Topdressing 101: Organic Matter Management for Cool-Season Putting Greens

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Outline

- Historical perspective
  - Greens Construction
  - New Management Paradigm
    - Firm and Fast
    - Organic Matter Accumulation
- Fine tuning
  - Topdressing
  - Cultivation

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THE FIFTH GREEN AT THE ESSEX COUNTY COUNTRY CLUB

1930 Advertisement

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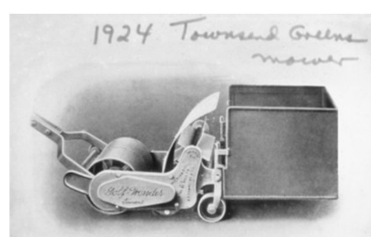
Closer cut mowers



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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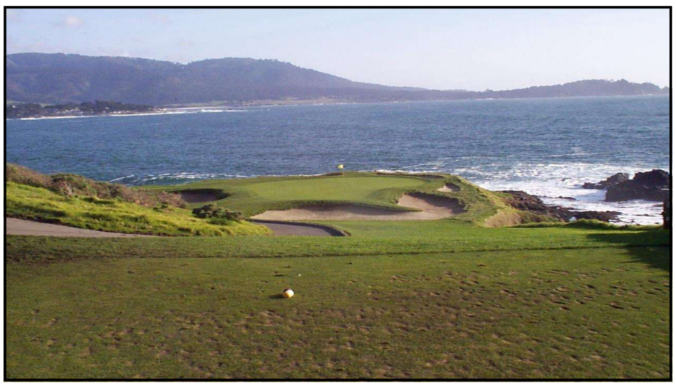

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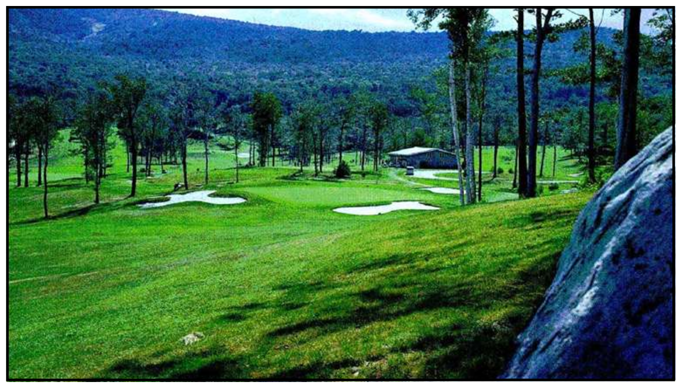

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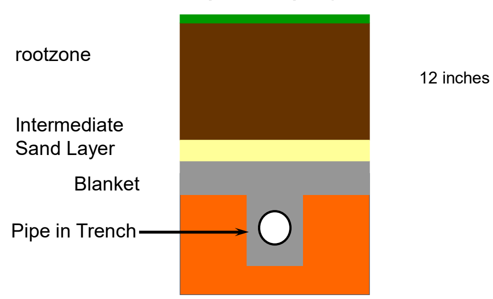
Three Tier (USGA) System



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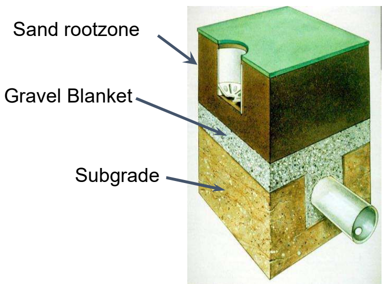
Two Tier System (USGA)



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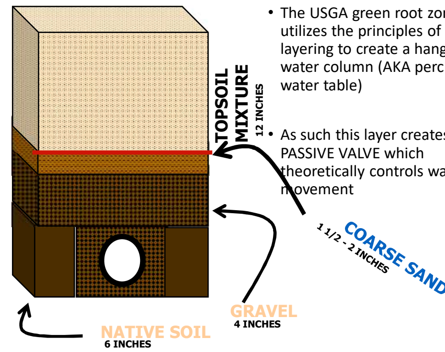

- The USGA green root zone utilizes the principles of soil layering to create a hanging water column (AKA perched water table)
- As such this layer creates a PASSIVE VALVE which theoretically controls water movement

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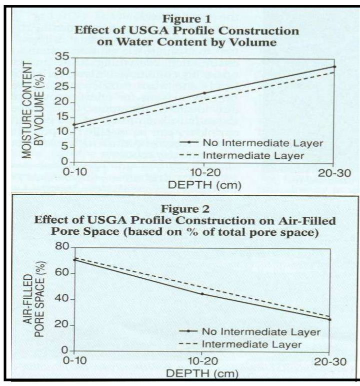

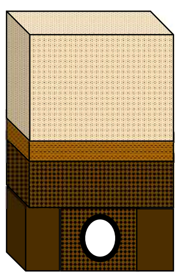

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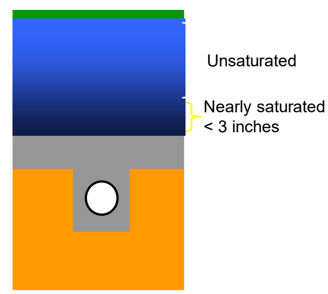
Displacement of Saturated Zone



Sand-based System at Field Capacity

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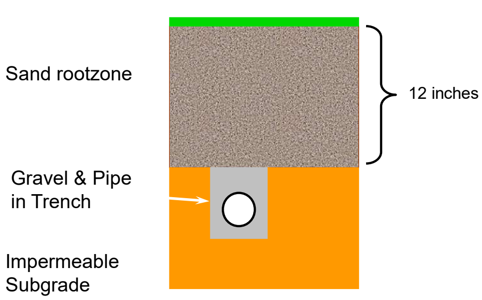
One Tier System (California)



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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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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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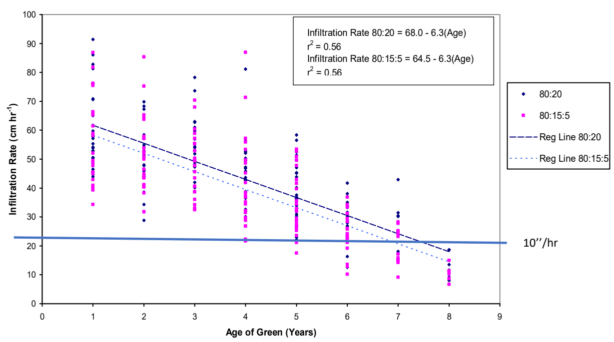

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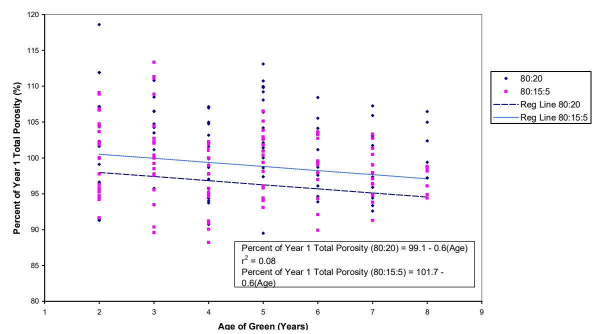

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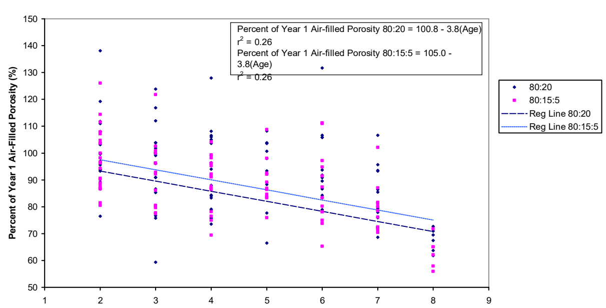

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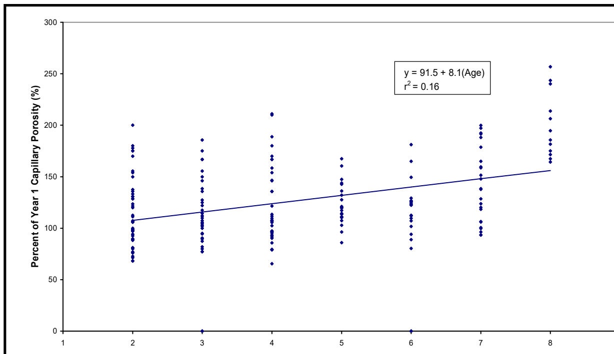

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Microbial Properties

(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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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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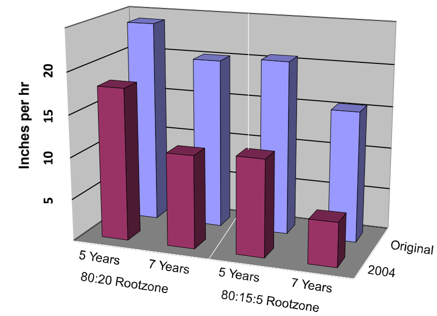

Comparison of preconstruction K_{sat} values to K_{sat} values taken 10/04.

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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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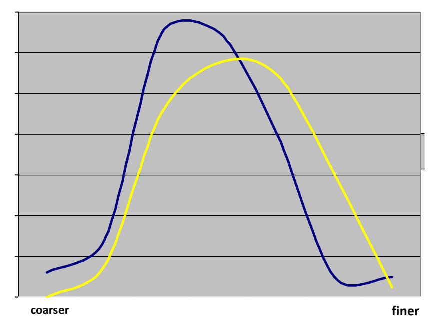

USGA sand size compared to sand used in topdressing program for USGA plots at Mead, NE.

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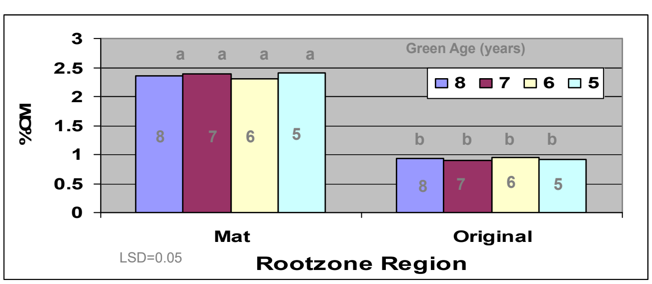
Rootzone vs Mat: Organic Matter



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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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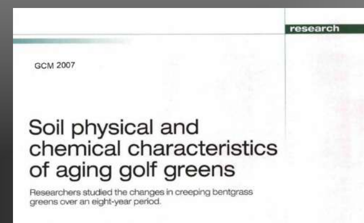
Want to know more?

- 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

Researchers studied the changes in creeping bentgrass greens over an eight-year period.

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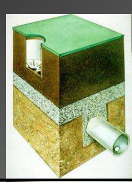
10+ Years of Research on Putting Green Root Zones at Rutgers University



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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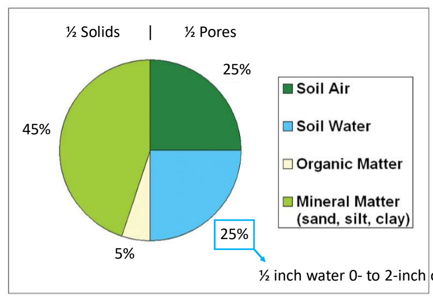
Idealized Proportions of Solids and Pores in Soil



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

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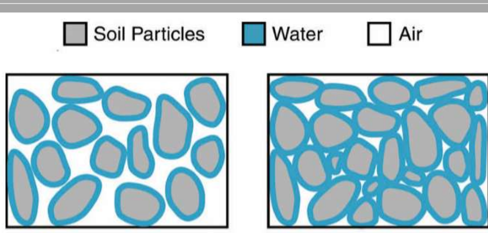

Non-compacted

Compacted
or more smaller
particles (sand/silt/clay)

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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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Acknowledgements

USGA
Golf Course Superintendents Association New Jersey 1926
GCSAA
Rutgers University Center for Turfgrass Science, New Jersey Agricultural Experiment Station
Tri State Turf Research Foundation
New Jersey Turfgrass Association

U.S. Silica (formerly Unimin, formerly Morie Sand)
Dawson Corporation
Koonz Sprinkler
AT Sales
New Jersey State Golf Association

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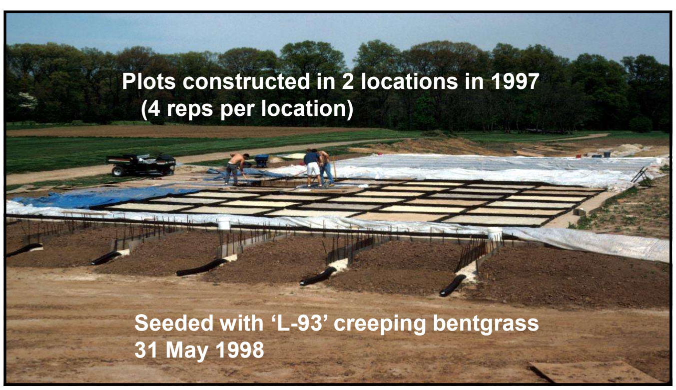

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Open Location

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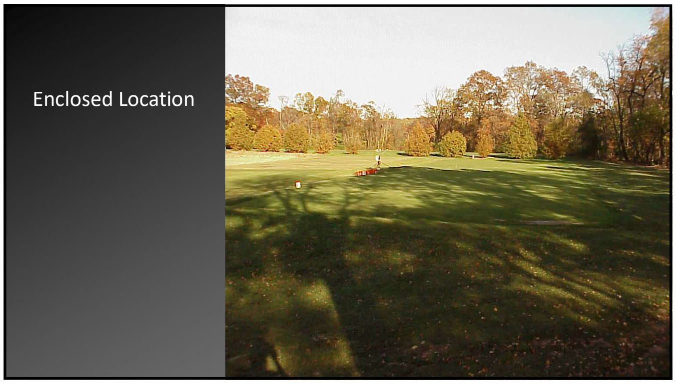

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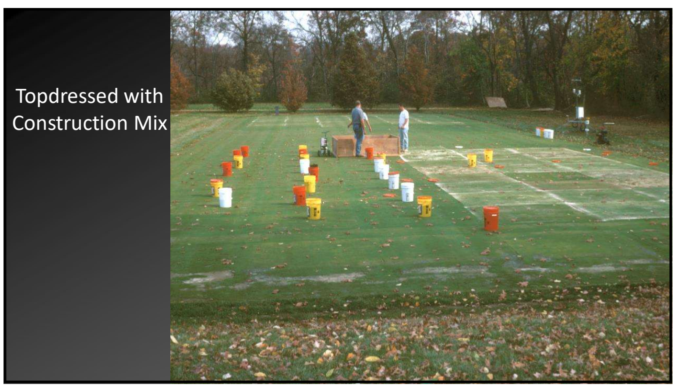

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Sand size distributions of five root zones.

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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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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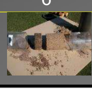
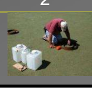
K_{sat} and Field Water Infiltration in 2004

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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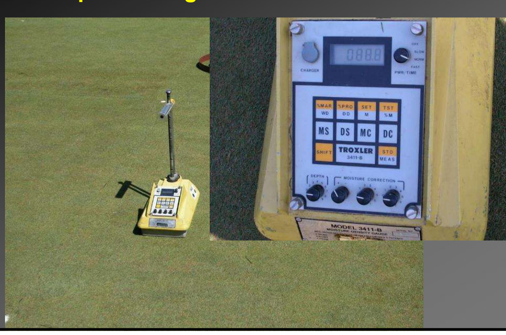
Plot Specific Irrigation



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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	Turf Quality 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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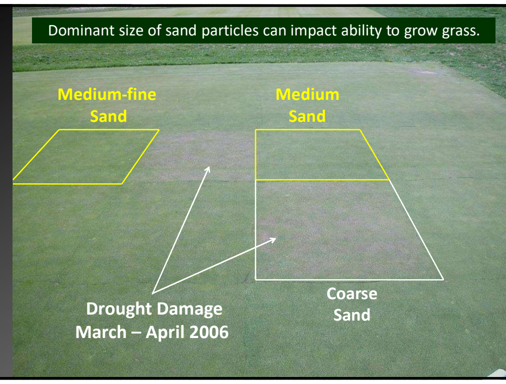

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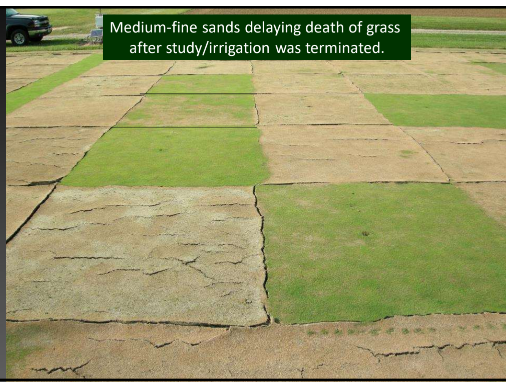

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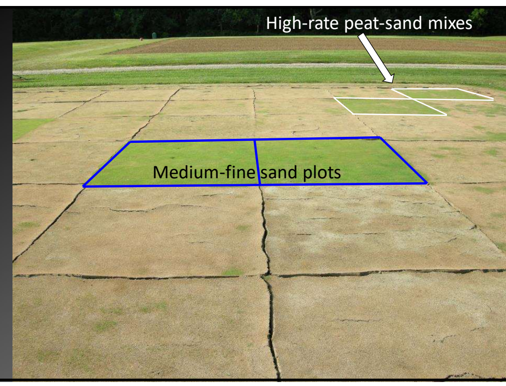

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Algae forms when plots are not allowed to dry sufficiently between irrigations (i.e., plot specific irrigation discontinued)

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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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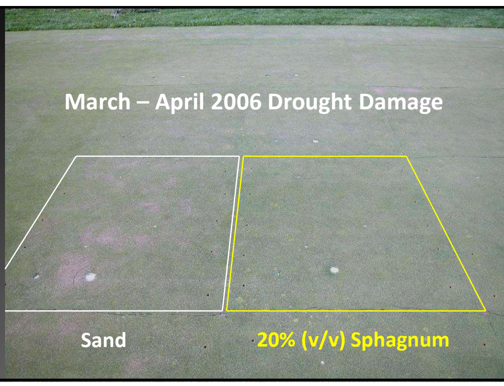

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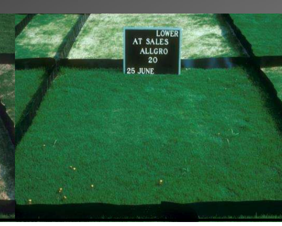
Compost

- 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/ US Composting Council



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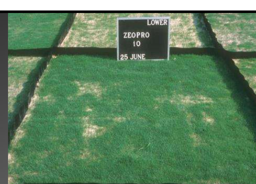
Inorganic amendments

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



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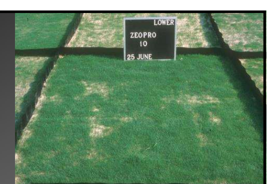
Inorganic Amendments

- 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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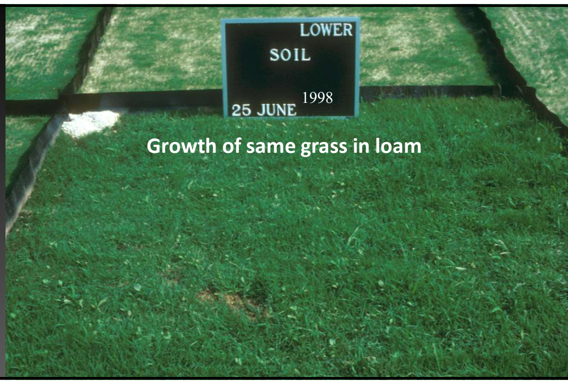

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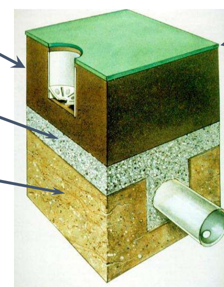
USGA Sand-based Rootzone



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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

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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.

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Mat Layer versus Root Zone Physical Properties

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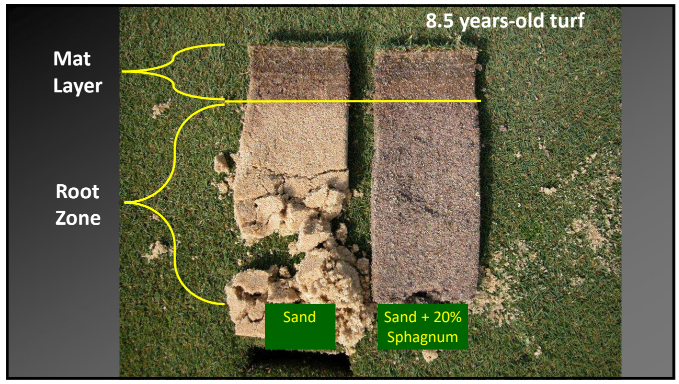

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Sand

Layer	OM
	%
Mat	4.5
Root Zone	0.3

20% Sphagnum

Layer	OM
	%
Mat	5.4
Root Zone	0.7

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Sand

Layer	K_{sat}
	in/hr
Mat	8
Root Zone	26

20% Sphagnum

Layer	K_{sat}
	in/hr
Mat	11
Root Zone	23

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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

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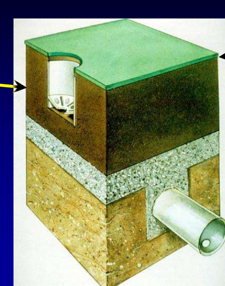
USGA Sand-based Rootzone



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Research Need (2004)

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

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OM accumulates as sand greens age

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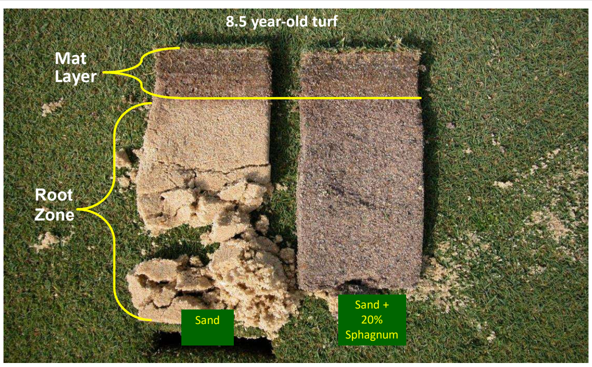


94

Practices to change thatch into mat include topdressing and …

95

96

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

97

Treatments

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

98

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

99

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

Equilibrated to identify differences of the practices in question

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

100

Materials and Methods

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

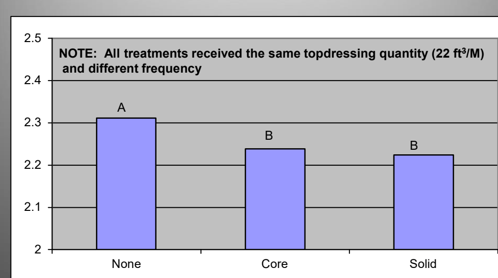
101

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

102

Effect of Tines on OM after 1 yr



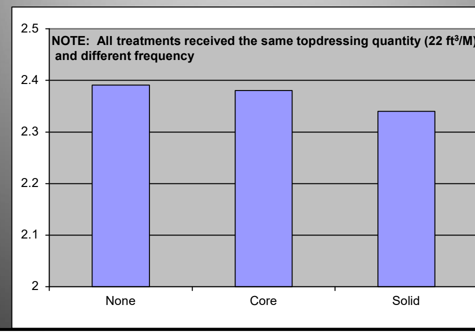
103

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

104

Effect of Tines on OM after 2 yrs



105

106

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

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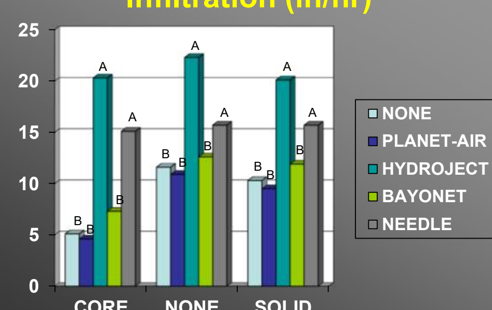
*Topdressing interval relative to Tine/Venting combinations (22 cu ft/M)**

- 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

108

Infiltration (in/hr)



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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

Abstract
Soil cultivation is commonly used to manage organic matter (OM) accumulation in golf course putting greens. Our objectives were to determine: (i) if hollow-tine cultivation is more effective than solid-tine cultivation at managing OM and water infiltration, (ii) if venting methods are effective at managing OM and water infiltration, and (iii) if venting alters or interacts with effects of early- or late-season cultivation. The study was a 3 × 5 factorial repeated on two 'Providence' creeping bentgrass (*Agrostis stolonifera* L.) research putting greens. Tine treatments were hollow-tine, solid-tine, or no-tine cultivation. Venting treatments were Hydroject, PlanetAir, quad needle tine, bayonet tine, or no venting. Soil samples were collected and analyzed for OM content using loss on ignition. Water infiltration rates were determined in situ. After 2 years, there were few consistent differences found among the tine and venting treatments, and there were no significant interactions regarding OM concentration. This response was attributed to the small amount of surface area impacted by cultivation and to the equalization of topdressing quantity across all treatment combinations. Hollow-tine and solid-tine cultivation increased infiltration compared with no cultivation. In general, Hydroject treatments increased water infiltration rates more than all other venting treatments regardless of tine treatment.

Dep. of Agronomy and Horticulture, Univ. of Nebraska–Lincoln, 279 Plant Science Hall, Lincoln, NE 68583. Received 27 Mar. 2014. *Corresponding author (chasschmid@gmail.com).

Abbreviations: HTC, hollow-tine cultivation; LOI, loss on ignition; OM, organic matter; STC, solid-tine cultivation.

Conversions: For unit conversions relevant to this article, see Table A.

ORGANIC MATTER ACCUMULATION in creeping bentgrass putting greens has been a concern since the innovation of sand-based root zones (Gaussoin et al., 2013). Accumulation of OM can increase thatch in a putting green, creating a soft, saturated surface that results in decreased playability (Glasgow

Published in Applied Turfgrass Science
DOI 10.2134/ATS-2014-0032-RS

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Project Objective

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

111

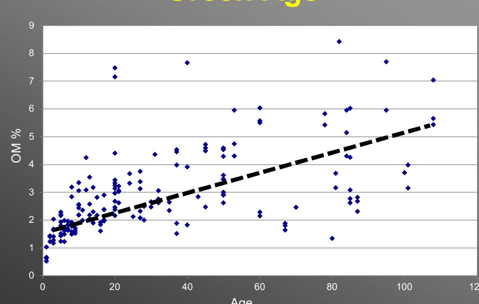
2006/07/08 Samples

- 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

112

113

Green Age

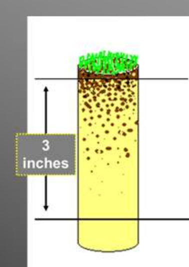


114

SIDE BAR

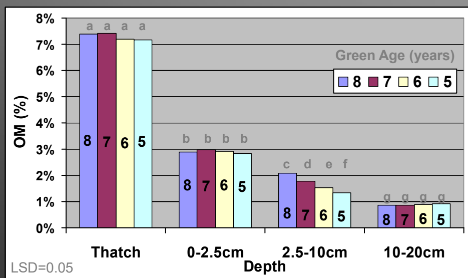
Is the age effect misleading?

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



115

Organic Matter in USGA Specification Rootzones



116

Mat Development with Age

8 7 6 5

Green Age (years)

117

Developing a Standard for Measuring Organic Matter in Putting Green Soils

- Collaborators:
  - ***Roch Gaussoin*** / Professor / University of Nebraska-Lincoln
  - ***Doug Linde*** / Professor / Delaware Valley University
  - ***James Murphy*** / Professor / Rutgers University
  - ***Doug Soldat*** / Professor / University of Wisconsin-Madison
  - ***Travis Miller*** / Graduate Student / University of Wisconsin-Madison
  - ***Brian Whitlark*** / USGA

Funded by

USGA **Mike Davis Program for Advancing Golf Course Management**

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A Standard Method for Measuring Putting Green Surface Organic Matter

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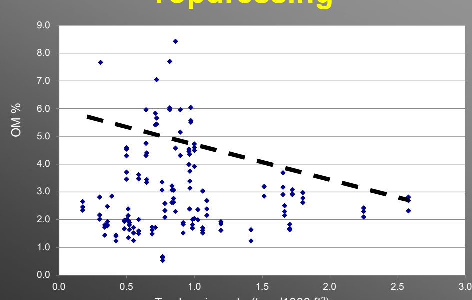
Topdressing



120

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

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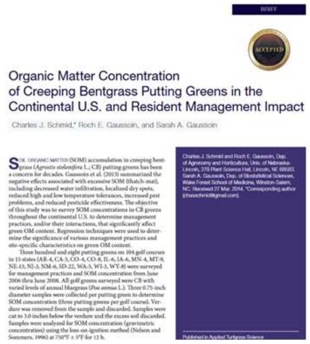
Organic Matter Concentration of Creeping Bentgrass Putting Greens in the Continental U.S. and Resident Management Impact

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

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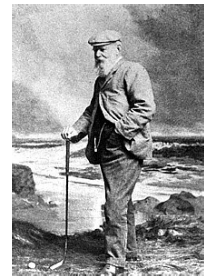
Topdressing

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).

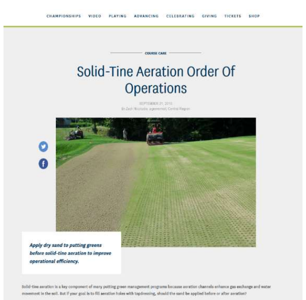
J.B. Beard is his classic textbook "Turfgrass Science & Culture, 1973 writes:

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



123

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



124

"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

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Aer-aider.com

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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 Lawso

128

Research on…

- Topdressing
  - ✓ Sand Size
  - ✓ Rate
- Cultivation

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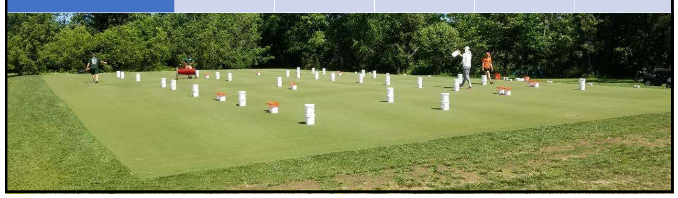
Research Objectives:

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?

130

	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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	Factors in the Experiment				
Treatment No.	Sand Size	Topdressing Rate during Growing Season	Cultivation (twice/year; May & Oct) Hollow Tine	Backfill / Topdress	Annual Quantity of Sand Applied
		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

132

	Factors in the Experiment				
Treatment No.	Sand Size	Topdressing Rate during Growing Season	Cultivation (twice/year; May & Oct) Solid Tine ⅝-inch	Backfill / Topdressing	Annual Quantity of Sand Applied
		lb / 1,000 sq ft		lb / 1,000 sq ft	lb / 1,000 sq ft
1	Medium-coarse	50	None	400	1,300
2	Medium-coarse	50	Solid Tine	600	1,700
3	Medium-coarse	100	None	400	1,800
4	Medium-coarse	100	Solid Tine	600	2,200
5	Medium-fine	50	None	400	1,300
6	Medium-fine	50	Solid Tine	600	1,700
7	Medium-fine	100	None	400	1,800
8	Medium-fine	100	Solid Tine	600	2,200
9	Fine-medium	50	None	400	1,300
10	Fine-medium	50	Solid Tine	600	1,700
11	Fine-medium	100	None	400	1,800
12	Fine-medium	100	Solid Tine	600	2,200
13	None	0	None	0	0
14	None	0	Solid Tine	600	1,200

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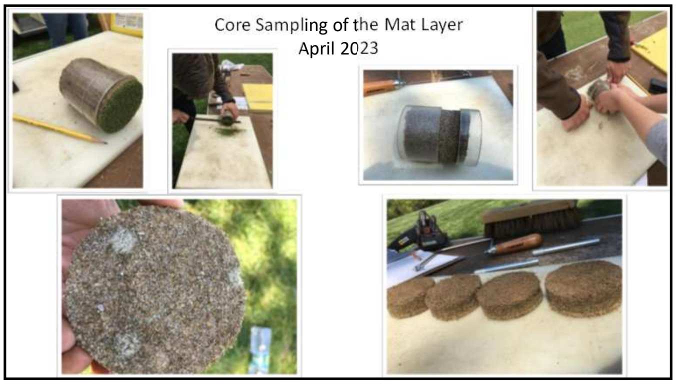
Cultivation Factor

- Solid tine twice/year (May and Oct)
- Holes backfilled with medium-coarse sand at 600 lb / 1,000 sq ft
- At same time, non-cored plots topdressed with respective sand size at 400 lb / 1,000 sq ft

134

Core Sampling of the Mat Layer April 2023



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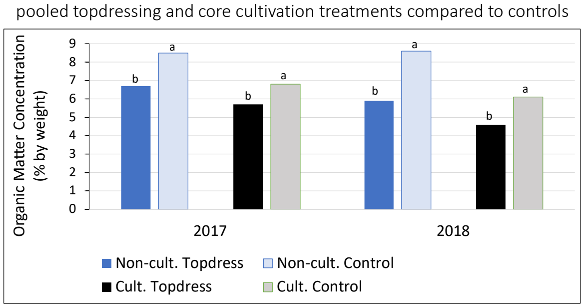

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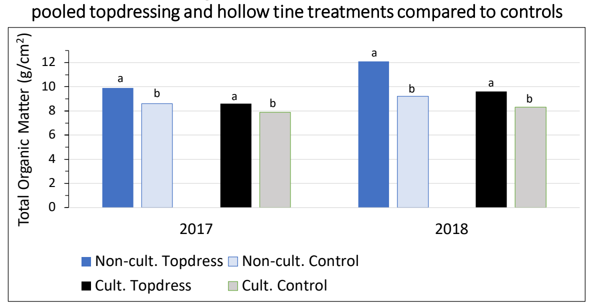

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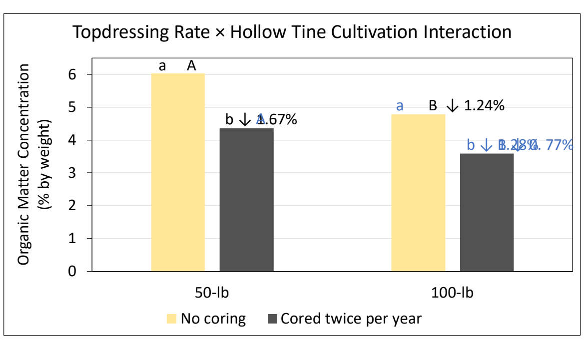


Pooled over all topdressing treatments, controls not included

138

Double-ring Infiltration Test (August 2019)

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

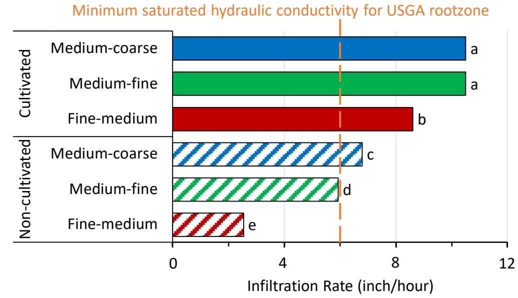
139

ANOVA of Water Infiltration Rate (August 2019)

Source of Variation	1st round	2nd round	3rd round
	------- Infiltration Rate -------		
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

140

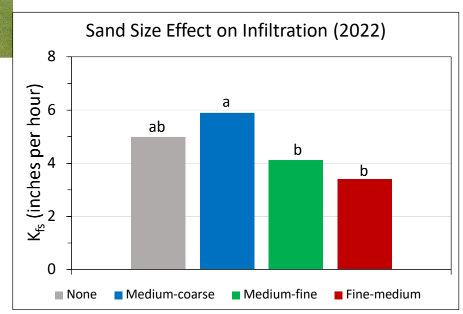
Sand Size x Core Cultivation Interaction
3rd round of 1-inch of water



141

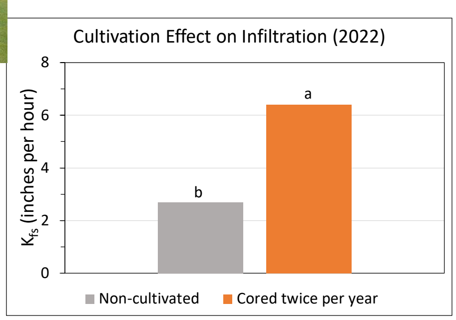
Field Saturated Hydraylic Conductivity, K_{fs} (2022)

142



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

143

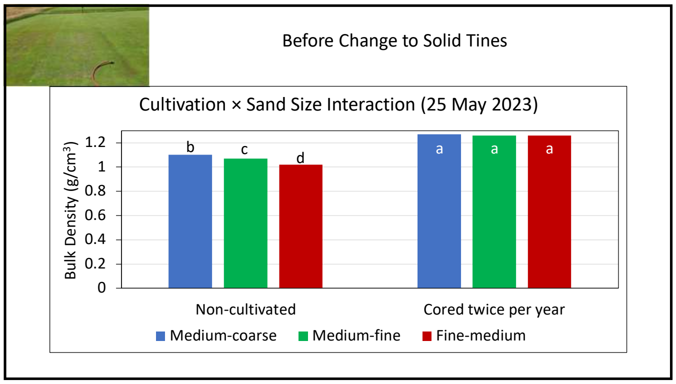


Pooled across all levels of topdressing sand size.

144

Bulk Density
Surface Hardness
Volumetric Water Content

145



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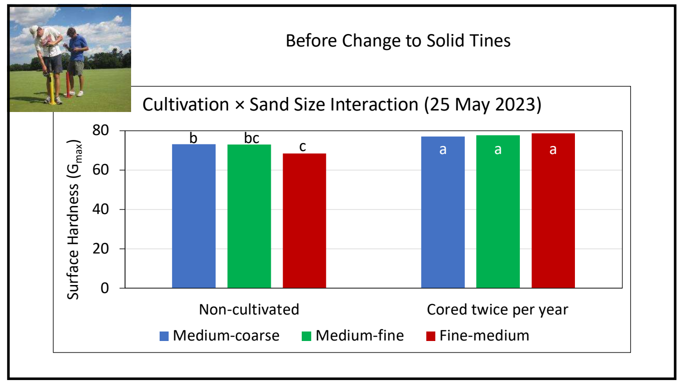

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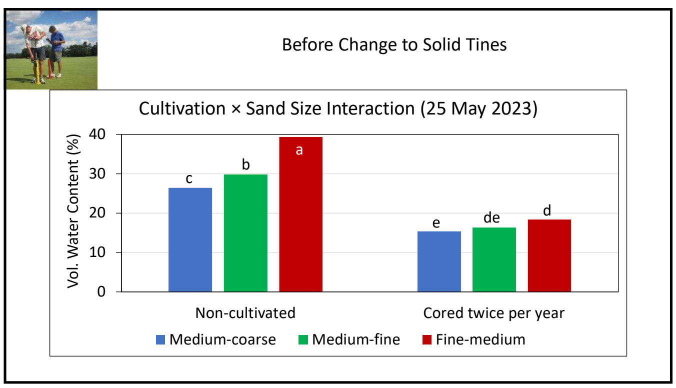

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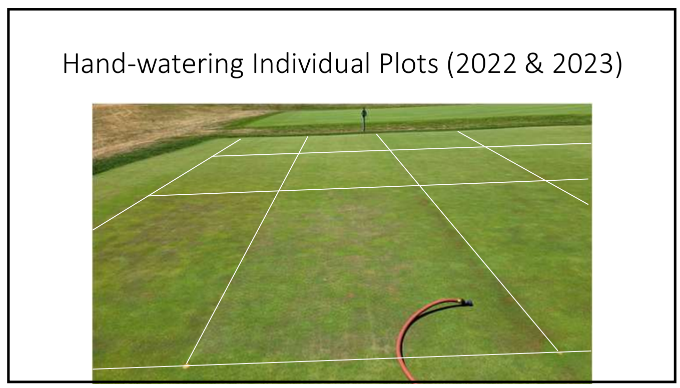

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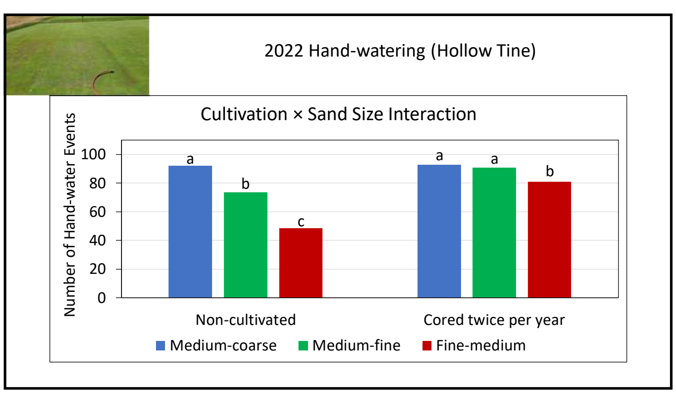

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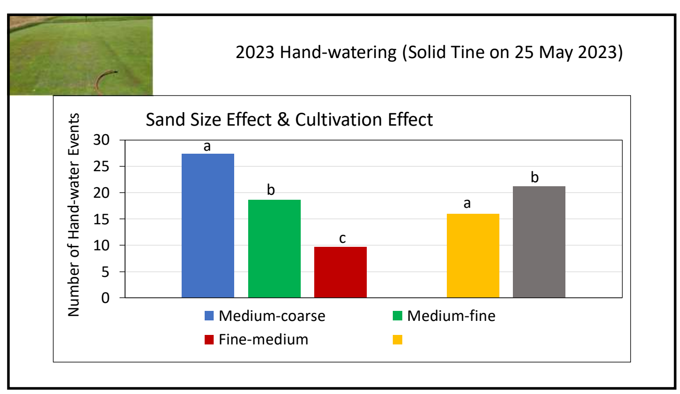


151

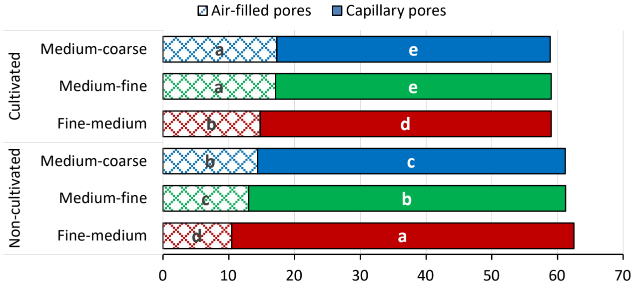
Mat-layer Physical Properties

152

ANOVA of Mat-layer Physical Properties

Source of Variation	---Pore Size Distribution---- Total	Air-filled	Capillary	------Sand Particle Size Fraction------ Very Coarse	Coarse + Medium	Fine	Very Fine
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

153



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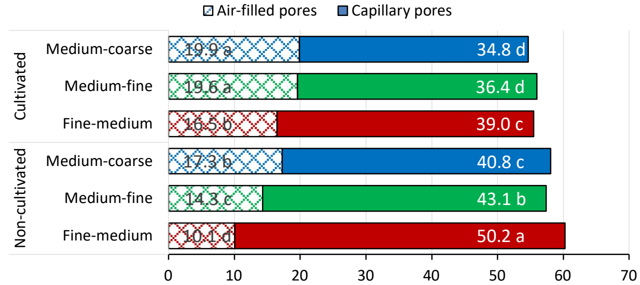
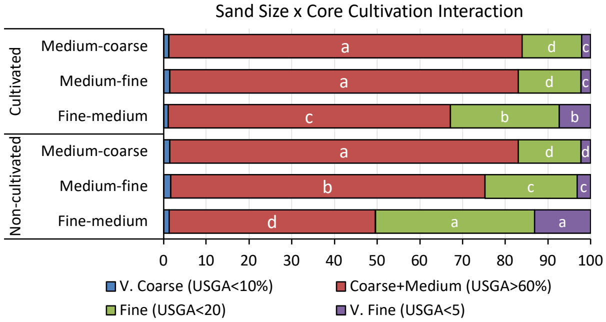


155



156

Conclusions

In the absence of HTC:

- Fine-medium sand immediately and substantially increased VWC, resulting in a wetter and softer surface compared to surfaces topdressed with medium-coarse and medium-fine sands.

When HTC was employed:

- The impact of sand size was reduced, and, in fact, there were no differences in VWC between the medium-coarse and medium-fine sands.
- However, after 4 years, HTC could not fully offset the effect of topdressing with fine-medium sand on surface wetness.

The effect of topdressing rate also became dependent on cultivation after 4 years.
The lower topdressing rate led to a wetter surface than the higher topdressing rate in the absence of cultivation, but not when HTC was applied.

157

Conclusions

HTC effectively dried and created firmer surfaces in the long run but also disrupted the turf surface, resulting in poorer turf quality throughout the season.

Better turf quality and higher NDVI (turf cover) on plots without cultivation corroborate superintendents' strong interest in reducing or eliminating HTC from their management programs.

More data coming on the impact of **solid tine** cultivation on creeping bentgrass putting green quality and surface characteristics.

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Managing for Drier Surface

Topdressing

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

Core Cultivation

- Very effective at producing a drier surface
- Cost and time for healing are greatest limitations

Solid Tine Cultivation

- Too soon to have a lot of data, but some initial data not as positive of response as hollow tine – stay tuned

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New Trials

Two cultivation trials initiated on creeping bentgrass in 2023 to compare hollow tine and solid tine cultivation.

Evaluating:

1. Turf quality
2. Healing of tine holes
3. Residual sand after topdressing
4. Volumetric water content at the 0- to 3-inch depth zone
5. Dual-head infiltrometers
6. Clegg soil hardness
7. Ball roll distance – GS3
8. Trueness of ball roll – GS3
9. Smoothness of ball roll – GS3
10. Firmness – drop test with GS3

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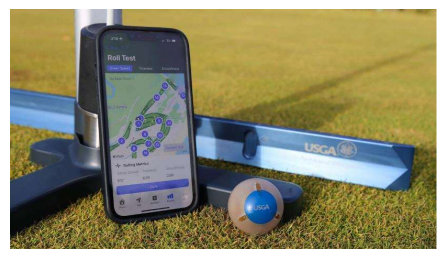
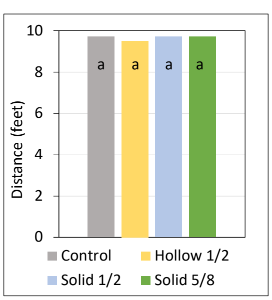
USGA GS3 Device for Playability

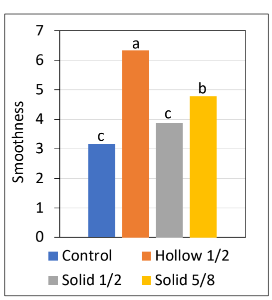
- Distance
- Trueness
- Smoothness
- Firmness



161

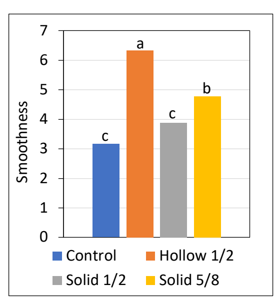
Ball roll characteristics on 20 Nov. 2023, 40 days after cultivation in Trial 8A.

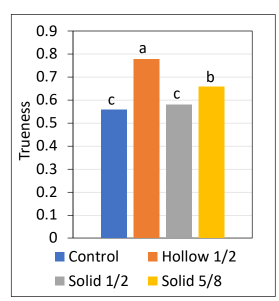




162

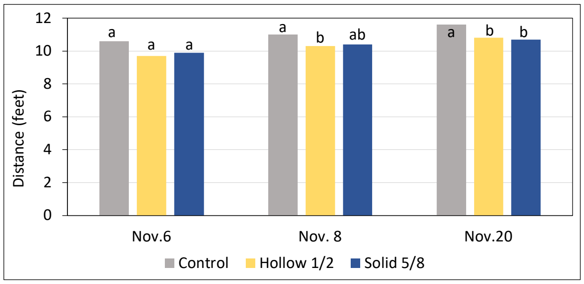
Ball roll characteristics on 20 Nov. 2023, 40 days after cultivation in Trial 8A.





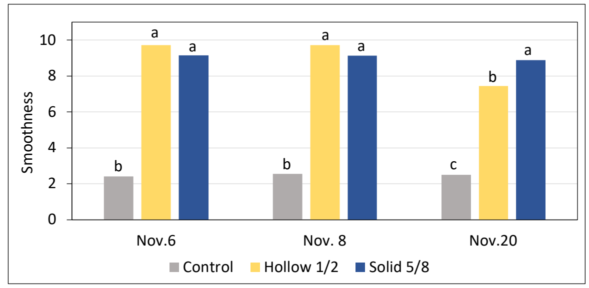
163

Ball roll distance 19 to 33 days after cultivation on 18 Oct. 2023 in trial 13A.



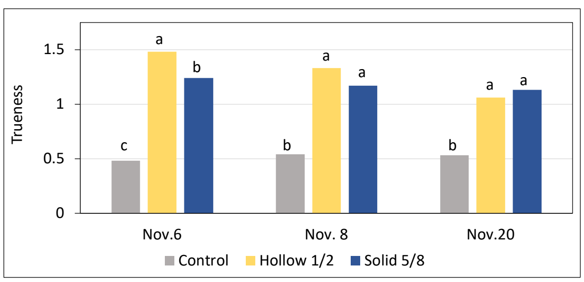
164

Ball roll smoothness 19 to 33 days after cultivation on 18 Oct. 2023 in trial 13A.



165

Ball roll trueness 19 to 33 days after cultivation on 18 Oct. 2023 in trial 13A.



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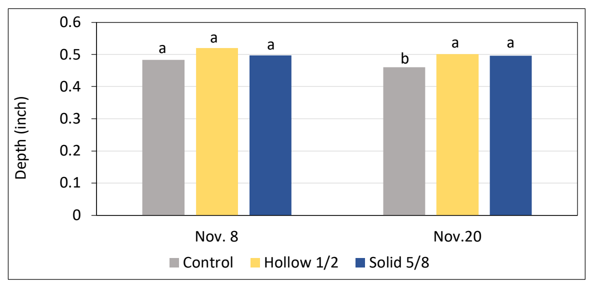
Ball drop test 21 to 33 days after cultivation on 18 Oct. 2023 in trial 13A.



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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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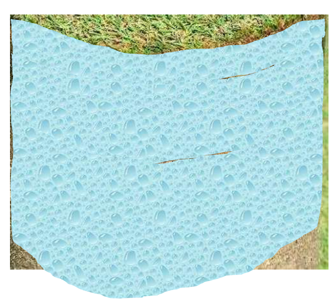

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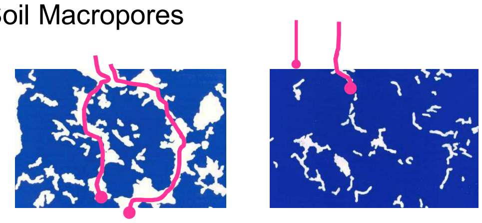
Soil Macropores



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Layering

- Aeration alone not that effective
- Must topdress to dilute OM (change its pore size distribution) and use deficit irrigation

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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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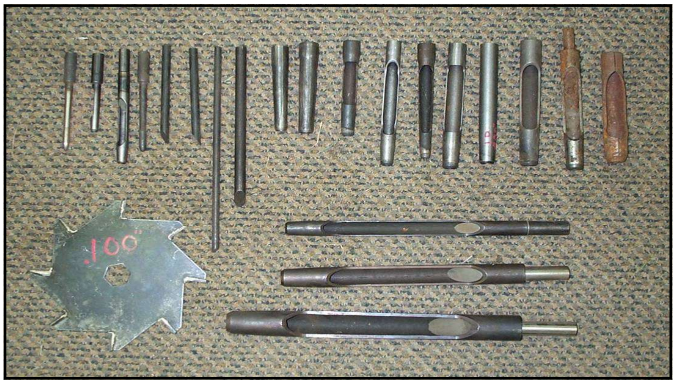

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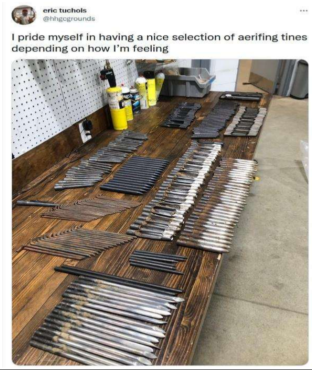

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Research Need (2004)

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

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Tine Trial Fall 2021

- Check
- Hollow ½" ID
- Solid ½"OD
- DryJect (3x3)
- ¼" Solid (Needle)
- DryJect (3x2)
- Needle + Solid
- Needle + Hollow

Procore 648 - 3" target depth on all tines
Dryject = 5"

Sampled for OM the day after
Treatment in 1' depth increments to 4 "

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Treatment	% OM 0-4"	
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
- ***<u>Data is preliminary</u>***

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Spring 2023 Tine Trial

- ~~9~~ 28 tine types/configurations including Viper tines
- 2 devices (ProCore 648 and DryJect)
- Timing (spring/fall)
- Topdressing before or after
- Data
  - OM
  - Surface parameters using the USGA GS3
  - Other data

Equipment and Tine Support Provided by

TORO. CTI Ceres Turf, Inc. DryJect Heartland Golf & Turf Services LLC

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Treatments (Spring, FB Oct 3 except DryJect on Oct 16)

- Main Plots (42' X 60' with a 6' border between)
  - 1. Topdress before tines with 0.25"(0.125" on October 2023) on surface (equates to 1 (1/2 fall) ton/1000 ft^2 or 20 ft^3/1000ft^2)
  - 2. Topdress after tines
- Sub-plots (tine treatments) set at 3" depth
  - ***1. 5/8' Viper Nose™***
  - ***2. 1/2" Viper Nose™***
  - 3. 3/8" solid
  - ***4.*** ½" solid cross
  - 5. Untined control
  - 6. ¼ " solid
  - 7. .50" solid
  - ***8. 3/8" hollow, side eject***
  - 9. 1/2" solid cross
  - 10. .75" solid slicing
  - **11. 1/2" hollow, tapered**
  - **12. 1/2" hollow side eject**
  - **13. DryJect 3X3**
  - 14. Untined Control
  - 15. **DryJect 2X3**

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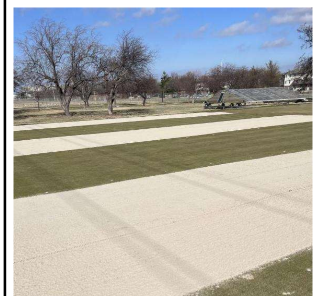


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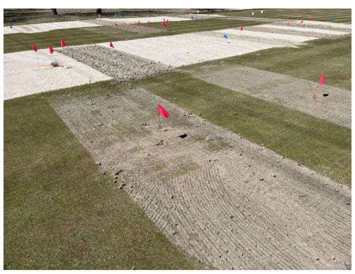


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Plot after dragging and several mowings and irrigation

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Data Collection

- Organic matter, 3-5 days after treatment directly over aeration hole
- Infiltration approx. weekly
- NDVI (cover measured digitally) every few days
- Firmness
- Surface Moisture TDR 0-3'; 3-6"
- GS3
  - Ball roll
  - Smoothness
  - Trueness

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Fall 2023 Data Results (<.05 = statistical difference)

ANOVA	10-Oct	18-Oct	21-Oct	26-Oct		9-Oct	16-Oct	25-Oct
Effect	NDVI-1	NDVI-2	NDVI-3	NDVI-4	%OM	Infil-1	Infil-2	Infil-3
Topdressing (TD)	0.1161	0.5583	0.6987	0.2785	0.0466	0.3444	0.188	0.1061
Tine TRT	<.0001	0.0049	0.0353	0.114	<.0001	<.0001	<.0001	<.0001
TD*TRT	0.0761	0.925	0.2796	0.1175	0.0107	0.1	0.0076	0.4673

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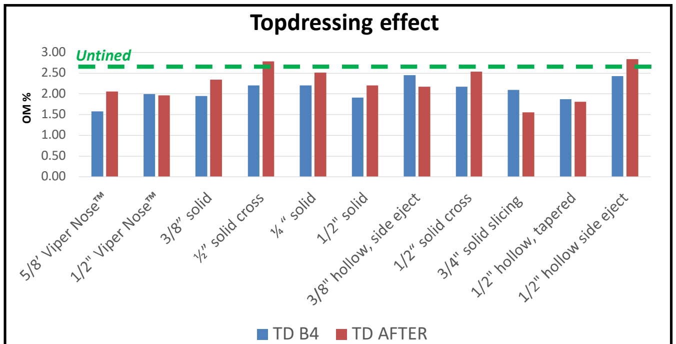

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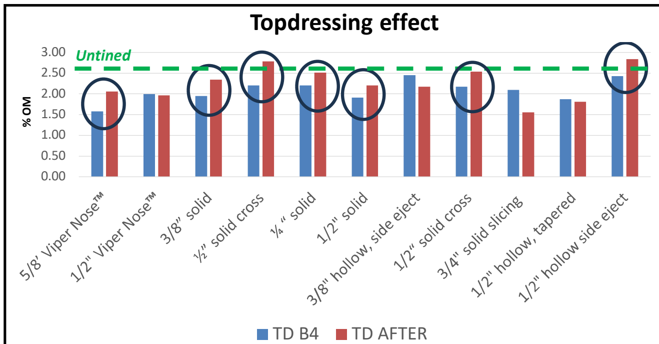

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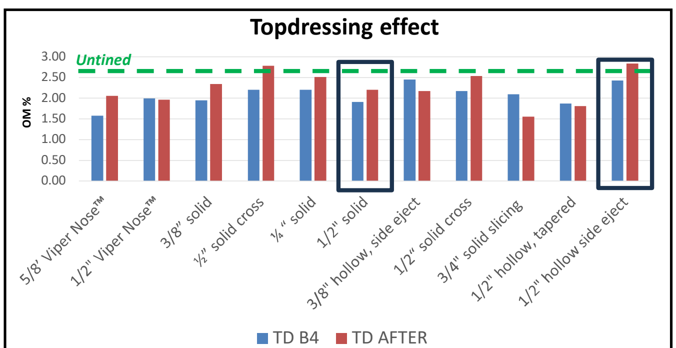

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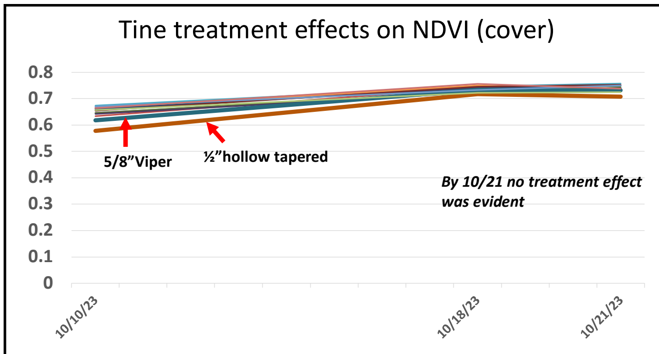

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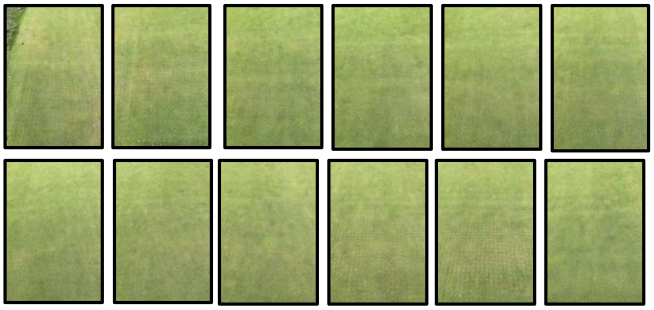
All treatments-October 21



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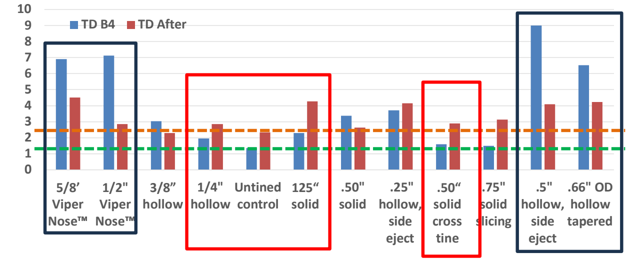
Tine/TD effects on Infiltration (inches per hr)
2.5 weeks post aeration



Positive effect on infiltration was greater for ½" or larger hollow tine & TD before aeration

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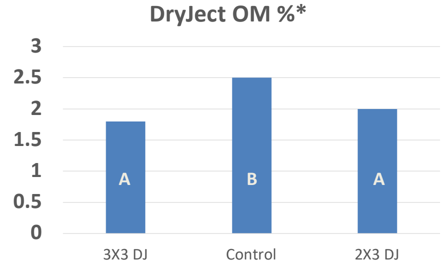
DryJect OM %*



*No topdressing effect; numerically equivalent to most other tine treatments

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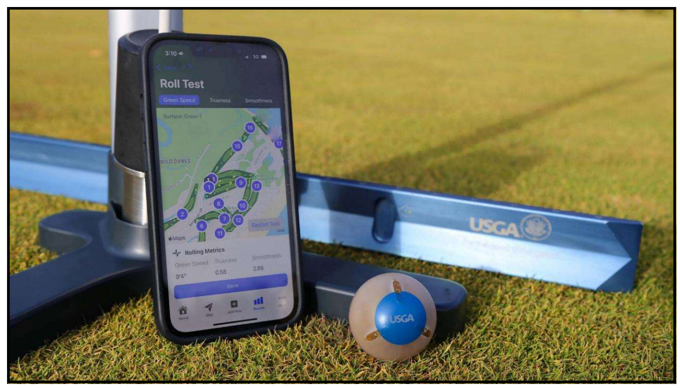

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Fall 2023 GS3 Data Results (≤.05 = statistical difference)

Ball Roll 1 WAT		
Effect	**F Value**	**Pr > F**
TD	**5.5**	**0.1437**
TRT	**4.44**	**<.0001**
TRT*TD	**2.85**	**0.0027**

TD before aerification increased ball roll more for ½" or greater hollow tines than same diameter solid tines. Solid tines had higher ball roll than equivalent hollow tines. Effects were less evident 2 WAT.

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Fall 2023 GS3 Data Results (≤.05 = statistical difference)

Trueness 1 WAT		
Effect	**F Value**	**Pr > F**
TD	**0.16**	**0.7316**
TRT	**1**	**0.4689**
TRT*TD	**0.66**	**0.8037**

Smoothness 1 WAT		
Effect	**F Value**	**Pr > F**
TD	**0.33**	**0.6245**
TRT	**0.64**	**0.8234**
TRT*TD	**0.83**	**0.636**

Results were similar and NS 2 & 3 WAT

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Treatments would appear to be visually different and when data were captured ball deviations appeared evident. Visual STRI Smoothness data were not collected.

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Deeper Dive Into Data

Confounding data due to excessive enthusiasm of researcher

Different statistical approach to isolate specific factors of interest

Orthogonal comparisons

This approach successfully separated out differences not evident from traditional ANOVA analysis for other data. GS3 data still needs to be investigated.

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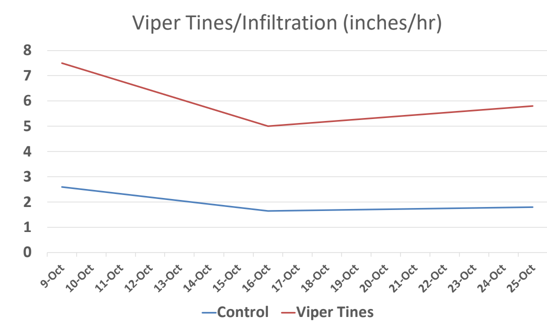

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1/2 Solid	1/2 Hollow
% OM	
1.8	2.4

**

Oct-25 Infiltration	
1/2 Solid	1/2 Hollow
Inch/hr	
2.8	6.6

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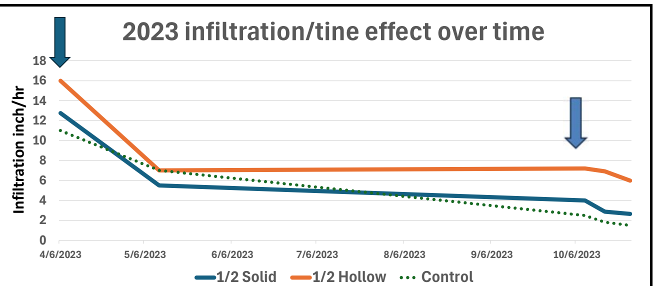

Prior to study, area was aerated with ½" solid tines 2X/yr and topdressed with medium-fine sand for 5 years. Initial infiltration in 2018 was 12"/hr.

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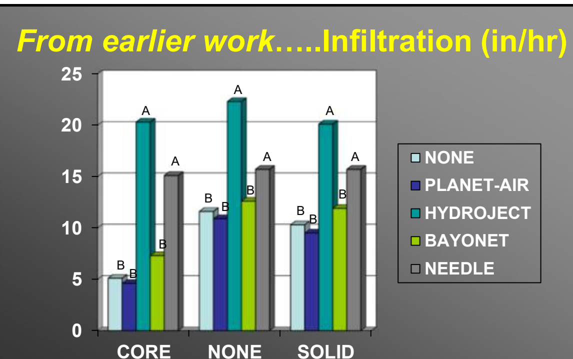

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Early Results

- Topdressing before aeration, even with *some* hollow tines will incorporate more sand
- Higher and prolonged infiltration greater for hollow tines ½” or larger than any solid tines
- Viper tines had greatest increase in infiltration over time than any other tine
- ***Uninterrupted use of solid tines over years needs to be rethought in infiltration is considered***
  - ***Venting will help***
  - ***Occasional hollow tine will help***

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Spring 2024 Results

- Cumulative effect of 3 cultivation events
- Similar outcomes to Fall 2023
- “Better” GS3 data

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% OM 1-3” after 3 cultivation events

Topdressing	OM
Before	3.02 A
After	3.27 B

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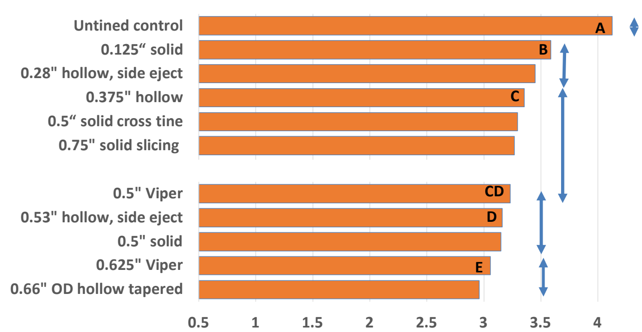

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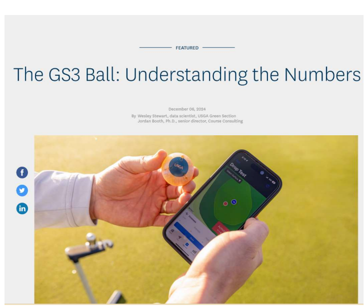

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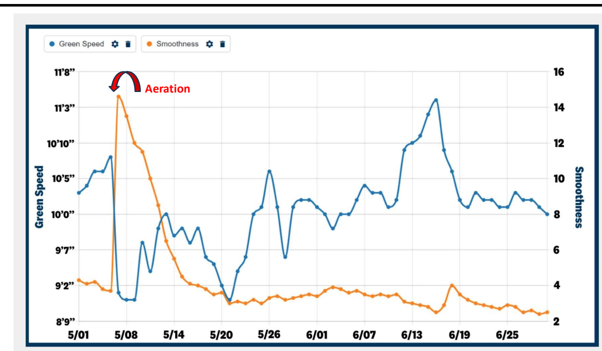

From USGA Green Section Record

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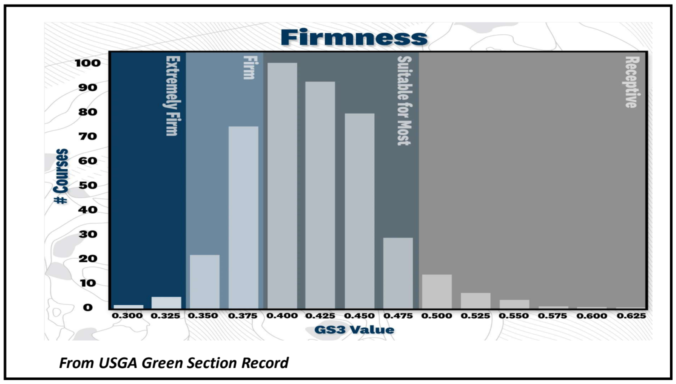

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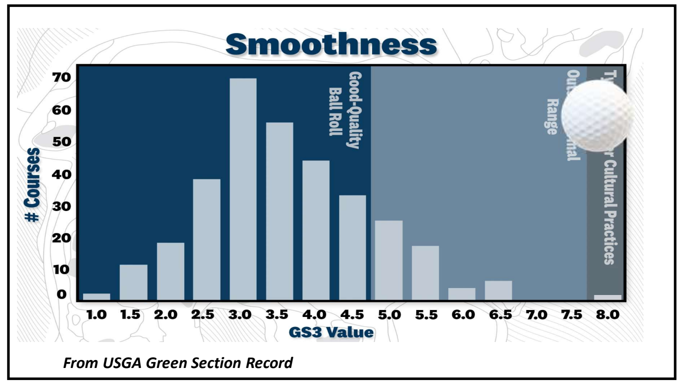

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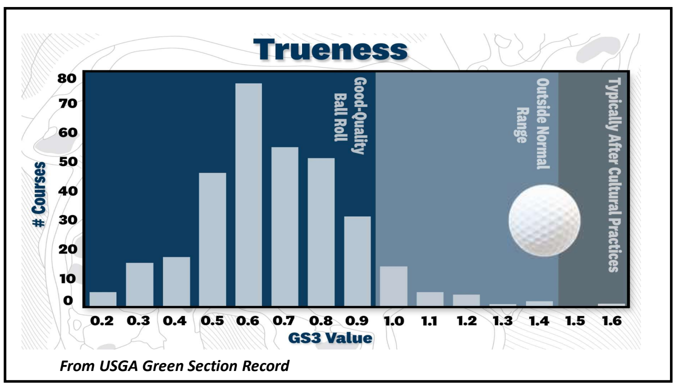

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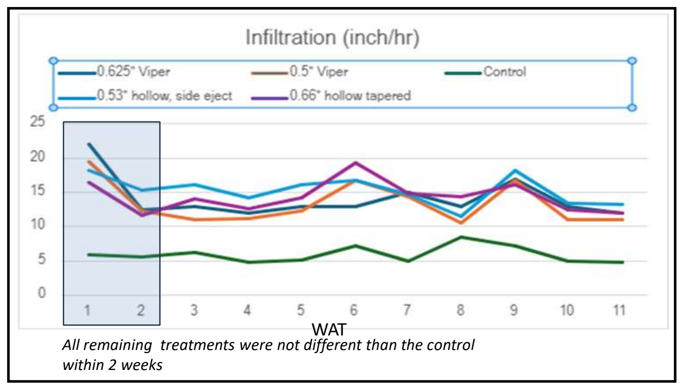

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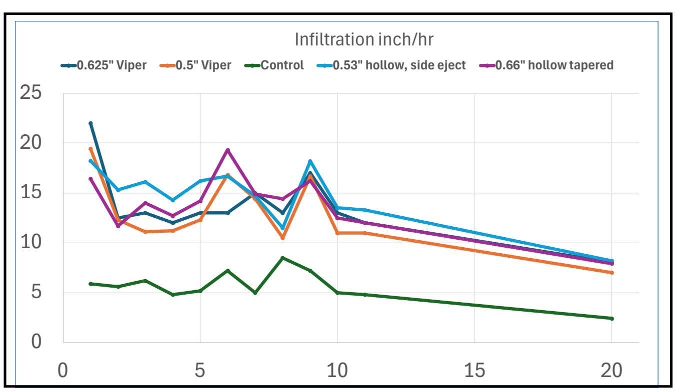

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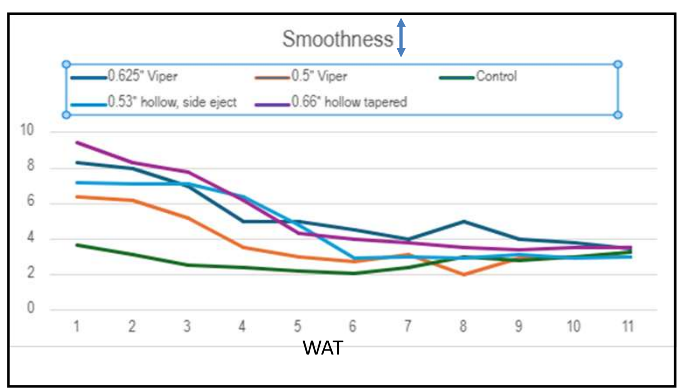

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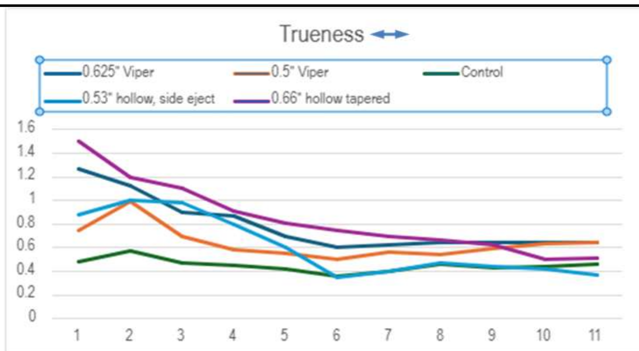

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What have we learned?

- 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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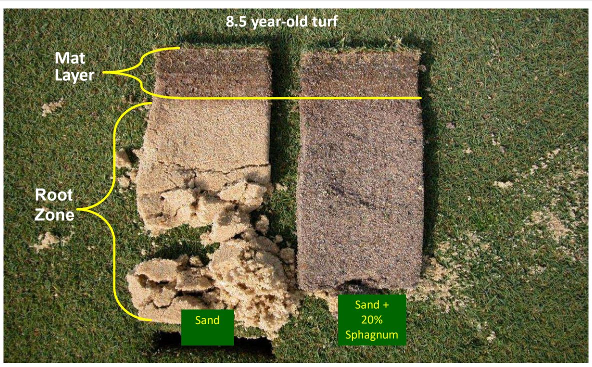

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It matters how you manage the accumulating thatch/mat layer

- 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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It matters how you manage the accumulating thatch/mat layer

- Topdressing before cultivation increases sand incorporation and decreases OM
- Larger diameter hollow (>0.5”) tines increase sand incorporation, infiltration and surface uniformity disruption; surface disruption duration is much shorter than infiltration benefit
- Solid tines decrease OM and infiltration more so than hollow tines over time, care must be taken to include venting or occasional hollow tine cultivation

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Acknowledgements (RU)

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GCSAA
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New Jersey Turfgrass Association

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Dawson Corporation Koonz Sprinkler
AT Sales New Jersey State Golf Association

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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 and best wishes for 2025!

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