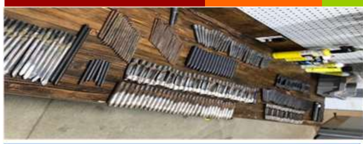
It's about tine(s)

(or a closer look at aeration and sand incorporation)



2024 CAROLINAS GCSA CONFERENCE & TRADE SHOW

Roch Gaussoin, Emeritus Professor, University of Nebraska

N EXTENSION

1

Acknowledgements

- USGA Davis Program
- Environmental Institute for Golf
- Nebraska GCSA
- GCSA of South Dakota
- Peaks & Prairies GCSA
- Jacobsen, Toro, DryJect, Ceres Turf Inc, JRM
- Nebraska Turfgrass Association

3

Historical Perspective: USGA Green Section Record and Precursors 1921-2024

Key Word search		*First mention; First "modern" mention*
• Topdressing	473 hits	• 1921; 1951
• Aeration	187 hits	• 1921; 1945
• Organic Matter	146 hits	• 1921; 1952
• Aerification	117 hits	• 1927; 1952
• Aerify	115 hits	• 1927; 1952
• Compaction	112 hits	• 1921; 1921
• Core	79 hits	• 1927; 1956
• Cultivation	74 hits	• 1923; 1945
• Coring	47 hits	• 1963; same
• Tine(s)	42 hits	• 1930; 1945

4

Reasons golf boomed post-WW2:

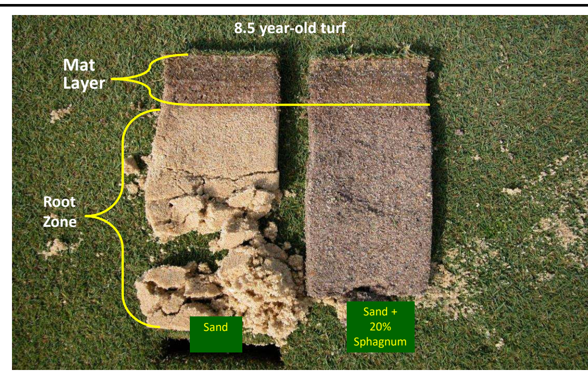
- Prosperous economic times allowed recreational spending.
- Returning veterans looked for leisure activities.
- Golf on TV showcased the sport to wider audiences.
- Golf became part of corporate culture for networking and deals.
- New technologies and equipment made golf easier for the average player.
- Retirees had time to take up the game.
- Golf became part of suburban lifestyles and country club status.

……..increase in traffic, participants and play led to the 1960 release of the USGA recommendations for green construction

5

OM accumulates as sand greens age

6



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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

10

Treatments

Tine Treatment
None
2X Hollow tine
2x Solid tine

Venting Treatment
None
PlanetAir
Hydroject
Bayonet tine
Needle tine

11

Treatments

Tine Treatment
None
2X Hollow tine
2x Solid tine

Venting Treatment
None
PlanetAir
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

12

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*

13

Materials and Methods

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

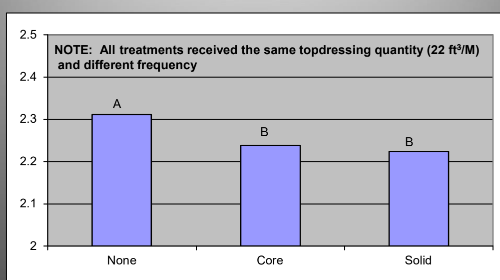
14

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

15

Effect of Tines on OM after 1 yr



16

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

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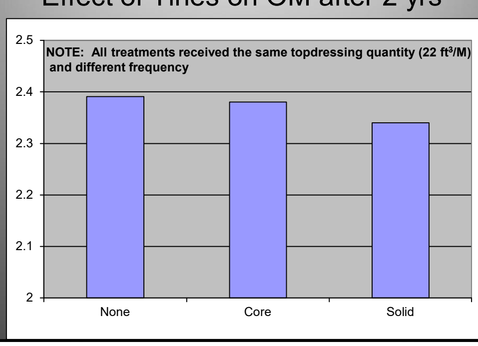
Effect of Tines on OM after 2 yrs



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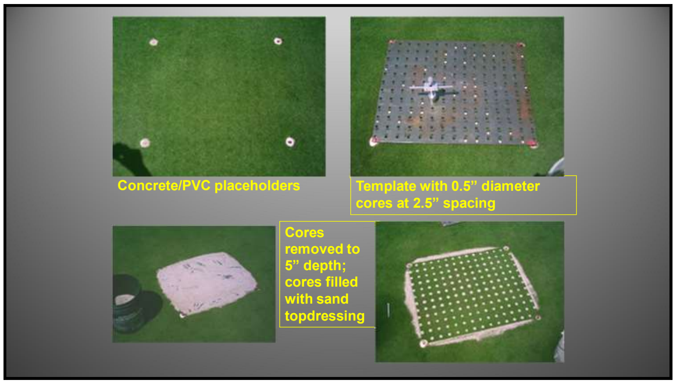
Let's take a quick look at that…

19



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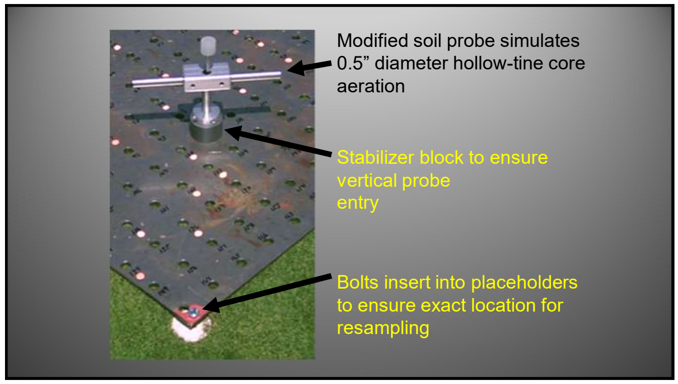

21

- Study initiated 22 June 2005; concluded 11 Nov. 2005
- 2 USGA Putting Greens
  - Constructed in 1997 and 2000
- Sample every 2 weeks for 20 weeks
- 2 depths of interest
  - 3 & 6”

22

		Time after core creation (weeks)							
		2	4	6	8	10	12	14	16
Putting Green	Depth	Organic Matter Reduction (%)							
9 yr	3”	*79*	73	70	71	69	66	67	*66*
	6”	*71*	64	60	63	59	56	57	*56*
5 yr	3”	*73*	66	61	62	62	62	61	*59*
	6”	*66*	56	51	51	52	52	51	*49*

23

24

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

25

*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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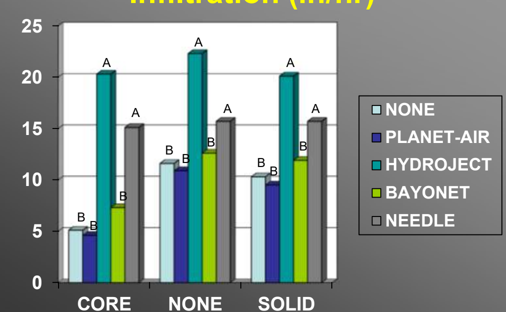

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Project Objective

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

29

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

30

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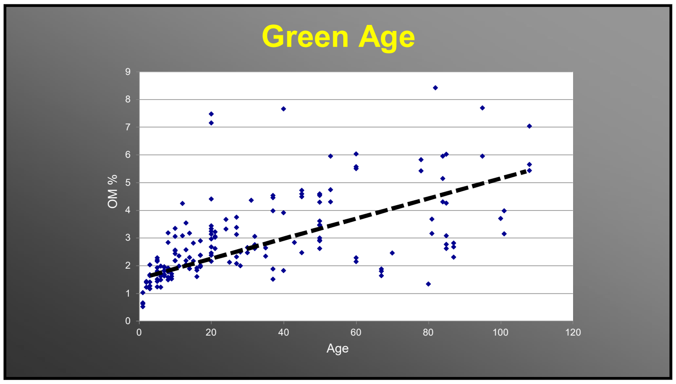

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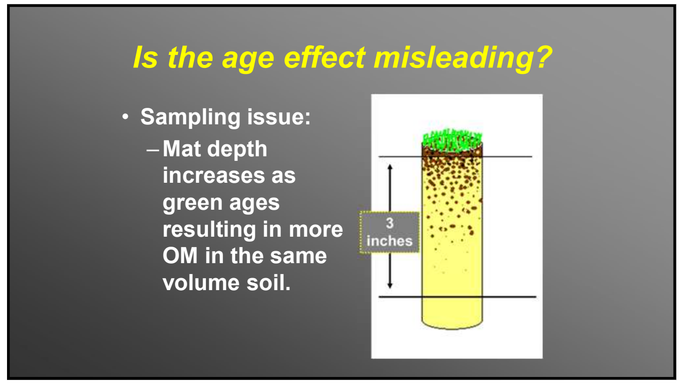

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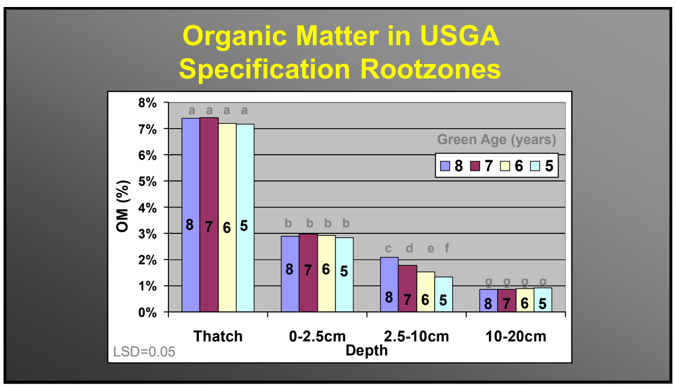

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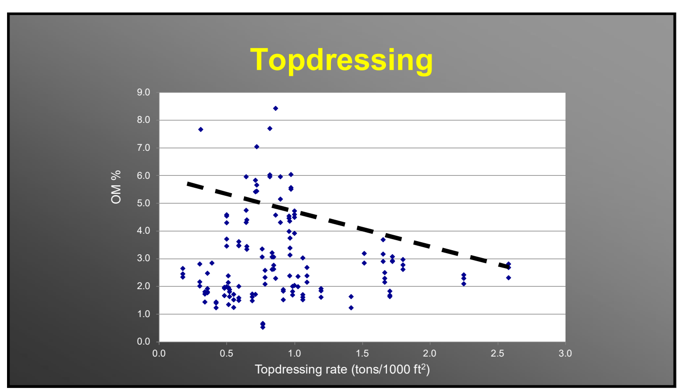
A Standard Method for Measuring Putting Green Surface Organic Matter

36



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

38


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

39

Topdressing

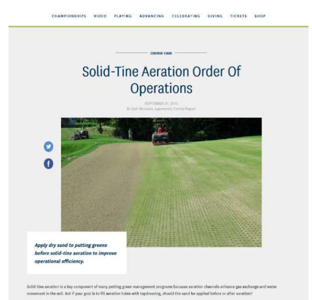
Old Tom Morris (1821–1908) is thought to have discovered the benefits of topdressing accidentally when he spilled a wheelbarrow of sand on a putting green and noted how the turf thrived shortly afterward (Hurdzan, 2004).

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

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

40

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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"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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Research Need (2004)

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

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45

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 "

46

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

- ~~19~~ 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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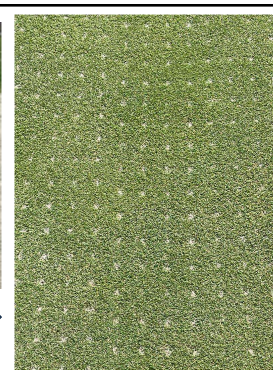
Plot after dragging and several mowings and irrigation



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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

55

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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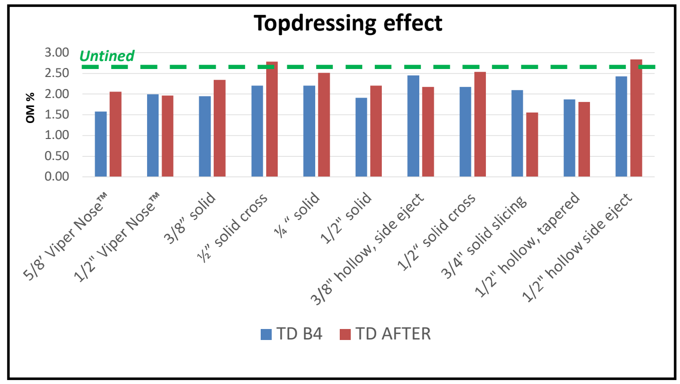

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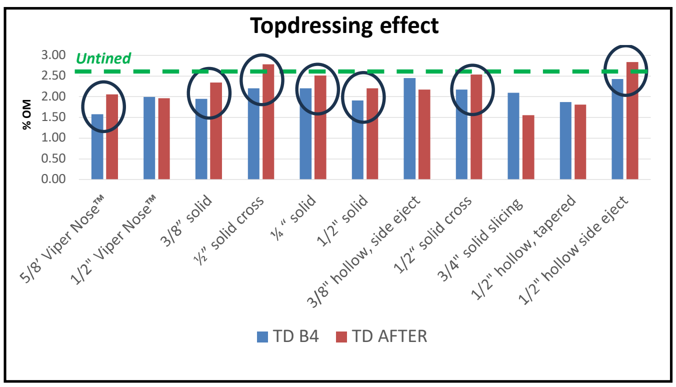

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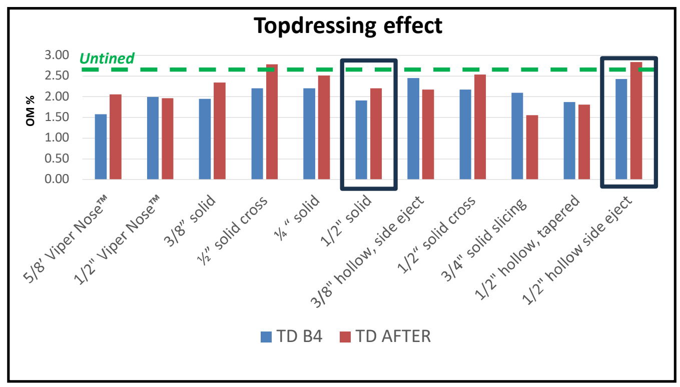

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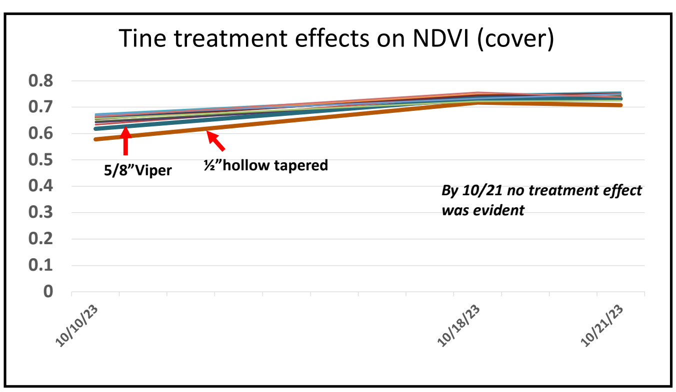

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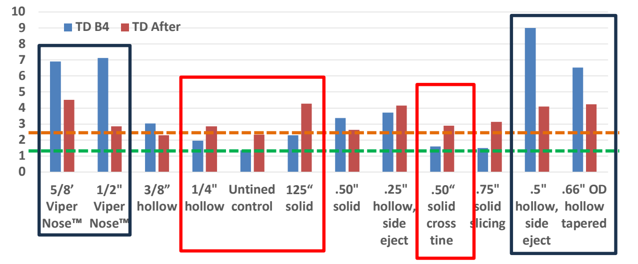
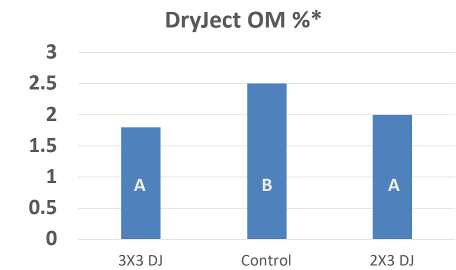
Tine/TD effects on Infiltration (inches per hr)
2.5 weeks post aeration



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

62



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

63

64

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.

67

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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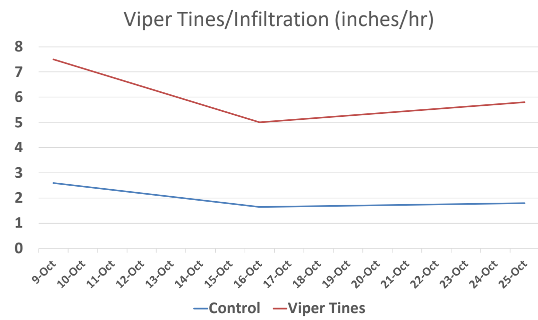

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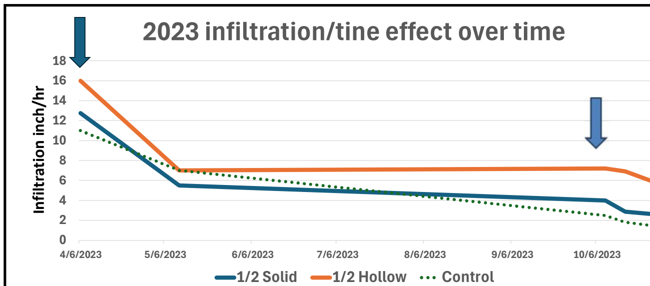
1/2 Solid	1/2 Hollow
% OM	
1.8	2.4

**

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

70



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.

71

Early Results

- Lots of stuff going on
- 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 needs to be rethought***

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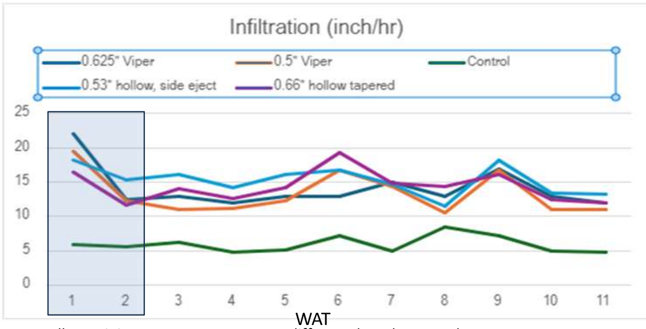
Spring 2024 Results

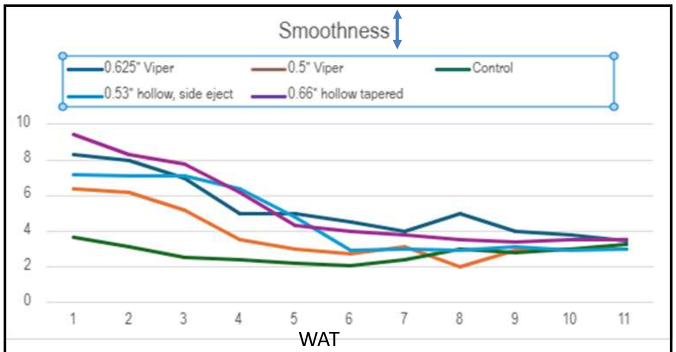
- Cumulative effect of 3 cultivation events
- Similar outcomes to Fall 2023
- "Better" GS3 data

73



All remaining treatments were not different than the control within 2 weeks

74



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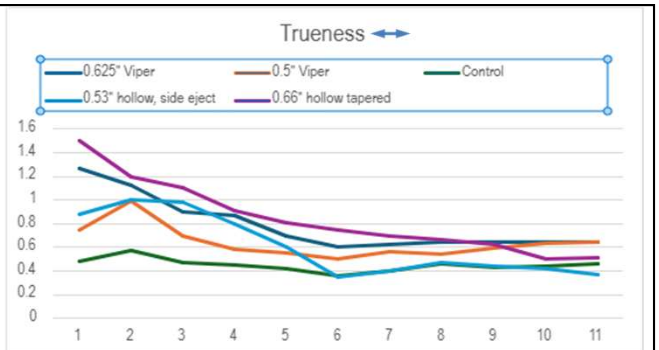

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Research data from others

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Core Cultivation of a Putting Green with Hollow and Solid Tines (1993, MSU)
J. A. Murphy, P. E. Rieke, A. E. Erickson
https://doi.org/10.2134/agronj1993.00021962008500010001x

- 'Penneagle' creeping bentgrass loamy sand putting green
- hollow (HTC) or solid (STC) tines for 3 years
- treatments were applied at 2 soil moistures (moist or wet)
- Infiltration and air porosity were 49 and 21% greater, with HTC vs STC.
- wet soil cultivation reduced infiltration 31% compared to moist soil cultivation.
- HTC lowered the organic matter fraction of the thatch/mat layer, but increased total organic matter vs STC.
- STC exhibited the potential for development of a cultivation pan.

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Effects of Core Cultivation Tine Entry Angle on Golf Putting Greens
Christian M. Baldwin, Haibo Liu, Philip Brown (Clemson University, 2006)
DOI: https://doi.org/10.21273/HORTTECH.16.2.0265

SUMMARY. Hollow tine cultivation is a routine practice on golf course putting greens, where the tine entry angle normally is 90°. Effects of various tine entry angles impacting putting green surfaces have not been investigated. The hypothesis was that different tine entry angles during cultivation would impact a greater area of the soil profile by enhancing water infiltration rates, reducing localized dry spots, and enhancing turf quality. Therefore, a 2-year field study in 2003 and 2004 was conducted to determine the impact of core cultivation tine entry angle on 'Crenshaw' creeping bentgrass (*Agrostis stoloniferous* var. *palustris*). Treatments included three angles of hollow tine entry at 50°, 70°, and 90° and an untreated plot without cultivation. Manual cultivators consisted of four 1/4-inch- and 1/2-inch-diameter hollow tines 3 inches in length, spaced 2 inches apart. Treatment applications were in April, May, September, and October. Measurements included visual turfgrass quality (TQ), molarity ethanol droplet test (MED), and water infiltration. No treatment (control, 50°, 70°, 90°) effects in years I and II for TQ were noted. MED scores in May were 23% higher than in August and September. Tines of 1/2-inch diameter reduced soil hydrophobicity (MED) 6% compared to tines of 1/4-inch-diameter tines. Tines of 50°, 70°, and 90° had 129%, 163%, and 211% greater water infiltration than the untreated, respectively.

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USGA Ultradwarf Bermudagrass Putting Green Properties as Affected by Cultural Practices, J. H. Rowland, J. L. Cisar, G. H. Snyder, J. B. Sartain, A. L. Wright (2009, UF)
https://doi.org/10.2134/agronj2009.0154

Accumulation of organic matter (OM) at the soil surface (mat OM) and below (soil OM) can negatively affect putting green performance characteristics. The objective of this study was to evaluate cultural practices for control of OM and their effects on performance characteristics of a mature, USGA-specified ultradwarf bermudagrass [*Cynodon dactylon* (L.) Pers. × *C. transvaalensis* Burt Davy] green in a subtropical climate. Two ultradwarf cultivars, 'TifEagle' and 'Champion', were subjected to hollow tine aerification (HTA) 1, 2, or 3 times yr^{-1}, *verticutting* (VC) 3 times yr^{-1}, solid tine aerification (STA) 5 times yr^{-1}, and no treatment (control) for two consecutive years. Cultivars and treatments were arranged in a split-plot, randomized complete block design. Although mat OM depth was similar among treatments, concentration was reduced after 2 yr by VC, HTA 2 times yr^{-1}, and HTA 3 times yr^{-1}. Solid TA (5 times yr^{-1}) and hollow TA (2 and 3 times yr^{-1}) reduced soil OM concentration compared with the control. Since VC also provided the highest turfgrass quality, firmest surface, least mower scalping, and least localized dry spots (LDS), it proved to be the best cultural practice tested, particularly since HTA 3 times yr^{-1} increased saturated hydraulic conductivity (K_{sat}), which reduced volumetric water content and increased LDS. TifEagle was the better performing cultivar, as it had higher quality and less mower scalping.

80

Applied Turfgrass Science **Effects of Venting Aeration on Neglected Bermudagrass Putting Greens (2011, Texas A&M)**
Charles H. Fontanier, Kurt Steinke, James C. Thomas, Richard H. White
https://doi.org/10.1094/ATS-2011-1201-01-RS (fee for full print-out)

- hollow-tine aeration is disruptive
- thatchy, mature 'Tifeagle,' 'Tifdwarf,' and 'Mini-Verde' USGA putting green
- compared effects of small diameter tine core aeration to venting aeration at three frequencies, ***plots did not receive topdressing sand during the study***
- venting aeration alone may not be an effective practice for thatch management or improving water infiltration if substantial undiluted organic matter layers exist.

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Planet Air

Treatment[x]	Symbol	Timing interval	Spacing (cm)	Depth (cm)	Width (cm)	Length (cm)	Surface area impacted (%)	Surface area impacted annually (%)
Control	NC	–	–	–	–	–	–	–
Venting aeration	V1	Monthly	5.1	10.2y	0.32z	3.8z	2.1	7.4-9.5
Venting aeration	V2	Biweekly	5.1	10.2	0.32	3.8	2.1	14.7-18.9
Venting aeration	V4	Weekly	5.1	10.2	0.32	3.8	2.1	29.4-37.8
Hollow tine aeration	HT	Three weeks	5.1	10.2	0.64y	-	2.8	14.0-16.8
Solid tine aeration	ST	Three weeks	5.1	10.2	0.64	-	2.8	14.0-16.8

[x] Treatments applied for 18 weeks in 2008 and 14 weeks in 2009.
[y] Manufacturer's specified tine or knife dimensions.
[z] In-field measurements of holes.

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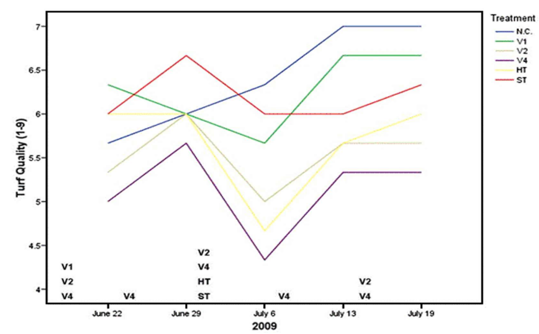

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Table 2. Cultivation treatment effects on turf quality (1 to 9, 6 = acceptable) of three hybrid bermudagrass putting greens having a USGA specified rootzone, 2008-2009, College Station, TX. Data were averaged across 18 dates over two years.

Treatment[x]	Tifeagle	Tifdwarf	Mini-verde
	Turf Quality		
V1y	6.0 abz	5.5 ab	6.2 a
V2	5.3 bc	5.3 ab	6.1 a
V4	4.4 d	5.0 bc	4.3 a
HT	4.9 cd	4.2 c	4.9 a
ST	5.7 b	4.8 bc	5.3 a
NC	6.6 a	6.1 a	6.6 a
$HSD_{0.05}$	0.7	0.9	NS

[x] Treatments were applied from May to September 2008 and May to August 2009.
[y] V1, V2, and V4 = PlanetAir venting aeration 1×, 2×, and 4× per month; HT = hollow-tine core aeration; ST = solid-tine core aeration; NC = Non-cultivated control.
[z] Means followed by the same letter in a given column are not significantly different (Tukey's $HSD_{0.05}$).

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Table 3. Cultivation treatment did not affect thatch-mat accumulation (TMA), organic matter dry mass (OMM), and root mass (RM) of three hybrid bermudagrass putting greens having a USGA specified rootzone, 2008-2009, College Statio, TX. Data are averaged across two years (n = 6).

Treat-ment[w]	Thatch-mat accumulation (mm/year)			Organic matter density (mg/cm³)			Relative root density (mg/cm³)		
	Te[x]	Td	Mv	Te	Td	Mv	Te	Td	Mv
V1y	8.3 az	1.6 a	8.9 a	20.6 a	17.4 a	15.9 a	0.88 a	1.36 a	0.87 a
V2	2.2 a	5.9 a	3.9 a	21.6 a	19.9 a	20.2 a	0.99 a	1.76 a	0.78 a
V4	5.0 a	2.7 a	9.5 a	15.5 a	16.1 a	19.1 a	0.87 a	1.73 a	0.64 a
HT	6.4 a	4.8 a	2.6 a	18.7 a	19.3 a	21.3 a	0.96 a	1.57 a	0.86 a
ST	3.7 a	4.9 a	5.7 a	19.1 a	17.2 a	18.2 a	1.13 a	1.57 a	0.74 a
NC	5.9 a	4.3 a	6.3 a	23.7 a	19.1 a	18.8 a	1.28 a	1.56 a	1.28 a

[w] Treatments were applied from May to September 2008 and May to August 2009.
[x] Te = 'Tifeagle'; Td = 'Tifdwarf'; Mv = 'Mini-verde'.
[y] V1, V2, and V4 = PlanetAir venting aeration 1×, 2×, and 4× per month; HT = hollow-tine core aeration; ST = solid-tine core aeration; NC = Non-cultivated control.
[z] Means followed by the same letter in a given column within a cultivar are not significantly different (Tukey's $HSD_{0.05}$).

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Cultivar	Treatment[x]	VWC (76 mm)	VWC (120 mm)	K_{sat} (cm/h)
		(m³/m³)		
Tifeagle	V1[y]	24.9d[z]	19.3c	23.6ab
	V2	27.1ab	20.8a	16.7b
	V4	26.7bc	20.6ab	17.8ab
	HT	27.6a	21.0a	19.8ab
	ST	27.4a	21.0a	29.5a
	NC	26.1c	20.4b	26.1ab
	$HSD_{0.05}$	0.6	0.4	12.1
Tifdwarf	V1[x]	26.6b	20.9bc	26.3ab
	V2	26.8b	21.3b	23.4abc
	V4	28.1a	21.9a	11.0c
	HT	26.0c	20.3d	33.0a
	ST	24.4d	19.2e	29.3a
	NC	26.6b	20.8c	15.4bc
	$HSD_{0.05}$	0.5	0.4	13.7
Mini-verde	V1[x]	23.4e	18.0d	28.4a
	V2	28.0b	21.6a	19.0ab
	V4	28.7a	21.6a	12.2b
	HT	25.1d	19.2c	30.2a
	ST	26.8c	20.1b	28.7a
	NC	23.9e	18.2d	26.0a
	$HSD_{0.05}$	0.6	0.4	12.8

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Impact of Dry-injection Cultivation to Maintain Soil Physical Properties for an Ultradwarf Bermudagrass Putting Green (2016, MSU) JM. Craft, C M Baldwin, WH. Philley, JD McCurdy, BR Stewart, M Tomaso-Peterson, EK Blythe
doi: 10.21273/HORTSCI11018-16

"It can be concluded that DI would be best used in combination with HT 1.3 or 0.6 cm diameter tine sizes to improve soil physical properties; however, the DI + HT 0.6 cm diameter tine size treatment resulted in minimum surface disruption while stilli improving soil physical properties compared with the noncultivated control"

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Table 1. Treatments implemented on a 'MS-Supreme' ultradwarf bermudagrass putting green in Starkville, MS, from 1 June to 31 Aug. 2014 and 2015.

Treatment	Aerification[z]	Tine size[y]	Dry-injection[x] frequency
Noncultivated control	—	—	—
HT 1.3	HT	1.3	—
HT 0.6	HT	0.6	—
DI 5	—	—	5[w]
HT 1.3 + DI 2	HT	1.3	2
HT 0.6 + DI 5	HT	0.6	5
HT 0.6 + DI 4	HT	0.6	4
HT 0.6 + DI 2	HT	0.6	2

[z]All aerification (hollow-tine) treatments were applied once a year on 2 July 2014 and 17 July 2015.
[y]The 1.3 and 0.6 cm treatments were set to a depth of 7.6 cm with 2.5 cm spacing.
[x]Dry-injection nozzles were spaced at 7.6 cm and set to a 12.6 cm depth.
[w]Total number of applications over the 2-year study period. Dry-injection treatments occurred on 3 June 2014, 2 July 2014, 8 Aug. 2014, 6 June 2015, and 17 July 2015.

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Table 2. Percent recovery and chlorophyll index in July on a 'MS-Supreme' ultradwarf bermudagrass putting green following various aerification and dry-injection cultivation treatments in Starkville, MS, from 1 June to 31 Aug. 2014 and 2015.

	Recovery %[z]				Chlorophyll index[y]	
	(0–100)				(0–900)	
Treatment[x]	5 DAT[w]	8 DAT	12 DAT	15 DAT	14 DAT	28 DAT
Noncultivated control	100 a[v]	100 a	100 a	100 a	284 a	300
HT 1.3	50 c	67 cd	83 cd	90 b	263 b	282
HT 0.6	70 b	82 b	93 ab	99 a	274 ab	301
DI 5[u]	73 b	83 b	96 ab	98 a	273 ab	292
HT 1.3 + DI 2	45 c	62 d	80 d	91 b	267 b	284
HT 0.6 + DI 5	70 b	78 bc	92 ab	97 a	275 ab	297
HT 0.6 + DI 4	69 b	75 bcd	90 bc	100 a	270 ab	286
HT 0.6 + DI 2	67 b	77 bc	89 bc	96 a	270 ab	284

[z]A 0% to 100% linear scale was used to estimate recovery where 100% = full coverage.
[y]Three readings were taken in randomly selected locations per plot, which were then averaged to get an overall chlorophyll index of each plot.
[x]HT = hollow tine; DI = dry injection; 1.3 = 1.3 cm diameter tine; 0.6 = 0.6 cm diameter tine.
[w]DAT = days after treatment.
[v]Means within each column followed by the same letter are not significantly different according to the Shaffer-simulated test ($P \leq 0.10$).
[u]Values following DI represent the number of dry-injection applications over the 2-year study period. Dry-injection applications occurred on 3 June 2014, 2 July 2014, 8 Aug. 2014, 6 June 2015, and 17 July 2015.

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Table 4. Water infiltration (cm·hr^{-1}) rates at two depths on a 'MS Supreme' ultradwarf bermudagrass putting green as affected by various core aerification and dry-injection treatments in Starkville, MS, from 1 June to 31 Aug. 2014 and 2015.

	0 to 7.6 cm depth	7.6 to 10.1 cm depth
	14 DAT[y]	1 Oct. 2015
Treatment[z]	cm·hr^{-1}	
Noncultivated control	6.50 b[x]	144 b
HT 1.3	25.83 a	196 ab
HT 0.6	14.10 ab	171 ab
DI 5[w]	12.66 ab	211 ab
HT 1.3 + DI 2	19.80 ab	192 ab
HT 0.6 + DI 5	11.60 b	178 ab
HT 0.6 + DI 4	13.80 ab	260 a
HT 0.6 + DI 2	16.60 ab	264 a

[z]HT = hollow tine; DI = dry injection; 1.3 = 1.3 cm tine diameter; 0.6 = 0.6 cm tine diameter.
[y]DAT = days after treatment.
[x]Means within each column followed by the same letter are not significantly different according to the Shaffer-simulated test ($P \leq 0.10$).
[w]Values following DI represent the number of dry-injection applications over the 2-year study period. Dry-injection applications occurred on 3 June 2014, 2 July 2014, 8 Aug. 2014, 6 June 2015, and 17 July 2015.

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Consider the Potential of Less-Aggressive Aeration, 2023
Elliott L. Dowling, regional director, East Region, USGA

ISTRC
International Sports Turf Research Center
Aerification Displacement Chart

Tine Size	1.25" x 1.25" Centers	1.5" x 1.5" Centers	2.0" x 2.0" Centers	2.5" x 2.5" Centers	5.0" x 5.0" Centers
1/4" Hollow Tines	3.14%	2.18%	1.23%	0.79%	
3/8" Hollow Tines	7.07%	4.91%	2.76%	1.77%	
1/2" Hollow Tines	12.57%	8.73%	4.91%	3.14%	
5/8" Hollow Tines		13.64%	7.67%	4.91%	
5/8" Hollow Vertidrain					1.23%
3/4" Hollow Tines				7.07%	1.77%
3/4" Hollow Vertidrain					1.77%
1" Hollow Tines					3.14%
1" Hollow Vertidrain					3.14%
7/8" Drill and Fill (7" Centers)					1.23%
Graden Verticutter 15 Blades at 1" Spacings	1mm Blade 3.93%	2mm Blade 7.87%	3mm Blade 11.81%		

Notes:
1/4" quad tines remove as much material as regular 1/2" hollow tines
3/8" minimum for ease of topdressing fill if replacement of material is required
For double aerification make two passes at approx. 37° (slightly less than 45°) to minimize overlap

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PROCORE 648 VS 648S: Is there a difference in tine displacement and sand reception?

EXTENSION

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Fall 2023

- Is there a difference in solid tine displacement and sand reception?

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Champions Run, Omaha, NE

Aerated on separate areas of the sand-based nursery putting green at 0.125” HOC, with ½” solid tines set at 3” with a 648S and 648. Each area was 60 ft^2.

Sampled for OM with a 1” probe above aeration hole; 0-3” and 3-6” with 10 random locations per aerator. By extension, lower OM soon after aerification = greater sand incorporation.

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Results

	648	648S
OM % 0-3"	2.2a	1.6b
OM % 3-6"	1.6a	1.4a

Different letters within a row indicate statistically significant differences at P < .01 based on a paired t-test with 18df

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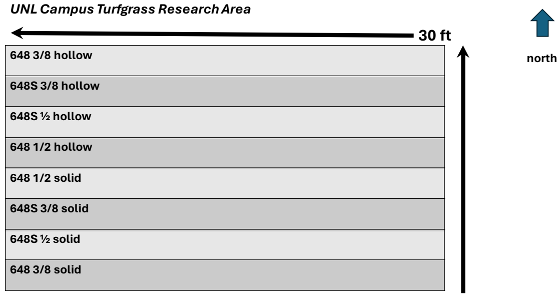
ProCore 648 vs 648S *Spring 2024*
- *Single pass (48” wide E to W)*
- *UNL Campus Turfgrass Research Area*



96

Aerators (set to identical configurations)

- **648S**
  - Champions Club, Omaha, NE
  - 72.5 hours
  - 3” depth
  - Thanks to Superintendent Greg Jones for loan
- **648**
  - Happy Hollow Club, Omaha, NE
  - 17.7 hours
  - 3” depth
  - Thanks to Superintendent Peter Schmidt for loan

Thanks to Dan Parr, Midwest Turf & Irrigation for aerator transport and assistance.

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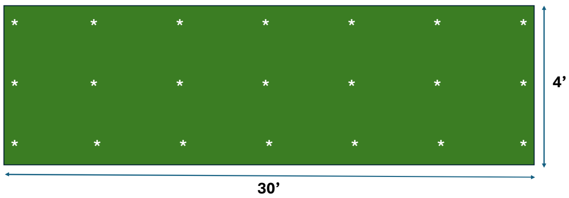
Sampling Locations

Sampled for OM with a 1" probe above aeration hole; 0-3" with 21 locations per plot.
By extension, lower OM soon after aerification = greater sand incorporation.



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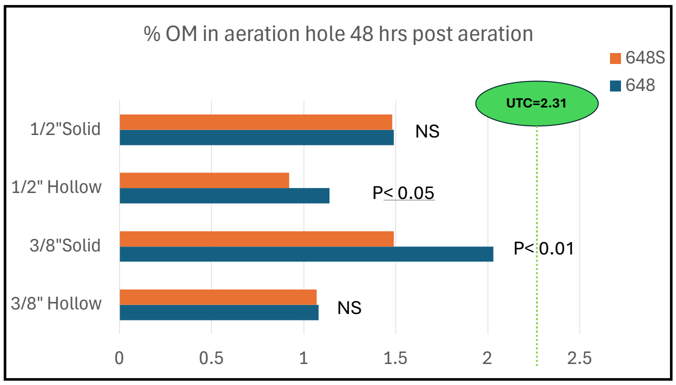
648 648S

99



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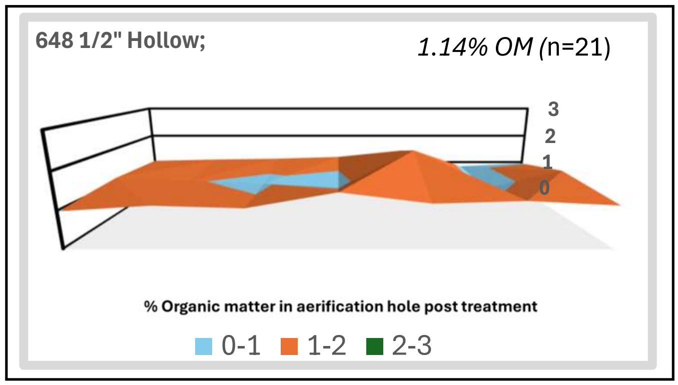

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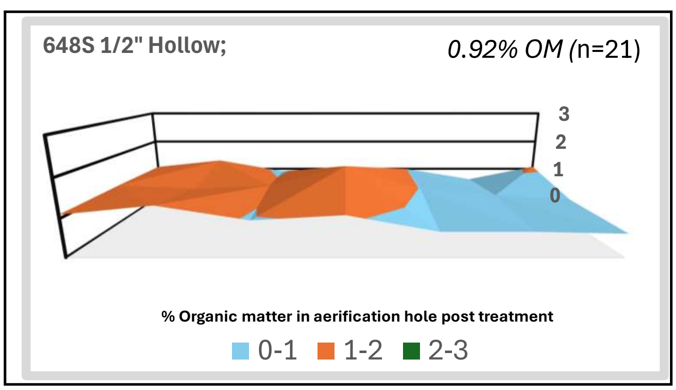

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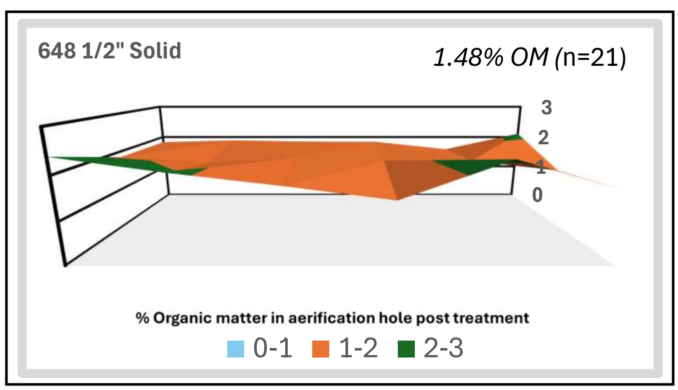

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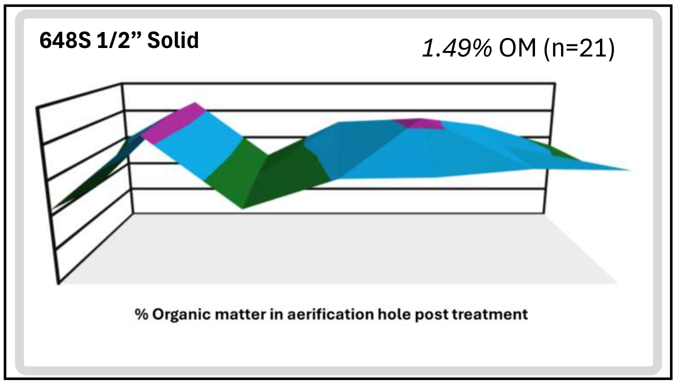

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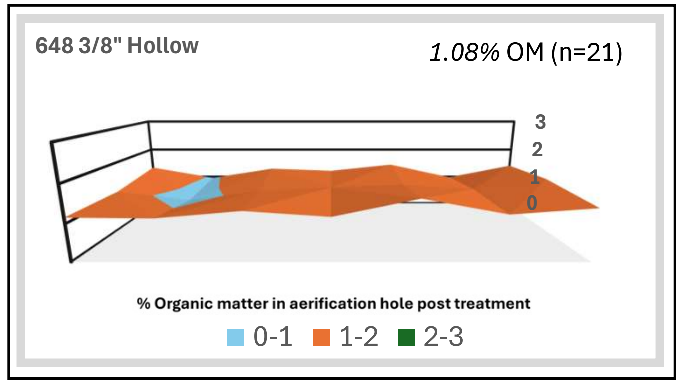

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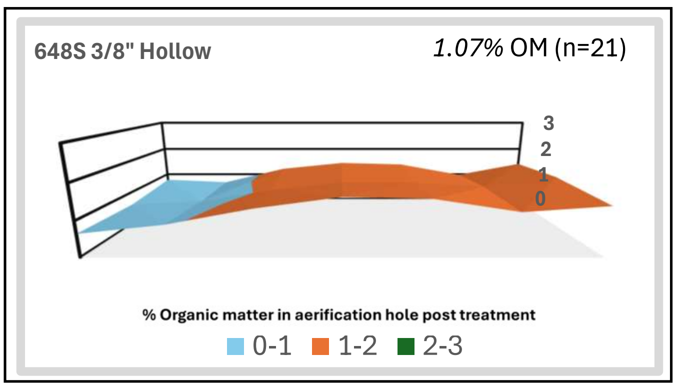

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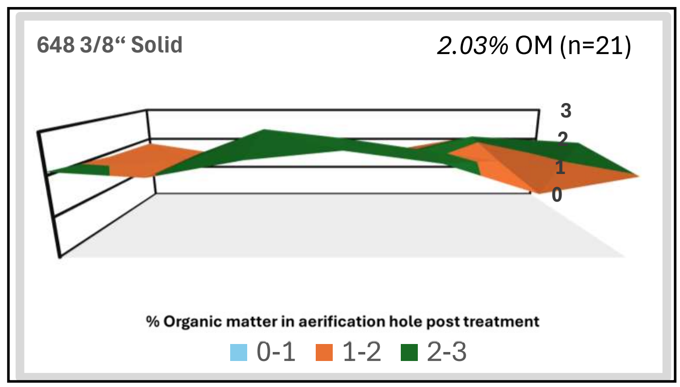

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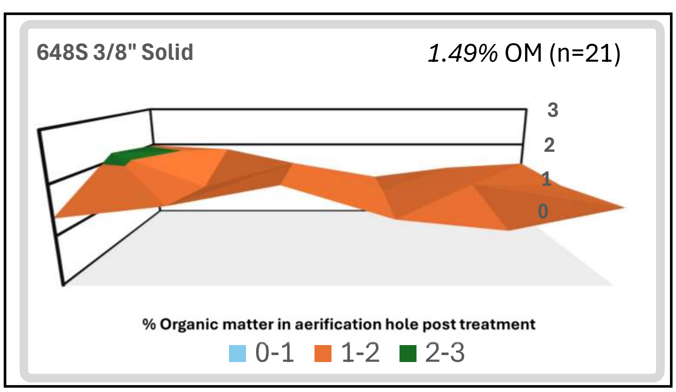

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Random Thoughts

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Bentgrass/ Annual Bluegrass

- 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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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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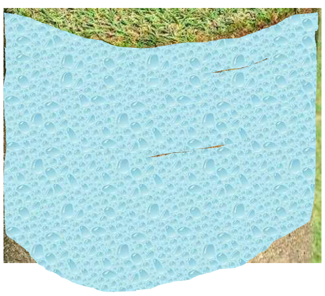

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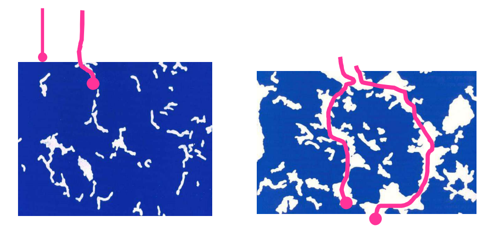
Discontinuous Pore Space



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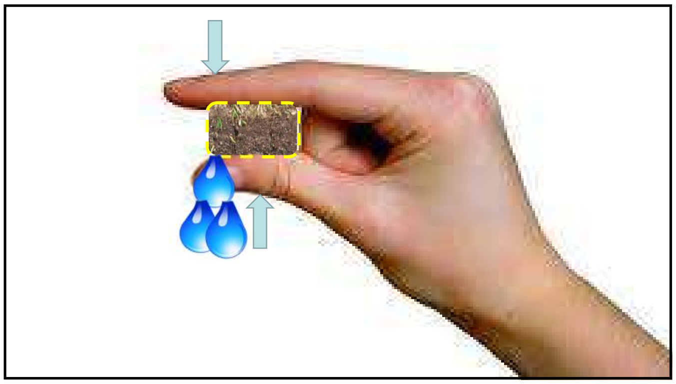

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Soil Moisture Content Prior to Aeration on clay and silt soils

moist — dryer

hollow tine, very compacted ↔ solid tine, slicing, spiking

use soil moisture content to optimize desired effect

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Contact Information

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Thank you!

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