MLSN Guidelines and Growth Potential

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and
Larry Stowell, Ph.D., PACE Turf

What you will learn

- How soil and plant nutrient guidelines are developed
- What turf nutrients are really needed
- Developing a nutrient budget
- MLSN & GP adoption at Pender Harbour
- Estimating nutrient input from organic matter and irrigation water
- MLSN, GP and new nutrient restrictions

Who am I?

- Superintendent at Pender Harbour Golf Club for past 10 years
- Blogger
- Citizen scientist

Who am I?

- jturf27@gmail.com
- @PenderSuper
- www.turfhacker.com
- www.linkedin.com/in/jasonhaines1

Who am I?

- Husband and Dad
- Rope Rescue Team Leader for Sunshine Coast Search and Rescue

Where am I?

- Semi Private 9 hole course.
- 1 acre poa/bent greens
- 10 acres fairways
- 0.75 acres tee

Where am I?

- One of the most northerly courses in N. America that is open year-round

Who am I?

- Turfgrass researcher and consultant, 28 years
- Ph.D. in Plant Pathology, 1982
- Post Doc University of California, Davis
- Certified Professional Agronomist - retired
- Author of 4 book chapters, 2 patents, many publications
- Owner of PACE Turf, LLC with Dr. Wendy Gelernter

Who am I?

- stowell@paceturf.org
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- @paceturf
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- www.facebook.com/mlsnturf
- www.linkedin.com/in/larrystowell
- www.researchgate.net/profile/Larry_Stowell

Who am I?

- Micah Woods, Ph.D.
- info@asianturfgrass.com
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- @asianturfgrass
- www.facebook.com/mlsnturf
- www.facebook.com/globalsoilsurvey
- www.linkedin.com/in/micah-woods-57a94522
- www.subscribepage/mlsn

Keep it simple

- MLSN (minimum levels for sustainable nutrition) are baseline soil nutrient concentrations – don't let soils drop below these levels
- No nutrient response is expected when soil levels are maintained above the MLSN values
- GP (Growth Potential) is a method to estimate plant needs to help predict what fertilizers are required to maintain soil levels above MLSN guidelines

Keep it simple
Mehlich-3 extraction

	MLSN ppm
P	**21**
K	**37**
Ca	**331**
Mg	**47**
S	**7**
pH	**5.5-8.5**

Global Soil Survey

Mehlich 3	SLAN	MLSN	GSS	GSS Median
P	50	21	23	71
K	110	37	32	61
Ca	750	331	254	623
Mg	140	47	39	84
S	15 - 40	7	8	15

Conventional soil test

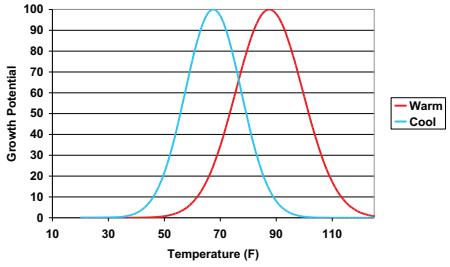
Bill Kreuser
University of Nebraska
Extension Publication
G2265

Figure 1. Soil test reports consist of three parts. Results (red) are the nutrient values produced by the laboratory. Interpretations (purple) and recommendations (blue) are included to make sense of the values in the results section.

Turf Growth Potential

- A simple growing degree day model based upon the standard normal distribution
- Used to predict cool- vs. warm-season turf performance in different locations
- Calculated by comparing the average temperature in a location with the optimum growth temperatures for a given turf type
- Growth potential >50% results in vigorous growth

Growth Potential
Estimate what the plant needs

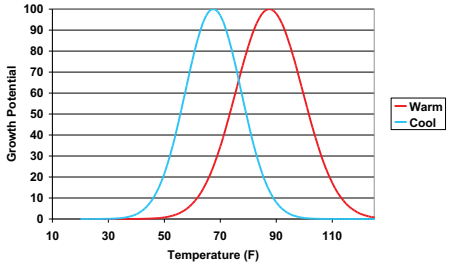


$$GP := 100 \cdot \left[\frac{1}{e^{\frac{1}{2} \cdot \left[\frac{(obsT - optT)}{sd} \right]^2}} \right]$$

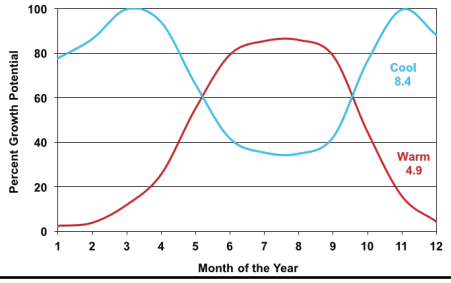
- GP = Growth Potential
- obsT = observed temperature (F)
- optT = mean optimum growth temp. (68 for C3, 88 for C4)
- sd = standard deviation (10 for C3, 12 for C4)
- e = natural logarithm base (2.718282…)

Cool-season turf
grows best 60-75F (X=68)
poor growth >80F & <50F

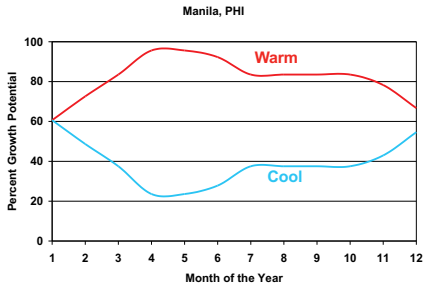
Warm-season turf
grows best 80-95F (X= 88)
poor growth <55 (dormancy)



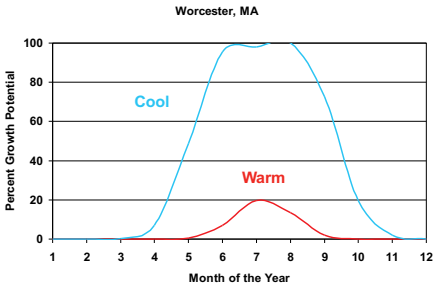
Growth Potential
Orlando, FL



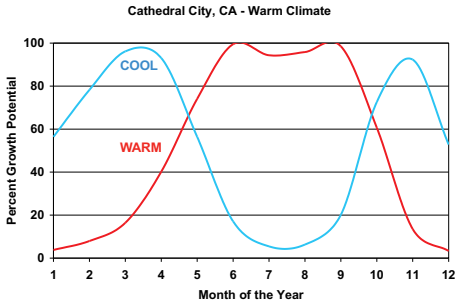
Clear dominance of warm-season turf



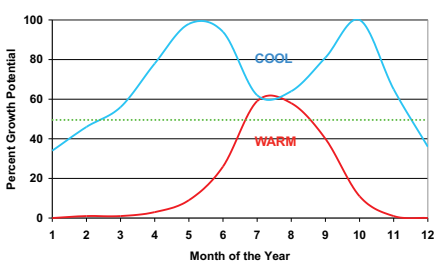
Clear dominance of cool-season turf



Transition environment



Transition environment



Why MLSN & GP?

Why MLSN & GP?

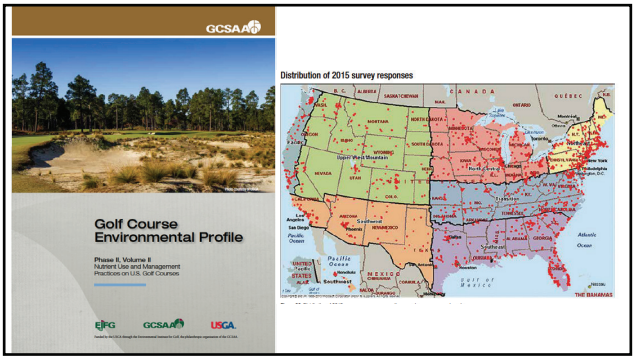
Apply the right amount of fertilizer – just what the grass requires

Why MLSN & GP

- Best grass possible – just what is needed
- Save money
- Avoid applying products that are not needed
- Reduce environmental impact
- Increase sustainability

Why MLSN & GP?

- Since 2006, 618 US golf facilities have closed (9%)
- Nitrogen based fertilizer cost has increased by >60%
- Phosphorus and potash fertilizer costs have increased by >100%



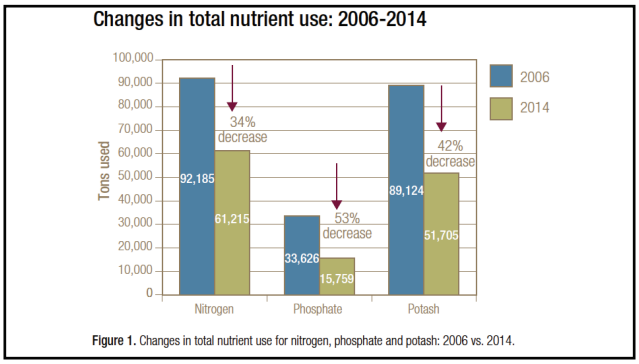


Figure 1. Changes in total nutrient use for nitrogen, phosphate and potash: 2006 vs. 2014.

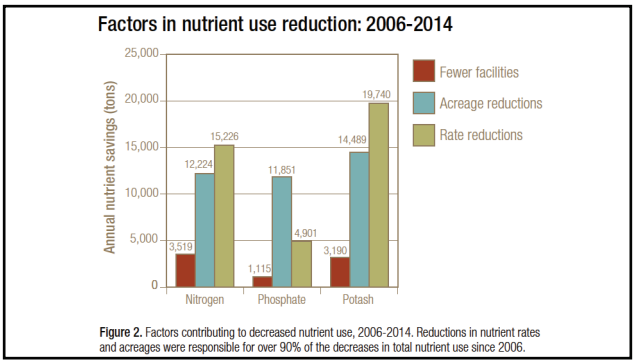


Figure 2. Factors contributing to decreased nutrient use, 2006-2014. Reductions in nutrient rates and acreages were responsible for over 90% of the decreases in total nutrient use since 2006.

Restrictions on fertilizer applications

Restriction type	% of 18 hole facilities with restriction	
	2006	2014
Nutrient restrictions of any type	8 a	24 b
Phosphorus (total yearly amount or amount/ application)	5 a	19 b
Required buffer strips	3 a	8 b
Date restrictions for applications	<1 a	8 b
No-apply zones	2 a	7 b
Nitrogen (total yearly amount or amount/application)	2 a	6 b
Regional/state stormwater management plan	2 a	5 b
Potassium (total yearly amount or amount/application)	<1 a	<1 a

Table 3. Types of federal, state, local government or tribal authority restrictions on fertilizer applications reported by 18-hole facilities. Values within each two-column row that are followed by the same letter are not significantly different at the 90% confidence level.

Fertilizer application ratios for nitrogen, phosphate and potash

Region	2006			2014		
	Nitrogen	Phosphate	Potash	Nitrogen	Phosphate	Potash
North Central	4.0	1	3.2	10.0*	1	6.2**
Northeast	3.2	1	2.6	9.8*	1	6.2**
Pacific	3.3	1	2.6	4.7*	1	2.9
Southeast	3.5	1	3.6	5.9*	1	4.8**
Southwest	3.0	1	2.4	3.3	1	2.3
Transition	2.6	1	2.4	6.8*	1	4.4**
Upper West/ Mountain	3.5	1	2.7	8.0*	1	3.4**
U.S.	3.3	1	2.9	6.9*	1	4.4**

*Significant change in the proportion of nitrogen to other nutrients in 2006 vs. 2014 at a 90% confidence level.
**Significant change in the proportion of potassium to other nutrients in 2006 vs. 2014 at a 90% confidence level.

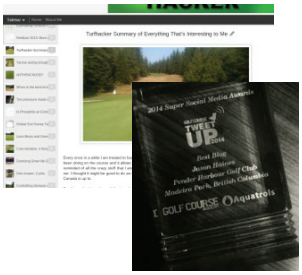
Median nitrogen use rates for 18-hole golf courses

Region	Median nitrogen use (pounds/1,000 square feet/year)													
	Greens		Tees		Fairways		Roughs		Practice		Grounds		Total Course	
	2006	2014	2006	2014	2006	2014	2006	2014	2006	2014	2006	2014	2006	2014
North Central	3.3 b	2.7 a	3.5b	2.7 a	2.8 b	2.1 a	1.7 b	1.4 a	2.9 b	2.4 a	2.4 b	1.9 a	2.2 b	1.7 a
Northeast	3.5 b	3.1 a	3.7 b	3.1 a	2.8 b	2.3 a	1.8 b	1.6 a	2.7 b	2.4 a	2.4 b	2.1 a	2.3 b	1.9 a
Pacific	4.8 b	3.7 a	4.3 b	3.3 a	3.3 b	2.8 a	2.5 b	2.0 a	3.3 a	2.8 a	3.3 b	2.6 a	2.6 a	2.2 a
Southeast	7.4 b	5.6 a	5.6 b	4.1 a	4.5 b	3.5 a	3.9 b	2.7 a	4.9 b	3.5 a	3.6 b	2.9 a	4.2 b	3.0 a
Southwest	5.5 b	4.7 a	5.8 b	4.3 a	5.1 b	4.0 a	1.2 b	3.0 a	5.0 b	4.3 a	4.2 b	3.7 a	4.2 b	3.1 a
Transition	4.3 b	3.9 a	3.4 b	2.7 a	2.9 b	2.5 a	2.2 b	1.9 a	2.9 b	2.6 a	2.5 b	2.1 a	2.5 b	2.1 a
Upper West/ Mountain	3.7 b	3.4 a	3.7 b	3.1 a	3.1 b	2.5 a	2.5 b	2.0 a	3.1 b	2.8 a	2.8 b	2.4 a	2.7 b	2.0 a
U.S.	4.3 b	3.7 a	4.0 b	3.2 a	3.2 b	2.6 a	2.4 b	2.0 a	3.4 b	2.9 a	2.8 b	2.3 a	2.8 b	2.2 a

Table A5. Median nitrogen use in pounds/1,000 square feet for 18-hole golf courses. For each 2006 vs. 2014 comparison, values followed by the same letter are not significantly different at the 90% confidence level. No-mow acreage fertilization rates were omitted because there were too few responses to generate a valid analysis. Course-wide nitrogen use rates are lower than those for most features because significant portions of many golf courses are not fertilized at all (Table 1).

Jason's how and why MLSN?

- Started to blog in 2011
- Noticed audience was mostly Superintendents
- Quickly developed a theme of pesticide reduction.
- Even won an award!



Jason's how and why MLSN?

- Started using twitter
- Learned about the thing called minimalism where it's cool to be poor
- 2008 Recession demanded cost reductions

I've got excuses

- Low budget
- 9 holes
- Low expectations
- Dead grass isn't the end of the world
- Less pressure

Jason's how and why MLSN?

- Was using BCSR
- Fertilizer theory didn't agree with what I was seeing in real life
- Applying more of certain nutrients had no impact that I could see

Parameter (ppm)	Desired value* (Sufficiency level)	SURVEY RESULTS MN	Chicago, IL	Southern CA	FL Panhandle	LA/MS Coast
pH	6.0-7.5	7	7	7.1	6.5	6.9
Phosphorous	>50	240	105	99	85	28
Potassium	>110	146	170	156	88	37
Calcium	>750	1660	2726	1346	544	225
Magnesium	>140	160	343	174	91	53
Sulfur	15 - 40	12.5	63	139	20	4
Boron	0.5 - 1.5	---	<1	1	1.2	3
Copper	0.1 - 2.5	1.35	4	5	3.3	0.6
Iron	>90	108	248	185	42	59
Manganese	>30	24	34	30	2.9	6.7
Zinc	1 - 4	16	20	19	6.9	5.1
Sodium	<110	10	40	174	48	---
% Base Saturation						
% calcium	65 - 80%	69%	76%	69%	71%	69%
% potassium	2 - 7%	4%	3%	4%	4%	6%
% magnesium	10 - 20%	15%	17%	15%	20%	26%
% sodium	<3%	<1%	1%	8%	6%	---
Other values						
EC (dS/m)	<1.5	0.25	0.48	3.2	0.05	0.14
TEC (meq/100g)	>4	7.8	17.8	9.9	2.1	1.6
% Organic matter	<4%	Est.<3%	3%	2%	0.15%	0.15%

Ca

Parameter (ppm)	Desired value* (Sufficiency level)	SURVEY RESULTS MN	Chicago, IL	Southern CA	FL Panhandle	LA/MS Coast
pH	6.0-7.5	7	7	7.1	6.5	6.9
Phosphorous	>50	240	105	99	85	28
Potassium	>110	146	170	156	88	37
Calcium	>750	1660	2726	1346	544	225
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% Organic matter	<4%	Est.<3%	3%	2%	0.15%	0.15%

Mg

Parameter (ppm)	Desired value* (Sufficiency level)	SURVEY RESULTS MN	Chicago, IL	Southern CA	FL Panhandle	LA/MS Coast
pH	6.0-7.5	7	7	7.1	6.5	6.9
Phosphorous	>50	240	105	99	85	28
Potassium	>110	146	170	156	88	37
Calcium	>750	1660	2726	1346	544	225
Magnesium	>140	160	343	174	91	53
Sulfur	15 - 40	12.5	63	139	20	4
Boron	0.5 - 1.5	---	<1	1	1.2	3
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% potassium	2 - 7%	4%	3%	4%	4%	6%
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Other values						
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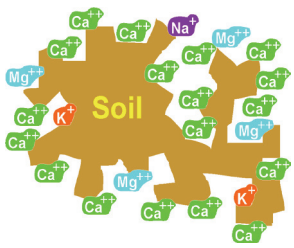
TEC (meq/100g)	>4	7.8	17.8	9.9	2.1	1.6
% Organic matter	<4%	Est.<3%	3%	2%	0.15%	0.15%

K

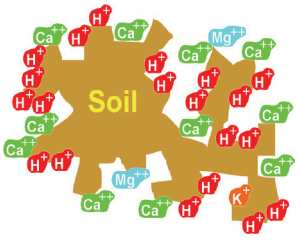
pH 7 and higher

Ca	18	36	76%
Mg	4	8	17%
K	2	2	4%
Na	1	1	2%
H	0	0	0%



pH 5

Ca	11	22	47%
Mg	2	4	9%
K	1	1	2%
Na	0	0	0%
H	20	20	42%



Extreme nutrient deficiency

- MLSN explained what I was seeing with regard to nutrient inputs
- Local club with severe Ca deficiency (10ppm)

Extreme nutrient deficiency

- Applied Ca and the greens got better

MLSN seemed low risk

- MLSN is simple
- I dove in head first
- If it didn't work I would go back to old way

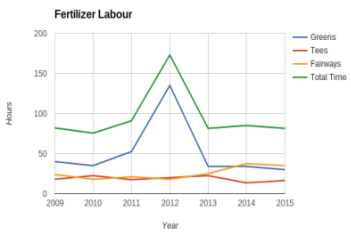
Started with a soil test

Pender Harbor Golf Club — Docket Summary — 12110201

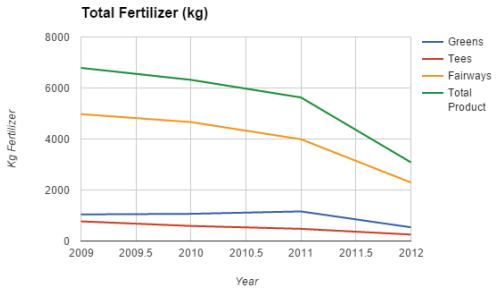
Area	TEC	pH	%OM	S	P-M3	Ca	Mg	K	Na	B	Fe	Mn	Cu	Zn	Cl	EC dS/m	N
	>4	>6		15	25	330	45	50	<110						<90	<2	<10
g 1689	3	6.1	1.7	15	53	318	43	46	25	0.4	294	19	4.5	4.9	9.4	0.6	4.7
g 23457	4	6.0	1.7	19	71	478	57	68	29	0.0	379	22	7.1	5.5	6.7	0.6	9.6
t 1-4	4	5.7	2.6	13	95	471	54	59	27	0.3	336	9	1.9	6.8	6.5	0.6	10.6
t 5-9	4	5.7	2.4	11	72	399	47	43	25	0.0	189	10	1.3	4.5	5.6	0.6	10.0

Year 1 results

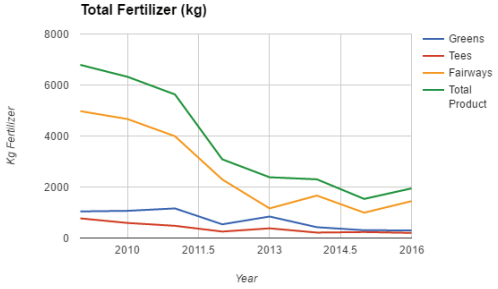
- Made switch to ag-grade soluble fertilizer to gain more control
- Bit of a learning curve



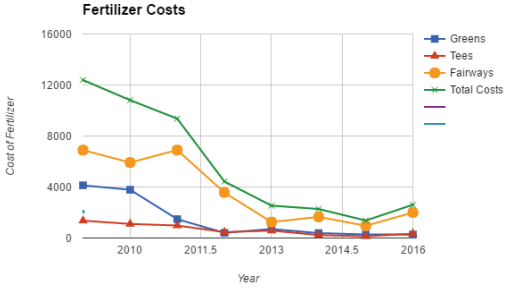
Year 1 results



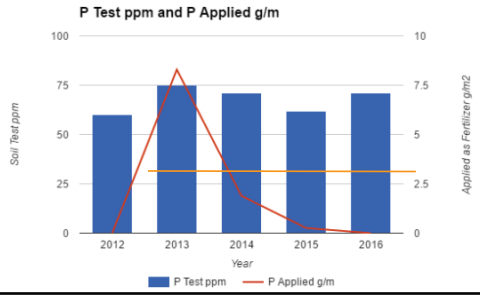
5 years later



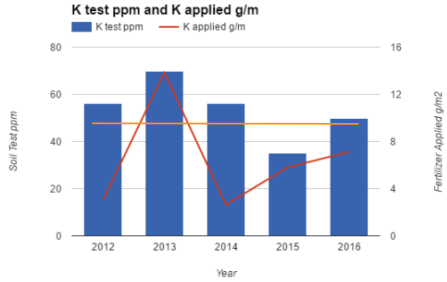
5 years later



Soil test vs Fertilizer Applied



Soil test vs Fertilizer Applied



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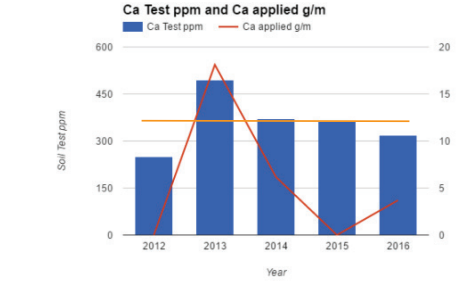

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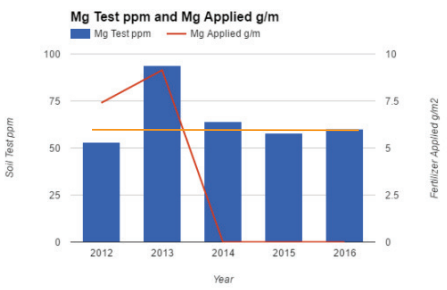
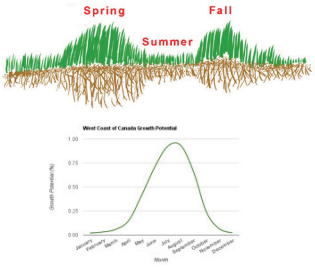


How does the MLSN Work

- 2 Options
  - Apply fertilizer used by the plant regardless of soil tests
  - Test soil and apply only the fertilizer that is required

Jason's how and why GP?

- Growth Potential explained the way grass grew in my climate



MLSN are not targets

- We are usually concerned with nutrient deficiencies
- What are the impacts of nutrient excesses?
- Where do nutrients that aren't needed go?

MLSN and GP for IPM

- We can apply all nutrients at the ratio determined by MLSN

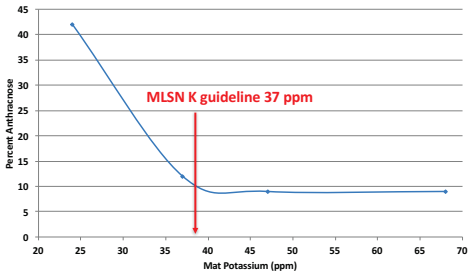
OR

- We can apply the amount of nutrients to reduce impacts of certain diseases and pests.

MLSN and GP for IPM

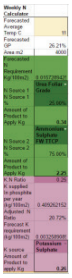
- Combine MLSN with GP and fine tune application timing
- GP High N in Summer for dollar spot and anthracnose, little N in winter for Fusarium
- MLSN K in Summer for anthracnose, not in winter for fusarium
- Ca in Summer not in winter for acidifying fusarium?

2012 data presented at the 2013 CSSA Meetings by Charles Schmid
Potassium Source and Rate Effect on Anthracnose Severity of Annual Bluegrass. Charles, J. Schmid, Bruce B. Clarke, James A. Murphy, Rutgers University.



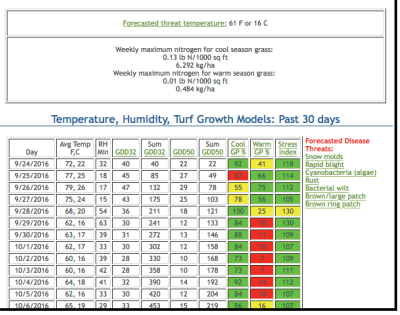
How do I use GP?

- Weekly fert apps on greens, monthly on fariways and every 3 weeks on Fairways
- Use forecasted average temp to determine rates
  - Only use 30 yr average for tees and fairways
- Adjust rate based on PGR use to 80%
- Adjust rates based on measured growth rates
- Not the rule, gets me into the right ballpark



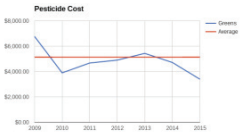
Web services

- PACE Turf.org provides estimated N requirement, growth potential and GDD globally
- igreenkeeping.com igkTool provides GP models in Europe



Reduction in Quantity, not Quality

- 80% reduction in quantity of fertilizer applied to course
- Improved turf, less thatch, less disease less money



Reduction in Quantity, not Quality

Psychology of making switch to MLSN

- Easy to have doubts with a radical shift in thinking
- Just because you learned it in school doesn't make it right
- Science is constantly improving

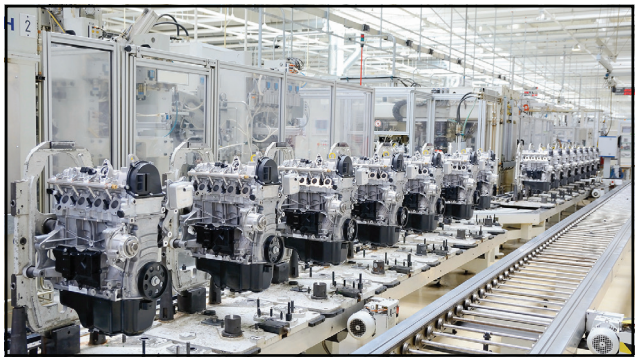
Psychology of making switch to MLSN

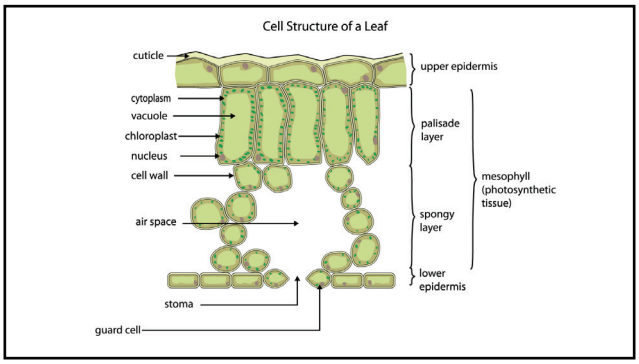
- First winter using MLSN my greens look like this
- Not fertilizer related
- Allows me to focus on real issues (shade, drainage)

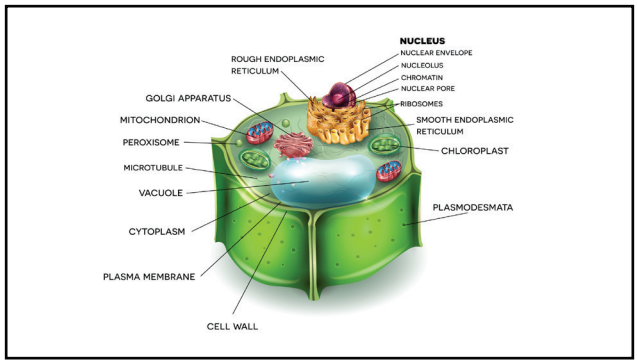
What the plant needs

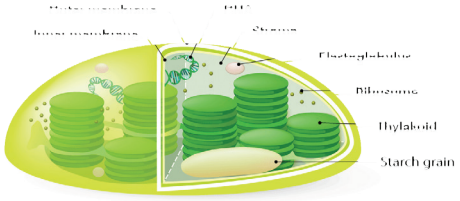
Plants are factories

1. Nano technology at it's finest
2. Manufacturing cells with precision
3. Plant growth is not a sloppy business
4. We know what plants require for growth
5. Provide what is needed and the system works fine
6. Provide too few of any of the components and cell manufacturing will slow and come to a halt
7. Applying excesses usually does not cause a problem – except for impact on budgets and environment

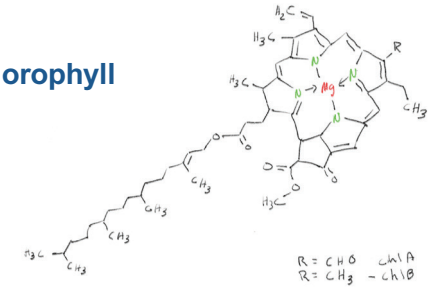


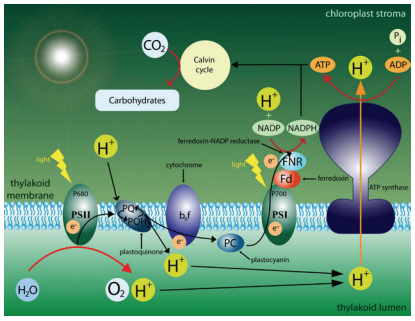


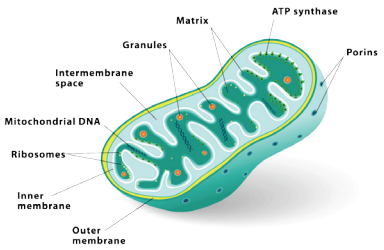




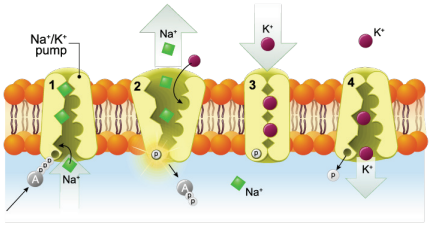
Chlorophyll

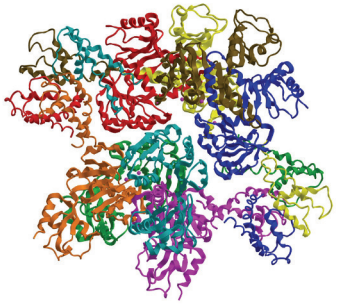






SODIUM-POTASSIUM PUMP





What does the plant need?

- All of the essential parts/elements
- Not more than the essential parts/elements, just like building an engine
- Having a large surplus of parts/elements is not necessary – it is wasteful and expensive

What does the plant need?

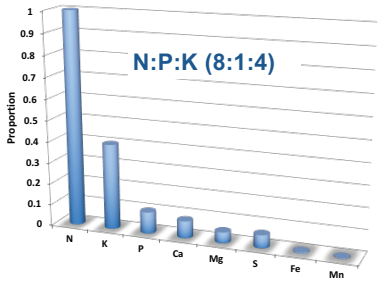
- Light
- CO_2
- H_2O
- Minerals from the soil
  - C H O P K N S Ca Fe Mg
    C. Hopkns CaFe Mighty Good
  - P K N S Ca Fe Mg

What is the nutrient content of turf clippings?

Element	Tissue ppm	Ratio:N
N	40000	1
K	20000	0.5
P	5000	0.13
Ca	4000	0.08
Mg	2500	0.05
S	3000	0.06
Fe	200	0.004
Mn	75	0.0015

Roughly 90% of dry matter is carbon

Proportional composition of turf tissue

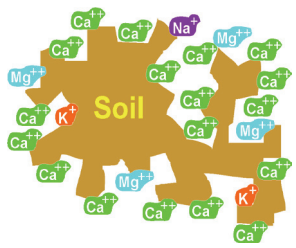


How are nutrients removed from the soil?

- Primarily by clipping removal
- By leaching if excessive nutrients are applied
- By leaching if the soil has high salts
- Leaching will not remove elements held on the cation exchange sites or associated with organic matter

pH 7 and higher

Ca	18	36	76%
Mg	4	8	17%
K	2	2	4%
Na	1	1	2%
H	0	0	0%



MLSN a+b-c=Q

a + b – c = Q

a = ppm removal per time x time (days, months, year) based upon GP
b = MLSN ppm baseline needed for good turf performance
c = ppm reported on soil report

Q = Quantity of element in ppm needed to maintain soil levels above the MLSN guideline for the specified time

Application of 1 lb element/1000 sq ft ~ 33 ppm in top 4 inches or 22 ppm in top 6 inches

		SURVEY RESULTS				
Parameter (ppm)	Desired value* (Sufficiency level)	MN	Chicago, IL	Southern CA	FL Panhandle	LA/MS Coast
pH	6.0-7.5	7	7	7.1	6.5	6.9
Phosphorous	>50	240	105	99	85	28
Potassium	>110	146	170	156	88	37
Calcium	>750	1660	2726	1346	544	225
Magnesium	>140	160	343	174	91	53
Sulfur	15 - 40	12.5	63	139	20	4
Boron	0.5 - 1.5	---	<1	1	1.2	3
Copper	0.1 - 2.5	1.35	4	5	3.3	0.6
Iron	>90	108	248	185	42	59
Manganese	>30	24	34	30	2.9	6.7
Zinc	1 - 4	16	20	19	6.9	5.1
Sodium	<110	10	40	174	48	---
% Base Saturation						
% calcium	65 - 80%	69%	76%	69%	71%	69%
% potassium	2 - 7%	4%	3%	4%	4%	6%
% magnesium	10 - 20%	15%	17%	15%	20%	26%
% sodium	<3%	<1%	1%	8%	6%	---
Other values						
EC (dS/m)	<1.5	0.25	0.48	3.2	0.05	0.14
TEC (meq/100g)	>4	7.8	17.8	9.9	2.1	1.6
% Organic matter	<4%	Est.<3%	3%	2%	0.15%	0.15%

K

Southern Climate

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg T (F)	64.5	66.9	70.0	73.3	78.2	81.9	83.1	83.2	82.4	78.5	72.1	66.8
Rainfall (in)	1.9	2.1	2.4	2.4	3.2	8.8	7.3	8.6	7.7	4.2	2.0	1.5

Warm Season Grass Maximum N/month lb/1000 sq ft = 1.00

Warm GP	15	21	32	47	72	88	92	92	90	73	42	21	Total lb/1000 sq ft	Soil ppm	Plus MLSN ppm
N lb/1000 sq ft	0.1	0.2	0.3	0.5	0.7	0.9	0.9	0.9	0.9	0.7	0.4	0.2	6.8	NA	NA
K lb/1000 sq ft	0.07	0.11	0.16	0.24	0.36	0.44	0.46	0.46	0.45	0.37	0.21	0.11	3.42	112	149
P lb/1000 sq ft	0.02	0.03	0.04	0.06	0.09	0.11	0.12	0.12	0.12	0.10	0.05	0.03	0.89	29	50
Ca lb/1000 sq ft	0.01	0.02	0.03	0.05	0.07	0.09	0.09	0.09	0.09	0.07	0.04	0.02	0.68	22	353
Mg lb/1000 sq ft	0.01	0.01	0.02	0.02	0.04	0.04	0.05	0.05	0.04	0.04	0.02	0.01	0.34	11	58
S lb/1000 sq ft	0.01	0.01	0.02	0.03	0.04	0.05	0.06	0.06	0.05	0.04	0.02	0.01	0.41	13	20
Fe lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.034	1	45
Mn lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.013	0	6

Q = a + b - c

"Q" = (desired ppm "a+b" – observed ppm "c")
Q/33 = lb/1000 sq ft
Q/6.6 = g/m²

MLSN

Potassium lb/1000 sq ft = (149 – 37)/33
Potassium lb/1000 sq ft = 3.4
Potassium lb/1000 sq ft x 1.2 = 4.1 lb K_2O/1000 sq ft
lb 0-0-50/1000 sq ft = 8.2/ 0.50 = 16.4 lb 0-0-50/1000 sq ft

SLAN

Potassium lb/1000 sq ft = (110 – 37)/33
Potassium lb/1000 sq ft = 2.2
Potassium lb/1000 sq ft x 1.2 = 2.6 lb K_2O/1000 sq ft
lb 0-0-50/1000 sq ft = 2.6/ 0.50 = 5.2 lb 0-0-50/1000 sq ft

		SURVEY RESULTS				
Parameter (ppm)	Desired value* (Sufficiency level)	MN	Chicago, IL	Southern CA	FL Panhandle	LA/MS Coast
pH	6.0-7.5	7	7	7.1	6.5	6.9
Phosphorous	>50	240	105	99	85	28
Potassium	>110	146	170	156	88	37
Calcium	>750	1660	2726	1346	544	225
Magnesium	>140	160	343	174	91	53
Sulfur	15 - 40	12.5	63	139	20	4
Boron	0.5 - 1.5	---	<1	1	1.2	3
Copper	0.1 - 2.5	1.35	4	5	3.3	0.6
Iron	>90	108	248	185	42	59
Manganese	>30	24	34	30	2.9	6.7
Zinc	1 - 4	16	20	19	6.9	5.1
Sodium	<110	10	40	174	48	---
% Base Saturation						
% calcium	65 - 80%	69%	76%	69%	71%	69%
% potassium	2 - 7%	4%	3%	4%	4%	6%
% magnesium	10 - 20%	15%	17%	15%	20%	26%
% sodium	<3%	<1%	1%	8%	6%	---
Other values						
EC (dS/m)	<1.5	0.25	0.48	3.2	0.05	0.14
TEC (meq/100g)	>4	7.8	17.8	9.9	2.1	1.6
% Organic matter	<4%	Est.<3%	3%	2%	0.15%	0.15%

P

Southern Climate

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg T (F)	64.5	66.9	70.0	73.3	78.2	81.9	83.1	83.2	82.4	78.5	72.1	66.8
Rainfall (in)	1.9	2.1	2.4	2.4	3.2	8.8	7.3	8.6	7.7	4.2	2.0	1.5

Warm Season Grass Maximum N/month lb/1000 sq ft = 1.00

Warm GP	15	21	32	47	72	88	92	92	90	73	42	21	Total lb/1000 sq ft	Soil ppm	Plus MLSN ppm
N lb/1000 sq ft	0.1	0.2	0.3	0.5	0.7	0.9	0.9	0.9	0.9	0.7	0.4	0.2	6.8	NA	NA
K lb/1000 sq ft	0.07	0.11	0.16	0.24	0.36	0.44	0.46	0.46	0.45	0.37	0.21	0.11	3.42	112	149
P lb/1000 sq ft	0.02	0.03	0.04	0.06	0.09	0.11	0.12	0.12	0.12	0.10	0.05	0.03	0.89	29	50
Ca lb/1000 sq ft	0.01	0.02	0.03	0.05	0.07	0.09	0.09	0.09	0.09	0.07	0.04	0.02	0.68	22	353
Mg lb/1000 sq ft	0.01	0.01	0.02	0.02	0.04	0.04	0.05	0.05	0.04	0.04	0.02	0.01	0.34	11	58
S lb/1000 sq ft	0.01	0.01	0.02	0.03	0.04	0.05	0.06	0.06	0.05	0.04	0.02	0.01	0.41	13	20
Fe lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.034	1	45
Mn lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.013	0	6

Q = a + b - c

"Q" = (desired ppm "a+b" – observed ppm "c")
Q/33 = lb/1000 sq ft
Q/6.6 = g/m²

MLSN

Phosphorus lb/1000 sq ft = (50 – 28)/33
Phosphorus lb/1000 sq ft = 0.7
Phosphorus lb/1000 sq ft x 2.29 = 1.6 lb P_2O_5
lb 11-55-0/1000 sq ft = 1.6 / 0.55 = 2.9 lb 11-55-0/1000 sq ft

SLAN

See above. Desired MLSN = SLAN = 50 ppm P

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Parameter (ppm)	Desired value* (Sufficiency level)	MN	Chicago, IL	Southern CA	FL Panhandle	LA/MS Coast
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Potassium	>110	146	170	156	88	37
Calcium	>750	1660	2726	1346	544	225
Magnesium	>140	160	343	174	91	53
Sulfur	15 - 40	12.5	63	139	20	4
Boron	0.5 - 1.5	---	<1	1	1.2	3
Copper	0.1 - 2.5	1.35	4	5	3.3	0.6
Iron	>90	108	248	185	42	59
Manganese	>30	24	34	30	2.9	6.7
Zinc	1 - 4	16	20	19	6.9	5.1
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% potassium	2 - 7%	4%	3%	4%	4%	6%
% magnesium	10 - 20%	15%	17%	15%	20%	26%
% sodium	<3%	<1%	1%	8%	6%	---
Other values						
EC (dS/m)	<1.5	0.25	0.48	3.2	0.05	0.14
TEC (meq/100g)	>4	7.8	17.8	9.9	2.1	1.6
% Organic matter	<4%	Est.<3%	3%	2%	0.15%	0.15%

Ca

Southern Climate

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Avg T (F)	64.5	66.9	70.0	73.3	78.2	81.9	83.1	83.2	82.4	78.5	72.1	66.8
Rainfall (in)	1.9	2.1	2.4	2.4	3.2	8.8	7.3	8.6	7.7	4.2	2.0	1.5

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N lb/1000 sq ft	0.1	0.2	0.3	0.5	0.7	0.9	0.9	0.9	0.9	0.7	0.4	0.2	6.8	NA	NA
K lb/1000 sq ft	0.07	0.11	0.16	0.24	0.36	0.44	0.46	0.46	0.45	0.37	0.21	0.11	3.42	112	149
P lb/1000 sq ft	0.02	0.03	0.04	0.06	0.09	0.11	0.12	0.12	0.12	0.10	0.05	0.03	0.89	29	50
Ca lb/1000 sq ft	0.01	0.02	0.03	0.05	0.07	0.09	0.09	0.09	0.09	0.07	0.04	0.02	0.68	22	353
Mg lb/1000 sq ft	0.01	0.01	0.02	0.02	0.04	0.04	0.05	0.05	0.04	0.04	0.02	0.01	0.34	11	58
S lb/1000 sq ft	0.01	0.01	0.02	0.03	0.04	0.05	0.06	0.06	0.05	0.04	0.02	0.01	0.41	13	20
Fe lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.034	1	45
Mn lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.013	0	6

Q = a + b - c

"Q" = (desired ppm "a+b" – observed ppm "c")
Q/33 = lb/1000 sq ft
Q/6.6 = g/m²

MLSN

Calcium lb/1000 sq ft = (353 – 225)/33
Calcium lb/1000 sq ft = 3.9
Gypsum (23% Ca) lb/1000 sq ft = 3.9 / 0.23 = 17 lb gypsum/1000 sq ft

SLAN

Calcium lb/1000 sq ft = (750 – 225)/33
Calcium lb/1000 sq ft = 16
Gypsum (23% Ca) lb/1000 sq ft = 16 / 0.23 = 70 lb gypsum/1000 sq ft

Q = a + b - c

"Q" = (desired ppm "a+b" – observed ppm "c")
Q/33 = lb/1000 sq ft
Q/6.6 = g/m²

MLSN

Deficit calcium g/m² = (353 – 225)/6.6
Deficit calcium g/m² = 19
Gypsum (23% Ca) g/m² = 19 / 0.23 = 83 g gypsum/m²

SLAN

Deficit calcium g/m² = (750 – 225)/6.6
Deficit calcium g/m² = 80
Gypsum (23% Ca) g/m² = 80 / 0.23 = 348 g gypsum/m²

		SURVEY RESULTS				
Parameter (ppm)	Desired value* (Sufficiency level)	MN	Chicago, IL	Southern CA	FL Panhandle	LA/MS Coast
pH	6.0-7.5	7	7	7.1	6.5	6.9
Phosphorous	>50	240	105	99	85	28
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Magnesium	>140	160	343	174	91	53
Sulfur	15 - 40	12.5	63	139	20	4
Boron	0.5 - 1.5	---	<1	1	1.2	3
Copper	0.1 - 2.5	1.35	4	5	3.3	0.6
Iron	>90	108	248	185	42	59
Manganese	>30	24	34	30	2.9	6.7
Zinc	1 - 4	16	20	19	6.9	5.1
Sodium	<110	10	40	174	48	---
% Base Saturation						
% calcium	65 - 80%	69%	76%	69%	71%	69%
% potassium	2 - 7%	4%	3%	4%	4%	6%
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% sodium	<3%	<1%	1%	8%	6%	---
Other values						
EC (dS/m)	<1.5	0.25	0.48	3.2	0.05	0.14
TEC (meq/100g)	>4	7.8	17.8	9.9	2.1	1.6
% Organic matter	<4%	Est.<3%	3%	2%	0.15%	0.15%

Mg

Southern Climate

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N lb/1000 sq ft	0.1	0.2	0.3	0.5	0.7	0.9	0.9	0.9	0.9	0.7	0.4	0.2	6.8	NA	NA
K lb/1000 sq ft	0.07	0.11	0.16	0.24	0.36	0.44	0.46	0.46	0.45	0.37	0.21	0.11	3.42	112	149
P lb/1000 sq ft	0.02	0.03	0.04	0.06	0.09	0.11	0.12	0.12	0.12	0.10	0.05	0.03	0.89	29	50
Ca lb/1000 sq ft	0.01	0.02	0.03	0.05	0.07	0.09	0.09	0.09	0.09	0.07	0.04	0.02	0.68	22	353
Mg lb/1000 sq ft	0.01	0.01	0.02	0.02	0.04	0.04	0.05	0.05	0.04	0.04	0.02	0.01	0.34	11	58
S lb/1000 sq ft	0.01	0.01	0.02	0.03	0.04	0.05	0.06	0.06	0.05	0.04	0.02	0.01	0.41	13	20
Fe lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.034	1	45
Mn lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.013	0	6

Q = a + b - c

"Q" = (desired ppm "a+b" – observed ppm "c")

Q/33 = lb/1000 sq ft

Q/6.6= g/m^2

MLSN

Magnesium lb/1000 sq ft = (58– 53)/33

Magnesium lb/1000 sq ft = 0.15

lb ($MgSO_4$*$7H_2O$)/1000 sq ft = 0.15/ 0.1 = 1.5 lb ($MgSO_4$*$7H_2O$) /1000 sq ft

SLAN

Magnesium lb/1000 sq ft = (140 – 53)/33

Magnesium lb/1000 sq ft = 2.6

lb ($MgSO_4$*$7H_2O$)/1000 sq ft = 2.6 / 0.1 = 26 lb ($MgSO_4$*$7H_2O$) /1000 sq ft

		SURVEY RESULTS				
Parameter (ppm)	**Desired value* (Sufficiency level)**	**MN**	**Chicago, IL**	**Southern CA**	**FL Panhandle**	**LA/MS Coast**
pH	6.0-7.5	7	7	7.1	6.5	6.9
Phosphorous	>50	240	105	99	85	28
Potassium	>110	146	170	156	88	37
Calcium	>750	1660	2726	1346	544	225
Magnesium	>140	160	343	174	91	53
Sulfur	15 - 40	12.5	63	139	20	4
Boron	0.5 - 1.5	---	<1	1	1.2	3
Copper	0.1 - 2.5	1.35	4	5	3.3	0.6
Iron	>90	108	248	185	42	59
Manganese	>30	24	34	30	2.9	6.7
Zinc	1 - 4	16	20	19	6.9	5.1
Sodium	<110	10	40	174	48	---
% Base Saturation						
% calcium	65 - 80%	69%	76%	69%	71%	69%
% potassium	2 - 7%	4%	3%	4%	4%	6%
% magnesium	10 - 20%	15%	17%	15%	20%	26%
% sodium	<3%	<1%	1%	8%	6%	---
Other values						
EC (dS/m)	<1.5	0.25	0.48	3.2	0.05	0.14
TEC (meq/100g)	>4	7.8	17.8	9.9	2.1	1.6
% Organic matter	<4%	Est.<3%	3%	2%	0.15%	0.15%

S

Southern Climate

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg T (F)	64.5	66.9	70.0	73.3	78.2	81.9	83.1	83.2	82.4	78.5	72.1	66.8
Rainfall (in)	1.9	2.1	2.4	2.4	3.2	8.8	7.3	8.6	7.7	4.2	2.0	1.5

Warm Season Grass Maximum N/month lb/1000 sq ft = 1.00

Warm GP	15	21	32	47	72	88	92	92	90	73	42	21	Total lb/1000 sq ft	Soil ppm	Plus MLSN ppm
N lb/1000 sq ft	0.1	0.2	0.3	0.5	0.7	0.9	0.9	0.9	0.9	0.7	0.4	0.2	6.8	NA	NA
K lb/1000 sq ft	0.07	0.11	0.16	0.24	0.36	0.44	0.46	0.46	0.45	0.37	0.21	0.11	3.42	112	149
P lb/1000 sq ft	0.02	0.03	0.04	0.06	0.09	0.11	0.12	0.12	0.12	0.10	0.05	0.03	0.89	29	50
Ca lb/1000 sq ft	0.01	0.02	0.03	0.05	0.07	0.09	0.09	0.09	0.09	0.07	0.04	0.02	0.68	22	353
Mg lb/1000 sq ft	0.01	0.01	0.02	0.02	0.04	0.04	0.05	0.05	0.04	0.04	0.02	0.01	0.34	11	58
S lb/1000 sq ft	0.01	0.01	0.02	0.03	0.04	0.05	0.06	0.06	0.05	0.04	0.02	0.01	0.41	13	20
Fe lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.034	1	45
Mn lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.013	0	6

Q = a + b - c

"Q" = (desired ppm "a+b" – observed ppm "c")

Q/33= lb/1000 sq ft

Q/6.6= g/m^2

MLSN

Sulfur lb/1000 sq ft = (20 – 4)/33

Sulfur lb/1000 sq ft = 0.48

lb (0-0-50)/1000 sq ft = 0.48/ 0.17 = 2.8 lb (0-0-50) /1000 sq ft

SLAN

Sulfur lb/1000 sq ft = (40 – 4)/33

Sulfur lb/1000 sq ft = 1.1

lb (0-0-50)/1000 sq ft = 1.1 / 0.1 = 11 lb (0-0-50) /1000 sq ft

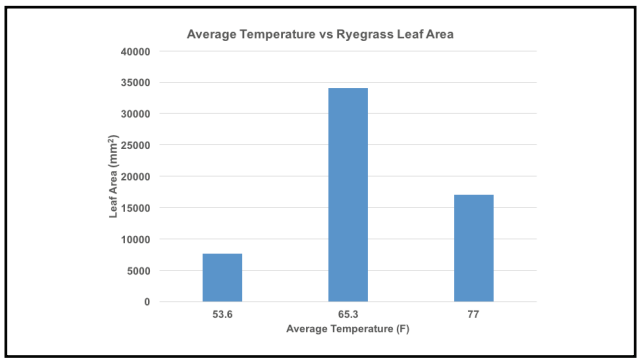
Growth rate/clipping yield

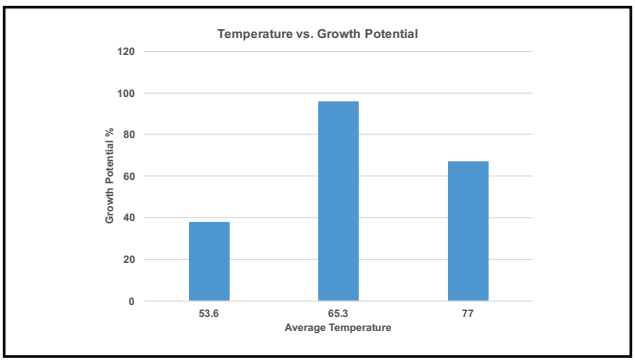
- Grow as slow as possible for desired performance
- Slower than the maximum potential of the plant to produce biomass
- **Growth is restricted primarily by regulating nitrogen applications**
- Typical annual yield is about 82 lbs/1000 sq ft (at 4% N in tissue = 3.3 lbs N/1000 sq ft)

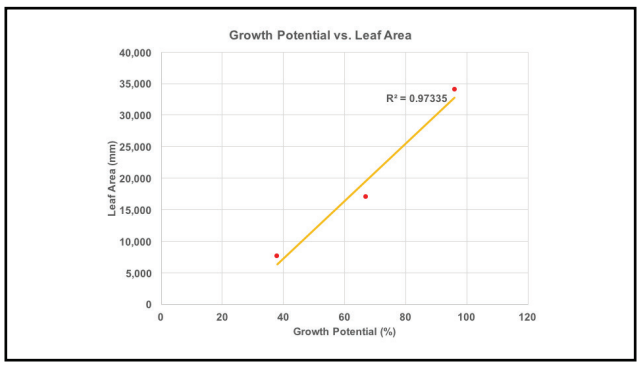
Model Validation Examples

Beevers and Cooper
1964 Crop Science 4:139-143

- Growth chamber study
- Ryegrass leaf yield
- Three day-night temperature regimes 12-12 C, 25-25 C, and 25-12 C (53.6-53.6 F, 77-77 F, 77-53.6 F avg 65.3 F)
- Relative humidity 65 – 75%
- 650 ft candles for 16 hrs per day (908 watts/m^2 or 165 mol/m^2) only need about 200 watts/m^2 or 41 mol/m^2
- Harvested leaves ¼ inch above soil surface and measured leaf area







Turf Growth and Soil Nitrate

- Geng et. al. 2014 University of Connecticut
- Field with no fertilization or irrigation for 20 years mixed turf and forbs
- Planted Kentucky bluegrass and tall fescue
- Applied urea at 0, 5, 10, 20, 30, 40, 50, 75, and 100 kg N/ha monthly (50 kg/ha = 5 g/m^2 = 1 lb/1000 sq ft)
- Sandy loam soil 6.3% organic matter
- Soil C:N 2.5:1 (lots of organic N available)
- Measured soil NO3-N, turf quality and turf growth every 14 days during the growing season for 3 yrs

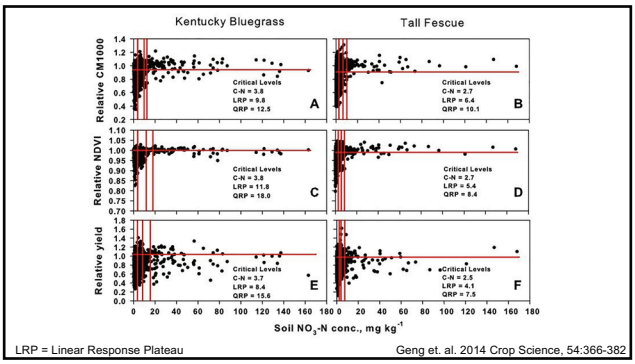
Storrs, CT Climate

Location: Storrs, CT

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg T (C)	-3.0	-3.0	1.0	7.0	13.0	18.0	21.0	20.0	16.0	10.0	4.0	-1.0
Rainfall (mm)	93.0	84.0	103.0	96.0	95.0	86.0	106.0	107.0	98.0	95.0	104.0	99.0

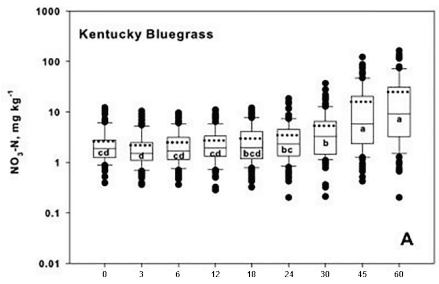
Cool Season Grass Maximum N/month g/sq m = 3.40

														10 cm depth	
Cool GP	0	0	0	6	45	94	98	100	77	20	2	0	Total	Soil ppm	MLSN Plus Soil ppm
N g/sq m	0.0	0.0	0.0	0.2	1.5	3.2	3.3	3.4	2.6	0.7	0.1	0.0	15.0	NA	NA
K g/sq m	0.000	0.000	0.000	0.110	0.769	1.593	1.673	1.700	1.312	0.336	0.027	0.000	7.52	49	86
P g/sq m	0.000	0.000	0.000	0.029	0.200	0.414	0.435	0.442	0.341	0.087	0.007	0.000	1.96	13	34
Ca g/sq m	0.000	0.000	0.000	0.022	0.154	0.319	0.335	0.340	0.262	0.067	0.005	0.000	1.50	10	341
Mg g/sq m	0.000	0.000	0.000	0.011	0.077	0.159	0.167	0.170	0.131	0.034	0.003	0.000	0.75	5	52
S g/sq m	0.000	0.000	0.000	0.013	0.092	0.191	0.201	0.204	0.157	0.040	0.003	0.000	0.90	6	13
Fe g/sq m	0.000	0.000	0.000	0.001	0.008	0.016	0.017	0.017	0.013	0.003	0.000	0.000	0.075	0	44
Mn g/sq m	0.000	0.000	0.000	0.000	0.003	0.006	0.006	0.006	0.005	0.001	0.000	0.000	0.028	0	6

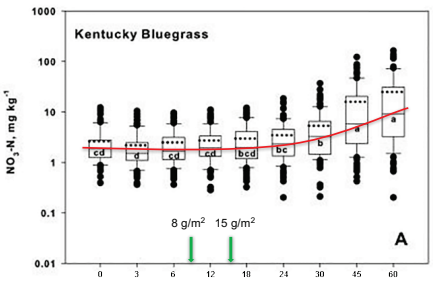


LRP = Linear Response Plateau

Geng et. al. 2014 Crop Science, 54:366-382



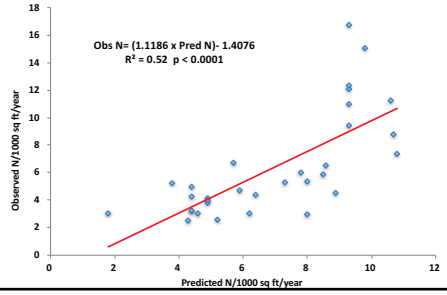
Geng et. al. 2014 Crop Science, 54:366-382



Geng et. al. 2014 Crop Science, 54:366-382

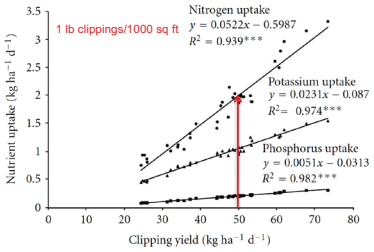
Predicted lb N/1000 sq ft vs Observed N/1000 sq ft

32 courses representing AL, CA, DE, FL, GA, MA, MI, NJ, NY, PA, TX, WV



What about P and K… and other nutrients?

Kussow, Soldat, Kreuser and Houlihan
Agronomy doi 10.5402/2012/359284



Kussow, Soldat, Kreuser and Houlihan
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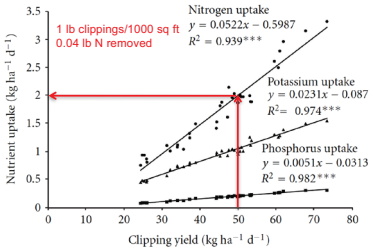

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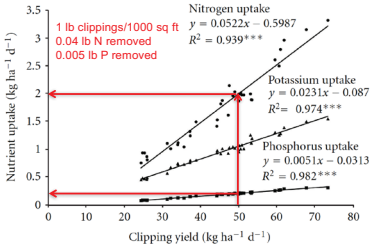

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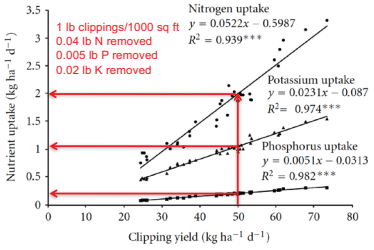

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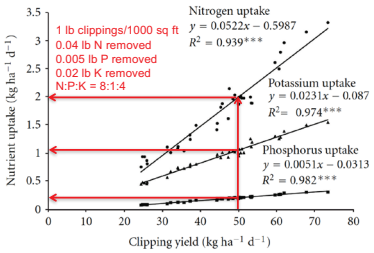


What is the nutrient content of turf clippings?

Element	Tissue ppm	Ratio:N
N	40000	1
K	20000	0.5
P	5000	0.13

How much will be removed when applying 4 lbs N/1000 sq ft/year?

Element	lb/1000 sq ft	Soil Test ppm in top 4 inches
K	2	65
P	0.5	16

Application of 1 lb element/1000 sq ft increases soil ppm by about:

32.7 ppm in the top 4 inches
21.8 ppm in the top 6 inches

4 lbs N/1000 sq ft
Sufficient nutrition for a full year

Element	lb/1000 sq ft	Soil Test (4 in) ppm	SLAN ppm	MLSN ppm	MLSN +
N	4				
K	2.0	65	110	37	102
P	0.5	16	50	21	37

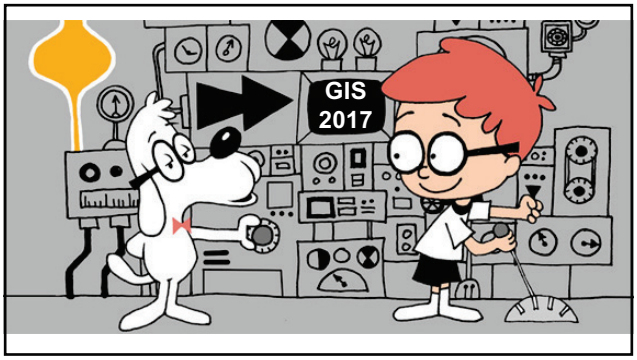
Rutgers University New Brunswick, NJ (C3)
http://www.paceturf.org/ipm/f_climate_english_20131025.xls

Location: New Brunswick, NJ

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg T (F)	31.4	32.0	40.4	50.6	61.0	69.8	74.4	72.6	66.3	56.0	44.9	34.0
Rainfall (in)	3.2	2.9	3.5	3.4	3.8	3.5	4.8	4.6	3.8	3.2	3.2	3.2

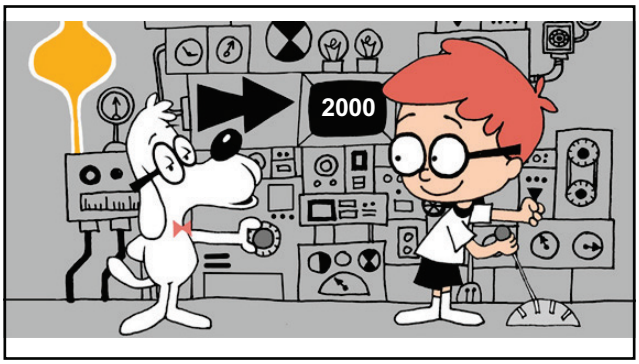
Cool Season Grass Maximum N/month lb/1000 sq ft = 0.70

Cool GP	0	0	2	22	78	98	81	90	99	49	7	0	Total lb/1000 sq ft	Soil ppm	Soil Plus MLSN ppm
N lb/1000 sq ft	0.0	0.0	0.0	0.2	0.5	0.7	0.6	0.6	0.7	0.3	0.0	0.0	3.7	NA	NA
K lb/1000 sq ft	0.00	0.00	0.01	0.08	0.27	0.34	0.29	0.31	0.34	0.17	0.02	0.00	1.84	60	97
P lb/1000 sq ft	0.00	0.00	0.00	0.02	0.07	0.09	0.07	0.08	0.09	0.04	0.01	0.00	0.48	16	37
Ca lb/1000 sq ft	0.00	0.00	0.00	0.02	0.05	0.07	0.06	0.06	0.07	0.03	0.00	0.00	0.37	12	343
Mg lb/1000 sq ft	0.00	0.00	0.00	0.01	0.03	0.03	0.03	0.03	0.03	0.02	0.00	0.00	0.18	6	53
S lb/1000 sq ft	0.00	0.00	0.00	0.01	0.03	0.04	0.03	0.04	0.04	0.02	0.00	0.00	0.22	7	14
Fe lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.018	1	45
Mn lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.007	0	6

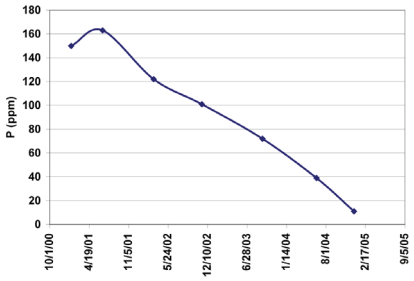


Declining A4 bentgrass
Overseeded Bermuda surrounds

Declining A4 bentgrass
Overseeded Bermuda surrounds



Trend in soil M3-P levels at Talega Country Club A4 Bentgrass



Rocket Science meets Soil Testing

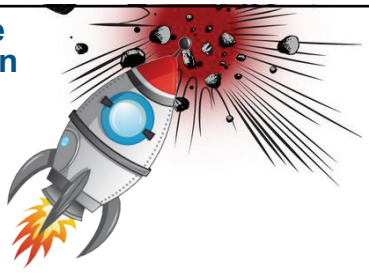
Fertilizer applied ppm/year
More than Needed ppm

Fertilizer applied ppm/year
Less than Needed ppm

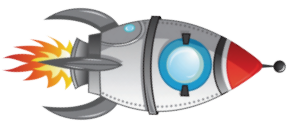
Deficit Fertilization

Fertilizer applied ppm/year
Less than Needed ppm

Excessive Fertilization



Fertilizer applied ppm/year
More than Needed ppm



Proper Maintenance Fertilization

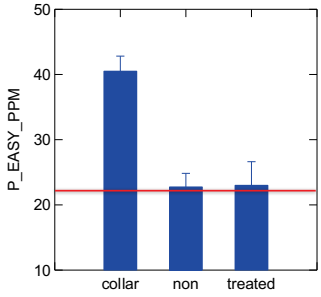
Declining A4 bentgrass
Healthy overseeded Bermuda surrounds

	SLAN	MLSN
Olsen P	**12**	**6**
Mehlich 3: P	**50**	**21**
K	**110**	**37**
Ca	**750**	**331**
Mg	**140**	**47**
S	**15 - 40**	**7**
pH	**--**	**5.5-8.5**

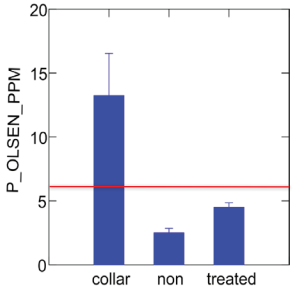
Talega Country Club
Knockout trial ½ lb MAP/1000 sq ft, 2 applications

Talega Country Club (pH 7.5)
Compare Treated vs. Non-Treated Soil

Talega Country Club (pH 7.5)



Talega Country Club (pH 7.5)



How much fertilizer is needed?

It depends upon how fast the grass grows at your location and how much N you provide.

Fun fact:

5 g/m^2 = 1 lb N/1000 sq ft = 33 ppm in top 4 inches

www.paceturf.org/journal/climate

25 ppm P/year @ 6 lbs N/1000 sq ft/year

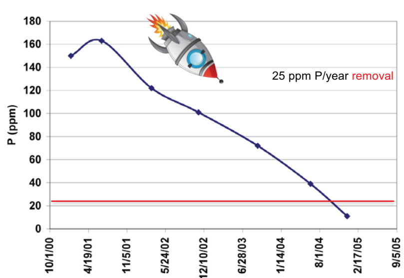
Location: Talega Golf Club

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg T (F)	54.5	54.5	57.9	61.5	65.1	68.8	74.8	75.6	73.5	66.3	58.6	53.3
Rainfall (in)	3.0	3.5	2.2	0.9	0.2	0.1	0.1	0.1	0.2	0.6	1.1	2.1

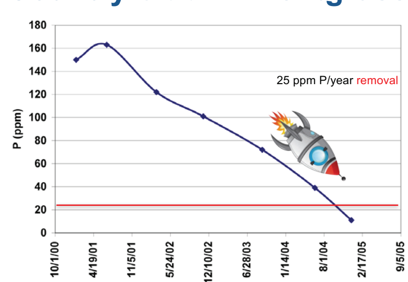
Cool Season Grass Maximum N/month lb/1000 sq ft = 0.70

Cool GP	40	40	60	81	96	100	79	75	86	99	64	34	Total lb/1000 sq ft	Soil ppm	Soil Plus MLSN ppm
N lb/1000 sq ft	0.3	0.3	0.4	0.6	0.7	0.7	0.6	0.5	0.6	0.7	0.5	0.2	6.0	NA	NA
K lb/1000 sq ft	0.14	0.14	0.21	0.28	0.34	0.35	0.28	0.26	0.30	0.34	0.23	0.12	2.99	98	135
P lb/1000 sq ft	0.04	0.04	0.05	0.07	0.09	0.09	0.07	0.07	0.08	0.09	0.06	0.03	0.78	25	46
Ca lb/1000 sq ft	0.03	0.03	0.04	0.06	0.07	0.07	0.06	0.05	0.06	0.07	0.05	0.02	0.60	20	351
Mg lb/1000 sq ft	0.01	0.01	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.01	0.30	10	57
S lb/1000 sq ft	0.02	0.02	0.03	0.03	0.04	0.04	0.03	0.03	0.04	0.04	0.03	0.01	0.36	12	19
Fe lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.030	1	45
Mn lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.011	0	6

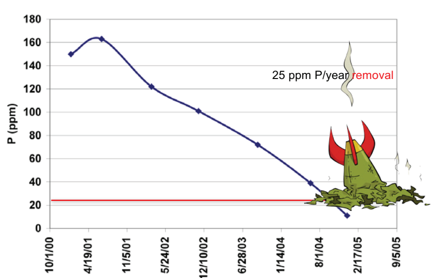
Trend in soil M3-P levels at Talega Country Club A4 Bentgrass



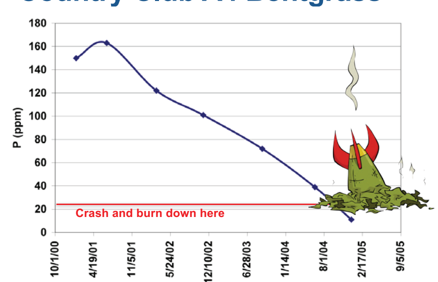
Trend in soil M3-P levels at Talega Country Club A4 Bentgrass



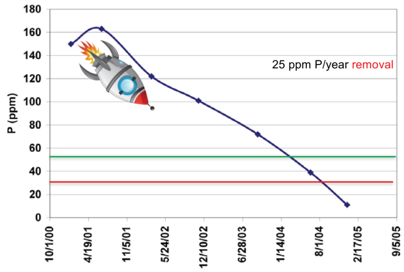
Trend in soil M3-P levels at Talega Country Club A4 Bentgrass



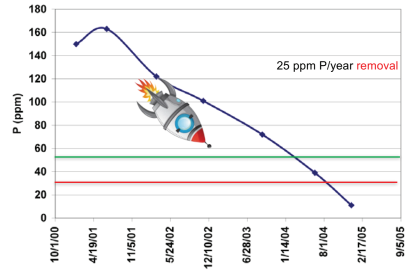
Trend in soil M3-P levels at Talega Country Club A4 Bentgrass



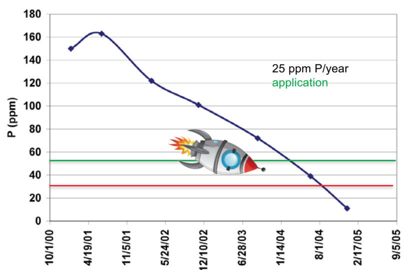
Trend in soil M3-P levels at Talega Country Club A4 Bentgrass



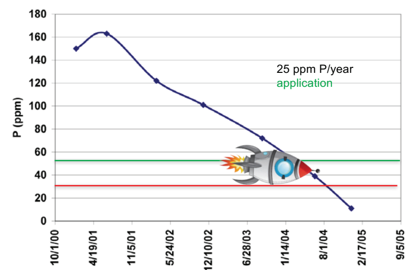
Trend in soil M3-P levels at Talega Country Club A4 Bentgrass



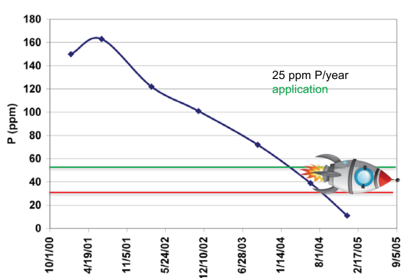
Trend in soil M3-P levels at Talega Country Club A4 Bentgrass



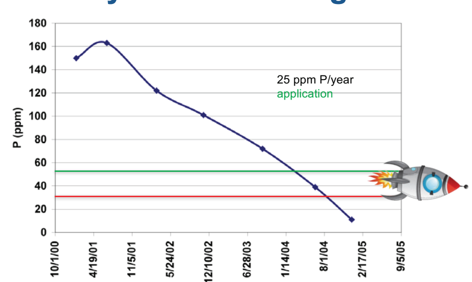
Trend in soil M3-P levels at Talega Country Club A4 Bentgrass



Trend in soil M3-P levels at Talega Country Club A4 Bentgrass



Trend in soil M3-P levels at Talega Country Club A4 Bentgrass



www.paceturf.org/journal/climate
25 ppm P/year @ 6 lbs N/1000 sq ft/year

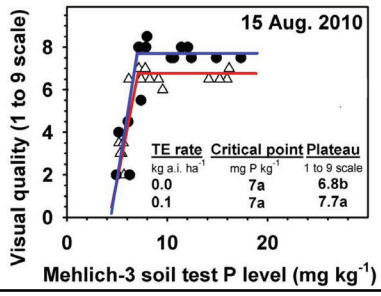
Location: Talega Golf Club

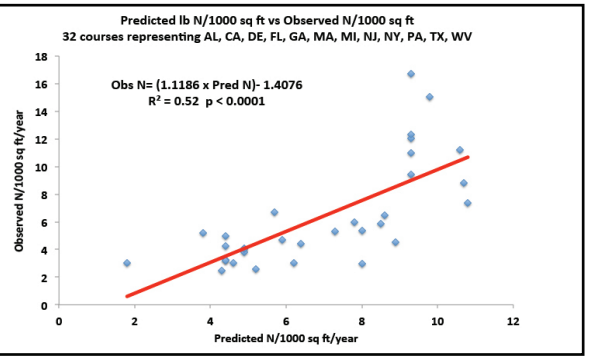
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg T (F)	54.5	54.5	57.9	61.5	65.1	68.8	74.8	75.6	73.5	66.3	58.6	53.3
Rainfall (in)	3.0	3.5	2.2	0.9	0.2	0.1	0.1	0.1	0.2	0.6	1.1	2.1

Cool Season Grass Maximum N/month lb/1000 sq ft = 0.70

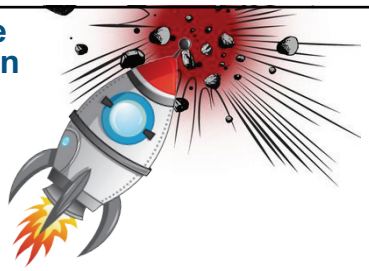
Cool GP	40	40	60	81	96	100	79	75	86	99	64	34	Total lb/1000 sq ft	Soil ppm	Soil Plus MLSN ppm
N lb/1000 sq ft	0.3	0.3	0.4	0.6	0.7	0.7	0.6	0.5	0.6	0.7	0.5	0.2	6.0	NA	NA
K lb/1000 sq ft	0.14	0.14	0.21	0.28	0.34	0.35	0.28	0.26	0.30	0.34	0.23	0.12	2.99	98	135
P lb/1000 sq ft	0.04	0.04	0.05	0.07	0.09	0.09	0.07	0.07	0.08	0.09	0.06	0.03	0.78	25	46
Ca lb/1000 sq ft	0.03	0.03	0.04	0.06	0.07	0.07	0.06	0.05	0.06	0.07	0.05	0.02	0.60	20	351
Mg lb/1000 sq ft	0.01	0.01	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.01	0.30	10	57
S lb/1000 sq ft	0.02	0.02	0.03	0.03	0.04	0.04	0.03	0.03	0.04	0.04	0.03	0.01	0.36	12	19
Fe lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.030	1	45
Mn lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.011	0	6

Soldat and Kreuser, 2012 Wisc. Soil Report





Excessive Fertilization

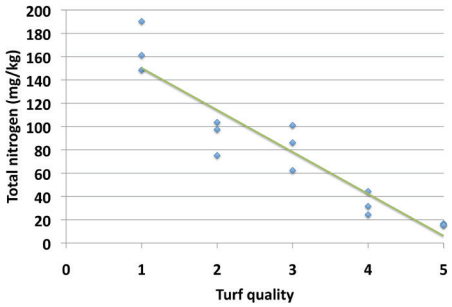


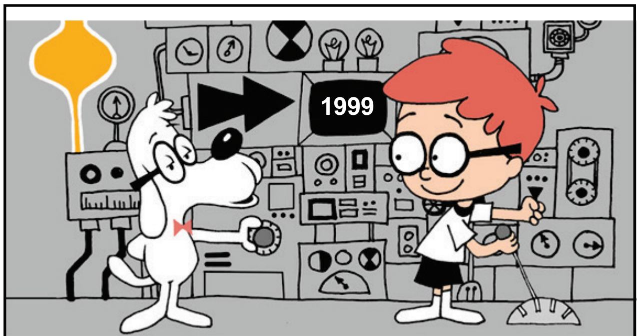
Fertilizer applied ppm/year

More than Needed ppm

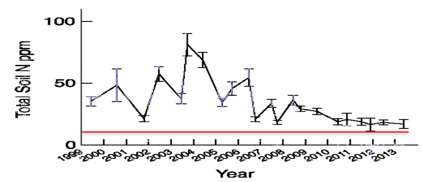
Recycled Water With 13 ppm Total N

Recycled Water With 13 ppm Total N

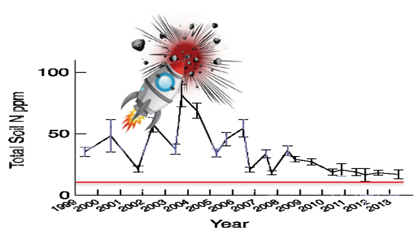




Recycled Water With 13 ppm Total N



Recycled Water With 13 ppm Total N



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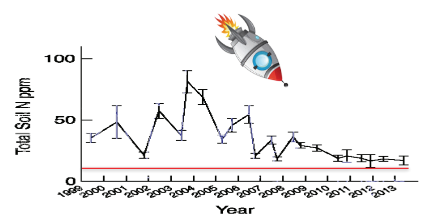
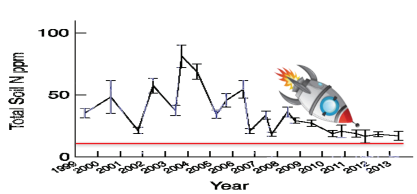
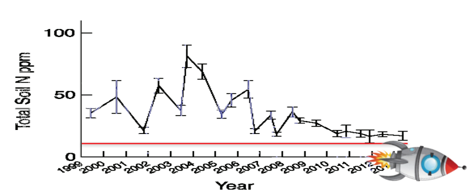


Recycled Water With 13 ppm Total N

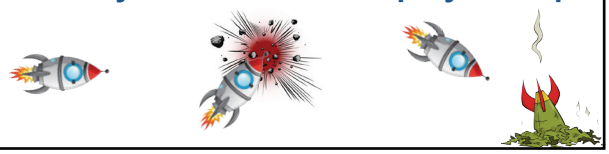


Recycled Water With 13 ppm Total N

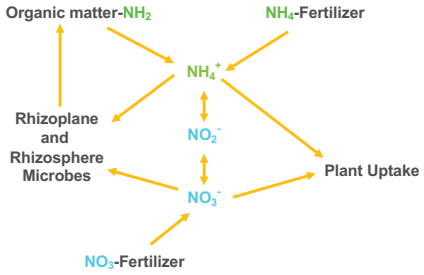


Each soil test result only represents a single point in time.

Keep all soil test results in case Mr. Peabody and Sherman stop by to help



Take all potential N sources into account

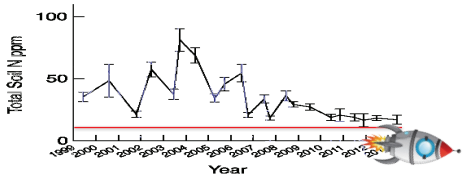


Elemental N release from organic matter soil OM% ⇒ Soil N ppm

If OM <= 1 Then
ENR = 20 + ((OM - 0.5) * 40)
Elself OM > 1 And OM <= 3 Then
ENR = 40 + ((OM - 1) * 20)
Elself OM > 3 And OM <= 5 Then
ENR = 80 + ((OM - 3) * 10)
Elself OM > 5 And OM <= 10 Then
ENR = 100 + ((OM - 5) * 5)
Elself OM > 10 And OM <= 20 Then
ENR = 125 + ((OM - 10) * 0.5)
Elself OM > 20 Then
ENR = 130

% OM	N ppm	Lb N/1000 sq ft	% OM	N ppm	Lb N/1000 sq ft
1	40	1.2	11	125.5	13
2	60	2.4	12	126	15
3	80	3.6	13	126.5	16
4	90	4.8	14	127	17
5	100	6.1	15	127.5	18
6	105	7.3	16	128	19
7	110	8.5	17	128.5	21
8	115	9.7	18	129	22
9	120	11	19	129.5	23
10	125	12	20	130	24

Recycled Water With 13 ppm Total N



Elemental contribution from irrigation water

2.72 x ppm = lb/acre ft
Acre ft/year x lb/acre ft = total pounds applied per acre
lb/acre * 0.5 = ppm in top 6 inches

2.72 x 13 ppm NO3-N = 35 lb N/acre ft
35 lb N/acre ft x 3 acre ft/year = 105 lb N/acre/year
105 lb N/acre/year/43.56 = 2.4 lb N/1000 sq ft/year
105 lb N * 0.75 = 79 ppm N increase in top 4 inches

Location: Newport Beach, CA

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg T (F)	55.0	55.8	56.8	58.8	61.6	64.1	67.2	68.3	67.1	64.0	59.6	55.9
Rainfall (in)	2.2	2.3	1.8	0.9	0.2	0.1	0.0	0.1	0.2	0.4	1.1	1.9

Warm Season Grass Maximum N/month lb/1000 sq ft = 1.00

Warm GP	2	3	3	5	9	14	22	26	22	14	6	3	Total lb/1000 sq ft	Soil ppm	Plus MLSN ppm
N lb/1000 sq ft	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.3	0.2	0.1	0.1	0.0	1.3	NA	NA
K lb/1000 sq ft	0.01	0.01	0.02	0.03	0.04	0.07	0.11	0.13	0.11	0.07	0.03	0.01	0.64	21	58
P lb/1000 sq ft	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.03	0.03	0.02	0.01	0.00	0.17	5	26
Ca lb/1000 sq ft	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.03	0.02	0.01	0.01	0.00	0.13	4	335
Mg lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.06	2	49
S lb/1000 sq ft	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.01	0.01	0.00	0.00	0.08	3	10
Fe lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.006	0	44
Mn lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.002	0	6

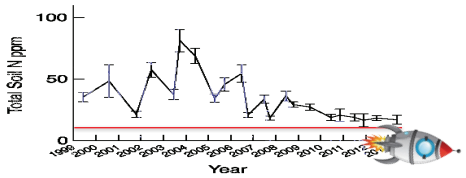
Estimate demand and supply

1.3 lb N/1000 sq ft (demand) x 43.56 = 57 lb/acre (demand)

57 lb/acre – 105 lb/acre (in water) = - 48 lb/acre (excess)

48 lb/acre x 0.75 = - 36 ppm (excess)

Recycled Water With 13 ppm Total N



www.paceturf.org/journal/climate
25 ppm P/year @ 6 lbs N/1000 sq ft/year

Location: Talega Golf Club

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg T (F)	54.5	54.5	57.9	61.5	65.1	68.8	74.8	75.6	73.5	66.3	58.6	53.3
Rainfall (in)	3.0	3.5	2.2	0.9	0.2	0.1	0.1	0.1	0.2	0.6	1.1	2.1

Cool Season Grass Maximum N/month lb/1000 sq ft = 0.70

Cool GP	40	40	60	81	96	100	79	75	86	99	64	34	Total lb/1000 sq ft	Soil ppm	Soil Plus MLSN ppm
N lb/1000 sq ft	0.3	0.3	0.4	0.6	0.7	0.7	0.6	0.5	0.6	0.7	0.5	0.2	6.0	NA	NA
K lb/1000 sq ft	0.14	0.14	0.21	0.28	0.34	0.35	0.28	0.26	0.30	0.34	0.23	0.12	2.99	98	135
P lb/1000 sq ft	0.04	0.04	0.05	0.07	0.09	0.09	0.07	0.07	0.08	0.09	0.06	0.03	0.78	25	46
Ca lb/1000 sq ft	0.03	0.03	0.04	0.06	0.07	0.07	0.06	0.05	0.06	0.07	0.05	0.02	0.60	20	351
Mg lb/1000 sq ft	0.01	0.01	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.01	0.30	10	57
S lb/1000 sq ft	0.02	0.02	0.03	0.03	0.04	0.04	0.03	0.03	0.04	0.04	0.03	0.01	0.36	12	19
Fe lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.030	1	45
Mn lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.011	0	6

Estimate demand and supply

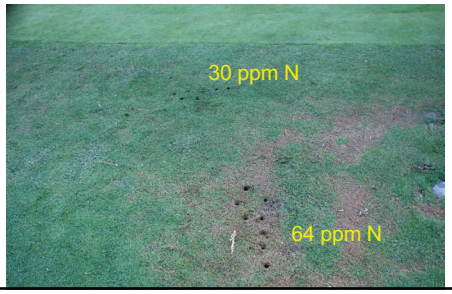
6.0 lb N/1000 sq ft (demand) x 43.56 = 261 lb/acre (demand)

261 lb/acre – 105 lb/acre (in water) = 156 lb/acre (deficit)

(156 lb/acre)/43.56 = 3.6 lb/1000 sq ft (deficit)

Excessive nitrogen stress in collars
(4 lbs N/1000 sq ft using ureaformaldehyde the previous year)

Excessive nitrogen stress in collars
(4 lbs N/1000 sq ft using ureaformaldehyde the previous year)

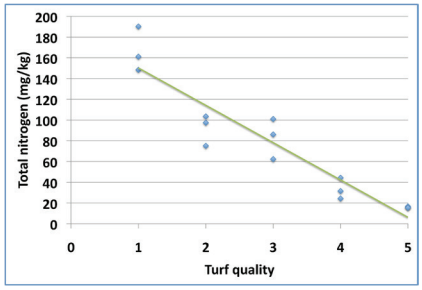


15-0-0 faulty sprayer agitator – random patterns of damage

15-0-0 faulty sprayer agitator – random patterns of damage

77 ppm N **22 ppm N**

Recycled Water With 13 ppm Total N



A quick test for soil nitrate levels with Hach water test strips. Dip into soil saturated with water, incubate 60 sec.

Nitrate levels (ppm) = (Dipstick X 1.5) + 2.9

(15 X 1.5) + 2.9 = 25.4 ppm

Potassium

MLSN

If soil K ppm drop near 37 ppm, use a 1:2 N:K fertilizer

37 – 110 ppm K use a 2:1 N:K fertilizer

If soil K ppm exceeds 150 ppm, withhold K

Range for annual N requirements

Lake Tahoe, CA : 1.8 lb N/1000 sq ft

Boca Raton, FL: 6.8 lb N/1000 sq ft

K requirements

Lake Tahoe, CA : 1.8 lb N/1000 sq ft

How much K will be needed:

1) 1.8 lb K/1000 sq ft
2) 0.9 lb K/1000 sq ft
3) 4.0 lb K/1000 sq ft

K requirements

Lake Tahoe, CA : 1.8 lb N/1000 sq ft

How much K will be needed:

1) 1.8 lb K/1000 sq ft
2) **0.9 lb K/1000 sq ft**
3) 4.0 lb K/1000 sq ft

K Requirements

Boca Raton, FL: 6.8 lb N/1000 sq ft

How much K will be needed:

1. 9.8 lb K/1000 sq ft
2. 13.6 lb K/1000 sq ft
3. 3.4 lb K/1000 sq ft

K Requirements

Boca Raton, FL: 6.8 lb N/1000 sq ft

How much K will be needed:

1. 9.8 lb K/1000 sq ft
2. 13.6 lb K/1000 sq ft
3. **3.4 lb K/1000 sq ft**

Rutgers University New Brunswick, NJ (C3)

http://www.paceturf.org/ipm/f_climate_english_20131025.xls

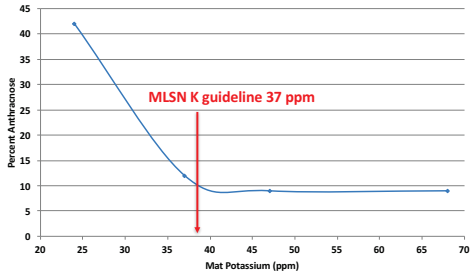
Location: New Brunswick, NJ

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg T (F)	31.4	32.0	40.4	50.6	61.0	69.8	74.4	72.6	66.3	56.0	44.9	34.0
Rainfall (in)	3.2	2.9	3.5	3.4	3.8	3.5	4.8	4.6	3.8	3.2	3.2	3.2

Cool Season Grass Maximum N/month lb/1000 sq ft = 0.70

Cool GP	0	0	2	22	78	98	81	90	99	49	7	0	Total lb/1000 sq ft	Soil ppm	Soil Plus MLSN ppm
N lb/1000 sq ft	0.0	0.0	0.0	0.2	0.5	0.7	0.6	0.6	0.7	0.3	0.0	0.0	3.7	NA	NA
K lb/1000 sq ft	0.00	0.00	0.01	0.08	0.27	0.34	0.29	0.31	0.34	0.17	0.02	0.00	1.84	60	97
P lb/1000 sq ft	0.00	0.00	0.00	0.02	0.07	0.09	0.07	0.08	0.09	0.04	0.01	0.00	0.48	16	37
Ca lb/1000 sq ft	0.00	0.00	0.00	0.02	0.05	0.07	0.06	0.06	0.07	0.03	0.00	0.00	0.37	12	343
Mg lb/1000 sq ft	0.00	0.00	0.00	0.01	0.03	0.03	0.03	0.03	0.03	0.02	0.00	0.00	0.18	6	53
S lb/1000 sq ft	0.00	0.00	0.00	0.01	0.03	0.04	0.03	0.04	0.04	0.02	0.00	0.00	0.22	7	14
Fe lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.018	1	45
Mn lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.007	0	6

2012 data presented at the 2013 CSSA Meetings by Charles Schmid Potassium Source and Rate Effect on Anthracnose Severity of Annual Bluegrass. Charles, J. Schmid, Bruce B. Clarke, James A. Murphy, Rutgers University.



Clippings
N:P:K
8:1:4 for cool season
3:1:2 for bermuda
3:1:3 for paspalum

Apply 4 lbs N
you need 0.5lb P and 2.0 lb K
for replacement (8:1:4 N:P:K)

4lb N
0.5 lb P x 2.29 = 1.1 lb P_2O_5
2 lb K x 1.2 = 2.4 lb K_2O

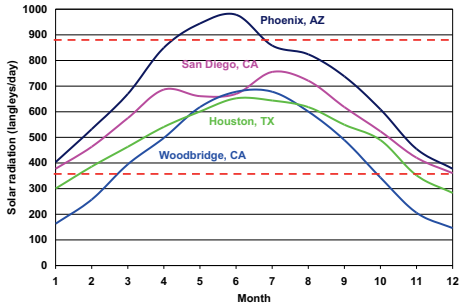
Fertilizer: 4:1:2 (N:P_2O_5:K_2O)

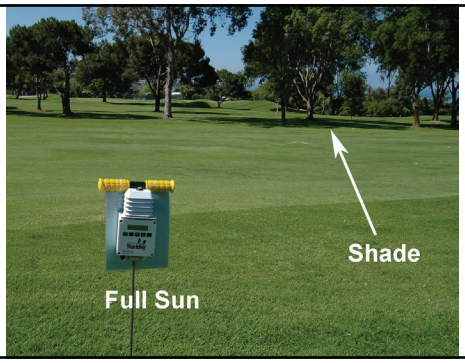
Optimum Solar Radiation

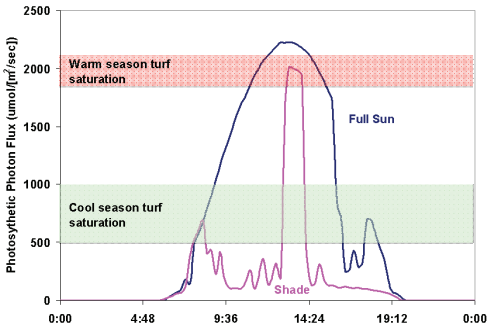
- Cool-Season Turf:
  - 242 - 485 Ly/da (midpoint about 360 Ly/da)
  - 116 - 233 w/m²/da (midpoint about 175 w/m²/da)
  - 21 - 42 mol/m²/da (midpoint about 31 mol/m²/da)
- Warm-Season Turf:
  - 812 - 969 Ly/da (midpoint about 890 Ly/da)
  - 390 - 465 w/m²/da (midpoint about 427 w/m²/da)
  - 70 – 83 mol/m²/da (midpoint about 76 mol/m²/da)

w/m²/da = 0.48 Ly/da

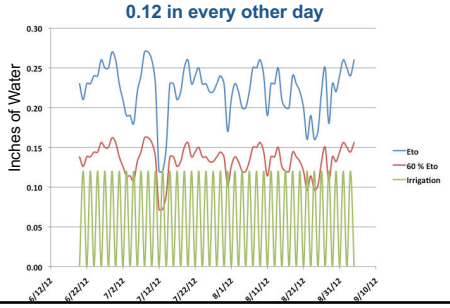
w/m²/da = 5.6 * mol/m²/da





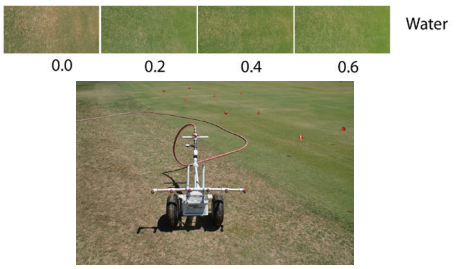


Barona Creek Golf Club, Sandy Clark, CGCS
Weekly average 1.05 in (60% Eto), 0.48 in delivered weekly using 0.12 in every other day

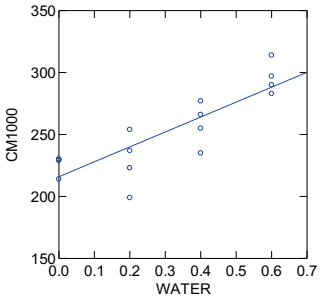


Irrigation

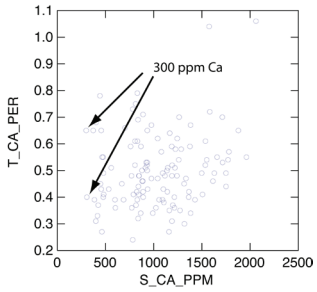
Inches of supplemental water per week
0.6 inches of supplemental water = 60% ETo



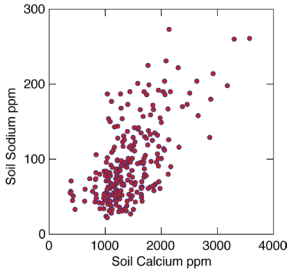
Irrigation



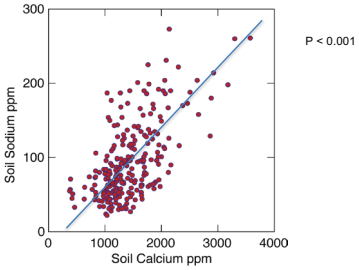
Calcium in Soil vs. Tissue
Looking for a plant response



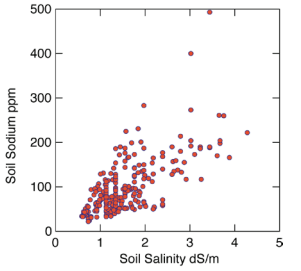
Soil Calcium vs. Sodium
Looking for a soil response



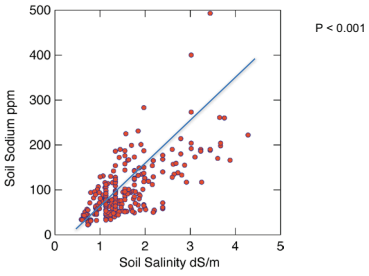
Soil Calcium vs. Sodium
Looking for a soil response



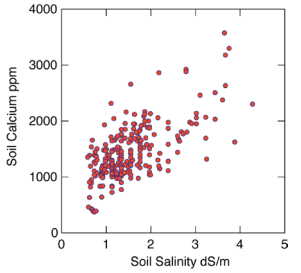
Soil Salinity vs. Sodium
Looking for a soil response



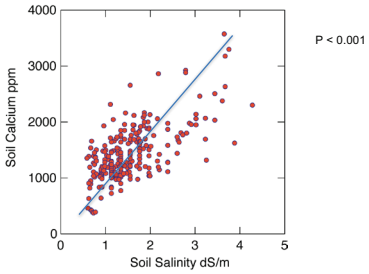
Soil Salinity vs. Sodium
Looking for a soil response



Soil Salinity vs. Calcium
Looking for a soil response



Soil Salinity vs. Calcium
Looking for a soil response



General Guideline Development

1. Calibration studies under controlled conditions
2. Observations when deficits are observed and fertilizers are added to correct the deficits and a positive response is observed
3. Data mining to determine the level of nutrients in soils that are associated with good turf performance (MLSN).

MLSN Development

Data set:

- Good performing turf only (evaluated by turf manager)
- Total exchange capacity (by summation M3 extraction of cations) less than 6 cmol/kg
- Soil pH between 5.5 and 8.5
- Soil pH above 7.5 for Olsen P
- About 1500 samples are used in most of the analyses, 270 samples meet Olsen pH restrictions

MLSN: Initial Observations

- None of the data were normally distributed based upon skewness ($-0.65 < G_1 < 0.65$) and kurtosis ($0.95 < G_2 < 1.75$)
- Selection of 1.5 standard deviations below the mean resulted in negative values for several parameters
- Therefore, use of the normal distribution was not feasible

Distribution Fitting

- EasyFit by Mathwave used to identify an appropriate model for the data
- Log logistic was selected due to significant fit evaluated by Kolmogrov Smirnov statistic

Distribution Fitting

	Kolmogorov Smirnov	
	Log-Logistic p	Normal p
Olsen P	0.05	0.14
Bray 2 P	0.03	0.16
Mehlich 3		
P	0.02	0.16
PSI	0.03	0.14
K	0.04	0.08
Ca	0.05	0.04
Mg	0.03	0.05
S	0.03	0.14
KCL Extract		
NO3-N	0.04	0.24
NH4-N	0.09	0.21
Total-N	0.02	0.20

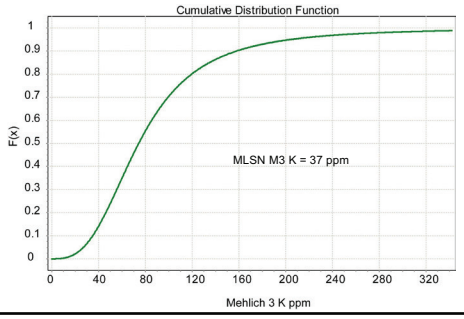
MLSN

- Defined as the soil nutrient concentration (ppm) at which 10% of the population falls below (10th percentile).
- Calculated using the best-fit log-logistic cumulative distribution function for:

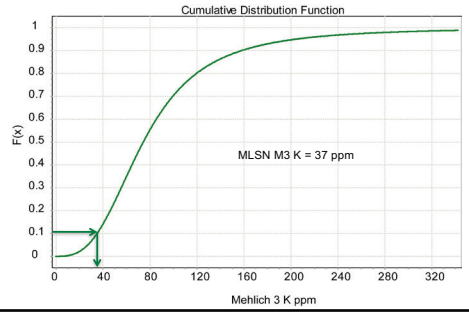
F(x) = 0.10

$$F(x) = \left(1 + \left(\frac{\beta}{x - \gamma}\right)^{\alpha}\right)^{-1}$$

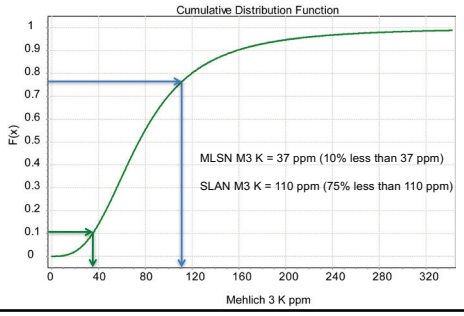
Mehlich 3 Potassium



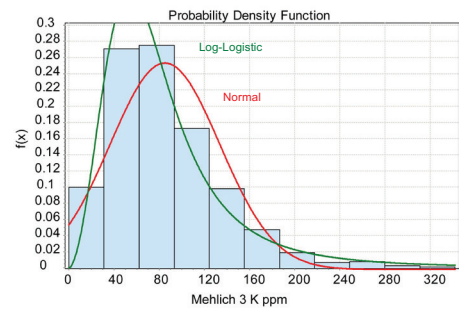
Mehlich 3 Potassium



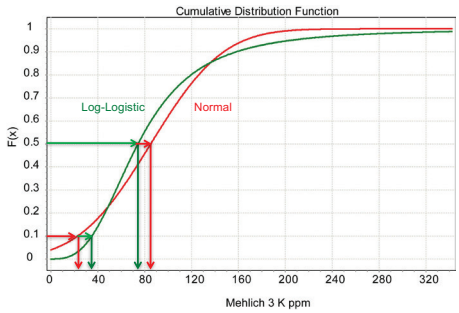
Mehlich 3 Potassium



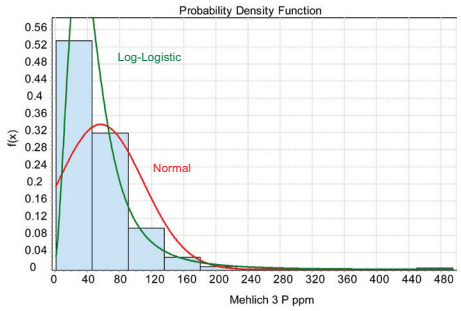
Mehlich 3 Potassium



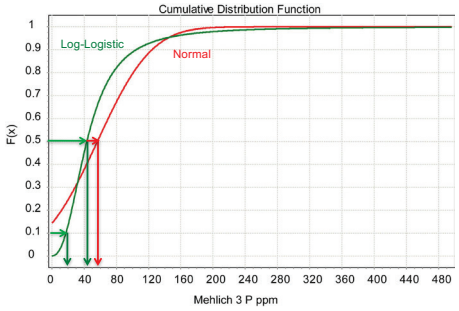
Mehlich 3 Potassium



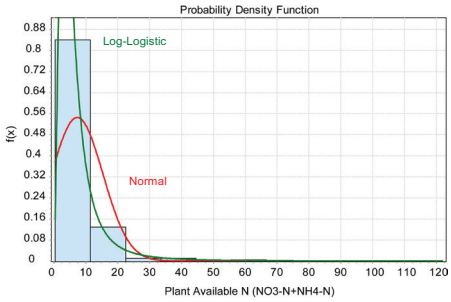
Mehlich 3 Phosphorus



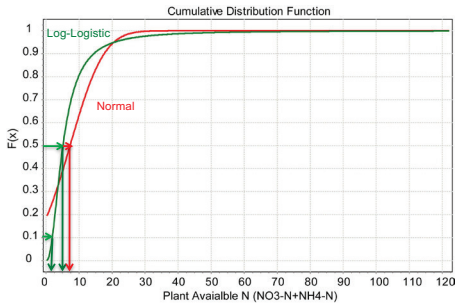
Mehlich 3 Phosphorus



Plant Available Nitrogen



Plant Available Nitrogen



Fertilization

- Use the minimum nitrogen to meet turf performance expectations
- Apply N, P and K in a ratio of 8:1:4 (N:P:K) if soil levels are in the sufficiency range – this will maintain balance between tissue removal and inputs
- Adjust N:P:K maintenance ratios as needed if P and K soil levels drop toward MLSN guidelines or start to increase
- Supplement maintenance applications if soil levels drop below sufficiency

Global soil survey

- Citizen science project to validate and expand on MLSN guidelines
- Turf managers from around the world contribute soils from good performing turf
- Analytical results (Brookside Labs) pooled with existing database
- MLSN guidelines revised as needed
- Raw data available to academic community

GLOBAL SOIL SURVEY

Global Soil Survey

Mehlich 3	SLAN	MLSN	GSS 2014 N = 84	GSS 2015 N = 138
P	50	21	22	23
K	110	37	35	32
Ca	750	331	267	254
Mg	140	47	47	39
S	15 - 40	7	8	8

Global Soil Survey

Mehlich 3	SLAN	MLSN	GSS Median
P	50	21	71
K	110	37	61
Ca	750	331	623
Mg	140	47	84
S	15 - 40	7	15

Regulations and fertilizer management

Delaware fertilizer use restrictions and MLSN

Water Quality
Best Management Practices:
Nutrients, Irrigation and Pesticides
for Golf Course, Athletic Turf,
Lawn Care and Landscape Industries

Delaware Nutrient Management Commission

2006

Delaware fertilizer use restrictions and MLSN

Chart 2: TOTAL NITROGEN RATES FOR TURFGRASSES PER YEAR

Species	Standard Maintenance* rates in lbs. per 1,000 ft²	High Maintenance* rates in lbs. per 1,000 ft²
Creeping Bentgrass	3 lbs.	4-5 lbs.
Perennial Ryegrass	2 lbs.	4-5 lbs.
Kentucky Bluegrass	2 lbs.	4-5 lbs..
Poa Annua	3-4 lbs.	5-6 lbs.
Tall Fescue	2 lbs.	3-4 lbs.
Fine Fescue (K-31)	2 1bs.	3-4 lbs.
Bermudagrass	3-4 lbs.	4-6 lbs..
Zoysiagrass	2-3 lbs.	4-5 lbs.

*See site considerations below for determining standard or high maintenance.
Source: Delaware Nutrient Management BMPs for Commercial and Residential Turf Management 2-12-03 Policy

Delaware fertilizer use restrictions and MLSN

Standard maintenance

- Little traffic on turf area or minimal response to plant growth as a result of traffic
- Grass clippings recycled into the soil surface
- Native healthy soil structure

Delaware fertilizer use restrictions and MLSN

High maintenance

- Irrigated and grass clippings removed
- Vehicle or personnel traffic that creates visual damage to the turf area
- Insect pest pressure or disease pressure that demonstrates visual damage and stress to the plant
- The introduction of sandy growth medium for improved drainage, such as California greens

% OM	N ppm	Lb N/1000 sq ft	% OM	N ppm	Lb N/1000 sq ft
1	40	1.2	11	125.5	13
2	60	2.4	12	126	15
3	80	3.6	13	126.5	16
4	90	4.8	14	127	17
5	100	6.1	15	127.5	18
6	105	7.3	16	128	19
7	110	8.5	17	128.5	21
8	115	9.7	18	129	22
9	120	11	19	129.5	23
10	125	12	20	130	24

Delaware fertilizer use restrictions and MLSN

Location: Newark, DE

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg T (F)	32.1	33.4	42.3	52.5	62.9	71.3	75.9	74.1	67.7	56.2	45.6	35.5
Rainfall (in)	3.2	2.8	3.9	3.4	4.0	3.7	4.6	4.1	3.9	3.2	3.2	3.5

Cool Season Grass Maximum N/month lb/1000 sq ft = 0.70

Cool GP	0	0	4	30	88	95	73	83	100	50	8	1	Total lb/1000 sq ft	Soil ppm	Soil Plus MLSN ppm
N lb/1000 sq ft	0.0	0.0	0.0	0.2	0.6	0.7	0.5	0.6	0.7	0.3	0.1	0.0	3.7	NA	NA
K lb/1000 sq ft	0.00	0.00	0.01	0.11	0.31	0.33	0.26	0.29	0.35	0.17	0.03	0.00	1.86	61	98
P lb/1000 sq ft	0.00	0.00	0.00	0.03	0.08	0.09	0.07	0.08	0.09	0.05	0.01	0.00	0.48	16	37
Ca lb/1000 sq ft	0.00	0.00	0.00	0.02	0.06	0.07	0.05	0.06	0.07	0.03	0.01	0.00	0.37	12	343
Mg lb/1000 sq ft	0.00	0.00	0.00	0.01	0.03	0.03	0.03	0.03	0.03	0.02	0.00	0.00	0.19	6	53
S lb/1000 sq ft	0.00	0.00	0.00	0.01	0.04	0.04	0.03	0.03	0.04	0.02	0.00	0.00	0.22	7	14
Fe lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.019	1	45
Mn lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.007	0	6

Delaware fertilizer use restrictions and MLSN

Location: Newark, DE

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg T (F)	32.1	33.4	42.3	52.5	62.9	71.3	75.9	74.1	67.7	56.2	45.6	35.5
Rainfall (in)	3.2	2.8	3.9	3.4	4.0	3.7	4.6	4.1	3.9	3.2	3.2	3.5

Warm Season Grass Maximum N/month lb/1000 sq ft = 0.70

Warm GP	0	0	0	1	11	38	60	51	24	3	0	0	Total lb/1000 sq ft	Soil ppm	Plus MLSN ppm
N lb/1000 sq ft	0.0	0.0	0.0	0.0	0.1	0.3	0.4	0.4	0.2	0.0	0.0	0.0	1.3	NA	NA
K lb/1000 sq ft	0.00	0.00	0.00	0.00	0.04	0.13	0.21	0.18	0.08	0.01	0.00	0.00	0.66	22	59
P lb/1000 sq ft	0.00	0.00	0.00	0.00	0.01	0.03	0.05	0.05	0.02	0.00	0.00	0.00	0.17	6	27
Ca lb/1000 sq ft	0.00	0.00	0.00	0.00	0.01	0.03	0.04	0.04	0.02	0.00	0.00	0.00	0.13	4	335
Mg lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.01	0.00	0.00	0.00	0.07	2	49
S lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.02	0.01	0.00	0.00	0.00	0.08	3	10
Fe lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.007	0	44
Mn lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.002	0	6

Maryland fertilizer use restrictions and MLSN

UNIVERSITY OF MARYLAND EXTENSION
Solutions in your community

HOME & GARDEN Information Center

HG 112
2013

Turfgrass Maintenance Calendars for Maryland Lawns

Maryland fertilizer use restrictions and MLSN

Table 1. UME Turf Fertilizer Recommendations

Grass Type	Date of Application	Pounds of nitrogen per 1000 sq. ft.
Tall fescue	September/October	0.9 - 1.8 lbs a year- 0.9 lb. in September and 0.9 lb. in October
Kentucky bluegrass	September/October	0.9 - 1.8 lbs a year- 0.9 lb. in September and 0.9 lbs. in October
Fine fescue	October	0.9 lb.
Zoysiagrass	June	0.9 lb.
Bermudagrass	June/July	0.9 lb. in June and 0.9 in July

- If clippings are left on the lawn you may only need one application per year regardless of your lawn's age.
- Healthy lawns established longer than twelve years may only need one application per year.
- No fertilizer can be applied between November 15 and March 1.

Maryland fertilizer use restrictions and MLSN

Optional Turf Applications		
Grass Type	Date of Application	Pounds of nitrogen per 1000 sq. ft.
Tall fescue	Late May or early June	0.5 to 0.9 lb.
Fine fescue	Late May or early June	0.5 lb.
Kentucky bluegrass	Late May or early June	0.5 to 0.9 lb.
Zoysiagrass Bermudagrass	July or August	0.5 to 0.9 lb.

Tall fescue and particularly Kentucky bluegrass may need moderate additional applications of fertilizer to maintain density and reduce pest and weed problems. The optional applications may help your lawn if:

- clippings are removed
- there is a severe crabgrass problem
- the lawn is heavily used
- there has been pest or other damage
- lawn was seeded the previous fall
- the previous fall fertilization was missed

Maryland fertilizer use restrictions and MLSN

Maryland fertilizer use restrictions and MLSN

Table 3. Annual nitrogen recommendation rates for commercially maintained turfgrass

Total Nitrogen Annually (pounds of N per 1,000 square feet)		
Cool-Season Grasses	**Years 1 Through 2**	**Subsequent Years**
Kentucky bluegrass	3.0 - 4.0	2.0 - 3.5
Turf-type tall fescue	2.5 - 3.5	2.0 - 3.0
Fine fescue	1.0 - 2.0	0.0 - 1.5
Perennial ryegrass	2.5 - 3.5	2.0 - 3.0
Warm Season Grasses	**Years 1-2**	**Subsequent Years**
Bermudagrass	2.0 - 4.0	2.0 - 3.0
Zoysiagrass	1.0 - 2.0	0.0 - 2.0

(Turner, 2013)

Maryland fertilizer use restrictions and MLSN

Location: College Park, MD

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg T (F)	34.1	35.4	44.4	54.0	63.9	72.4	76.8	75.0	68.7	57.1	46.4	36.6
Rainfall (in)	24.6	25.3	33.2	41.5	51.5	60.5	65.4	63.6	56.8	44.7	35.4	27.2

Cool Season Grass Maximum N/month lb/1000 sq ft = 0.70

Cool GP	0	0	6	38	92	91	68	78	100	55	10	1	Total lb/1000 sq ft	Soil ppm	Soil Plus MLSN ppm
N lb/1000 sq ft	0.0	0.0	0.0	0.3	0.6	0.6	0.5	0.5	0.7	0.4	0.1	0.0	3.8	NA	NA
K lb/1000 sq ft	0.00	0.00	0.02	0.13	0.32	0.32	0.24	0.27	0.35	0.19	0.03	0.00	1.89	62	99
P lb/1000 sq ft	0.00	0.00	0.01	0.03	0.08	0.08	0.06	0.07	0.09	0.05	0.01	0.00	0.49	16	37
Ca lb/1000 sq ft	0.00	0.00	0.00	0.03	0.06	0.06	0.05	0.05	0.07	0.04	0.01	0.00	0.38	12	343
Mg lb/1000 sq ft	0.00	0.00	0.00	0.01	0.03	0.03	0.02	0.03	0.03	0.02	0.00	0.00	0.19	6	53
S lb/1000 sq ft	0.00	0.00	0.00	0.02	0.04	0.04	0.03	0.03	0.04	0.02	0.00	0.00	0.23	7	14
Fe lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.019	1	45
Mn lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.007	0	6

Maryland fertilizer use restrictions and MLSN

Location: College Park, MD

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg T (F)	34.1	35.4	44.4	54.0	63.9	72.4	76.8	75.0	68.7	57.1	46.4	36.6
Rainfall (in)	24.6	25.3	33.2	41.5	51.5	60.5	65.4	63.6	56.8	44.7	35.4	27.2

Warm Season Grass Maximum N/month lb/1000 sq ft = 0.70

Warm GP	0	0	0	2	13	43	65	56	27	4	0	0	Total lb/1000 sq ft	Soil ppm	Plus MLSN ppm
N lb/1000 sq ft	0.0	0.0	0.0	0.0	0.1	0.3	0.5	0.4	0.2	0.0	0.0	0.0	1.5	NA	NA
K lb/1000 sq ft	0.00	0.00	0.00	0.01	0.05	0.15	0.23	0.19	0.10	0.01	0.00	0.00	0.73	24	61
P lb/1000 sq ft	0.00	0.00	0.00	0.00	0.01	0.04	0.06	0.05	0.02	0.00	0.00	0.00	0.19	6	27
Ca lb/1000 sq ft	0.00	0.00	0.00	0.00	0.01	0.03	0.05	0.04	0.02	0.00	0.00	0.00	0.15	5	336
Mg lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.02	0.01	0.00	0.00	0.00	0.07	2	49
S lb/1000 sq ft	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.02	0.01	0.00	0.00	0.00	0.09	3	10
Fe lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.007	0	44
Mn lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.003	0	6

Maryland fertilizer use restrictions and MLSN

CHESAPEAKE BAY PHOSPHORUS REDUCTION ACT OF 2009

Maryland's Chesapeake Bay Phosphorus Reduction Act of 2009 mandated that only low phosphorus fertilizer may be applied to turf. Low phosphorus is defined as having 5 percent or less P_2O_5. The legislation also established labeling and reporting requirements. High phosphorus fertilizer is prohibited from being labeled for use on turf (for example, 10-10-10), and spreader settings are prohibited from appearing on the fertilizer bag. In addition, high phosphorus fertilizer is required to contain the following statement in ¾-inch letters on the front of the product bag: "NOT FOR USE ON ESTABLISHED LAWNS OR GRASS." Manufacturers are required to report to MDA the pounds of phosphorus sold in the state.

Michigan fertilizer use restrictions and MLSN

Michigan Department of Agriculture & Rural Development

New Michigan Fertilizer Legislation Restricts Phosphorus Applications on Turf

Beginning **January 1, 2012**, phosphorus fertilizer applications are restricted on residential and commercial lawns in Michigan, including athletic fields and golf courses statewide. This includes applications by both homeowners and commercial applicators.

The general rule in Public Act 299 of 2010 (Act 299) is no phosphorus fertilizer may be applied on residential or commercial lawns, unless it meets an exemption. The sale of phosphorus fertilizers in the marketplace is not impacted. Phosphorus applications for agriculture, gardens, trees, and shrubs are exempted; the restrictions are identified below.

Michigan fertilizer use restrictions and MLSN

Act 299 Highlights:

- Starting January 1, 2012, a person shall not apply any fertilizer with available phosphate (P_2O_5) to turf. Available phosphate (P_2O_5) may be applied at **specified rates** under the following instances:
  - When a soil test or plant tissue test indicates phosphorus is needed;
  - For new turf establishment using seed or sod;
  - A finished sewage sludge (biosolid), organic manure or a manipulated manure (like compost). The application rate is limited to 0.25 pounds of phosphorus per 1,000 square feet.
  - On golf courses whose manager(s) have completed a Michigan Department of Agriculture and Rural Development (MDARD) approved training program.

Michigan fertilizer use restrictions and MLSN

Location: East Lansing, MI

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg T (F)	22.2	24.0	33.9	46.5	57.5	67.0	70.6	69.1	62.0	50.1	39.0	27.2
Rainfall (in)	1.5	1.2	1.9	2.8	3.0	3.4	3.1	3.1	3.2	2.4	2.5	1.8

Cool Season Grass Maximum N/month lb/1000 sq ft = 0.70

Cool GP	0	0	0	10	58	100	97	99	84	20	1	0	Total lb/1000 sq ft	Soil ppm	Soil Plus MLSN ppm
N lb/1000 sq ft	0.0	0.0	0.0	0.1	0.4	0.7	0.7	0.7	0.6	0.1	0.0	0.0	3.3	NA	NA
K lb/1000 sq ft	0.00	0.00	0.00	0.03	0.20	0.35	0.34	0.35	0.29	0.07	0.01	0.00	1.64	54	91
P lb/1000 sq ft	0.00	0.00	0.00	0.01	0.05	0.09	0.09	0.09	0.08	0.02	0.00	0.00	0.43	14	35
Ca lb/1000 sq ft	0.00	0.00	0.00	0.01	0.04	0.07	0.07	0.07	0.06	0.01	0.00	0.00	0.33	11	342
Mg lb/1000 sq ft	0.00	0.00	0.00	0.00	0.02	0.03	0.03	0.03	0.03	0.01	0.00	0.00	0.16	5	52
S lb/1000 sq ft	0.00	0.00	0.00	0.00	0.02	0.04	0.04	0.04	0.04	0.01	0.00	0.00	0.20	6	13
Fe lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.016	1	45
Mn lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.006	0	6

MSU Soil Testing Lab Recommendations for Phosphorus Applications to Turfgrass 3/8/2012

Bray P1, Mehlich 3 Soil Test Value (ppm): pH<7.4	Olsen Soil Test Value (ppm) pH>7.4	Sand based rootzone establishment: Recommendation (lbs. P_2O_5/1000 ft.^{2})	Golf greens and tees est. or mature; Kentucky bluegrass or perennial ryegrass athletic fields est. or mature; sand based rootzone mature: Recommendation (lbs. P_2O_5/1000 ft.^{2})	Lawns, golf course fairways; establishment or mature: Recommendation (lbs. P_2O_5/1000 ft.^{2})	Establishment without soil test: Recommendation (lbs. P_2O_5/1000 ft.^{2})
0	0	4.4	3.4	2.5	2.5 lbs. year (Maximum single application of 1.5 lbs.)
2	1.3	4.1	3.1	2.2	
4	2.7	3.9	2.7	1.9	
6	4	3.6	2.4	1.6	
8	5.3	3.4	2.0	1.3	
10	6.7	3.1	1.7	1.0	
12	8	2.8	1.4	0.7	
14	9.3	2.6	1.0	0.4	
16	10.7	2.3	0.7	0.1	
18	12	2.1	0.3	0.0	
20	13.3	1.8	0.0		
22	14.7	1.5			
24	16	1.3			
26	17.3	1.0			
28	18.7	0.8			
30	20	0.5			
32	21.3	0.2			
34	22.7	0.0			

Web resources: www.turf.msu.edu or www.bephosphorussmart.msu.edu

New Hampshire fertilizer use restrictions and MLSN

University of New Hampshire Cooperative Extension

Food & Agriculture

AGRICULTURE FACT SHEET
Spring 2014

New Hampshire's Turf Fertilizer Law What You Should Know

MARGARET HAGEN, Extension Field Specialist

New Hampshire fertilizer use restrictions and MLSN

431:4-a Nitrogen Content of Fertilizer.

I. Limit to 0.7 lb soluble N/1000 sq ft per application
II. Limit to 0.9 lb total N/1000 sq ft per application – 20% slow release N
III. Limit to **3.25 lb N/1000 sq ft per year**
IV. No enhanced efficiency fertilizer shall exceed a single application rate of 2.5 lbs. N/1000 sq ft nor release at greater than 0.7 pounds per 1,000 square feet per month

New Hampshire fertilizer use restrictions and MLSN

Location: Durham, NH

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg T (F)	3.2	24.9	34.1	44.8	55.4	64.5	70.0	68.0	60.6	50.0	39.3	27.6
Rainfall (in)	13.1	14.4	23.7	33.1	42.7	51.9	57.6	55.6	48.3	38.0	29.4	18.3

Cool Season Grass Maximum N/month lb/1000 sq ft = 0.70

Cool GP	0	0	0	7	45	94	98	100	76	20	2	0	Total lb/1000 sq ft	Soil ppm	Soil Plus MLSN ppm
N lb/1000 sq ft	0.0	0.0	0.0	0.0	0.3	0.7	0.7	0.7	0.5	0.1	0.0	0.0	3.1	NA	NA
K lb/1000 sq ft	0.00	0.00	0.00	0.02	0.16	0.33	0.34	0.35	0.27	0.07	0.01	0.00	1.55	51	88
P lb/1000 sq ft	0.00	0.00	0.00	0.01	0.04	0.09	0.09	0.09	0.07	0.02	0.00	0.00	0.40	13	34
Ca lb/1000 sq ft	0.00	0.00	0.00	0.00	0.03	0.07	0.07	0.07	0.05	0.01	0.00	0.00	0.31	10	341
Mg lb/1000 sq ft	0.00	0.00	0.00	0.00	0.02	0.03	0.03	0.04	0.03	0.01	0.00	0.00	0.15	5	52
S lb/1000 sq ft	0.00	0.00	0.00	0.00	0.02	0.04	0.04	0.04	0.03	0.01	0.00	0.00	0.19	6	13
Fe lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.015	1	45
Mn lb/1000 sq ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.006	0	6