Topdressing 101: Organic Matter Management for Cool-Season (with a little bit of warm-season) *Putting Greens*

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Outline

- Historical perspective
  - Greens Construction
  - New Management Paradigm
    - Firm and Fast
    - Organic Matter Accumulation
    - OM in warm season vs cool season
- Fine tuning
  - Topdressing
  - Cultivation

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THE FIFTH GREEN AT THE ESSEX COUNTY COUNTRY CLUB

1930 Advertisement

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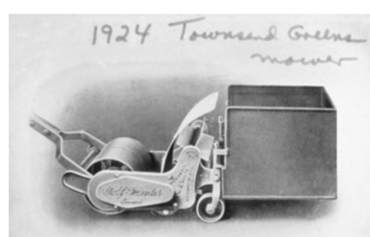
Closer cut mowers



As low as 0.25”

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In 1932, a fruit farmer, Orton Englehardt, invented the impact sprinkler.

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USGA Method of Putting Green Construction

- Original Specifications in 1960
  - Since then, this method has been regularly researched, improved and amended
- Other methods
  - California Style (1990)
  - Purr-wick (1966)
  - Dutch Green (1960-70; primarily the Netherlands)
  - Native soil or push-up greens

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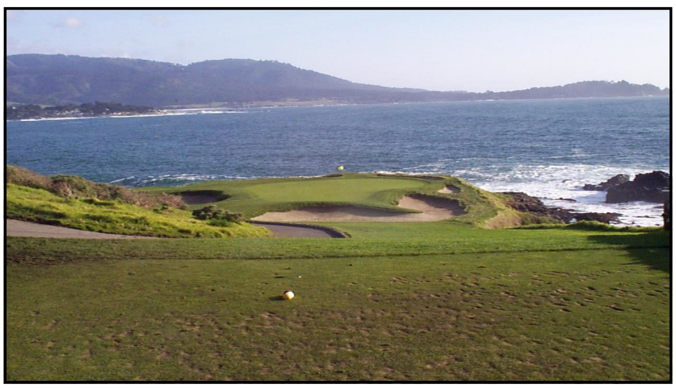

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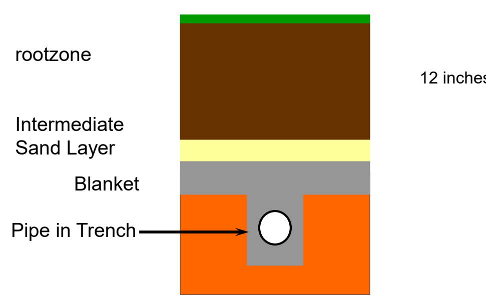
Three Tier (USGA) System



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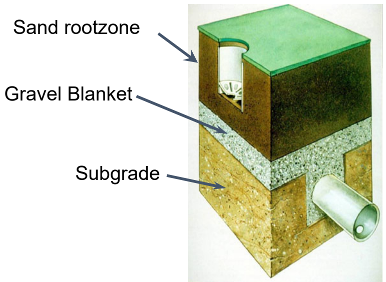
Two Tier System (USGA)



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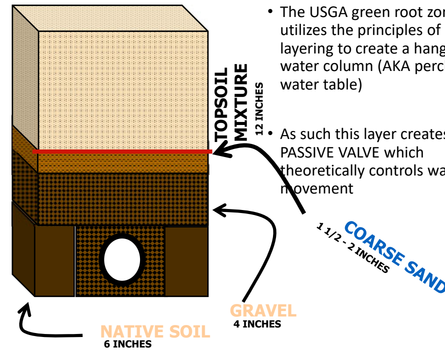

- The USGA green root zone utilizes the principles of soil layering to create a hanging water column (AKA perched water table)
- As such this layer creates a PASSIVE VALVE which theoretically controls water movement

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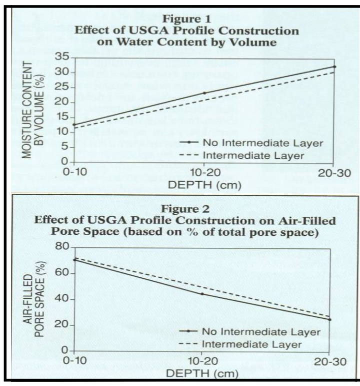

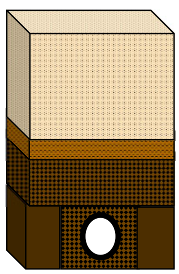

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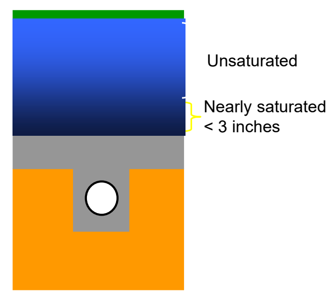
Displacement of Saturated Zone



Sand-based System at Field Capacity

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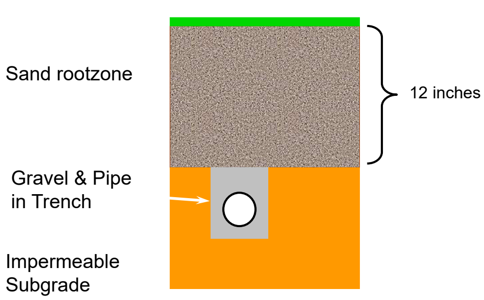
One Tier System (California)



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Organic Matter – Cool vs Warm Season

Provided by:

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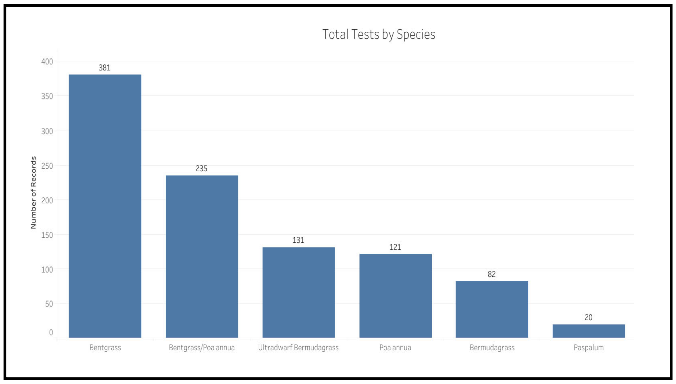

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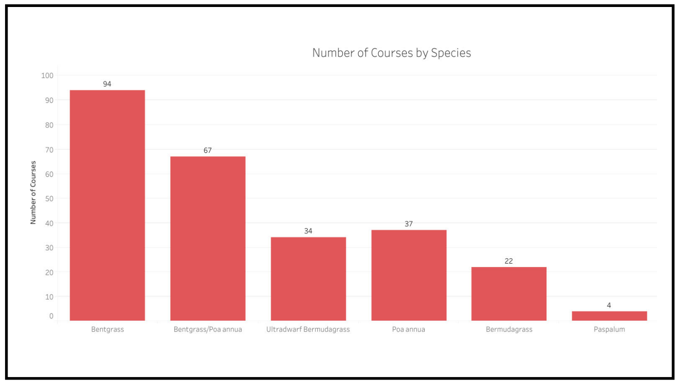

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	Number Courses	Number of Records
CA	45	189
AZ	41	186
OH	29	121
OR	23	102
WA	15	47
TX	16	40
IL	13	51
NV	8	47
MI	6	17
HI	6	25
NM	5	21
MN	5	15
CO	5	9
WI	4	13
UT	4	9
SC	4	9
KY	4	11
IN	4	12
IA	3	5
PA	2	7
MT	2	6
MO	2	6
WY	1	3
WV	1	2
OK	1	3
NJ	1	1
NE	1	7
GA	1	3
FL	1	4
AR	1	3
Grand Total	254	974

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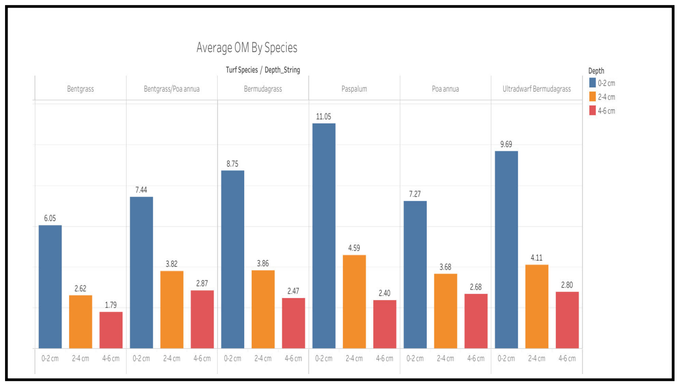

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Turf Species Summary

Turf Species	Organic Matter 0-2 cm	2-4 cm	4-6 cm
Null	8.1	6.2	3.6
Bentgrass	6.1	2.6	1.8
Bentgrass/Poa annua	7.4	3.8	2.9
Bermudagrass	8.7	3.9	2.5
Paspalum	11.1	4.6	2.4
Poa annua	7.3	3.7	2.7
Ultradwarf Bermudagrass	9.7	4.1	2.8

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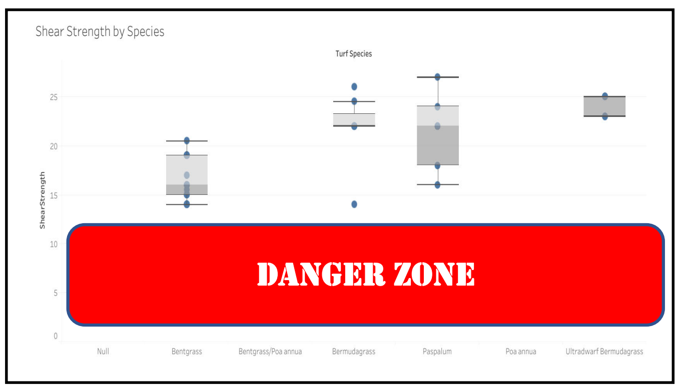

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Bentgrass

- OM lower
- Less Physically Complex
  - Lower lignin; no rhizomes
- Faster Degradation
- More receptive to sand

Bermudagrass

- OM higher
- More Physically Complex
  - Higher lignin; rhizomes
- Slower Degradation
- Less receptive to sand

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Root Zone Properties

Before 2004

USGA K_{sat} guidelines

Normal: 6-12 inches per hour
Accelerated: 12-24 inches per hour

Account for substantial climatic differences

Normal: temperate to dry climates
Accelerated: high rain subtropical and tropical climates or regions with frequent dust storms

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Physical properties of sand-based root zones over time
1996-2005
University of Nebraska-Lincoln

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Objectives

- **Develop a better understanding of the impact of grow-in procedures on putting green establishment and performance.**
- **Investigate temporal changes in the soil physical properties of USGA putting greens.**

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Materials and Methods

- Field experiment initiated in 1997
- Greens constructed every year for four years
- Two rootzone mixtures
  - 80:20 Sand:Peat (v:v)
  - 80:15:5 Sand:Peat:Soil (v:v:v)
- Two establishment treatments
  - Accelerated
  - Controlled

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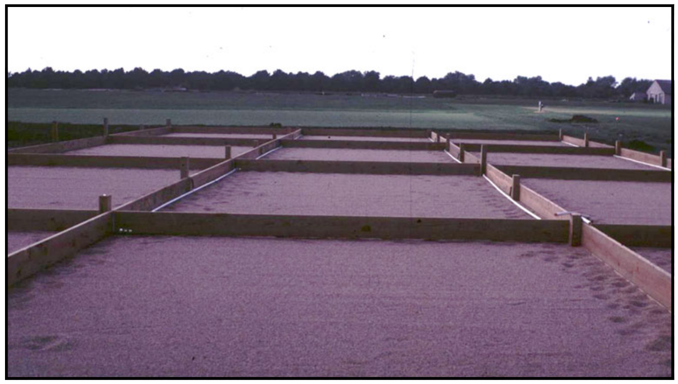

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Project Schedule (Phase I)

1996 | **1997** | **1998** | **1999** | **2000**

Greens construction (one set per year)

Seeding

Data collection on soil physical, chemical, and microbial characteristics influenced by root zone materials and grow-in procedures.

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Project Schedule (Phase II)

2002 | **2003** | **2004** | **2005**

Data collection on soil physical and chemical characteristics as influenced by age, root zone materials and grow-in procedures.

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Materials and Methods

5 yr old green	6 yr old green	7 yr old green	8 yr old green

As of 2004

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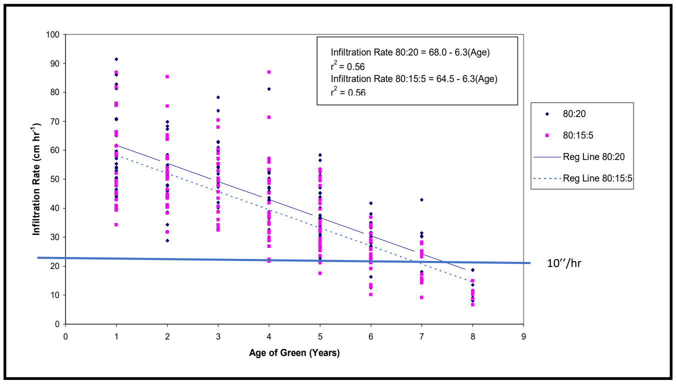

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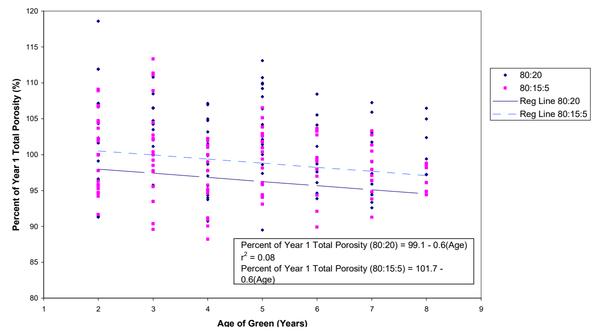

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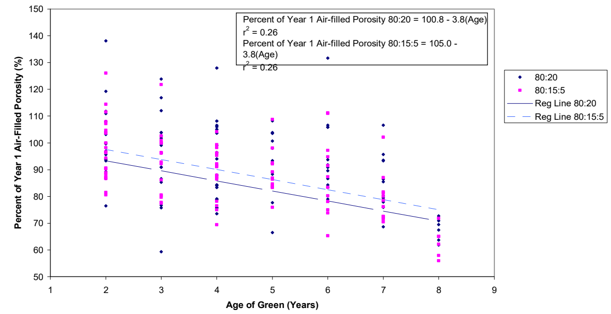

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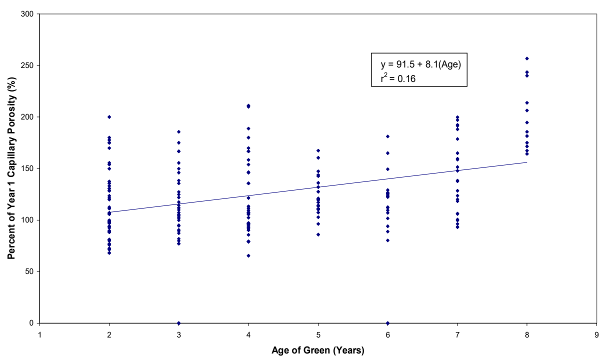

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Microbial Properties

(data from O.J. Noer/USGA project on aging golf greens) and microbial survey of regional golf courses

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Microbial Biomass & Stability

As a green matures the bacterial population shifts from aerobic to anaerobic

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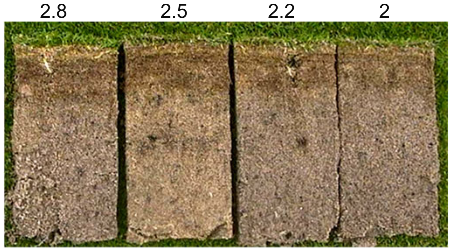
Mat development (cm)

2.8 2.5 2.2 2



8 7 6 5

Green age (years)

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Formation of Mat

- Formation of mat layer increased approximately 0.25” (0.65 cm) annually (following establishment year).
- No visible layering, only a transition is evident between mat and original rootzone.
- Topdressing program
  - Light, Frequent
    - every 10-14 days (depending on growth) and combined with verticutting
  - Heavy, Infrequent
    - 2x annually (spring/fall) and combined with core aerification

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Annual organic matter accumulation in a sand/ peat green

Year 1	2	3
0.65%	3.0%	6.0%

USGA spec. green constructed with 20% (by volume) organic matter

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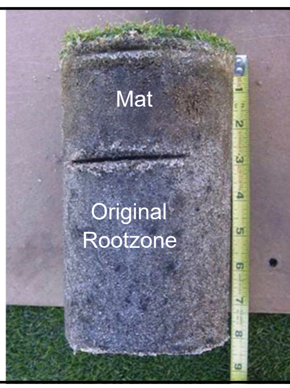

- 2004 USGA research committee site visit
- original rootzone
- mat development

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Materials and Methods

- 2004 rootzone samples taken below mat layer from each soil treatment and sent to Hummel labs for Quality Control Test (24 total samples)
- Tested against original quality control test (z-score).

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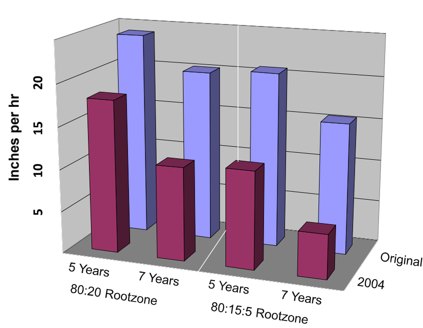

Comparison of preconstruction K_{sat} values to K_{sat} values taken 10/04.

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Change in Rootzone Particle Size Distribution

- All rootzones tested in 2004 showed increased proportion of fine sand (0.15 – 0.25 mm) with decreased proportion of gravel (> 2.0 mm) and very coarse sand (2.0 – 1.0 mm).

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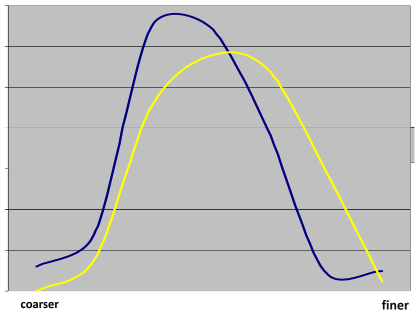

USGA sand size compared to sand used in topdressing program for USGA plots at Mead, NE.

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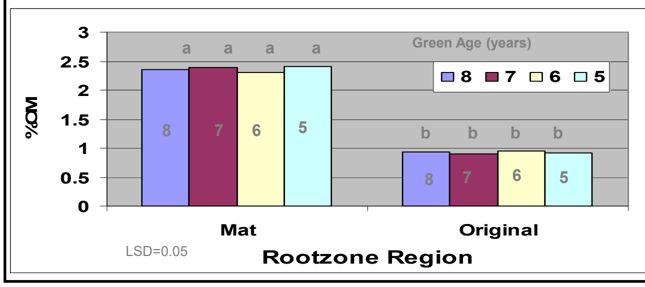
Rootzone vs Mat: Organic Matter



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Root Zone: Mat vs. Original

(samples taken July 15, 2004)

- pH: Mat < Original
- Mat > Original: CEC, OM, microbes and all nutrients

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Conclusions

- Based on *in situ* green testing K_{SAT} decreased, and surface moisture increased, over time due to organic matter accumulation above the original rootzone and increased fine sand content originating from topdressing sand
- Organic matter did result in positive agronomic change: pH, CEC, nutrient holding capacity, microbial stability and amount

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Want to know more?

- Gaussoin, R., R. Shearman, L. Wit, T. McClellan, and J. Lewis. 2007. Soil physical and chemical characteristics of aging golf greens. *Golf Course Manage.* 75(1):p. 161-165.


research
GCM 2007
Soil physical and chemical characteristics of aging golf greens

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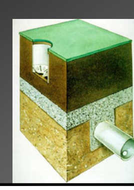
10 Years of Research on Putting Green Root Zones at Rutgers University



T.J. Lawson, H. Samaranayake, J.A. Honig
B. Wolverton, B. Cashel, J. Devaney,
D. Gimenez, S.L. Murphy, M. Koch,
and numerous other undergraduate
and short course students

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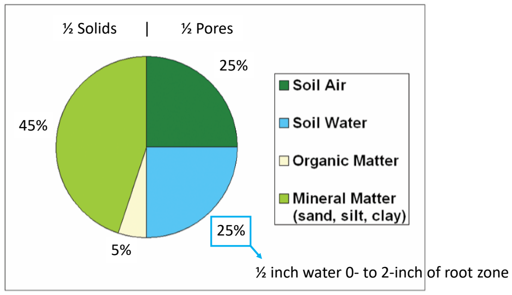
Idealized Proportions of Solids and Pores in Soil



Source: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_052836.pdf

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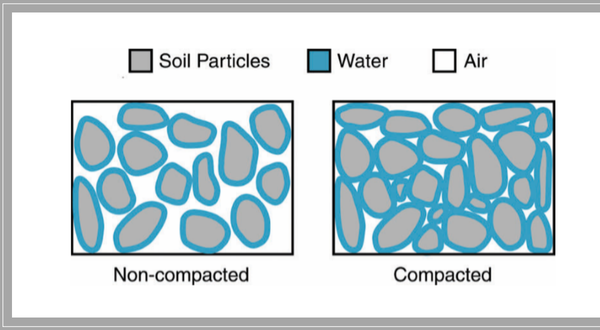

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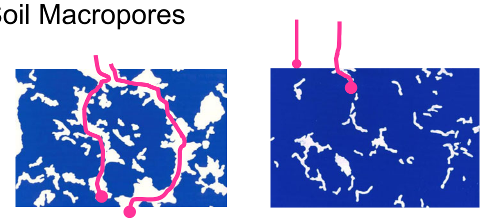
Soil Macropores



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Sand – particle size

Size
- Medium (0.5 – 0.25 mm) sand has very rapid drainage

- Very Fine Sand, Silt and Clay
  - increase water retention and stability of sand
  - but slow water flow (drainage)
  - Maximum 10% fines, less is usually preferable if drainage is critical

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Particle Size Distribution for Drainage (USGA)

Particle Name	Diameter (mm)	Recommendation (by weight)
Fine Gravel	2 – 3.4	Not more than 10% total, maximum of 3% fine gravel
Very Coarse Sand	1 – 2	
Coarse Sand	0.5 – 1	Minimum of 60%
Medium Sand	0.25 – 0.5	
Fine Sand	0.15 – 0.25	Not more than 20%
Very Fine Sand	0.05 – 0.15	Not more than 5%
Silt	0.002 – 0.05	Not more than 5%
Clay	< 0.002	Not more than 3%
Total Fines	very fine sand + silt + clay	Less than or equal to 10%

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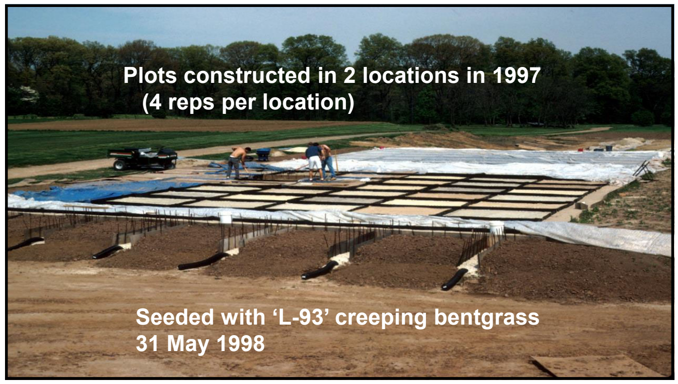

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Open Location

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Enclosed Location

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Topdressed with Construction Mix

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Mircoenvironment effect on annual mean turf quality averaged over root zone amendment treatments.

	1999	2000	2001	2002	2003	2004	2005
	9 = best, 5 = least acceptable turf quality						
Open	6.9	6.7	7.6	6.0	6.6	7.5	7.6
Enclosed	6.7	6.9	7.0	5.3	5.5	6.7	6.2
F test	*	NS	***	***	**	***	***

- As expected, turf quality poorest in the enclosed microenvironment (ME).
- More importantly, relative differences among treatment was similar across MEs; no evidence to justify building differently based on ME.

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Sand size distributions of five root zones.

Root Zone Mixes	Very Coarse	Coarse	Medium	Fine	Very Fine
	%				
Coarse	6	61	32	1	0
Coarse-medium	5	48	38	7	1
Medium	6	26	49	17	2
Medium-fine-1	4	11	53	26	6
Medium-fine-2	0	7	56	30	7
USGA rec	*≤ 10*	*≥ 60*		*≤ 20*	*≤ 5*

All sands mixed with sphagnum peat at 10% by volume

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Pre-construction Properties of Root Zone Materials

Root Zone Sand	K_{sat}	Air-filled Porosity	Capillary Porosity
	in / hr	----- % ------	
Coarse	37	35	7
Coarse-Medium	30	27	13
Medium	25	20	20
Medium-Fine-1	16	17	25
Medium-Fine-2	24	14	29
$LSD_{0.05}$	3	1.6	1.2

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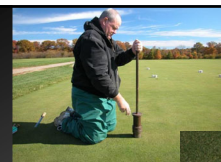

Intact Core Sampling

Physical Property Tests

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K_{sat} of Root Zone Mixes

Root Zone Sand	Pre-Construction	1999	2001	2004
	inches per hour			
Coarse	37	32	56	96
Coarse-Medium	30	32	43	48
Medium	25	27	31	35
Medium-Fine-1	16	24	22	22
Medium-Fine-2	24	24	22	24
$LSD_{0.05}$	3	4	4	6

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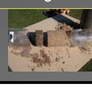
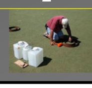
K_{sat} and Field Water Infiltration in 2004

Root Zone Sand	Field Core K_{sat}	Field Infiltration
	inches per hour	
Coarse	96	7
Coarse-Medium	48	5
Medium	35	4
Medium-Fine-1	22	2
Medium-Fine-2	24	2
$LSD_{0.05}$	6	2





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Plot Specific Irrigation

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Plot Specific Irrigation

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Total Hand Water from May to October 2001

Root Zone Sand	Hand Water	Air-filled Porosity	Capillary Porosity
	inches	----- %	------
Coarse	8.8	34.5	7.3
Coarse-Medium	7.4	26.8	13.3
Medium	5.4	19.5	20.4
Medium-Fine-1	3.1	17.1	25.0
Medium-Fine-2	3.4	14.2	28.5
$LSD_{0.05}$	1.6	1.6	1.2

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Total Hand Water from May to October 2001

Root Zone Sand	Hand Water	Turf Quality 1999	2000
	inches	9 = best	
Coarse	8.8	5.7	5.6
Coarse-Medium	7.4	6.7	6.8
Medium	5.4	7.0	7.0
Medium-Fine-1	3.1	7.9	8.0
Medium-Fine-2	3.4	7.8	7.5
$LSD_{0.05}$	1.6	0.4	0.4

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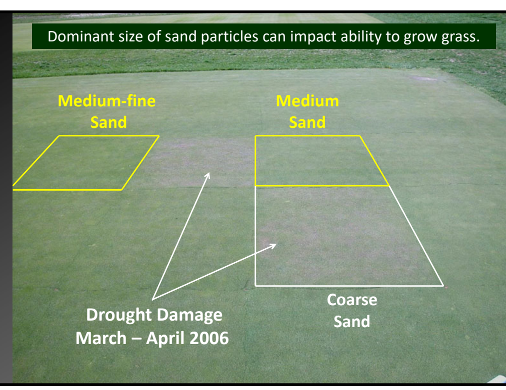

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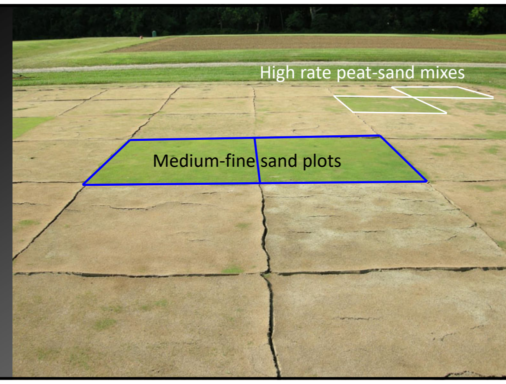

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Algae forms when plots are not allowed to dry sufficiently between irrigations (i.e., plot specific irrigation discontinued)

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Amendments for Sand

- Materials vary based on individual preference/bias
- Peat successful for many decades
- Numerous replacements for peat proposed and used
  - Native soil
  - Composts
  - Inorganic materials

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Amendment Treatments (rate - % by volume)

Sand

Soil 2.5, 5 and 20%
Soil 5% subgrade
Soil 100%

Sphagnum 5, 10 and 20%
Reed Sedge 5 and 10%
Irish peat 10 and 20%

Fertl-soil compost 5%
AllGro compost 10%
AT Sales sand + AllGro compost 20%

Axis 10%
Greenschoice 10%
Isolite 10%
Profile 10 and 20%
ZeoPro 10%
ZeoPro 10% surface 4"
ZeoPro + micros 10% surface 4"

Kaofin 10%

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Straight Sand (un-amended) Root Zones

- OM remains very low (probably too low) over time
- Results in more frequent and intensive inputs to maintain proper plant nutrition and avoid drought stress.

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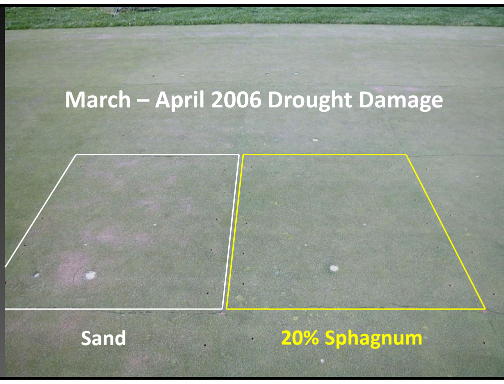

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Compost

- Provided good to excellent turf performance (as good or better than peat)
- … but identification of a high quality compost can be difficult and is critical to success
- http://www.compostingcouncil.org/programs/

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Inorganic amendments

Internally porous granules
- ✓ ceramics (kiln-fired clays)
- ✓ natural minerals (zeolite, diatomaceous earth)

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Inorganic Amendments

- Greater nutrient retention than 100% sand
- Greater water availability but not a dramatic improvement in carrying capacity (days between irrigations)
- Subtle improvement in turf quality
- Cost of these materials is significant, cost-benefit?

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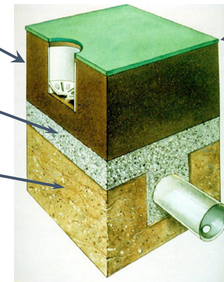
USGA Sand-based Rootzone



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Straight Sand (un-ameneded) Root Zones

Popular with some architects, builders and superintendents.

- Ease of construction
- Initial cost savings - no blending and less testing
- Reputed to be useful in managing the accumulation of organic matter

93

Straight Sand (un-ameneded) Root Zones

Advocates suggest organic matter (OM) accumulation will "amend" the sand over time

i.e., do not need to amend the sand it will happen anyway.

94

Mat Layer versus Root Zone Physical Properties

95

96

Sand		20% Sphagnum	
Layer	OM	Layer	OM
	%		%
Mat	4.5	Mat	5.4
Root Zone	0.3	Root Zone	0.7

97

Sand		20% Sphagnum	
Layer	K_{sat}	Layer	K_{sat}
	in/hr		in/hr
Mat	8	Mat	11
Root Zone	26	Root Zone	23

98

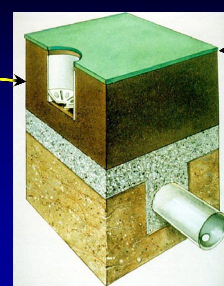
Profile	Total Porosity	Air-filled Porosity	Capillary Porosity
	--------------- % (by volume) ---------------		
Mat Layer	51	11	40
Rootzone	40	20	20

2" deep mat layer stores 0.8" of water

2" deep root zone stores 0.4" of water

99

USGA Sand-based Rootzone



100

Research Need (2004)

- Comprehensive evaluation of sand quantity, particle size, sampling protocol and cultivation methods

101

OM accumulates as sand greens age

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Organic Matter Management Study

Objectives

1. Determine if conventional hollow tine is more effective than solid tine aerification at managing organic matter accumulation
2. Determine if venting methods are effective at managing OM accumulation

106

Treatments

Tine Treatment	Venting Treatment
None	None
2X Hollow tine	PlanetAir
2x Solid tine	Hydroject
	Bayonet tine
	Needle tine

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Treatments

Tine Treatment	Venting Treatment
None	None
2X Hollow tine	PlanetAir
2x Solid tine	Hydroject
	Bayonet tine
	Needle tine

15 Trts per Rep
6 Reps per year
2 different years
= A whole lot of fun for one graduate student or 180 trts

108

All treatments received the same topdressing quantity (22 ft^3/M*) but different frequency

Equilibrated to identify differences of the practices in question

*1 ft³ = 100 lbs of dry sand; yd³ = 2700 lbs

109

Materials and Methods

- **Green Age:**
  - **12 years**
  - **9 years**
- **Data collected:**
  - **OM% (pre-cultivation/monthly)**
  - **Single wall infiltration (monthly)**

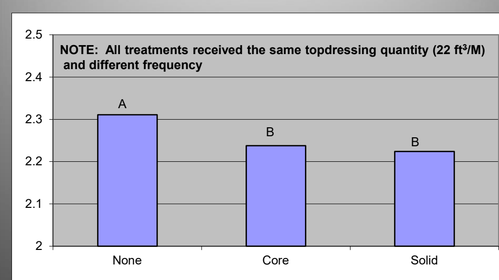
110

OM Data Analysis Year 1

- **No differences between green age except for higher % in older green**
- **No differences among venting methods**
- **No interactions with solid/hollow/none**

111

Effect of Tines on OM after 1 yr



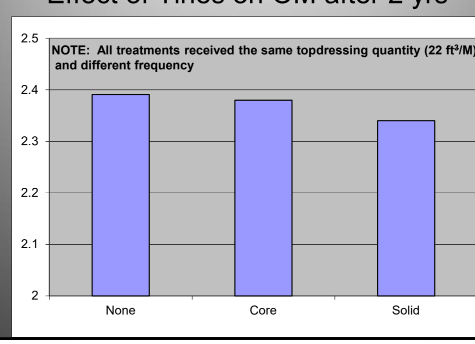
112

OM Data Analysis Year 2

- **No differences between green age except for higher % in older green**
- **No differences among venting methods**
- **No interactions with solid/hollow/none**
- **No differences among solid/hollow/none**

113

Effect of Tines on OM after 2 yrs



114

115

What these data do/don't suggest

- Cultivation, when topdressing quantity was equal, was insignificant as a means to control OM
- However, a superintendent must use whatever tools they have at their disposal to ensure sand is making it into the profile and not the mower buckets

116

Topdressing interval relative to Tine/Venting combinations (22 cu ft/M)*

- NONE/NONE
  - 5-10 days
- Solid & Hollow/NONE
  - 7-14 days
- Solid & Hollow/Venting
  - 14-18 days

*Observed and calculated based on displacement and surface area opened

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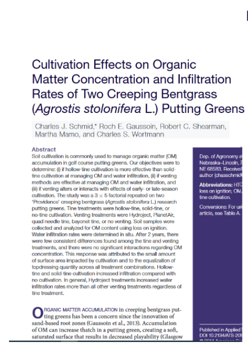

RESEARCH

Cultivation Effects on Organic Matter Concentration and Infiltration Rates of Two Creeping Bentgrass (*Agrostis stolonifera* L.) Putting Greens

Charles J. Schmid,* Roch E. Gaussoin, Robert C. Shearman, Martha Mamo, and Charles S. Wortmann

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Project Objective

- National Survey
  - Determine cause and effect relationship among maintenance practices and their interactions relative to surface OM accumulation

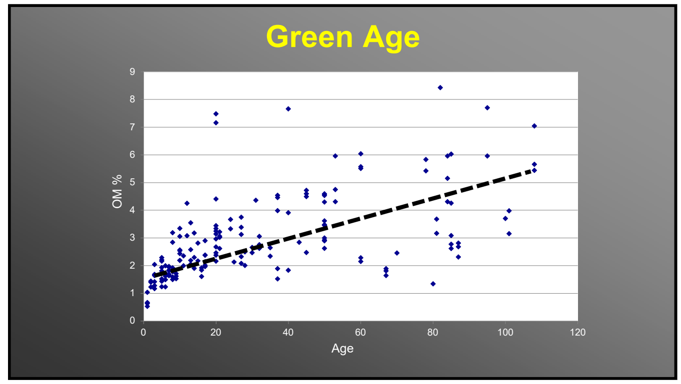
119

2006/07/08 Samples

- Sixteen states
  - Nebraska, South Dakota, Iowa, Wyoming, Colorado, Washington, Wisconsin, Illinois, New Jersey, Minnesota, New Mexico, Montana, Hawaii, California, Connecticut, Arkansas.
- 117 golf courses sampled
  - More than 1600 samples

120

121



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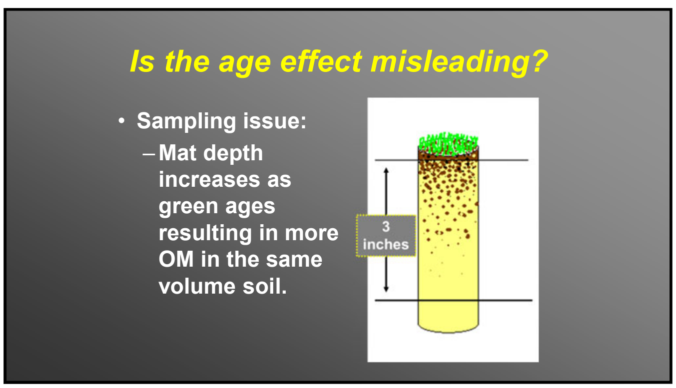

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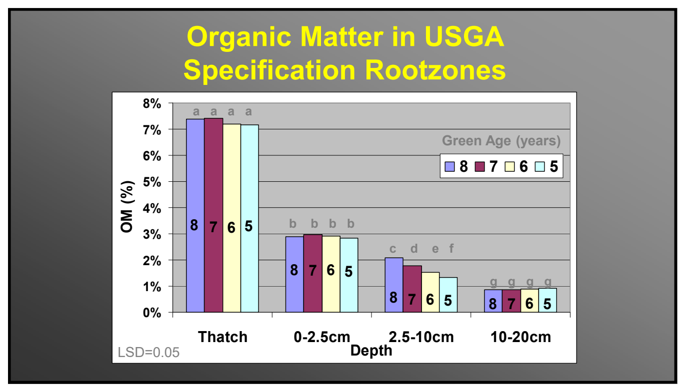

124

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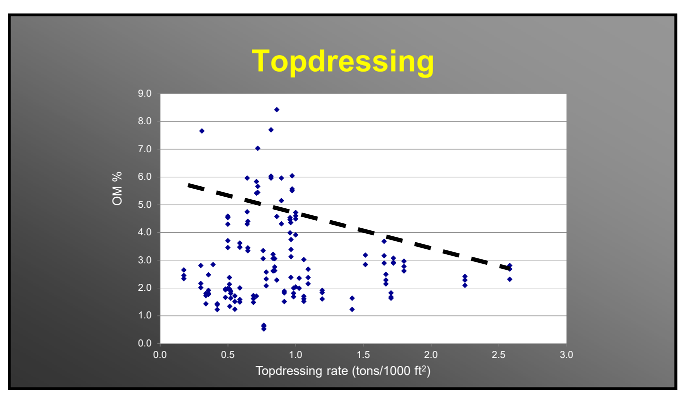

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Survey Summary

- None of the variables collected, by themselves, or in combination with others, *predicted* OM
- Courses using >18 cubic ft*/M of topdressing with or without "venting" had lower OM
- Of the *known* cultivars, no differences in OM were evident

***1 ft^3 = 100 lbs of dry sand; yd^3 = 2700 lbs**

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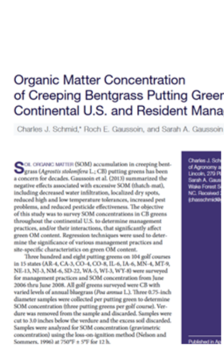


Organic Matter Concentration of Creeping Bentgrass Putting Greens in the Continental U.S. and Resident Management Impact

Charles J. Schmid,* Roch E. Gaussoin, and Sarah A. Gaussoin

128

Topdressing

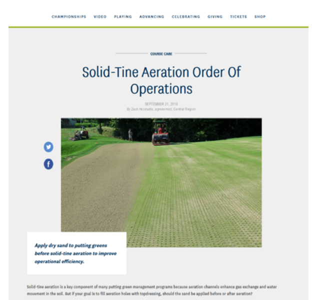
Old Tom Morris (1821–1908) is thought to have discovered the benefits of topdressing accidentally when he spilled a wheelbarrow of sand on a putting green and noted how the turf thrived shortly afterward (Hurdzan, 2004).

J.B. Beard is his classic textbook "Turfgrass Science & Culture, 1973 writes:

"The most important management practice for OM management is topdressing"

129

https://www.usga.org/content/usga/home-page/course-care/regional-updates/central-region/2018/solid-tine-aeration-order-of-operations.html



130

"Advocates of solid-tine aeration report that they get the same benefits of thatch and organic matter reduction with less labor for the collection and removal of aeration cores. Whether you pull a core or use solid tines, it's all about sand volume and the ability to dilute organic matter in the rootzone. Regardless of the method, the most important factor is filling the hole with sand. It's all about dilution, and if you can do that with less of a mess and less labor, then solid-tine aeration is a viable alternative."

From: https://www.usga.org/content/usga/home-page/course-care/regional-updates/central-region/2018/solid-tine-aeration-order-of-operations.html

131

132

AER-AIDER

133

Please mark all that apply. In the last 5-10 years, on our greens, our facility has:

- Increased topdressing quantity
- Increased topdressing frequency
- Increased hollow tine (equal or greater than 0.5") aeration
- Increased solid tine (equal or greater than 0.5") aeration
- Decreased hollow (equal or greater than 0.5") tine aeration
- Decreased solid tine (equal or greater than 0.5") aeration
- Made minimal changes in topdressing application quantity/frequency.
- Made minimal changes in cultivation practices.
- Increased "venting" practices.

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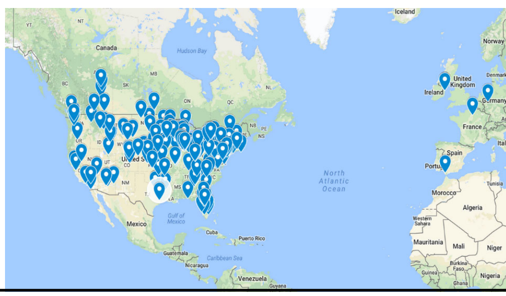
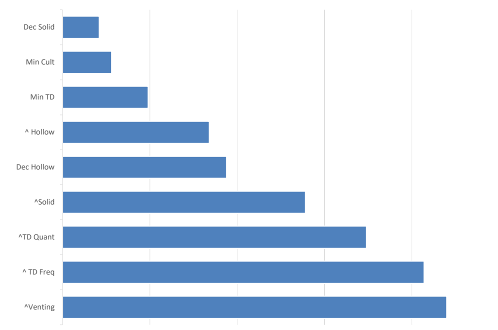
2016 Survey Respondents via Greenkeeper

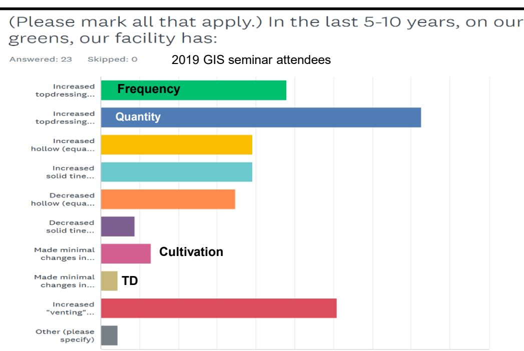


135

303 Responses



136



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USGA

Golf Course Superintendents Association New Jersey 1926

New Jersey Turfgrass Association

Rutgers New Jersey Agricultural Experiment Station

Center for Turfgrass Science

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Sand Particle Size (1-mm and 0.5-mm sands)

Particle Name	Diameter (mm)
Fine Gravel	2 – 3.4
Very Coarse Sand	1 – 2
Coarse Sand	0.5 – 1
Medium Sand	0.25 – 0.5
Fine Sand	0.15 – 0.25
Very Fine Sand	0.05 – 0.15
Silt	0.002 – 0.05
Clay	< 0.002


Photo: TJ Lawson

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Research on…

- Topdressing
  - ✓ Sand Size
  - ✓ Rate
- Cultivation

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Research Objectives:

1. Effects of topdressing with sand lacking coarse particles
2. Does core cultivation and backfilling holes with medium-coarse sand offset any negative effects of topdressing with sands lacking coarse particles?

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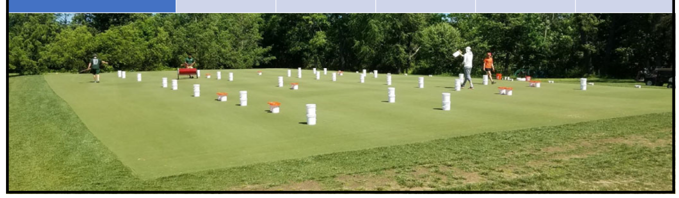
	2-1 mm	1-0.5 mm	0.5-0.25 mm	0.25-0.15 mm	0.15-0.05 mm
Sand Size	Very Coarse	Coarse	Medium	Fine	Very Fine
	----------------------- % (by weight) retained ----------------------				
Medium-coarse (1-mm)	0	30	60	10	< 1
Medium-fine (0.5-mm)	0	0	74	24	2
Fine-medium	0	4	27	48	21



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Treatment No.	Sand Size	Topdressing Rate during Growing Season	Cultivation (twice/year; May & Oct) Hollow Tine	Backfill / Topdress	Annual Quantity of Sand Applied
		Factors in the Experiment			
		lbs. / 1,000-sq.-ft.		lbs. / 1,000-sq.-ft.	lbs. / 1,000-sq.-ft.
1	Medium-coarse	50	None	400	1,300
2	Medium-coarse	50	Core + Backfill	600	1,700
3	Medium-coarse	100	None	400	1,800
4	Medium-coarse	100	Core + Backfill	600	2,200
5	Medium-fine	50	None	400	1,300
6	Medium-fine	50	Core + Backfill	600	1,700
7	Medium-fine	100	None	400	1,800
8	Medium-fine	100	Core + Backfill	600	2,200
9	Fine-medium	50	None	400	1,300
10	Fine-medium	50	Core + Backfill	600	1,700
11	Fine-medium	100	None	400	1,800
12	Fine-medium	100	Core + Backfill	600	2,200
13	None	0	None	0	0
14	None	0	Core + Backfill	600	1,200

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Cultivation Factor

- Cored twice per year (May and Oct)
- Holes backfilled with medium-coarse sand at 600 lbs/1,000 sq ft
- At coring, non-cored plots topdressed with respective sand size at 600 lbs/1,000 sq ft

144

Sand Picked-up with Mower Clippings


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Sand Picked-up with Mowing One Day after Topdressing

Sampling Date	7-Jul		17-Aug	
Mowing Height	0.110 inch		0.110 inch	
	Sand Picked-up	Portion of Sand Applied	Sand Picked-up	Portion of Sand Applied
	lbs/M	%	lbs/M	%
Sand Size				
Medium-coarse	4.0	5.1	5.4	7.0
Medium-fine	1.9	2.4	3.2	4.0
Fine-medium	1.9	2.5	1.8	2.3
LSD (5%)	0.4	0.5	0.5	0.6
Topdress Rate				
50 lbs/1000-ft^2	1.6	3.1	2.1	4.1
100 lbs/1000-ft^2	3.6	3.6	4.8	4.8
LSD (5%)	0.3	0.4	0.4	0.5

146

Double-ring Infiltration Test (August 2019)


- Measured 3 consecutive infiltration tests of 1-inch of water per double-ring
- One double-ring per plot

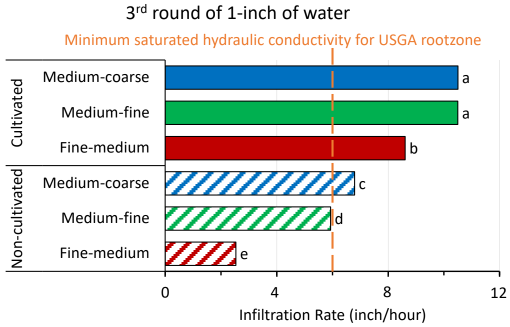
147

ANOVA of Water Infiltration Rate (August 2019)

	------- Infiltration Rate -------		
	1st round	2nd round	3rd round
Source of Variation			
Sand Size (SS)	***	***	***
Topdress Rate (TR)	ns	ns	ns
SS*TR	ns	ns	ns
Core Cultivation (CC)	***	***	***
SS*CC	ns	ns	*
TR*CC	ns	ns	ns
SS*TR*CC	ns	ns	ns

148

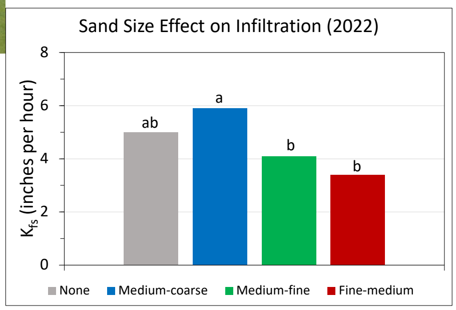
Sand Size x Core Cultivation Interaction
3rd round of 1-inch of water



149

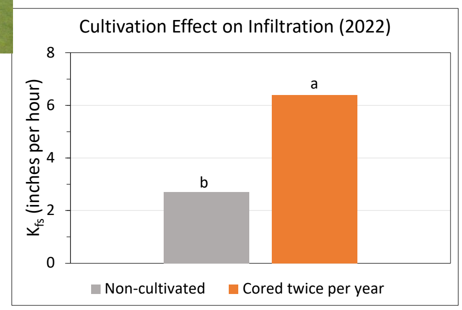
Field Saturated Hydraylic Conductivity, K_{fs} (2022)

150



Topdressing sands applied at 100-lb per 1,000 sq ft every 2 weeks during summer. Pooled over both levels of cultivation.

151



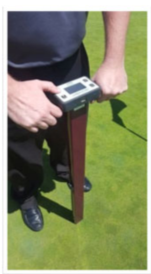
Pooled across all levels of topdressing sand size.

152

Water Content at 0- to 3-inch Depth Zone

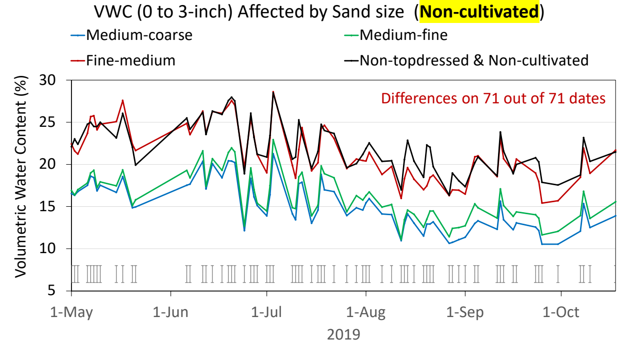
- Measured on 71 dates during 2019
- Sand Size x Core Cultivation Interaction

Source of Variation	Significant Dates ($P < 0.05$)
Sand Size (SS)	71
Topdress Rate (TR)	71
SS*TR	13
Core Cultivation (CC)	71
SS*CC	71
TR*CC	1
SS*TR*CC	0



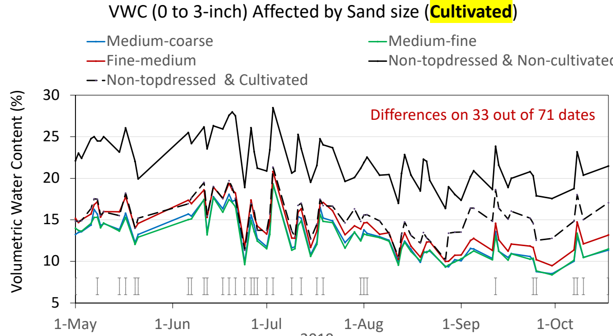
153

VWC (0 to 3-inch) Affected by Sand size (**Non-cultivated**)



154

VWC (0 to 3-inch) Affected by Sand size (**Cultivated**)



155

Surface Hardness

156

Surface hardness (Clegg) and VWC before cultivation in October 2022.

Interaction		Clegg, 0.5-kg	VWC, 0- to 3-inch
		G_{max}	%
Cultivation	Sand Size		
None	Medium-coarse	81.5 b	17.3 c
None	Medium-fine	80.8 bc	20.0 b
None	Fine-medium	77.8 c	26.5 a
Twice a Year	Medium-coarse	91.6 a	11.5 d
Twice a Year	Medium-fine	92.5 a	11.7 d
Twice a Year	Fine-medium	92.2 a	12.6 d

157

Surface hardness (Clegg) and VWC before cultivation in October 2022.

Interaction		Clegg, 0.5-kg	VWC, 0- to 3-inch
		G_{max}	%
Cultivation	Topdress Rate		
None	50-lb	78.8 c	23.0 a
None	100-lb	81.2 b	19.5 b
Twice a Year	50-lb	92.9 a	12.0 c
Twice a Year	100-lb	91.3 a	11.8 c

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Hand-watering Individual Plots (2022)

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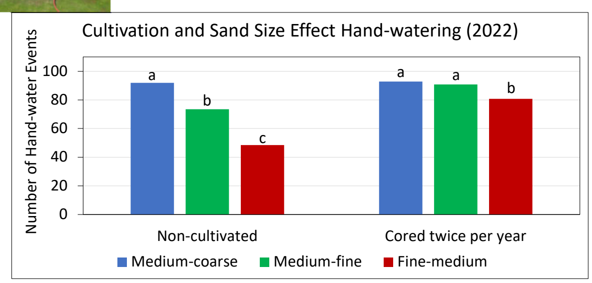

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Core Sampling of the Mat Layer






161

Mat Layer Depth and OM Concentration

	-----Depth (mm) -----		-------- OM (%) --------	
	2017	2018	2017	2018
Orthogonal Contrasts				
Non-Cultivated:				
Pooled Topdressed vs.	17.2 a	20.4 a	6.7 b	5.9 b
Non-topdressed Control	15.9 b	16.2 b	8.5 a	8.6 a
Core Cultivated:				
Pooled Topdressed vs.	16.9 a	19.3 a	5.7 b	4.6 b
Non-topdressed Control	15.0 b	15.9 b	6.8 a	6.1 a
Source of Variation				
Topdressing Rate	***	***	***	***
Core Cultivation	ns	*	***	***
Main Effect				
Topdressing Rate				
0.244 kg/m^2	16.5 b	18.8 b	6.5 a	5.6 a
0.488 kg/m^2	17.7 a	20.9 a	6.0 b	5.0 b
Core Cultivation				
None	17.2	20.4 a	6.7 a	5.9 a
Twice a Year	16.9	19.3 b	5.7 b	4.6 b

Mat layer depth was 6.3-mm and OM concentration was 6.7% at the initiation of treatments in 2016

162

Mat Layer Total OM Content

	-----OM (g/m²) ----- 2017	2018
Orthogonal Contrasts		
Non-Cultivated:		
Pooled Topdressed vs.	9.9 a	12.1 a
Non-topdressed Control	8.6 b	9.2 b
Core Cultivated:		
Pooled Topdressed vs.	8.6 a	9.6 a
Non-topdressed Control	7.9 b	8.3 b
Source of Variation		
Topdressing Rate	**	*
Core Cultivation	***	*
Main Effect		
Topdressing Rate		
0.244 kg/m²	9.0 b	10.5 b
0.488 kg/m²	9.4 a	11.2 a
Core Cultivation		
None	9.9 a	12.1 a
Twice a Year	8.6 b	9.6 b

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Mat-layer Physical Properties

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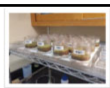
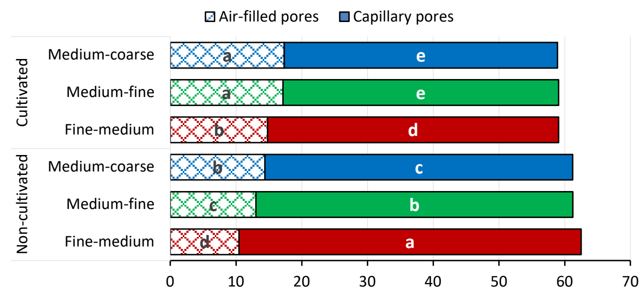
ANOVA of Mat-layer Physical Properties



	---Pore Size Distribution---- Total	Air-filled	Capillary	------Sand Particle Size Fraction------ Very Coarse	Coarse + Medium	Fine	Very Fine
Source of Variation							
Sand Size (SS)	*	***	***	ns	***	***	***
Topdress Rate (TR)	***	ns	***	**	ns	ns	ns
SS*TR	ns	ns	ns	ns	ns	ns	ns
Core Cultivation (CC)	***	***	***	**	***	***	***
SS*CC	ns	*	*	*	***	***	***
TR*CC	*	ns	ns	ns	ns	ns	ns
SS*TR*CC	ns	ns	ns	ns	ns	ns	ns

165

Pore Size Distribution as Affected by Sand Size x Core Cultivation Interaction



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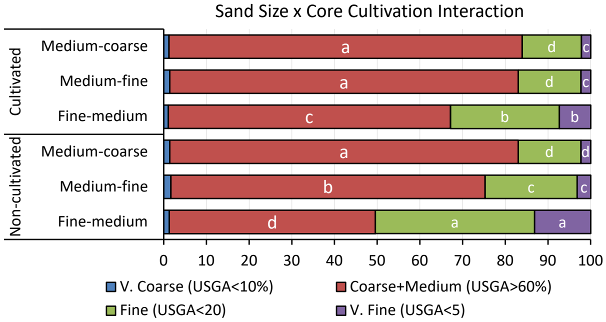
Sand Particle Size Fraction as Affected by Sand Size x Core Cultivation Interaction



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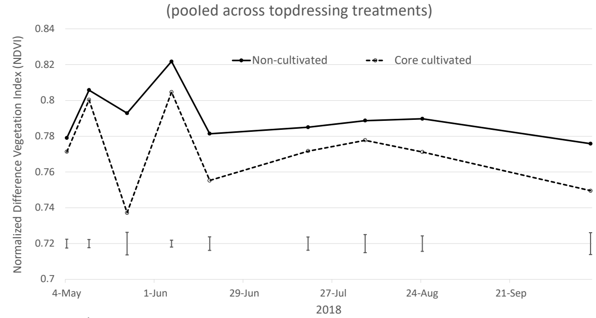
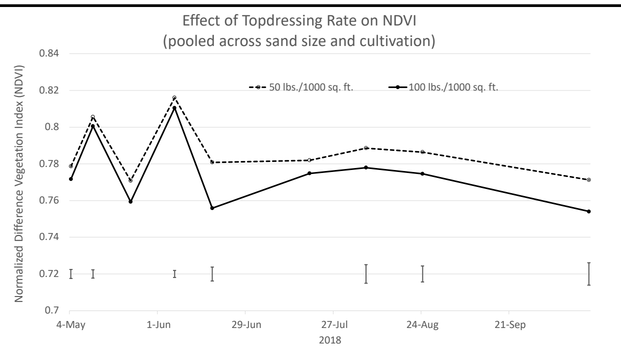
Effect of Coring on NDVI
(pooled across topdressing treatments)



168



Cored: May 17

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Conclusions

Strong impact of core cultivation plus backfilling with medium-coarse sand:
- reduced capillary porosity and OM
- increased air-filled porosity
- consistently drier playing surface

Sand size effects depended on the core cultivation factor (interaction)

Medium-coarse and medium-fine sands
- similar at reducing surface wetness and OM
- finer sand distribution in mat layer under topdressing with medium-fine sand but core cultivation corrected (matched medium-coarse sand topdressing)

Fine-medium sand
- Much greater surface wetness and reduced infiltration due to substantial increase in fine particle size and capillary porosity under non-cultivated conditions
- Core cultivation and backfilling with medium-coarse sand reduced these effects on surface and infiltration; however, the quantity of fine and very fine particles in the mat layer remained above 30% by weight

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Managing for Drier Mat Layer

Topdressing
- As much and as often as feasible (~1 ton / 1,000 sq ft / yr)
  - ***18-22 ft^3/M/YR****
- Select as coarse a sand as feasible
  - 0.5-mm sand okay if dominated by medium sand, not fine and very fine
- Cost and interference with play and mowing are the limiting factors

Core Cultivation
- Very effective at producing a drier surface
- Time for healing is greatest limitation
  - ***Solid Tine Cultivation?****

Gaussoin adds

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Layering

- Water retention is non-uniform
- Thatch/mat layers can store twice as much water than the root zone

NOT a function of drainage

Rather it is the difference in pore size distribution among layers

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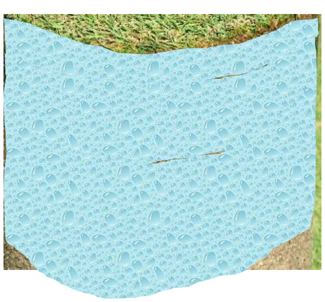

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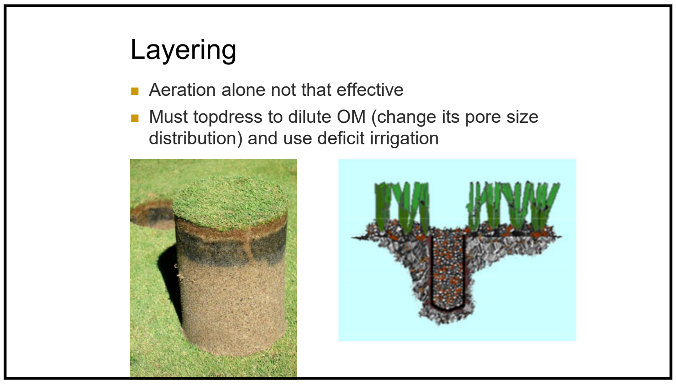
174



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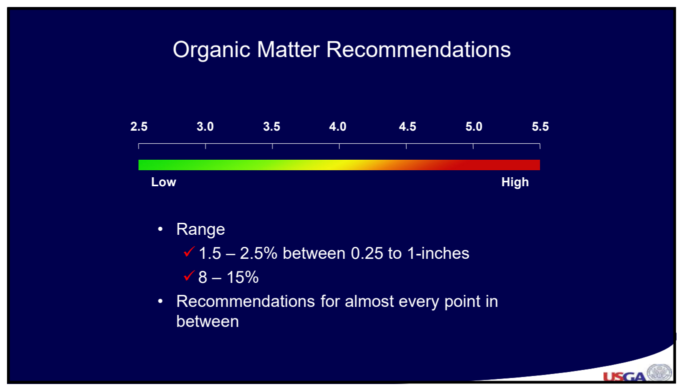

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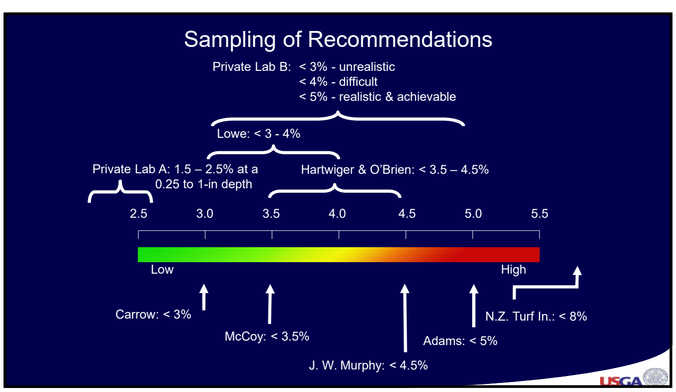

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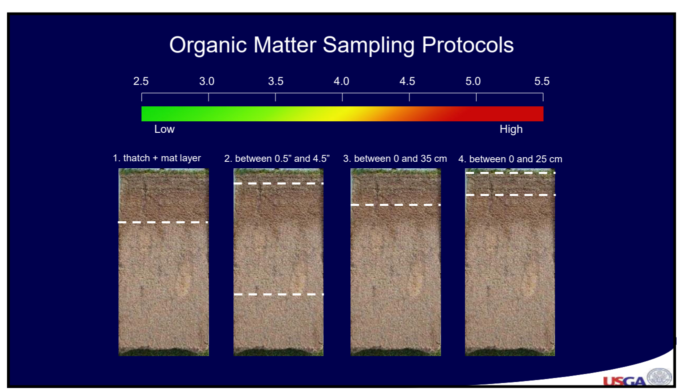

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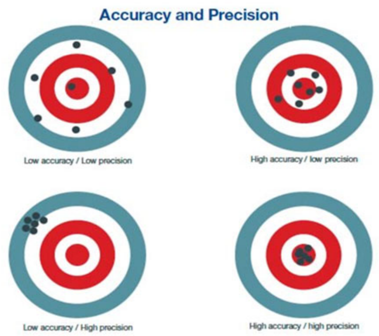

Need to have a root zone specific *sampling* and analysis protocol for OM in sand based rootzones

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What is the most common analytic test?

Loss on Ignition (LOI)

- 100-1200°C (370-420 °C norm)
- Sample is weighed, placed in oven, then weighed again
- OM% determined % by weight (or mg/g)
- Ovens are $1200-$2500

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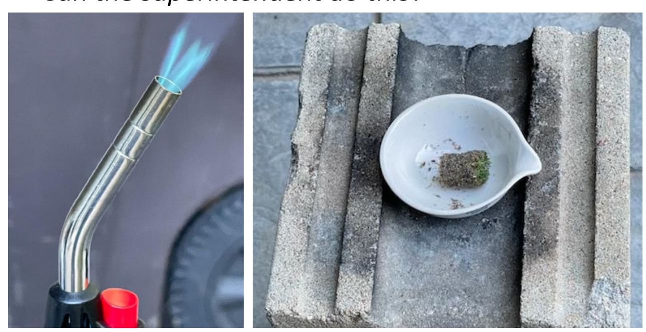
Can the superintendent do this?



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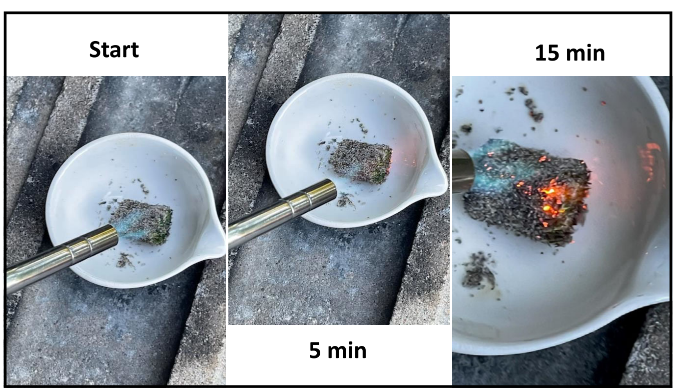

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Developing a simple, practical method for organic matter content determination by superintendents

Leifeld and Kogel-Knabner (2001)

Funded by

Mike Davis Program for Advancing Golf Course Management

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Don' try this at home…….

- Methods using hydrogen peroxide adapted from Leifeld and Kogel-Knabner (2001) were time-consuming and step intensive for practical use.
- *Attempts to find a correction factor were also not discovered.*
- Regression models based on data of the best attempt showed a high level of variation measuring OM percentages of pre-determined lab mixed samples.
- *A rapid, practical, inexpensive, and reliable method to test OM content on golf using equipment available on a typical golf course is not feasible.*
- Like the torch fiasco, you still need an analytic balance and other lab equipment

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Taking a representative sample

- Sample depth(s)
- Number of samples
- Sample location
- Sample size
- Time of year
- Verdure on or off?

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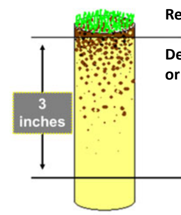
Historic Sampling Depth (as approved by the SSSA)

- Sampling issue:
  - Mat depth increases as green ages resulting in more OM in the same volume soil.



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Develop an accurate and efficient method for characterizing OM in sand root zones

Questions that need to be answered:

1. How does sample preparation affect mean SOM?
2. How does core diameter affect mean SOM?
3. How many samples are required to adequately characterize the mean SOM on a single putting green?
4. How far apart should samples be taken?

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How does sample preparation affect mean SOM?

- Some researches leave verdure on, some remove, how does this impact mean SOM?
- Most labs grind and sieve samples, how does this impact the mean SOM when verdure is left on?
- Does increased core diameter size affect the mean SOM?

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Site Characteristics

Samples were taken at the OJ Noer Turf Research Facility and University Ridge Golf Course in Verona, WI

50 samples were taken from five different root zones on a 10'X10' grid
- 3 from research plots
- 2 from putting greens

	Mean OM %
Putting Green 1	5.82
Putting Green 2	5.39
Research Green 2	5.23
Research Green 3	5.07
Research Green 1	4.74

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Sample Preparation

- Core diameter evaluation
  - 0.75 inch or 1.5 inch
- Verdure evaluation
  - removed above the thatch layer to remove all green material
  - left on
- Grinding/sieving evaluation
  - analyzed intact
  - ground with mortar and pestle and sieved with no. 10 sieve
- All samples were dried for 24 hr. at 105 C before weighing and burned and 360 C for 2 hours

Diameter (cm)	Verdure	Sieve
3.8	Yes	No
1.9	Yes	No
1.9	Yes	Yes
1.9	No	Yes
1.9	No	No

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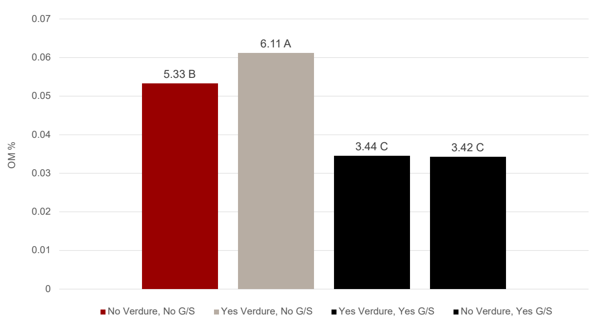
Questions 1: How does sample preparation affect mean SOM?



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Sample size

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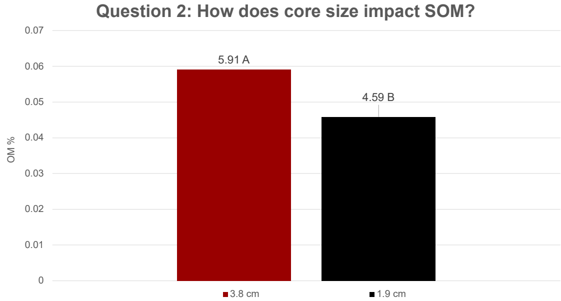
Question 2: How does core size impact SOM?



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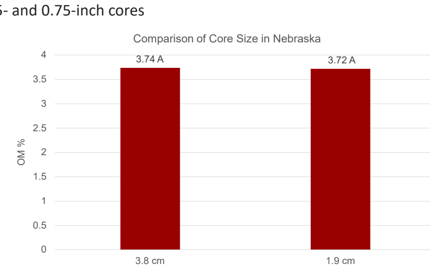
Core diameter difference not found in Nebraska

- Additional samples were taken on a Nebraska golf course on a 3*3m grid with both 1.5- and 0.75-inch cores



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Question 3: How many samples do we need to take?

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of samples and location

- 3 golf courses at different geographic locations
- 5 holes at each course
- Samples from N to and E to W on 10 ft centers

EXTENSION

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Loc	N	E
1	1	B
2	1	C
3	1	D
4	1	E
5	2	A
6	2	B
7	2	C

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With standard 0.75 inch probes most greens need only 5 samples to characterize the mean OM

Wisconsin		
Green	# Samples	Average OM
Chip	5	4.59
12	5	7.21
8	5	7.23
4	5	7.06
1	5	6.69

Pennsylvania		
Green	# Samples	Average OM
6	7	17.14
2	5	10.83
3	8	15.66
4	5	11.72
7	5	13.2

Nebraska		
Green	# Samples	Average OM
9	5	4.01
8	5	4.09
7	5	3.95
6	5	3.60
5	5	3.09

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With the 1.5 inch probe need between 4-5 samples to achieve the same precision

Nebraska Standard		
Green	# Samples	Average OM
9	5	4.01
8	5	4.09
7	5	3.95
6	5	3.60
5	5	3.09

Nebraska Large		
Green	# Samples	Average OM
9	4	3.96
8	5	4.09
7	5	3.90
6	4	3.62
5	4	3.20

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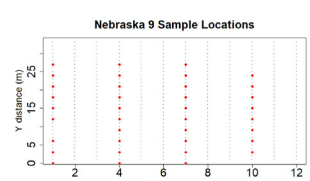
Question 4: How far apart should samples be taken?

- What we did
  - Same sampling technique, 3*3m grids, 0.75 inch probe on 5 greens at 3 courses
  - Analyzed the data using spatial variograms to determine sampling distance



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Initial findings for how to take samples

- Choose 5-10 random locations 25 -30 ft apart
- Use 0.75-inch diameter probe to a depth of 1 inch (larger cores acceptable but not necessary)
- Leave verdure on without grinding and sieving

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What these data do/don't suggest

- Cultivation, when topdressing quantity was equal, was insignificant in affecting OM
- Superintendents, however, must use ***whatever tools*** they have at their disposal to ensure sand is making it into the profile and not the mower buckets

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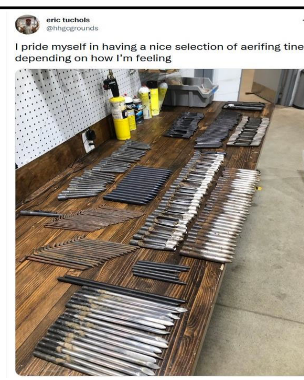

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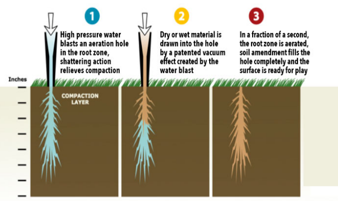
DryJect



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Dryject Trial Fall 2021

- Check
- Hollow ½" ID
- Solid ½"OD
- DryJect 1 (3x3)
- Needle
- DryJect 2 (3x2)
- Needle + Solid
- Needle + Hollow

Procore - 3" target depth on all tines except Dryject = 5"

Sampled day after treatment in 1' depth increments to 4 "

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Treatment	% OM	
Check	4.5	a
Hollow	3.7	b
Needle	3.1	c
DryJect (3x3)	2.7	d
Needle + Hollow	2.3	d
DryJect (3x2)	2.3	d
Needle + Solid	2.3	d
Solid	2.2	d

- No differences among depths
- Dilution only
- Dryject and needle tine were least surface disruptive
- Hollow tine response was unexpected
- ***Data is preliminary***

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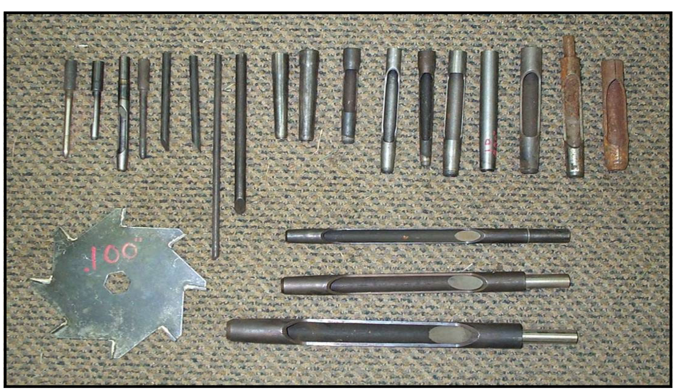

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Spring 2023 Tine Trial

- ~~8~~ 15 tine types/configurations
- 2 devices (ProCore and DryJect)
- Timing (spring/fall)
- OM by depth
- Surface firmness and ball roll using the USGA GS3 digital golf ball

Equipment and Tine Support Provided by

TORO DryJect WET CTI Ceres Turf, Inc.

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What have we learned?

- A high-quality sand and a well-built root zone are relatively stable and will perform properly for many years.
- What changes over time is the surface…

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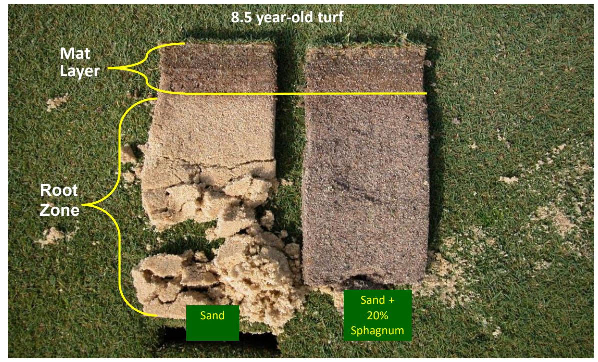

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It matters how you manage the accumulating thatch/mat layer

- Cultivation has a significant impact. At minimum, use practices that help incorporate sand.
- Topdressing is critical. Can use a fine sand (0.25-5 mm) to ensure enough sand will be applied during summer, in combo with a medium (< 1 mm) with more aggressive aerification (core, solid or injection). Avoid sands of < 0.15.

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Key is matching your growth rate to optimize topdressing + ...

How much sand to use for topdressing?

- Generic recommendation is 20-40 ft^3 per 1000 sq. feet/yr (about 0.5 inch/M/yr)
  - ***UNL worked showed 20-24 ft^3 for OM management***
- Varies by amount of:
  - Traffic
  - Grass species or cultivar
  - Nitrogen Applied
  - Water Applied
  - Microclimate/Location

225

#clipvol *"One bucket at a time"*

- Micah Woods, Asian Turfgrass Center
  - Asianturfgrass.com

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"Growth Potential"

- Pace Turf
  - https://www.paceturf.org/public/sand-and-growth-potential

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Acknowledgement (Rutgers)

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- Nebraska Turfgrass Association

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Chapter 12 ASA Monograph (3RD Edition)

Characterization, Development, and Management of Organic Matter in Turfgrass Systems

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Thank you!

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