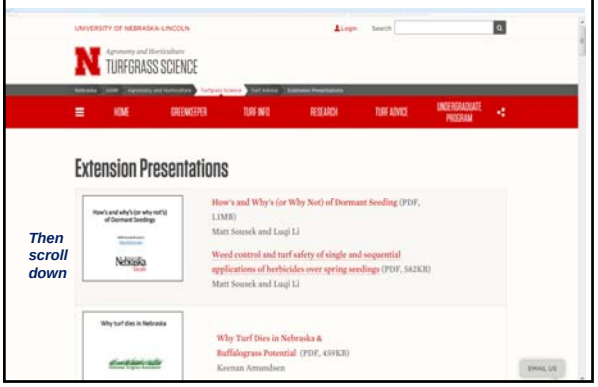
Rootzone Organic Matter Management

Roch Gaussoin
University of Nebraska-Lincoln
rgaussoin1@unl.edu
@rockinsince57

Denver, CO
Dec. 4-6, 2018

ROCKY MOUNTAIN REGIONAL TURFGRASS ASSOCIATION

https://turf.unl.edu/



Then scroll down

The organic matter journey……

- USGA/EIFG Greens Study (9 years).
- People a lot brighter than me
  - "Talking Turf" GCSAA conversation.
  - Paul Rieke, USGA visit
  - Conversation with Paul Vermeulen. Director, Competitions Agronomy at PGA TOUR, former USGA Agronomist.
- Great funding support from USGA (initially), NE-GCSA, GCSA of SD, Peaks and Prairies GCSA, industry and a slew of GC supers (3 years).
- Road Show.

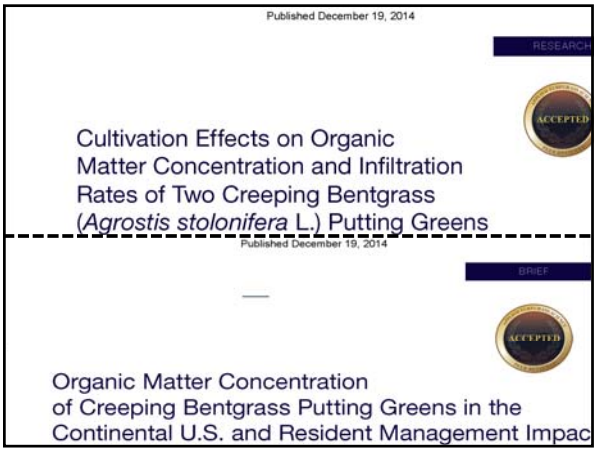
ASA Monograph (3RD Edition)

Chapter 12

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

R.E. Gaussoin, Dep. of Agronomy and Horticulture, Univ. of Nebraska
W.L. Berndt, Dep. of Resort and Hospitality Management, Florida Gulf Coast University
C.A. Dockrell, Teagasc College of Amenity Horticulture Dublin, Ireland
R.A. Drijber, Dep. of Agronomy and Horticulture, Univ. of Nebraska

What do we want to discuss today?



Organic matter development: ***Are We the Problem?***

Or:

is organic matter % the green speed of the new millennium?

How much OM is produced annually?

- Roots = 3500 lbs/acre
- Leaves = 2000 lbs/acre
- Other = 2500 lbs/acre
- TOTAL = ***8000 lbs/acre*** ***8967 kg/ha***

Fairway height blue/rye estimated annual production

How does organic matter accumulate?

- Organic matter; defined
  - dead or near dead plant residue which accumulates in the grass ecosystem

Where does organic matter accumulate?

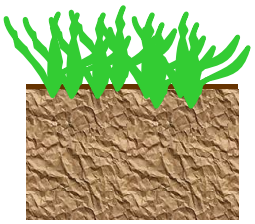
- Above ground
  - Thatch/Mat
  - clipping residue
    - relatively short term
    - "pseudo" thatch
- Below ground
  - root zone
  - rhizosphere

How does organic matter accumulate?

- As grasses mature there is a continual senescence of non or limited function parts (roots, shoots and leaves)
- Senescence also happens when damage or injury occurs

Importance of (P)OM in the rhizosphere

- deposition of particulate OM
- microbial niches
- nutrient uptake
- pathogen competition



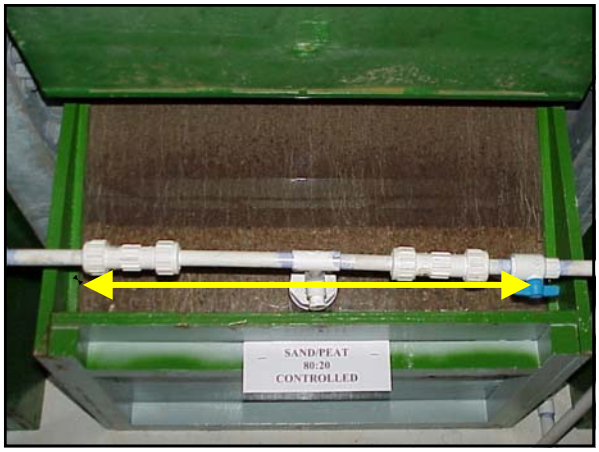
Factors influencing rootzone (P)OM accumulation

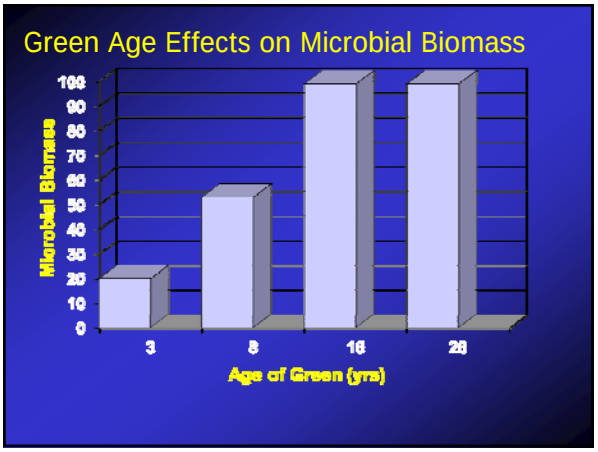
- Mowing
  - increase height=increase rooting
- Irrigation
  - root growth restricted in waterlogged soils
- Cultivation
  - increase or decrease
- Fertility
  - increase or decrease
- Stress

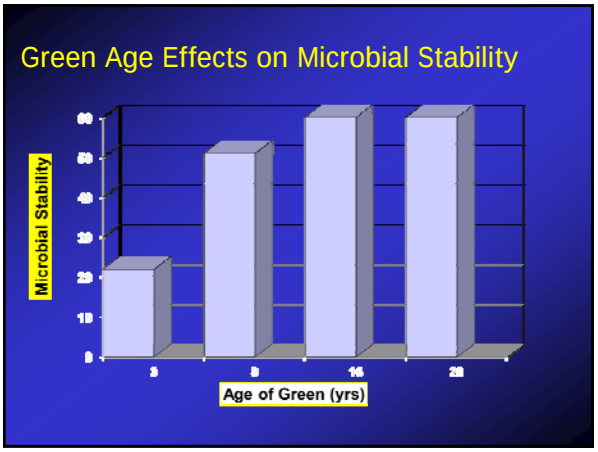
Rootzone accumulation yearly in sand green

Yr 1	2	3
0.65%	6.0%	3.0%

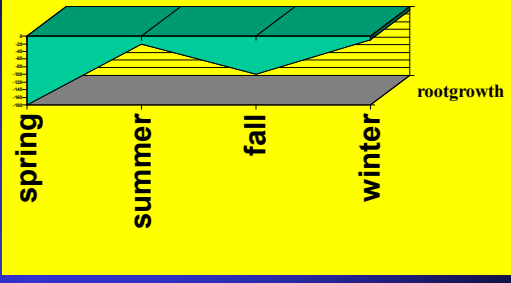
USGA spec. green constructed with 20% (by volume) Sphagnum peat moss



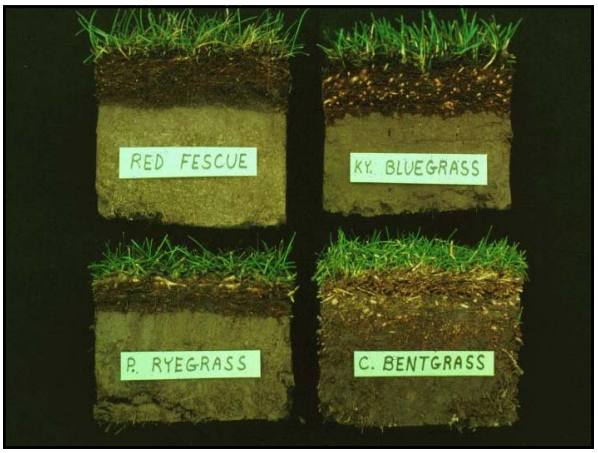




seasonal root growth



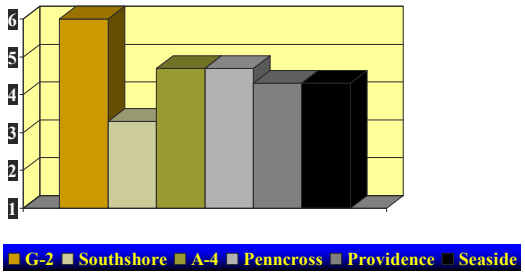
With todays genetics & management, is this still true?



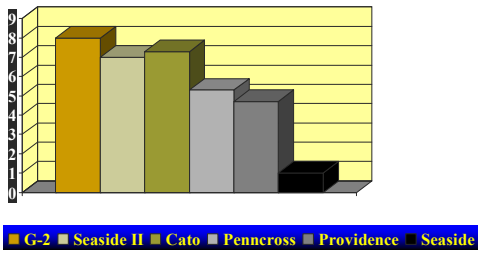
Thatch

A loose, intermingled, organic, layer of dead and living shoots, stems, and roots that develops between the zone of green vegetation and the soil

Greens Height Bentgrass Thatch Thickness (mm)



Fairway Height Bentgrass Thatch Thickness (mm)



Benefits of “Moderate” Thatch

- Improved resilience and cushion
- improved wear tolerance
- insulate soil/crown to temperature extremes

Problems with excessive thatch

- LDS

Problems with excessive thatch

- Footprinting

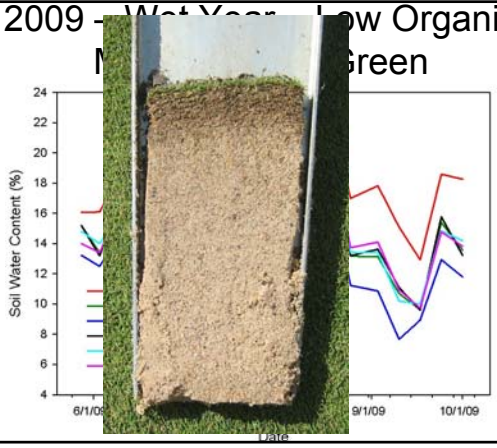
Doug Soldat’s work at UW

- Next 3 slides
- Wetting agents, year differences and low and high OM greens

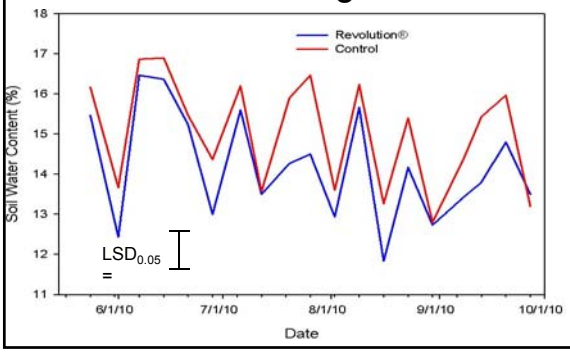
Problems with excessive thatch

- Scalping

2009 – Wet Year – Low Organic M… Green

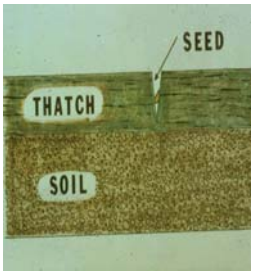


2010 – Wet Year – Low Organic Matter Putting Green

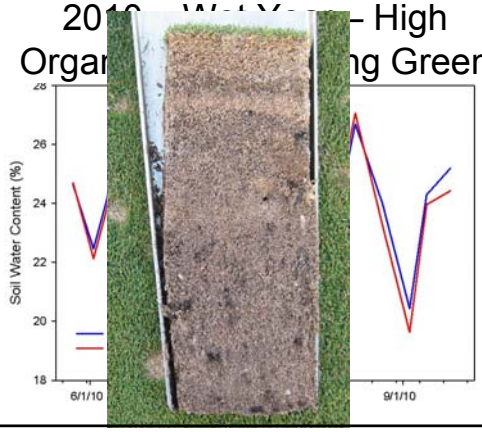


Problems with excessive thatch

- Overseeding Failure



201 – High Organ ng Green

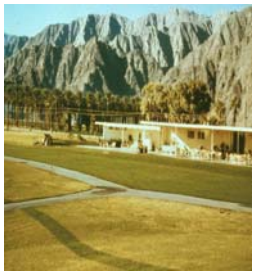


Mat

Thatch that has been intermixed with mineral (soil) matter

Problems with excessive thatch

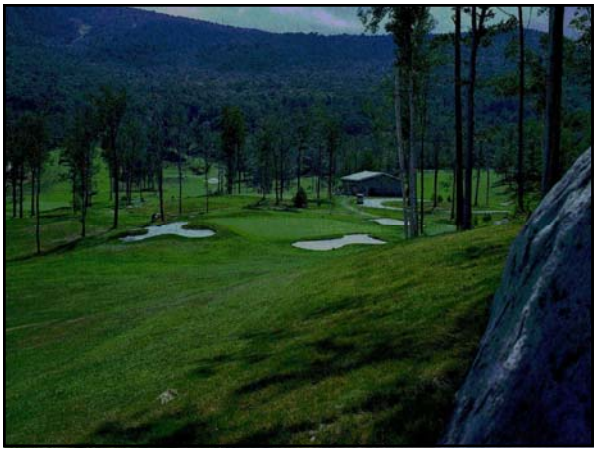
- Reduced Stress Tolerance



Because of inherent ambiguity in terminology and sampling techniques, the term "thatch-mat" has appeared frequently since the late 2000's (McCarty et al., 2007; Barton et al., 2009; Fu et al., 2009).

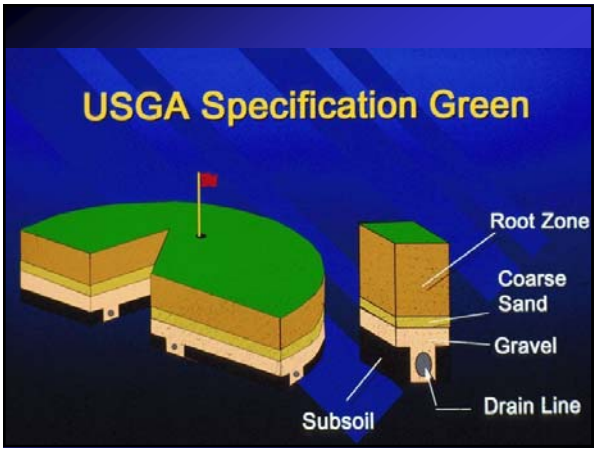
and yet one more definition……..

SOM- Soil Organic Matter



Physical And Chemical Characteristics Of Aging Golf Greens

Roch Gaussoin, PhD
Jason Lewis
Ty McClellan
Chas Schmid
Bob Shearman, PhD



Treatments

- rootzone Mix
  - 80:20 (sand/peat)
  - 80:15:5 (sand/peat/soil)
- Grow-In Procedure
  - Accelerated
  - Controlled

Materials and Methods

9 yr old green	10 yr old green	12 yr old green	13 yr old green

As of 2009

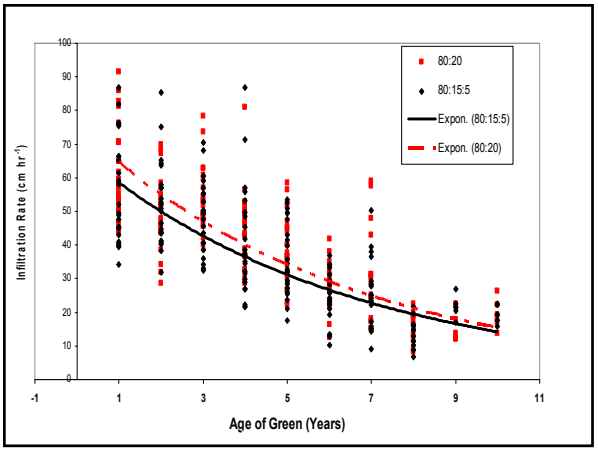
Project Schedule (Phase I)

1996 | 1997 | 1998 | 1999 | 2000

Greens construction (one set per year)

Seeding

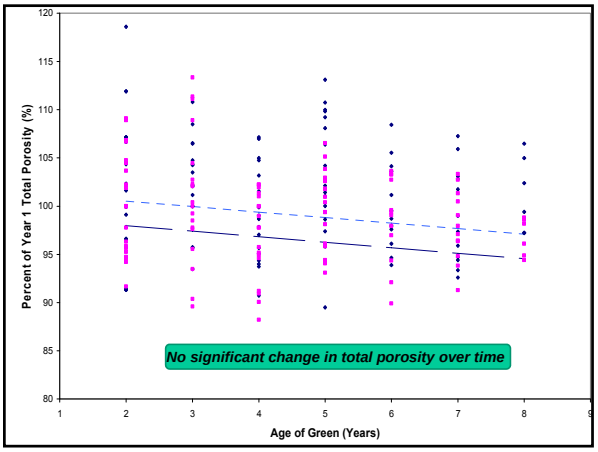
Data collection on soil physical, chemical, and microbial characteristics influenced by rootzone materials and grow-in procedures.

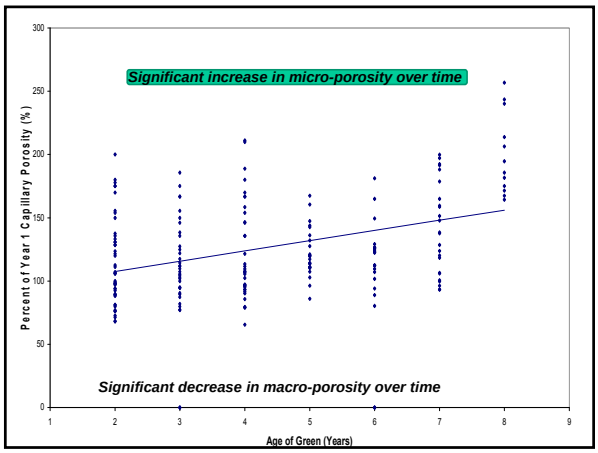


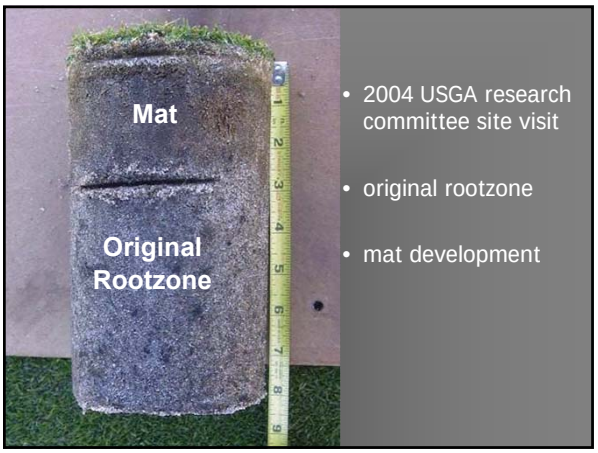
Project Schedule (Phase II)

2002 | 2003 | 2004 | 2005

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





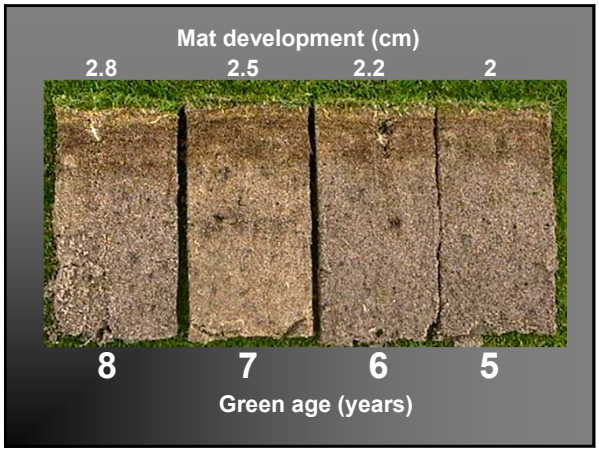


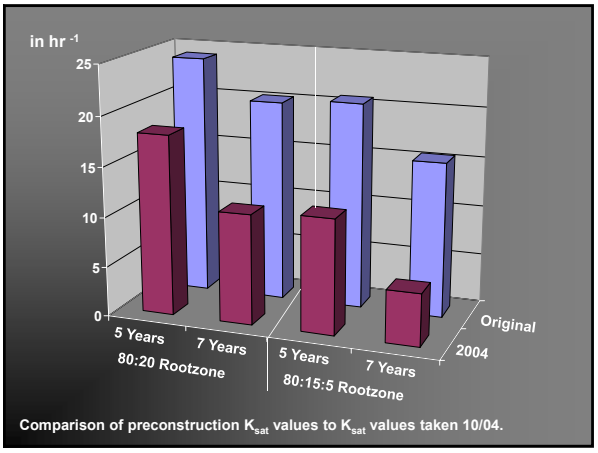
Formation of Mat

- Formation of mat layer increased approximately 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

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).**
- **Other analysis also completed**





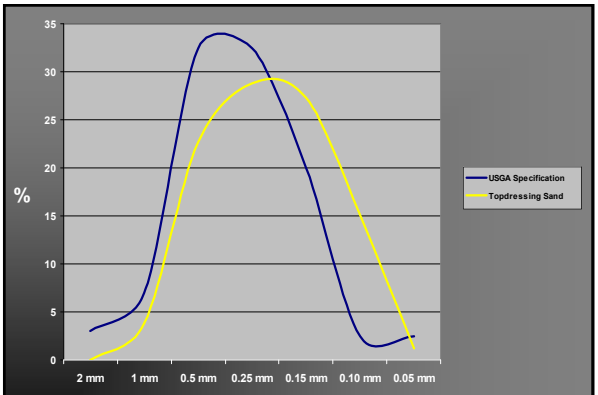
Comparison of preconstruction K_{sat} values to K_{sat} values taken 10/04.

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).**
- **5 of 8 rootzones were significant (z-score) for increased fine sand content.**

Root Zone: Mat vs. Original

- pH:
  - Mat < Original for all USGA and California Greens.
- CEC, OM, and all Nutrients tested:
  - Mat > Original for all USGA and California Greens.



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

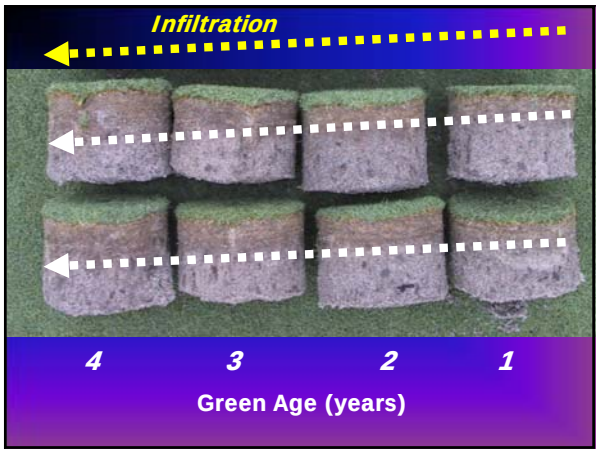
Want to know more?

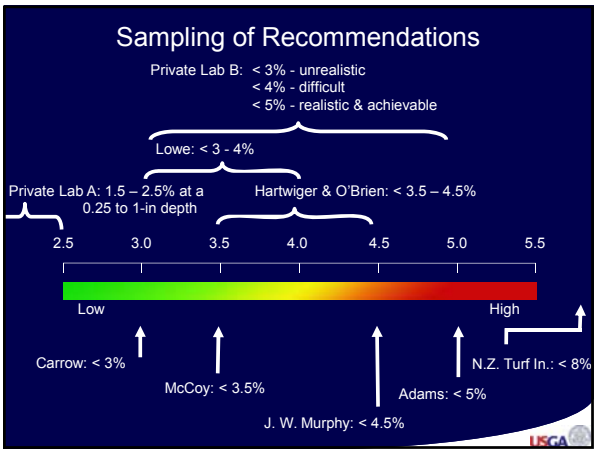
Conclusions

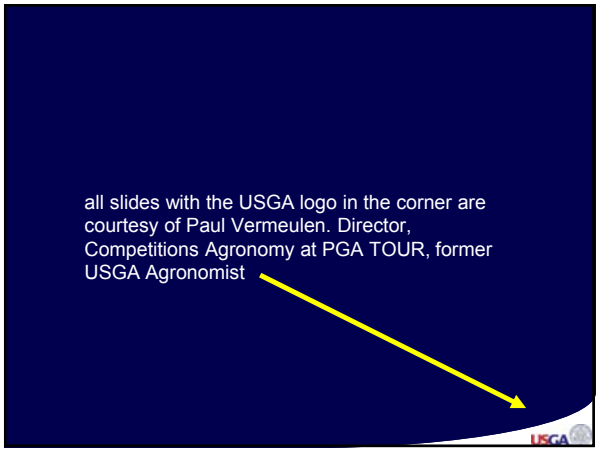
- **The K_{SAT} decrease over time *may* be due to organic matter accumulation above and in the original rootzone and/or the increased fine sand content originating from topdressing sand**

Why is high OM considered to be "bad"?

- **Loss of infiltration**
- **Decreased aeration**
- **Traps "toxic" gases**
- **Are these concerns real or imagined?**
- **Why the confusion?**

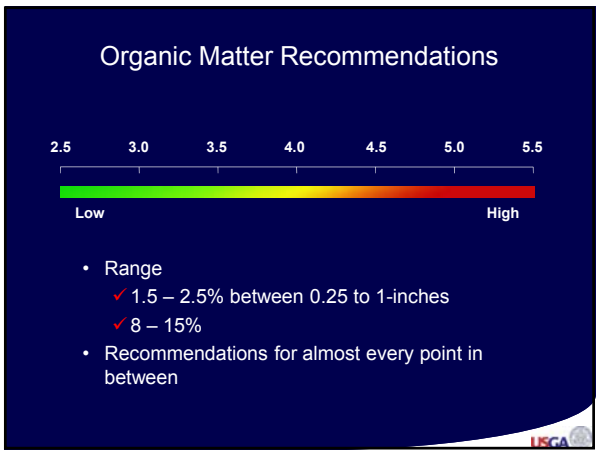


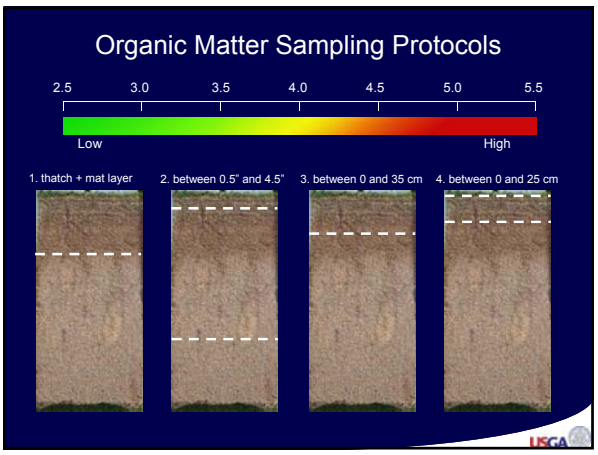




Analysis Methods

- Many exist, but the most relevant is "combustion" or "loss on ignition"
- The sample represents both dead and *living* organic matter
  - Food for thought……



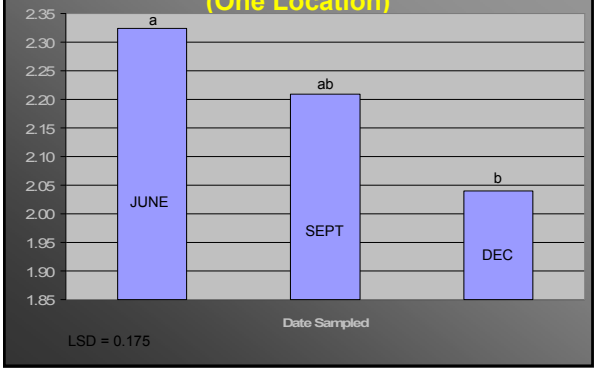


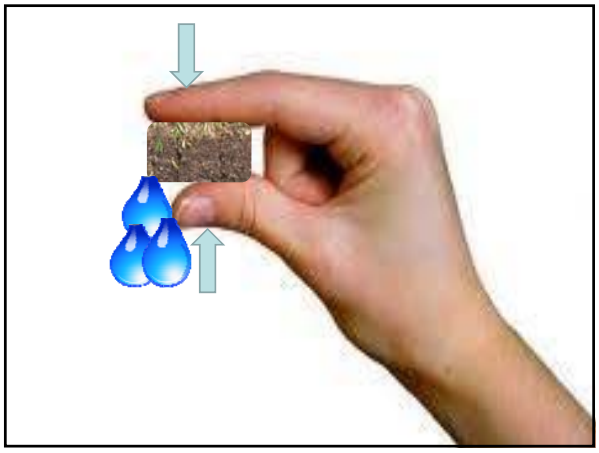
There is no "magic" number

OM Testing

- Know how your sample was taken and compare notes with others that use the same protocol
- Take annual tests to determine long-term trend
  - Same time of year
  - Same location and green
- Correlate your test results with turf quality and performance during stressful environmental conditions to determine need for changes in management program
- Threshold/critical levels likely vary across the United States and from course to course

Seasonal Variation
(One Location)





How do you get rid of OM?

?????

How do you get rid of OM?

- Decomposition (microbial)
  - Increase surface area and aeration
  - Inoculation (???)
- Removal
  - Power raking, verticutting, dethatching, core aerification
- Dilution
  - Topdressing

Locations

- **KY Bluegrass Tee Box**
  - **Native Soil**
- **Bentgrass Green**
  - **California Green**
- **KY Bluegrass Sports Turf**
  - **Sand based**
  - **2.5" Mowing**

Organic Matter Degradation Study

Plot Set-Up
14 Treatments, 3 Reps

Treatments

- Aerator (Granular)
- Aerator (Liquid)
- EXP072
- EXP074
- EXP076
- Carbo-Plex
- Bio-Blend
- *Carbo-Plex + Bio-Blend*
- Bio-Groundskeeper (Granular)
- *Bio-Groundskeeper (Liquid)*
- *Thatch X*
- EXPO70M
- EcoChem Lawn Thatch Reducer
- Untreated Control

Each Plot Core Aerified before Application of Products

Data Collection

- **Infiltration**
- **Penotrometer**
- **Thatch**
- **Organic Matter**
  - **Thatch, 0-3", 3-6"**

Summary

- No product increased degradation of OM

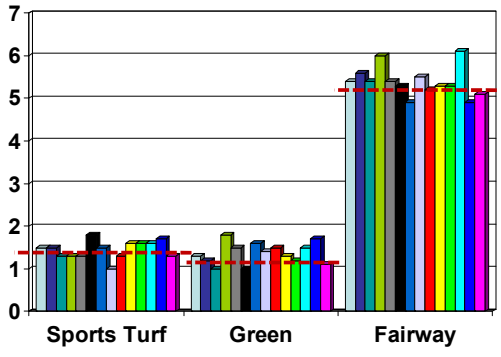
Analysis Summary

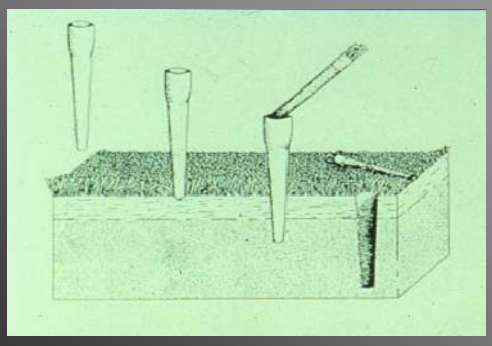
Source	Thatch (mm)	Clegg (g)	Infiltrat (in/hr)	Thatch (OM %)	0-3" (OM %)	3-6" (OM %)
Site	**	*	**	**	**	**
Trtmnt	NS	NS	NS	NS	NS	NS

How effective is removal?

- **Surface disruptive, short and long term**
- **Core aeration is the most widespread practice recommended for OM management**

0-3" OM %



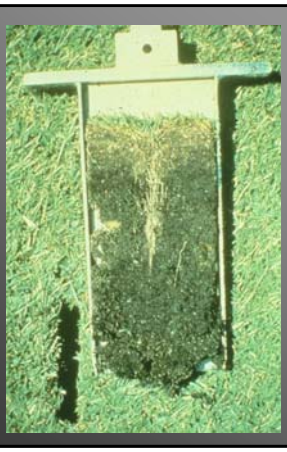


Tine Size and Surface Area Chart

Tine Size (in.)	Spacing (in.)	Holes/ft^2	Surface Area of One Tine	Percent Surface Area Affected
1/4	1.25^2	100	0.049	3.4%
1/4	2.5^2	25	0.049	0.9%
1/2	1.25^2	100	0.196	13.6%
1/2	2.5^2	25	0.196	3.4%
5/8	2.5^2	25	3.07	5.3%

Organic Matter Management

- Funded by:
  - USGA (2006)
  - Nebraska Golf Course Superintendents Assoc. (2007-2009)
  - Golf Course Superintendents Assoc. of South Dakota (2006-2009)
  - Peaks & Prairies GCSA (2007-2009)



Project Objective

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

Sampling Procedures

Years 1, 2, & 3

- At least 3 different greens per golf course sampled
- Soil samples taken from 3 different area per green
- Samples are evaluated for OM levels using LOI
- GPS location

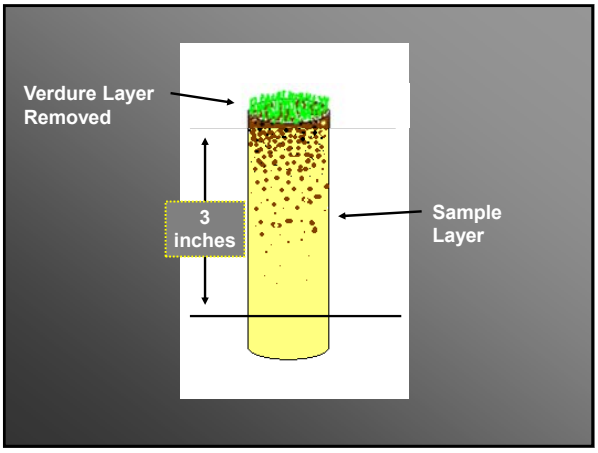
- ***Management & Site survey***

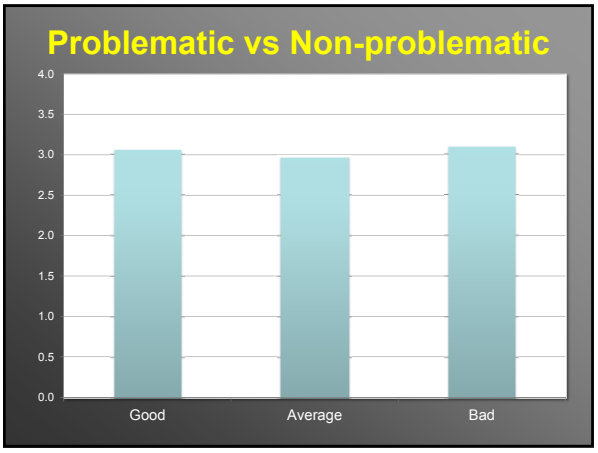
2006/07/08 Samples

- **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

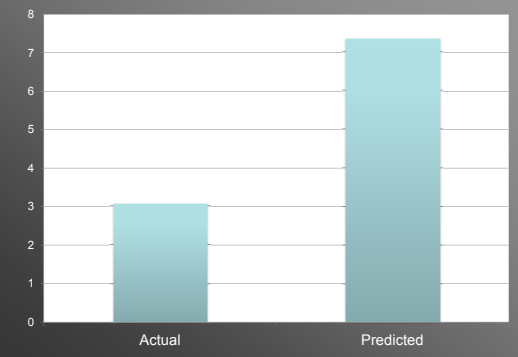
Sampling Methods

- Samples from at least 3 greens per course
  - (1) Problematic, (1) Non-problematic plus rebuilt or varied age/management
- 3 samples from each green
- Samples taken with ¾ inch soil probe

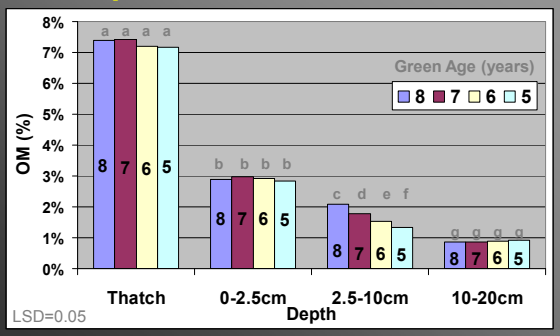




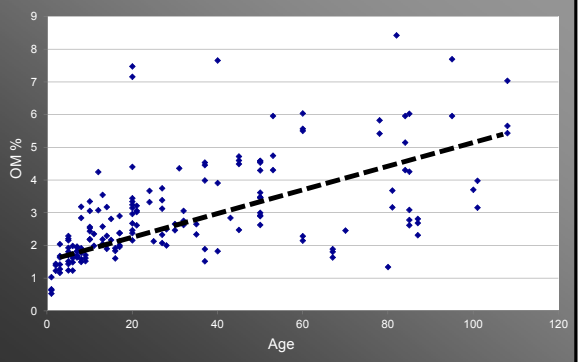
Superintendent predicted vs actual



Organic Matter in USGA Specification Rootzones



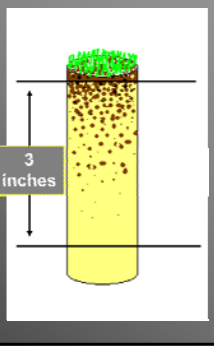
Green Age



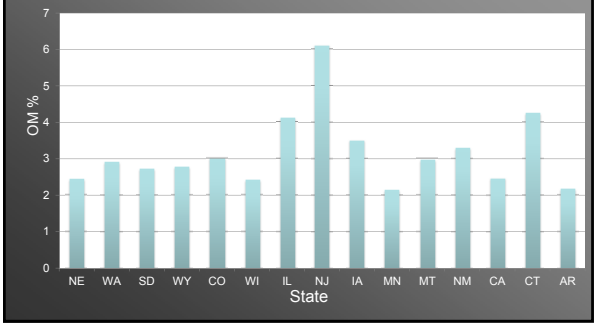
Mat Development with Age

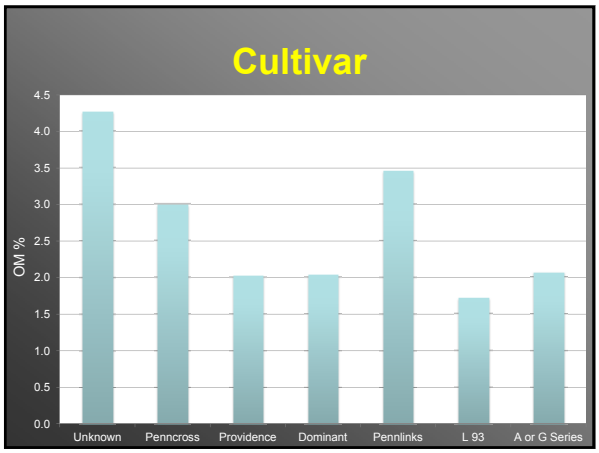
Is the age effect misleading?

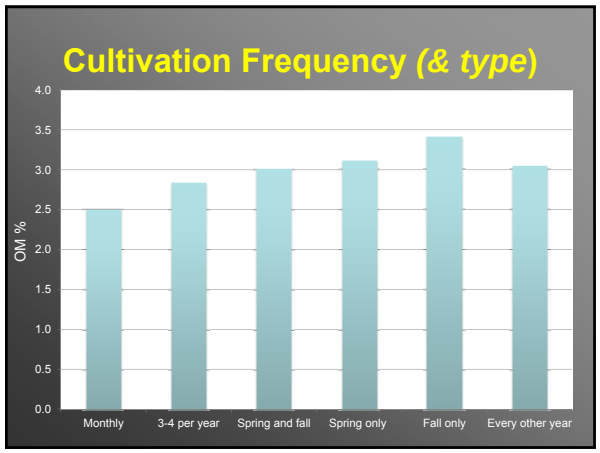
- **Sampling issue:**
  - **Mat depth increases as green ages resulting in more OM in the same volume soil.**

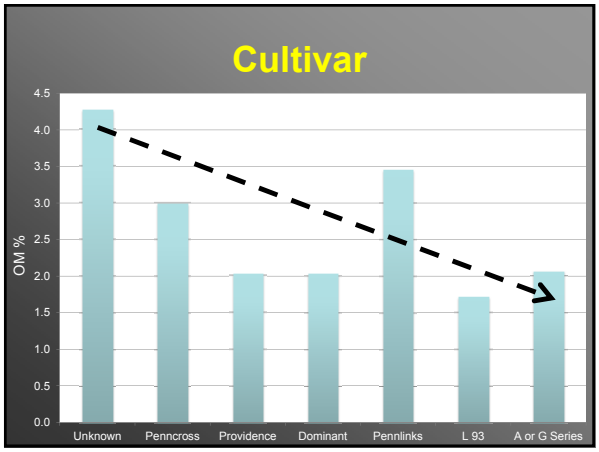


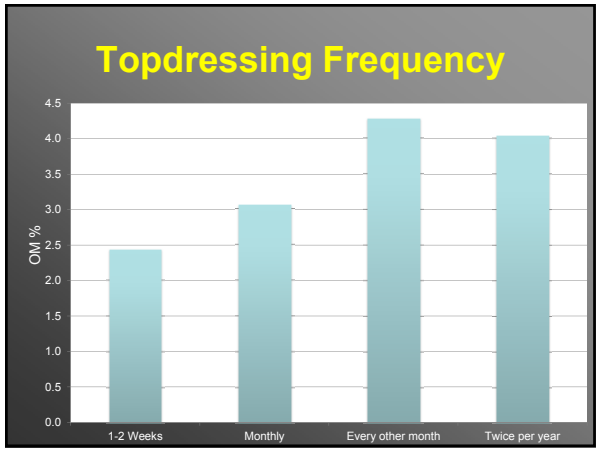
State Differences (highly correlated with age)

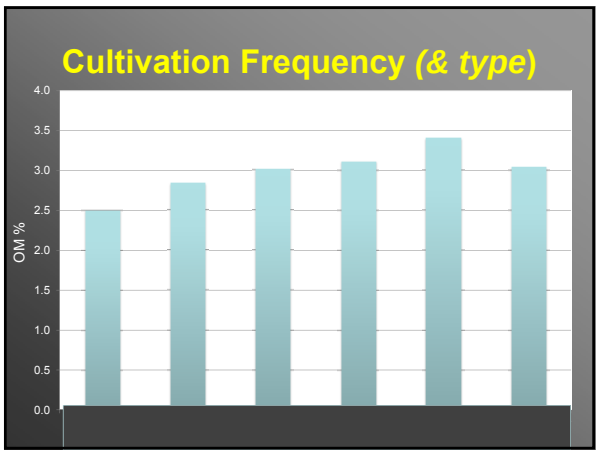


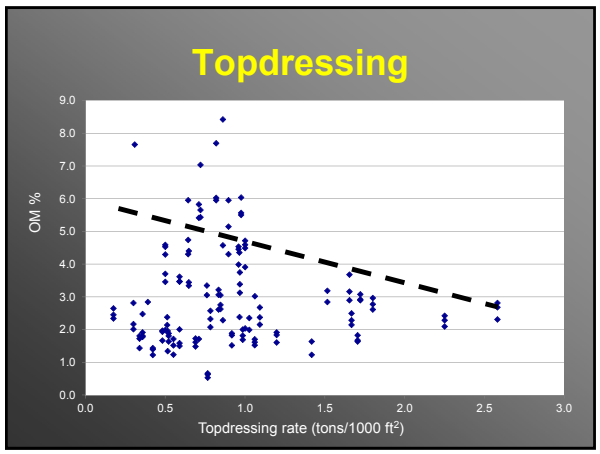

Cultivar
OM %
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Unknown
Penncross
Providence
Dominant
Pennlinks
L 93
A or G Series


Cultivation Frequency (& type)
OM %
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Monthly
3-4 per year
Spring and fall
Spring only
Fall only
Every other year


Cultivar
OM %
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Unknown
Penncross
Providence
Dominant
Pennlinks
L 93
A or G Series


Topdressing Frequency
OM %
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1-2 Weeks
Monthly
Every other month
Twice per year


Cultivation Frequency (& type)
OM %
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0

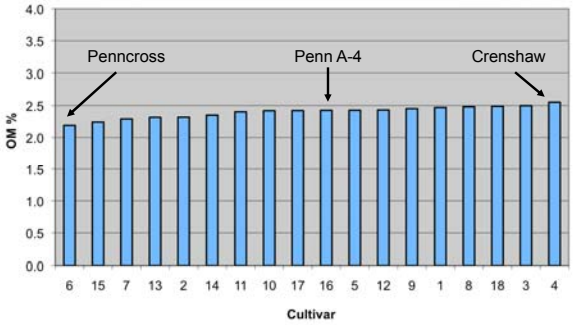

Topdressing
OM %
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Topdressing rate (tons/1000 ft²)

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" consistently had the lowest OM
- Of the ***known*** cultivars, no differences in OM were evident

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

Onsite NTEP Bentgrass Evaluation

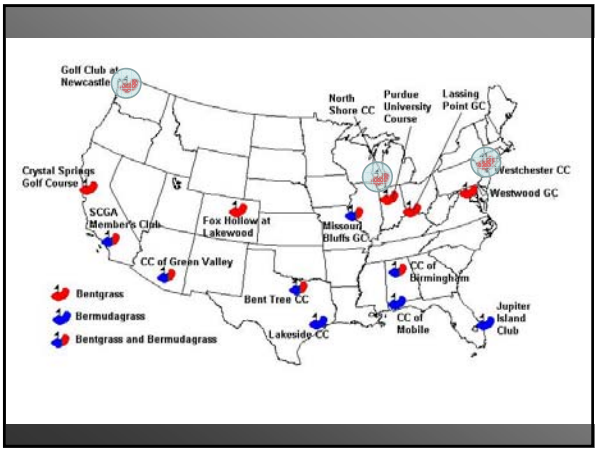


Onsite NTEP Cultivar Evaluation

1	L-93	10	SR 1020
2	Putter	11	SR 1119
3	Cato	12	Viper
4	Crenshaw	13	Century
5	LCB-103	14	Imperial
6	Penncross	15	Penn A-1
7	Backspin	16	Penn A-4
8	Trueline	17	Penn G-6
9	Providence	18	Penn G-1

"New ultra-dense varieties of bentgrass and bermudagrass are especially susceptible to excessive organic matter accumulation due to high shoot density and the ability to grow a deep, dense root system in sand-based rootzone material. Working topdressing into a tight canopy of turf is a challenge, and much of the sand can be removed with the clippings."

Vavrek, 2006



Topdressing and the new bents

Easy or hard???

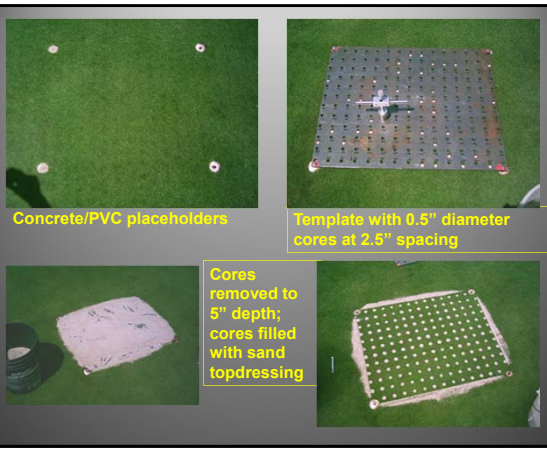
Pulling cores or poking holes?

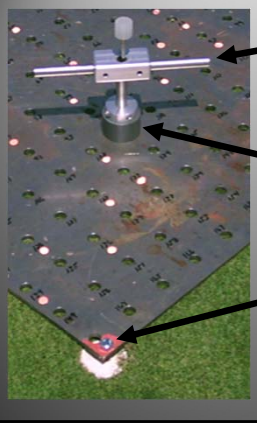
- In 2005, 45 of 141 courses surveyed* planned no core removal
  - Many had not pulled cores for 2-20 years
- 75 planned to pull cores
  - 35 of the 75 had no agronomic reason to pull a core (based on USGA Agronomist evaluation) while 40 "needed" to pull cores
- With current and evolving cultivation/topdressing/ rootzone technologies is pulling a core ***always*** necessary?
- Finally, is core cultivation an effective way to manage OM ?

* *Mid-continent region USGA*

Let's take a quick look at that…

New bents = denser and more upright





Organic Matter Management Study

Objectives

1. Determine if conventional hollow tine is more effective than solid tine aerification at managing organic matter accumulation

- 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”

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 (less invasive cultivation) methods are effective at managing OM accumulation

		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*

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

Survey Anticipated Results

- Cool-season - gradual increase in annual topdressing rate from north to south and east to west corresponding to length of growing season
- Warm-season – changes in annual topdressing rate corresponding to overseeding practices, length of growing season, annual rainfall
- Surveys are not research!
  - ✓ fertility
  - ✓ traffic
  - ✓ green construction
  - ✓ etc.

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

Survey Expectations

- Cool-season - gradual increase in annual topdressing rate from north to south and east to west corresponding to length of growing season
- Warm-season – changes in annual topdressing rate corresponding to overseeding practices, length of growing season, annual rainfall
- Surveys are not research!
  - ✓ fertility
  - ✓ traffic
  - ✓ green construction
  - ✓ etc.

Regional Survey

- Annual topdressing rate for 10 well maintained courses in each region
  - Stable maintenance program during past 5 growing seasons
  - Same general turf conditions
- Surveys are not research!
  - Fertility
  - Traffic
  - Green construction
  - Etc.

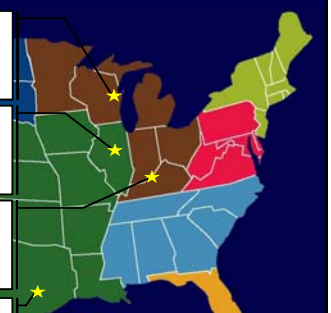
Central United States – Cool-season

North-Central, Elm Grove, WI	Topdressing (ft3/1,000ft2/yr)
Mean:	20.7
Range:	8.4 – 34.5
Standard Deviation:	8.2

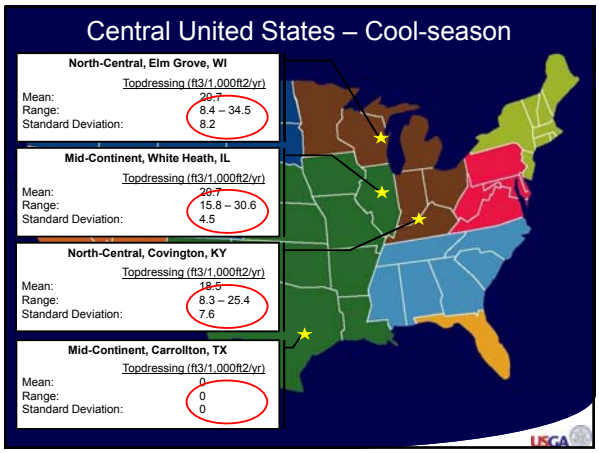
Mid-Continent, White Heath, IL	Topdressing (ft3/1,000ft2/yr)
Mean:	20.7
Range:	15.8 – 30.6
Standard Deviation:	4.5

North-Central, Covington, KY	Topdressing (ft3/1,000ft2/yr)
Mean:	18.5
Range:	8.3 – 25.4
Standard Deviation:	7.6

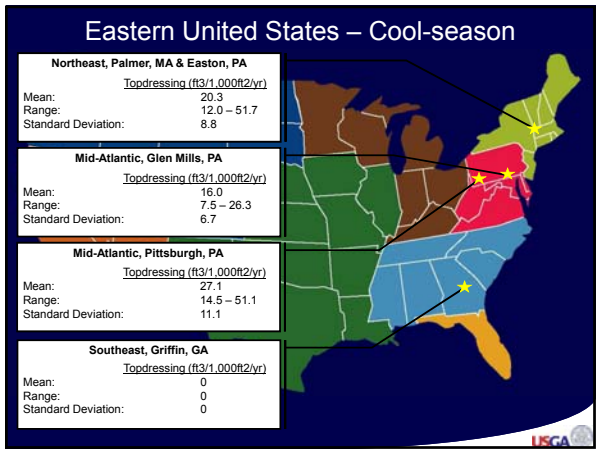
Mid-Continent, Carrollton, TX	Topdressing (ft3/1,000ft2/yr)
Mean:	0
Range:	0
Standard Deviation:	0



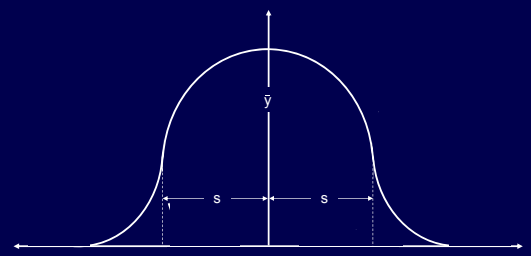
Central United States – Cool-season



Eastern United States – Cool-season

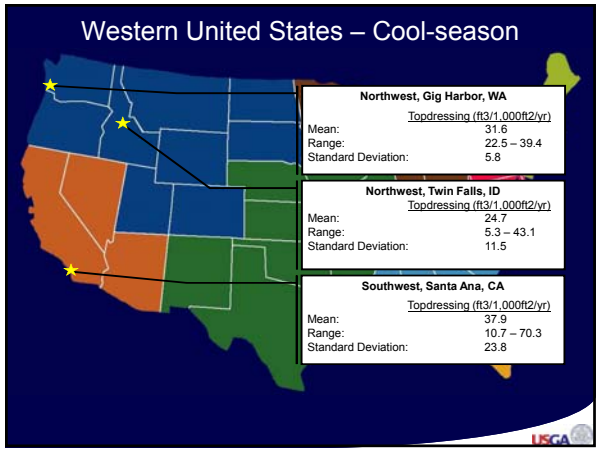


Empirical Rule

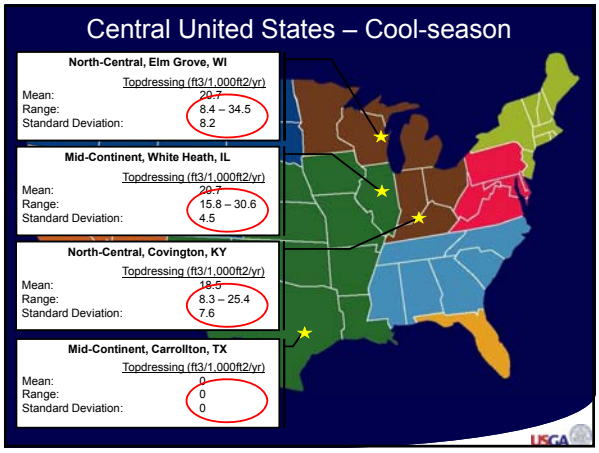


68% of measurements are within plus or minus one standard deviation (s) of the mean (ȳ)

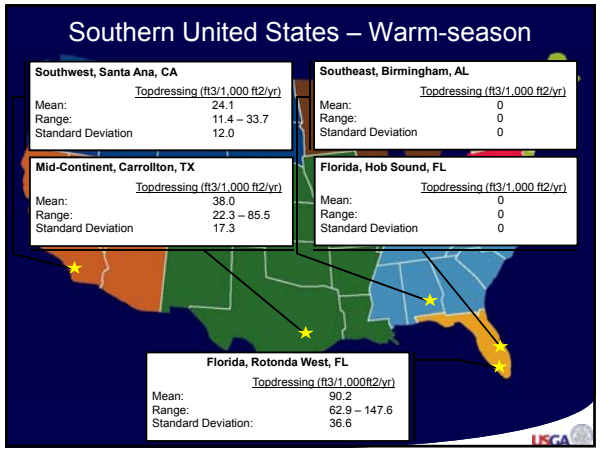
Western United States – Cool-season



Central United States – Cool-season



Southern United States – Warm-season



Regional Topdressing Survey Summary

Region/Turf	Ave. Rate $ft^3/1{,}000ft^2/yr$	Range $ft^3/1{,}000ft^2/yr$	Sample Standard Deviation
Florida – Upper / ultradwarf, overseeded			
Florida – Lower / ultradwarf, non-overseeded	90.2	62.9 – 147.6	36.6
Mid-Atlantic - Eastern / cool-season	15.8	7.5 – 26.3	6.7
Mid-Atlantic – Western / cool-season	27.1	16.2 – 51.1	11.1
Mid-Continent – Lower / cool-season			
Mid-Continent – Lower / ultradwarf, non-overseeded	38.1	22.3 – 85.5	17.3
Mid-Continent – Upper / cool-season	20.8	15.8 – 30.6	4.5
North-Central – Upper / cool-season	20.7	8.4 – 34.5	8.2
North-Central– Lower / cool-season	18.5	8.3 – 25.4	7.62
Northeast / cool-season	20.3	12.0 – 51.7	8.8
Northwest - Coastal / cool-season	31.6	22.5 – 39.4	5.8
Northwest - Inland Northern Rockies / cool-season	24.7	5.3 – 43.1	11.5
Southeast – Lower / ultradwarf, non-overseeded			
Southeast – Upper / cool-season			
Southwest - Coastal California / cool-season	38.0	10.7 – 70.3	23.8
Southwest - Desert / warm-season, overseeded	24.1	11.4 – 33.7	12.0

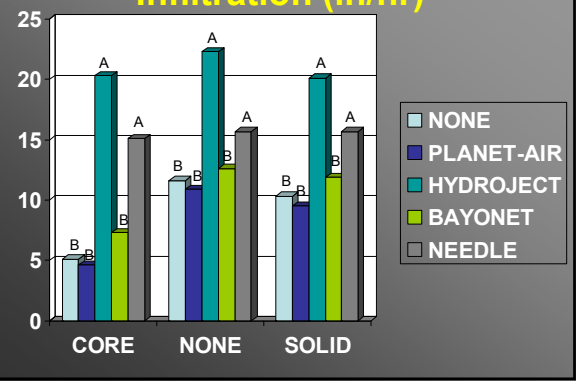
Materials and Methods

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

Survey Review

- Regional differences were found, however not exactly as predicted
- Some differences did not appear to have a basis in agronomy or climatic conditions
- Survey results generate multiple questions regarding current industry practices and suggest need to conduct further research in the area of organic matter management
- It is premature to conclude that the survey provides guidance for establishing sound topdressing recommendations due to the broad range of the data and the very high standard deviation found in most regions

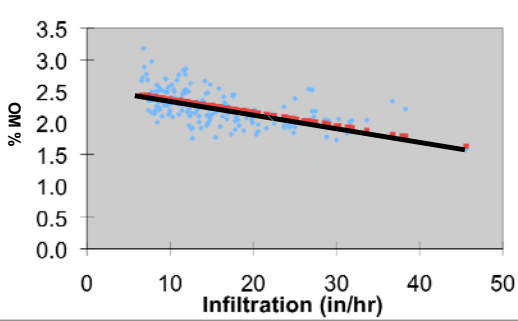
Infiltration (in/hr)



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

Equilibrated to identify differences of the practices in question

Relationship between OM and Infiltration

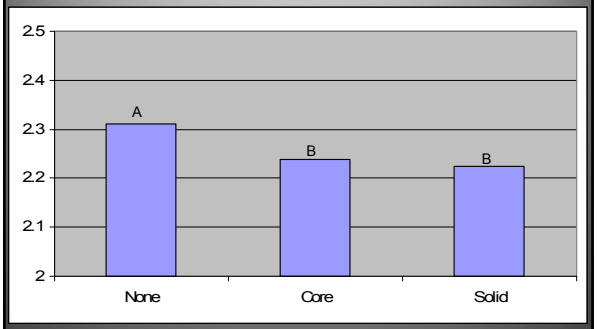


*Significant at α = 0.01

OM Data Analysis Year 1

- No differences between green age except for higher % in older green

Effect of Aerification on OM



OM Data Analysis Year 1

- No differences between green age except for higher % in older green
- No differences among venting methods

OM Data Analysis Year 2

- No differences between green age except for higher % in older green

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

OM Data Analysis Year 2

- No differences between green age except for higher % in older green
- No differences among venting methods

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

What these data do/don't suggest

- Topdressing is the most consistent and repeatable factor in OM management
- Cultivation was insignificant as a means to control OM
- However, a superintendent must use whatever tools they have at their disposal to insure sand is making it into the profile and not the mower buckets

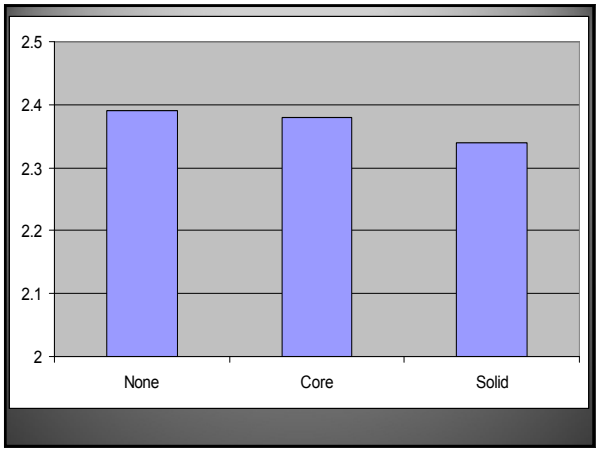
OM Data Analysis Year 2

- 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**

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

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

*Observed and calculated based on displacement and surface area opened



GreenKeeper Survey

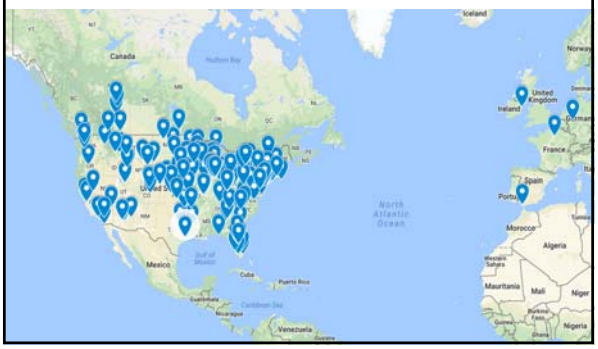
cool season only, mark all that apply

In the last 5-10 years, on our greens, our facility has:

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

"the solution to pollution is dilution"

Survey Respondents via Greenkeeper



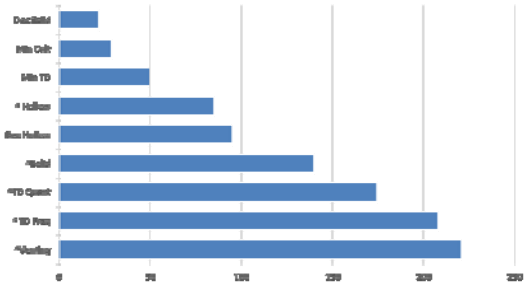
Topdressing

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"

303 Responses



How much sand to use for topdressing?

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

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

Growth Potential

- #clipvol
- Pace Turf
- Micah Woods
- Bill Kreuser
- Others….

Layering

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

NOT a function of drainage

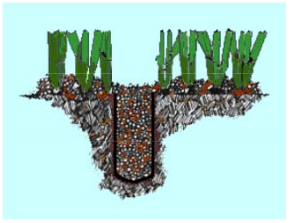
Rather it is the difference in pore size distribution among layers

Soldat's Hierarchy of Golf Course Soil Problems

- **Compaction**
- Excessive organic matter and thatch accumulation
- Layering

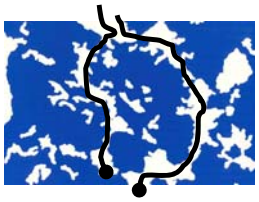
Layering

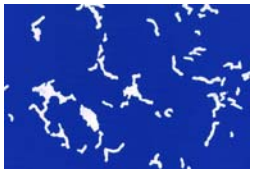
- Aeration alone not that effective
- Must topdress to dilute OM (change its pore size distribution) and use deficit irrigation



"the solution to pollution is dilution"

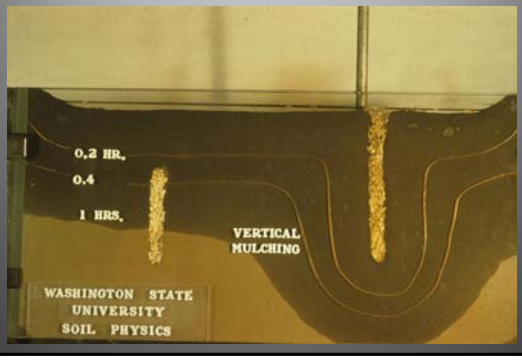
Soil Macropores





Compacted

Continuity of Soil Pores



How do you get rid of OM?

- Decomposition (microbial)
  - Increase surface area and aeration
  - Inoculation
- Removal
  - Power raking, dethatching, core aerification
- Dilution
  - Topdressing

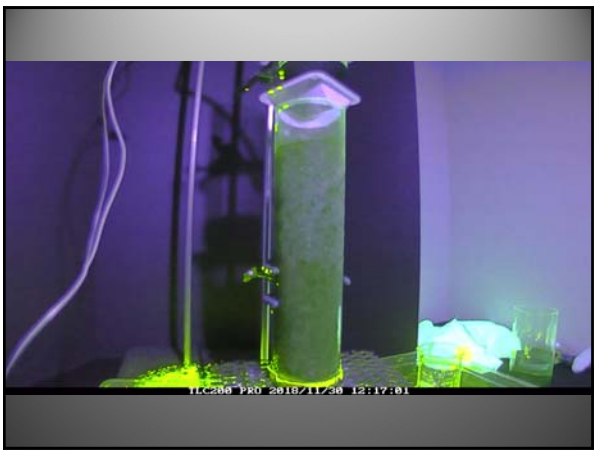
Clarification/over-simplification *regarding OM Management* on sand based rootzones

- One size does not fit all
- The optimal % OM has not been scientifically/universally determined and may be mythical
- Cultivation is critical to increase efficiency in sand incorporation
- Solid are not different than coring tines
- The benefits of topdressing continue to be identified.

What is the “best” way to get sand into the profile?

Organic Matter Update

- *“the solution to pollution is dilution”*
- Next Steps
  - Topdressing impacts on structure and fluid dynamics



Acknowledgements

- USGA
- Environmental Institute for Golf
- Nebraska GCSA
- GCSA of South Dakota
- Peaks & Prairies GCSA
- Jacobsen, Toro, JRM & PlanetAir
- Nebraska Turfgrass Association