 ft2 8.0 fl oz/1000ft2	14 day	CEGIKM	5.0 a	0.0 a	0.0 b
4	Maxtima	0.4 fl oz/1000ft2	14 day	CEGIKM	22.5 a	7.5 a	7.5 b
5	Maxtima	0.6 fl oz/1000ft2	14 day	CEGIKM	7.5 a	0.0 a	2.5 b
6	Velista	0.5 oz/1000ft2	14 day	CEGIKM	10.0 a	2.5 a	5.0 b
				LSD P=.05	28.06	28.76	20.79

[a] Anthracnose severity was visually assessed as percent disease. Means followed by the same letter do not significantly differ (P=.05, Fisher's LSD).
[b] Application dates: C = Jun 1, E = Jun 15, F = Jun 22, G = Jun 29, I = Jul 13, K = Jul 27, M = Aug 11

Table 2. Mean turf quality per treatment on creeping bentgrass/annual bluegrass maintained at fairway height at Yahara Hills Golf Course in Madison, WI during 2020.

	Treatment	Application Rate	App Interval	App Dates[b]	Turfgrass Quality[a]		
					Jul 28	Aug 11	Aug 24
1	Non-treated control				4.5 a	4.5 cd	4.0 c
2	Navicon	0.85 fl oz/1000ft2	14 day	CEGIKM	6.0 a	6.5 ab	7.0 a
3	Insignia Civitas One	0.7 fl oz/1000 ft2 8.0 fl oz/1000ft2	14 day	CEGIKM	6.5 a	7.5 a	7.0 a
4	Maxtima	0.4 fl oz/1000ft2	14 day	CEGIKM	5.0 a	6.0 abc	6.0 ab
5	Maxtima	0.6 fl oz/1000ft2	14 day	CEGIKM	6.0 a	7.0 a	6.5 ab
6	Velista	0.5 oz/1000ft2	14 day	CEGIKM	5.5 a	6.5 ab	6.5 ab
				LSD P=.05	2.21	1.86	1.52

[a]Turfgrass quality was rated visually on a 1 – 9 scale with 6 being acceptable. Means followed by the same letter do not significantly differ (P=.05, Fisher's LSD).
[b] Application dates: C = Jun 1, E = Jun 15, F = Jun 22, G = Jun 29, I = Jul 13, K = Jul 27, M = Aug 11

Early Season Dollar Spot Suppression on Golf Course Fairways

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OBJECTIVE

To determine how early season fungicide applications affect the use of the Smith-Kerns dollar spot prediction model.

MATERIALS AND METHODS

The study was conducted at the O. J. Noer Turfgrass Research and Education Facility in Madison, WI on a stand of 'Penncross' creeping bentgrass (*Agrostis stolonifera*) maintained at 0.5 inches. The individual plots measured 3 feet by 10 feet and were arranged in a randomized complete block design with four replications. Individual treatments were applied at a nozzle pressure of 40 p.s.i. using a CO_2-pressurized boom sprayer equipped with two XR Teejet AI8004 nozzles. All fungicides were agitated by hand and applied in the equivalent of 1.5 gallons of water per 1000 ft^2. Treatments 5, 6, and 7 were initiated on May 22nd, 2020 when GDDs (base 50°F) were close to reaching 140. Subsequent applications were made at 28-day intervals and were made when the Smith-Kerns model reached 20%, 30%, and 40%, respectively. Treatments 2, 3, and 4 were initiated when the Smith-Kerns model reached 20%, 30%, and 40%, respectively, with no early season application. Number of dollar spot foci per plot and turfgrass quality (1-9, 9 being excellent, 6 acceptable, and 1 bare soil) were visually assessed every 2 weeks. Disease severity and turf quality were subjected to an analysis of variance and means separated using Fisher's LSD (P = 0.05). Results of disease severity and turfgrass quality ratings can be found in table 1 and 2, respectively.

RESULTS AND DISCUSSION

Dollar spot developed within the plot area in early July. All fungicide treatments significantly reduced dollar spot severity when compared to the non-treated control. Despite intricate variations in reapplication intervals, only minor differences were observed between the treatments. The early season application did not appear to affect the use of the Smith-Kerns model according to this year data.

Table 1. Mean dollar spot severity per treatment on creeping bentgrass maintained at fairway height at the OJ Noer Turfgrass Research Facility in Madison, WI during 2020.

	Treatment	Rate	Application Code[b]	App Rule	Dollar Spot Severity[a]		
					Jul 8	Aug 5	Sep 2
1	Non-treated control				102.0a	222.3a	403.0a
2	Xzemplar	0.26 fl oz/M	BFJNR	20%	12.5b	21.0b	27.3b
3	Xzemplar	0.26 fl oz/M	BFJO	30%	13.5b	47.3b	54.5b
4	Xzemplar	0.26 fl oz/M	BFJO	40%	6.5b	31.5b	59.5b
5	Xzemplar	0.26 fl oz/M	AFJNR	GDD140, 20%	18.0b	38.3b	44.3b
6	Xzemplar	0.26 fl oz/M	AFJNR	GDD140, 30%	8.0b	33.8b	62.0b
7	Xzemplar	0.26 fl oz/M	AFJO	GDD140, 40%	18.5b	35.8b	57.0b
				LSD P=.05	31.36	35.28	130.15

[a]Dollar spot rated as number of dollar spot infection centers per plot. Means followed by the same letter do not significantly differ (P=.05, Fisher's LSD).
[b]Application code A = May 22, B = May 27, F (trt 5, 6) = Jun 22, F (trt 7) = Jun 23, F (trt 2, 3, 4) = Jun 24, J (trt 5, 6) = Jul 20, J (trt 7) = Jul 21, J (trt 2, 3, 4) = Jul 22, N (trt 5, 6) = Aug 17, N (trt 2) = Aug 19, O (trt 3) = Aug 24, O (trt 4, 7) = Aug 25, R (trt 5, 6) = Sep 14, R (trt 2) = Sep 17.

Table 2. Mean turfgrass quality per treatment on creeping bentgrass maintained at fairway height at the OJ Noer Turfgrass Research Facility in Madison, WI during 2020.

	Treatment	Rate	Application Code[b]	App Rule	Turfgrass Quality[a]		
					Jul 8	Aug 5	Sep 2
1	Non-treated control				4.3d	4.0b	4.0b
2	Xzemplar	0.26 fl oz/M	BFJNR	20%	6.3ab	5.3a	5.5a
3	Xzemplar	0.26 fl oz/M	BFJO	30%	5.8bc	5.0a	5.0a
4	Xzemplar	0.26 fl oz/M	BFJO	40%	6.8a	5.0a	5.0a
5	Xzemplar	0.26 fl oz/M	AFJNR	GDD140, 20%	5.3c	5.0a	5.0a
6	Xzemplar	0.26 fl oz/M	AFJNR	GDD140, 30%	6.0abc	5.0a	5.0a
7	Xzemplar	0.26 fl oz/M	AFJO	GDD140, 40%	5.8bc	5.0a	5.0a
				LSD P=.05	0.77	0.28	0.56

[a]Turfgrass quality was rated visually on a 1 – 9 scale with 6 being acceptable. Means followed by the same letter do not significantly differ (P=.05, Fisher's LSD).
[b]Application code A = May 22, B = May 27, F (trt 5, 6) = Jun 22, F (trt 7) = Jun 23, F (trt 2, 3, 4) = Jun 24, J (trt 5, 6) = Jul 20, J (trt 7) = Jul 21, J (trt 2, 3, 4) = Jul 22, N (trt 5, 6) = Aug 17, N (trt 2) = Aug 19, O (trt 3) = Aug 24, O (trt 4, 7) = Aug 25, R (trt 5, 6) = Sep 14, R (trt 2) = Sep 17.

Incorporating Clover into Kentucky Bluegrass Lawns

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INTRODUCTION

Kentucky bluegrass is the most widely used species for Wisconsin lawns. Kentucky bluegrass is tolerant of heat, drought, cold, and ice; however, it requires 2 to 4 lbs of N per 1000 square feet per year to remain competitive with dandelion and other weeds. Traditionally, white clover has been considered one of those weeds that competes with Kentucky bluegrass. However, clover fixes nitrogen from the atmosphere and may be able to transfer some of that nitrogen to surrounding Kentucky bluegrass, potentially reducing the amount of fertilizer required to maintain density high enough to exclude other weeds. The goal of this study was to investigate incorporating various clover species (white clover (*Trifolium repens*), Microclover® (*Trifolium repens*, var. Pipolina), and strawberry clover (*Trifolium fragiferum*) at various rates into lawns by overseeding and new establishment.

MATERIALS AND METHODS

Two studies were initiated in May 2019 at the O.J Noer Turfgrass Research and Education Facility in Verona, WI. The first evaluated establishment of clover lawns from bare soil. The existing turf was killed with glyphosate, tilled, smoothed, and then seeded with the various clover and turfgrass mixtures shown in Table 1 below. The seed was applied using hand-shakers, starter fertilizer applied to provide 1 lb of P_2O_5 per 1000 square feet, the area was lightly raked, then compacted by driving on the soil with a utility vehicle, straw mulch was applied to cover approximately 50% of the soil surface, and then the area was irrigated. Irrigation was applied three times per day to keep the soil surface moist during the establishment period. After plots had sufficiently established, irrigation was withheld. No additional fertilizer or any weed control was applied to the study area. The plots were arrayed in a randomized complete block design with four replications and individual plot size of 5 ft. by 5 ft. Data collection involved assessing the percent cover of turfgrass, clover, other weeds, and bare soil in spring summer and fall of 2019 and 2020. The plots are mowed as needed in 2019, and a robotic mower was used to maintain a consistent cutting height in 2020. No other cultural practices were applied.

Table 1. Description of the treatments used in the clover lawn establishment study.

Turfgrass and Clover Combinations Used	**Seeding Rate** (lbs/1000 sqft)
X-Seed Microlawn (85% tall fescue, 10% p. rye, 2.5% microclover)	5.0
Scotts Clover Lawn (strawberry clover)	2.0
Microclover (white clover, variety “Pipolina”)	1.0
Dutch White Clover (standard white clover)	0.75
Madison Parks (50% Kentucky bluegrass , 25% fine fescue, 25% p. rye)	3.0
Madison Parks + Scotts Clover Lawn	3 + 0.1
Madison Parks + Microclover	3 + 0.1
Madison Parks + Dutch White Clover	3 + 0.1
Madison Parks + Scotts Clover Lawn	3 + 0.3
Madison Parks + Microclover	3 + 0.3
Madison Parks + Dutch White Clover	3 + 0.3
Madison Parks + Scotts Clover Lawn + Microclover + Dutch White Clover	3 + 0.1 + 0.1 + 0.1

The second study evaluated different clover overseeding strategies into existing Kentucky bluegrass turfgrass. This study was also initiated in May 2019 with a randomized complete block design with four replications and 5 ft. by 5 ft. plots. Prior to seeding, a power rake was used to create channels in the bluegrass in two directions perpendicular to each other. After power raking, the plots were hand raked to remove the newly displaced vegetation which would have otherwise prevented some of the seed from finding the new soil channels. Then, the appropriate type and amount of clover seed (Table 2) was spread even across each plot using a hand-shaker. A utility vehicle was driven over the plot to create seed to soil contact. The plot was then irrigated with approximately 0.25 inches of water. No fertilizer or other inputs were applied during the study. The plots were mown as needed to a height of 2.5 inches approximately weekly during the growing season in 2019. In 2020, a robotic mower was used to mow the plots. Data collection involved assessing the percent cover of turfgrass, clover, and other weeds in spring summer and fall of 2019 and 2020. Turfgrass NDRE (a measure of reflectance of green light) and turfgrass visual quality rating (1-9, 9=best) were also recorded periodically.

Table 2. Description of the treatments used in the clover overseeding study.

Overseeding Treatment	**Overseeding Rate** (lbs/1000 sqft)
White clover	1.0
White clover	2.0
White clover	4.0
White clover	8.0
Strawberry clover	1.0
Strawberry clover	2.0
Strawberry clover	4.0
Strawberry clover	8.0
Microclover	1.0
Microclover	2.0
Microclover	4.0
Microclover	8.0
Control	0.0

RESULTS

Establishment from Bare Soil Study.

Evaluation of clover/Kentucky bluegrass stands is difficult because there is little information or context for understanding what an “ideal” ratio of bluegrass to clover is. If we assume that a relatively balance stand is desired, then a treatment that gives 25 to 75% clover and between 25 and 75% turf would be ideal. At the end of the 2020 season, the treatments that had between 25 and 75% of clover and turf included: X-Seed Microlawn, Scotts Clover Lawn, Madison Parks + Dutch White Clover (high rate), Madison Parks + Microclover (low rate and low rate).

Another way to evaluate the performance of these mixtures is to evaluate the non-clover weed cover. In October 2020, the Madison Parks treatment (non-overseeded) had the highest weed cover at 22% (Table 4). The two treatments that had statistically significantly lower weeds than this treatment and also had between 25% and 75% of turfgrass and clover were X-Seed Microlawn and Madison Parks + Microclover (low rate). Therefore, these two treatments appear to be good options for seeding a low maintenance lawn in Wisconsin.

Table 3. Clover and turfgrass composition of the treatments seeded to bare soil in May 2019 in early October 2020. Different letters following means within each column indicate statistically significant differences at the 95% confidence level.

Turfgrass and Clover Combinations Used	Clover Cover	Turfgrass Cover
X-Seed Microlawn (85% tall fescue, 10% p. rye, 2.5% microclover)	43.3 C	48.3 B
Scotts Clover Lawn (strawberry clover)	65.0 AB	19.3 C
Microclover (white clover, variety “Pipolina”)	80.0 A	11.7 C
Dutch White Clover (standard white clover)	60.0 B	21.7 C
Madison Parks (50% Kentucky bluegrass , 25% fine fescue, 25% p. rye)	0.7 F	70.0 A
Madison Parks + Scotts Clover Lawn (low rate)	4.3 F	73.3 A
Madison Parks + Microclover (low rate)	25.0 DE	66.0 A
Madison Parks + Dutch White Clover (low rate)	6.7 F	66.7 A
Madison Parks + Scotts Clover Lawn (high rate)	10.0 EF	66.7 A
Madison Parks + Microclover (high rate)	35.0 CD	46.7 B
Madison Parks + Dutch White Clover (high rate)	30.0 CD	56.7 AB
Madison Parks + Scotts Clover Lawn + Microclover + Dutch White Clover	23.3 DE	60.0 AB

Table 4. Non-clover weed composition of the treatments seeded to bare soil in May 2019 in early October 2020. Different letters following means within each column indicate statistically significant differences at the 95% confidence level.

Turfgrass and Clover Combinations Used	Non- Clover Weed Cover
X-Seed Microlawn (85% tall fescue, 10% p. rye, 2.5% microclover)	6.7 B
Scotts Clover Lawn (strawberry clover)	11.7 AB
Microclover (white clover, variety “Pipolina”)	8.3 B
Dutch White Clover (standard white clover)	16.7 AB
Madison Parks (50% Kentucky bluegrass , 25% fine fescue, 25% p. rye)	21.7 A
Madison Parks + Scotts Clover Lawn (low rate)	18.3 AB
Madison Parks + Microclover (low rate)	7.3 B
Madison Parks + Dutch White Clover (low rate)	21.7 A
Madison Parks + Scotts Clover Lawn (high rate)	18.3 AB
Madison Parks + Microclover (high rate)	18.3 AB
Madison Parks + Dutch White Clover (high rate)	10.0 AB
Madison Parks + Scotts Clover Lawn + Microclover + Dutch White Clover	15.0 AB

Overseeding Study

Using similar evaluation criteria as described above, the overseeding treatments that resulted in a good balance of turf and clover (between 25 and 75% for both) two growing seasons after overseeding were white clover at 1 or 2 lbs/1000 sqft, strawberry clover at 8 lbs/1000 sqft (Table 5). The 1 lb/1000 sqft treatment of Microclover just missed the list because it had slightly too much clover and not enough turf. It appears that a better seeding rate would be 0.5 lbs/1000 sqft. The Microclover was a vigorous colonizer of the Kentucky bluegrass relative to the other two species used, and rates of 4 and 8 lbs/1000 sqft of Microclover produced stands of >90% clover and <10% turf after less than two years. The strawberry clover was the weakest competitor of the three species, and only the highest overseeding rate was able to result in an acceptable level of clover. The other evaluation criteria used was how well the clover could reduce the occurrence of other non-clover weeds. The greatest weed non-clover weed cover was found in the control treatment at 12% weeds. Every Microclover and white clover treatment significantly reduced non-clover weed cover, however, none of the strawberry clover treatments were able to reduce weed cover relative to the control treatment (Table 5).

Table 5. Clover, non-clover weeds, and turfgrass composition of the treatments from early October 2020 overseeded into an existing stand of mature Kentucky bluegrass in May 2019. Different letters following means within each column indicate statistically significant differences at the 95% confidence level.

Overseeding Treatment	**Overseeding Rate** (lbs/1000 sqft)	**Clover Cover (%)**	**Non-Clover Weeds (%)**	**Turf (%)**
White clover	1.0	52.5 C	5.5 BCDE	42.0 B
White clover	2.0	61.3 BC	3.0 DE	35.8 BC
White clover	4.0	76.3 AB	2.3 DE	21.5 CD
White clover	8.0	78.8 AB	3.5 CDE	17.8 CD
Strawberry clover	1.0	20.5 D	10.0 ABC	69.5 A
Strawberry clover	2.0	18.8 D	11.3 AB	70.0 A
Strawberry clover	4.0	16.3 D	8.8 ABCD	75.0 A
Strawberry clover	8.0	25.0 D	7.5 ABCDE	67.5 A
Microclover	1.0	80.0 AB	1.3 E	18.8 CD
Microclover	2.0	87.5 A	1.8 E	10.8 D
Microclover	4.0	91.3 A	1.3 E	7.5 D
Microclover	8.0	95.0 A	1.0 E	4.0 D
Control	0.0	11.6 D	11.7 A	76.7 A

Conclusions

1. *Clover can reduce the amount of non-clover weeds in Wisconsin lawns. This may be desirable for low maintenance, non-fertilized lawns.*
2. *When establishing a lawn from seed, X-Seed Microlawn appears to be a good option when tall fescue is a desired grass, and a typical WI lawn grass mixture like Madison Parks + Microclover at a rate of 0.1 lbs/1000 square feet is ideal for non-tall fescue lawns.*
3. *If attempting to incorporate clover into an existing stand of Kentucky bluegrass, power rake the lawn in two directions and apply Microclover at a rate of 0.5 to 1.0 lbs/1000 sqft, or white clover at a rate between 1 and 2 lbs/1000 sqft.*
4. *Many questions remain regarding the best way to establish and maintain clover lawns in Wisconsin.*

Title: Review of Procedures to Measure Organic Matter of Putting Green Surfaces

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Objectives:

1. Create a comprehensive literature review of organic matter (OM) sampling procedures, preparation, and analysis from golf course putting greens.
2. Identify important research objectives that will help to create a unified method for these processes.
3. Publish findings and identify potential research interests.

Start Date: 2020
Project Duration: One year

Summary Points:

- Though similarities exist among putting green sampling procedures, there is no consensus on specific strategies.
- Loss-on-ignition (LOI) is the most common and practical method for analyzing OM in putting green samples.
- There are multiple studies that can be performed to answer questions identified in the review document.

Summary Text:

The purpose of this project was to review the strategies that have been, and are currently, used for OM analysis in putting greens, including: sample numbers and size, extraction from putting greens, storage and preparation, and laboratory analysis. Citations in the review included peer-reviewed literature, commercial laboratory procedures, first-hand experience from academics and professionals and other identified protocols. The draft document is appended to this summary.

As the literature was reviewed it was evident that few studies used the same protocol in the sampling process. Recommended sample quantity per green was inconsistent among sources. Most studies and laboratory protocols averaged five samples per green (Hannan, 2016; Lockyear, 2008; Schmid et al., 2014; Woods, 2020), yet Kauffman et al. (2013) reported that up to 67 samples were needed to determine a 0.25% OM difference in seashore paspalum putting greens. Han et al. (2016) used pre-treatment sampling in a variable forest soil in combination with a SAS bootstrapping method to accurately determine the number of samples required to determine bulk density. The group editing this literature review thought it would be useful to perform a similar study on putting greens to statistically determine how many samples are required per green.

Many studies took samples using a standard soil core sampler (19 mm) at a 100 mm depth and separated samples into sections at 20 mm depths for compositing. Samples can be composited at the same depths because OM concentration decreases with depth (Linde and Hannan, 2020). Considering golf course superintendents are most concerned with OM content closer to the playing surface, more accurate and practically useful OM analysis may result from dividing samples at predetermined depths.

As part of sample preparation, some individuals and laboratories prefer to remove verdure prior to OM analysis via LOI (Linde and Hannan, 2020; Schmid et al., 2014). Others do not recommend removal of verdure (Woods, 2020). There are legitimate arguments for and against this procedure. The removal of verdure could potentially be a source of error if removal is inconsistent. However, if verdure is not removed, the OM from the above-ground tissue would change the OM content as would verdure depth. Leaving verdure on samples could also simplify the pre-LOI process of analyzing OM. These conflicting and potentially confounding ideas led the authors to suggest a formal study be conducted comparing LOI results from putting green samples that have and have not had their verdure removed. Based on those results, an additional study could be conducted to determine the effect of grass height-of-cut on LOI results.

In soil characteristic investigations, it is common to grind soil samples and then sieve them to 2 mm prior to various analyses. This is typically done to ensure there are no large clods that would prevent inner particles from being included in the sample. Methods and laboratories were again split on the use of this practice for putting green OM analysis. Again, the authors thought that it would be useful to compare these practices side-by-side to determine what, if any, effect grinding, and sieving have on results.

Studies have shown that soil samples should be analyzed by LOI as soon as possible after extraction. Chapman (1997), Jones and Willett (2006), and Sun et at. (2013, 2015) all found changes in various chemical and physical structures when samples are analyzed more than 24 hours after being extracted from the soil. Lee et al. (2007) compared five storage methods for soil microbial activity and found that cooling samples at 20°C or freezing at -4°C were not different from each other and had little affect on results compared to air drying and rewetting. Based on these studies, samples should be analyzed as soon as possible after extraction from putting greens, ideally within 24 hours. However, due to the time it takes to extract, pack, ship, and finally get samples analyzed, this is most likely not possible for golf course superintendents. As a secondary option, samples should be cooled or frozen, and finally, if none of those options are available then air-drying is acceptable. In all cases, LOI should be performed as soon as possible after extraction.

Methods of measuring OM in soils have been modified throughout the years. In the 1920's, Robinson (1922) reported a successful method using hydrogen peroxide. Since then, hydrogen peroxide methods have been modified to be more accurate and efficient. Leifeld and Kogel-Knabner (2001) reported a method that was up to 90% effective at removing OM from soil samples, but it does take multiple applications of high-concentration hydrogen peroxide and between 1-3 days to complete the reaction. Other methods using various reagents have been used throughout the years, but most of them are no longer employed because of some combination of expensive and/or dangerous chemicals, time required to complete reactions, or environmentally hazardous byproducts. A method that does not need addition of chemicals is LOI. This process places samples under high heat for a specific amount of time until the OM has combusted and only non-combustible soil particles remain. There are different heating times and temperatures used for LOI analysis, but most agree that a temperature of 360°C and heating time of 2 hours, as proposed by Schulte and Hopkins (1996) is both accurate and time-efficient while avoiding overestimations that can occur under higher temperatures and longer times (Cambardella et al., 2001).

The literature review, in draft form, has identified historical procedures in sampling and analysis, identified current trends and more research to confirm and standardize procedures.

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