Interpreting Soil Sample Results

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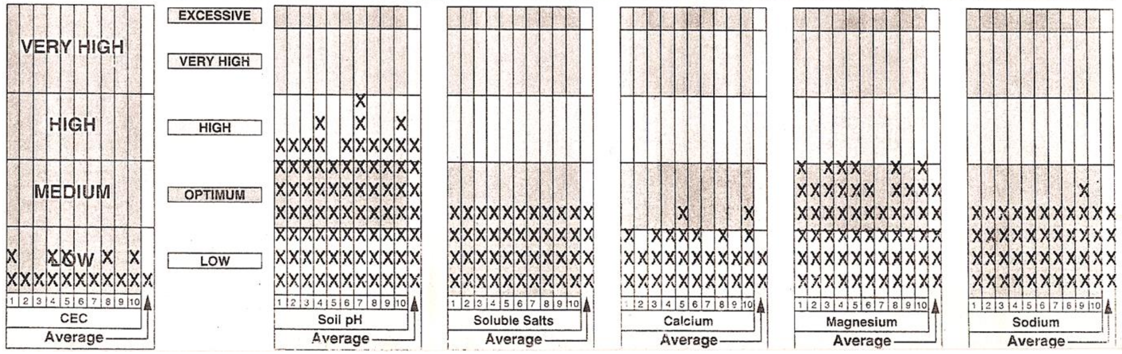
Soil Testing

635 | DATE REC'D. 07-Dec-93 | DATE REPORTED 08-Dec-93 | SAMPLE WILL BE KEPT UNTIL 07-Jan-94 | LABORATORY NUMBER 94290022-290031

ALL NUTRIENT RESULTS EXPRESSED IN PPM

CODE →	1	2	3	4	5	6	7	8	9	10	AVERAGES
Sample Description	GRN11	GRN12	GRN13	GRN14	GRN15	GRN16	GRN17	GRN18	PG	WARMUP	
CEC	3.4	2.8	3.1	4.2	4.4	3.2	2.5	4.1	2.7	4.3	3.5
Soil pH	6.7*	6.7*	6.7*	6.9*	6.4	6.8*	7.1*	6.8*	6.7*	7.0*	6.8*
Buffer pH	----	----	----	----	7.2	----	----	----	----	----	7.2
Soluble Salts	0.14	0.14	0.12	0.18	0.18	0.20	0.14	0.18	0.23	0.13	0.16
Exchangeable Calcium (Ca)	454*	366*	417*	597*	641	452*	334*	586*	344*	627	482*
Exchangeable Magnesium (Mg)	104	92	102	119	116	97	79	115	90	119	103
Exchangeable Sodium (Na)	10	10	9	10	10	8	7	14	16	8	10
% H Base Saturation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
% K Base Saturation	5.4*	5.2*	4.8*	3.7*	4.0*	3.8*	5.3*	4.0*	7.5*	4.2*	4.8*
% Mg Base Saturation	25.8*	27.5*	27.2*	23.7*	22.0*	25.1*	26.4*	23.3*	27.3*	22.8*	25.1*
% Ca Base Saturation	67.5	65.7	66.8	71.5	73.0	70.1	67.1	71.2	62.7	72.2	68.8
% Na Base Saturation	1.3	1.6	1.3	1.0	1.0	1.1	1.2	1.5	2.5	0.8	1.3



What is the purpose of a soil test?

- To increase crop yields
- Is increasing ‘yields’ important for turfgrass?

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How are soil test values interpreted?

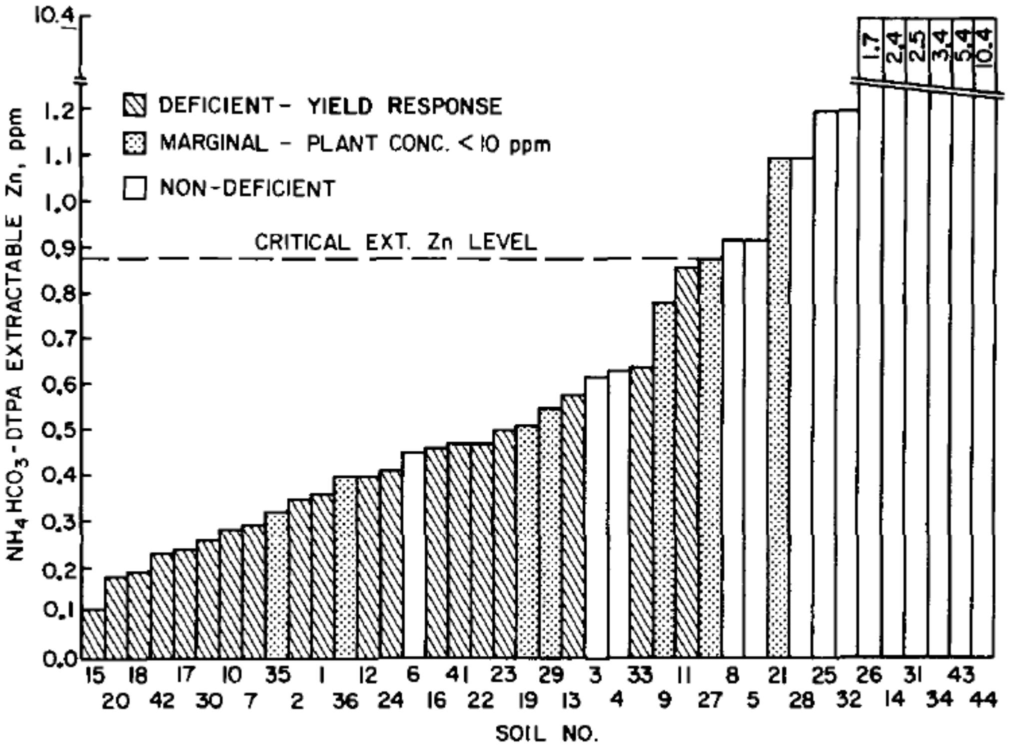

Fig. 3—Corn response of 40 Colorado soils to Zn as a function of NH_4HCO_3–DTPA soil test levels.

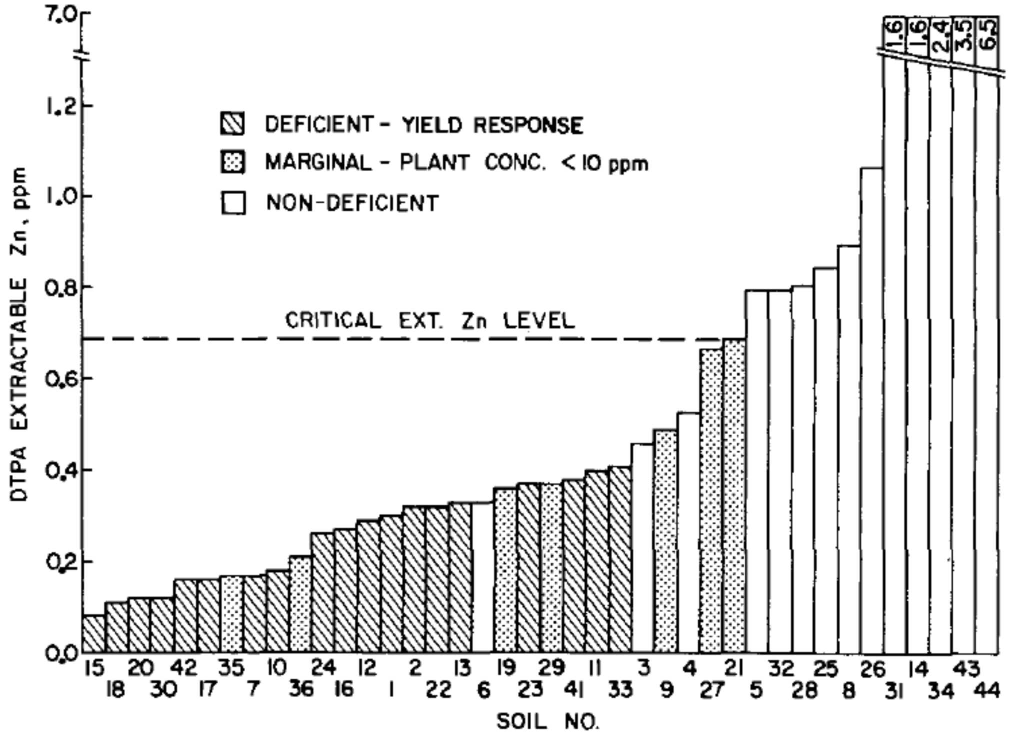

Fig. 4—Corn response of 40 Colorado soils to Zn as a function of DTPA soil test levels.

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Soil Science Society of America Journal 1981 45:70-75

Response Probability

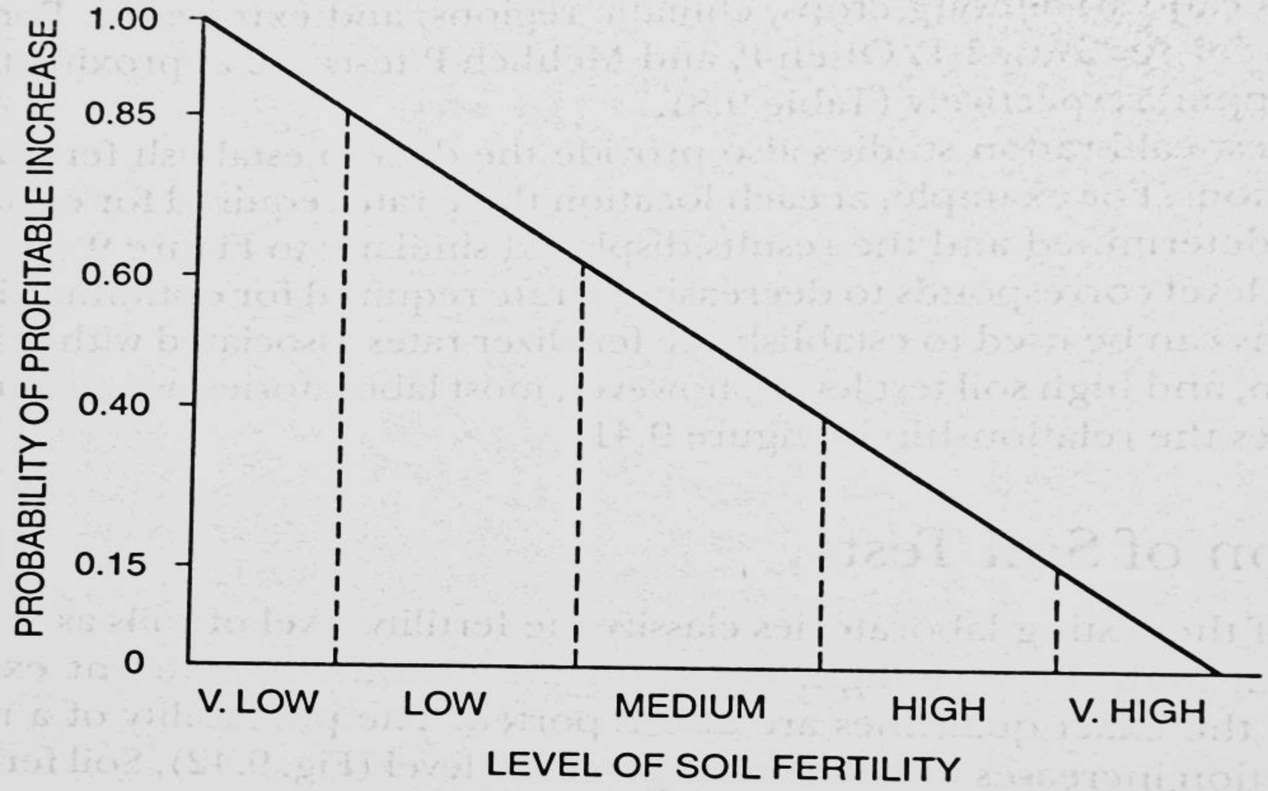

FIGURE 9.42 There is a greater probability of obtaining a profitable response from fertilization on soils testing low in an element than from soils testing high in that element.

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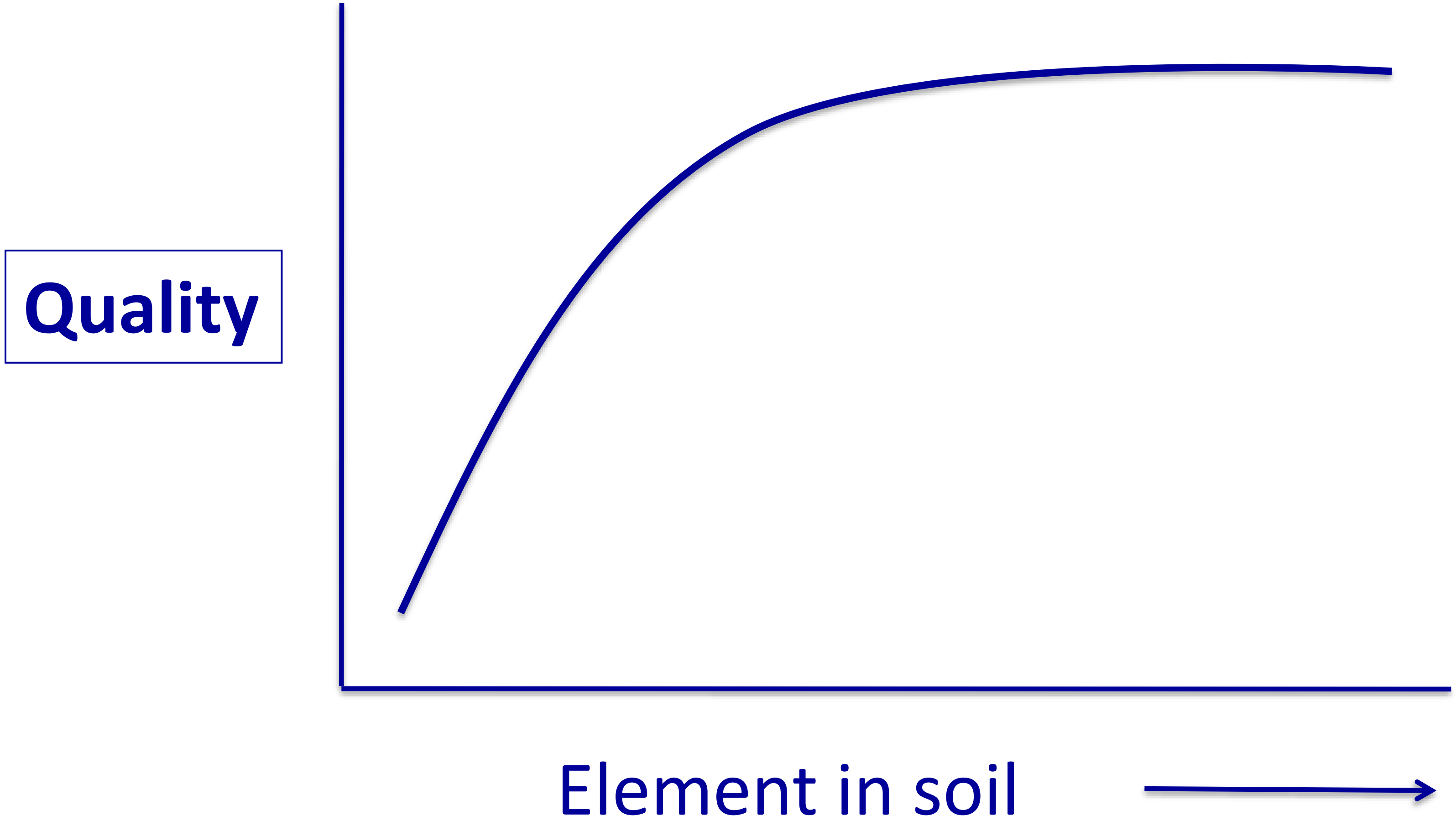
Soil Fertility and Fertilizers 1999 p. 344

Yield Curve



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Take a Representative Sample

- Collect from several locations
- Depth depends on lab
- Combine and mix samples
- Take a sub-sample, approximately 1 cup
- How often?

Soil Test Values

- Cation exchange capacity (CEC)
- pH
- Salinity and sodicity
- Organic matter (OM)
- Base saturation
- Nutrient concentrations

17 Essential Elements

- **Carbon (C)**
- **Hydrogen (H)**
- **Oxygen (O)**
- Nitrogen (N)
- Phosphorus (P)
- Potassium (K)
- Sulfur (S)
- Calcium (Ca)
- Iron (Fe)
- Magnesium (Mg)
- Boron (B)
- Manganese (Mn)
- Copper (Cu)
- Zinc (Zn)
- Molybdenum (Mo)
- Chlorine (Cl)
- Nickel (Ni)

Understanding Turf Nutrients

- Macronutrients
  - Plants need large amounts of these elements
    - Needs generally provided by conventional fertilization practices

Nitrogen (N)
Phosphorus (P)
Potassium (K)

- Secondary Nutrients
  - Plants require lesser amounts of these materials

Calcium (Ca)
Magnesium (Mg)
Sulfur (S)

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Understanding Turf Nutrients

- Micronutrients
  - The *term* micronutrients does not imply that these elements are **unimportant**; rather, it indicates that the amounts required are relatively low
    - Deficiencies generally associated with either excessive alkalinity (high pH) or excessive acidity (low pH)

Iron (Fe), Manganese (Mn), Boron (B), Copper (Cu), Zinc (Zn), Molybdenum (Mo), Chlorine (Cl)

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Basic Principles and Terminology

- CEC
- pH
- Salinity and sodicity
  - Electrical conductivity (EC)
  - Exchangeable sodium percentage (ESP)
  - Sodium adsorption ratio (SAR)

Cation/Anion Exchange Capacity (CEC)

- Cations (+)
  - Ca^{++}, Mg^{++}, K^{+}, Na^{+}, H^{+}, Al^{+++}
- Anions (-)
  - SO_4^{-}, $H_2PO_4^{-}$, HPO_4^{--}, NO_3^{-}, Cl^{-}
- CEC = the total quantity of cations which a soil can adsorb, expressed as milliequivalents per 100 gram dry soil or cmol kg^{-1}
  - This is a measure of the number of cations adsorption sites

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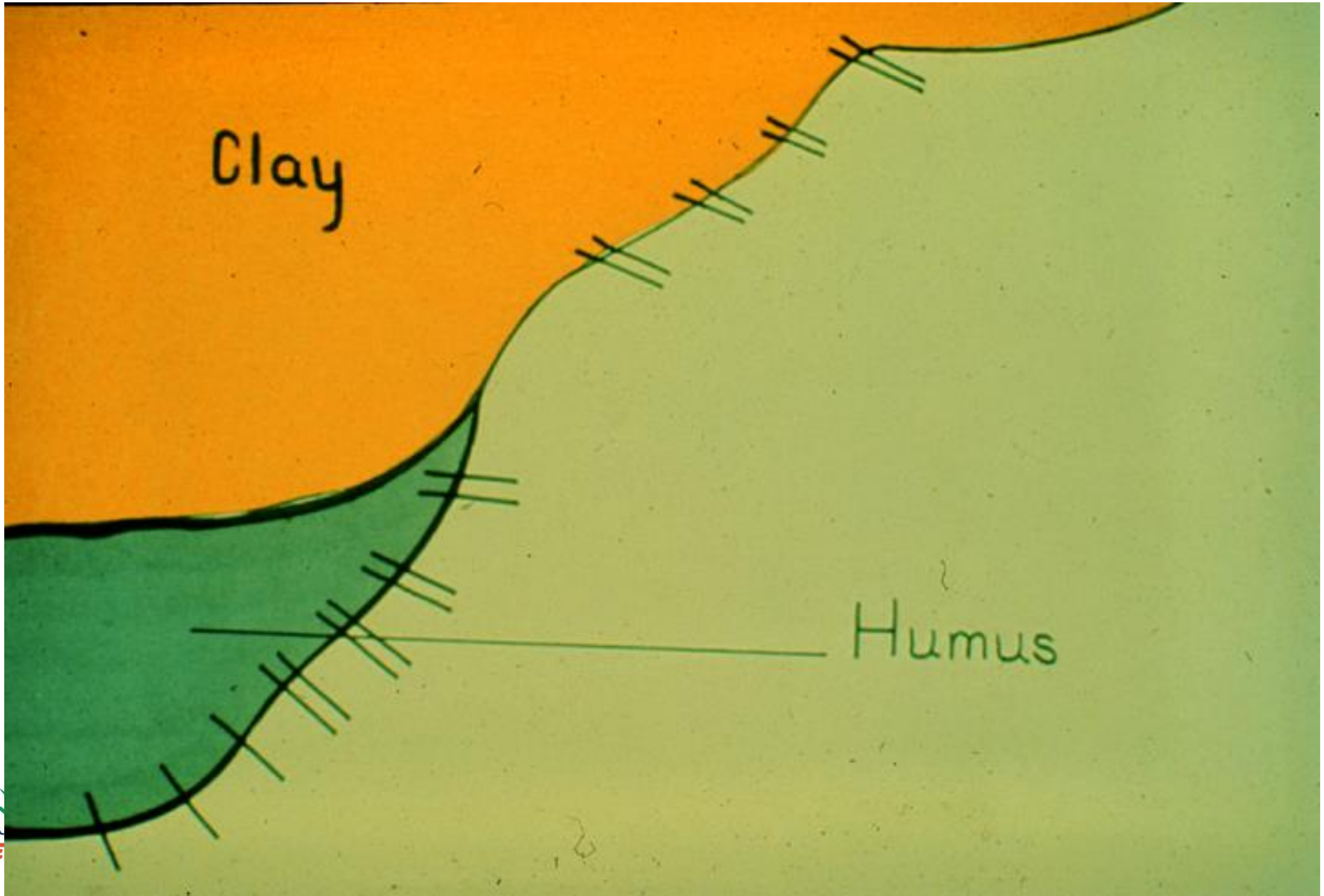
CEC



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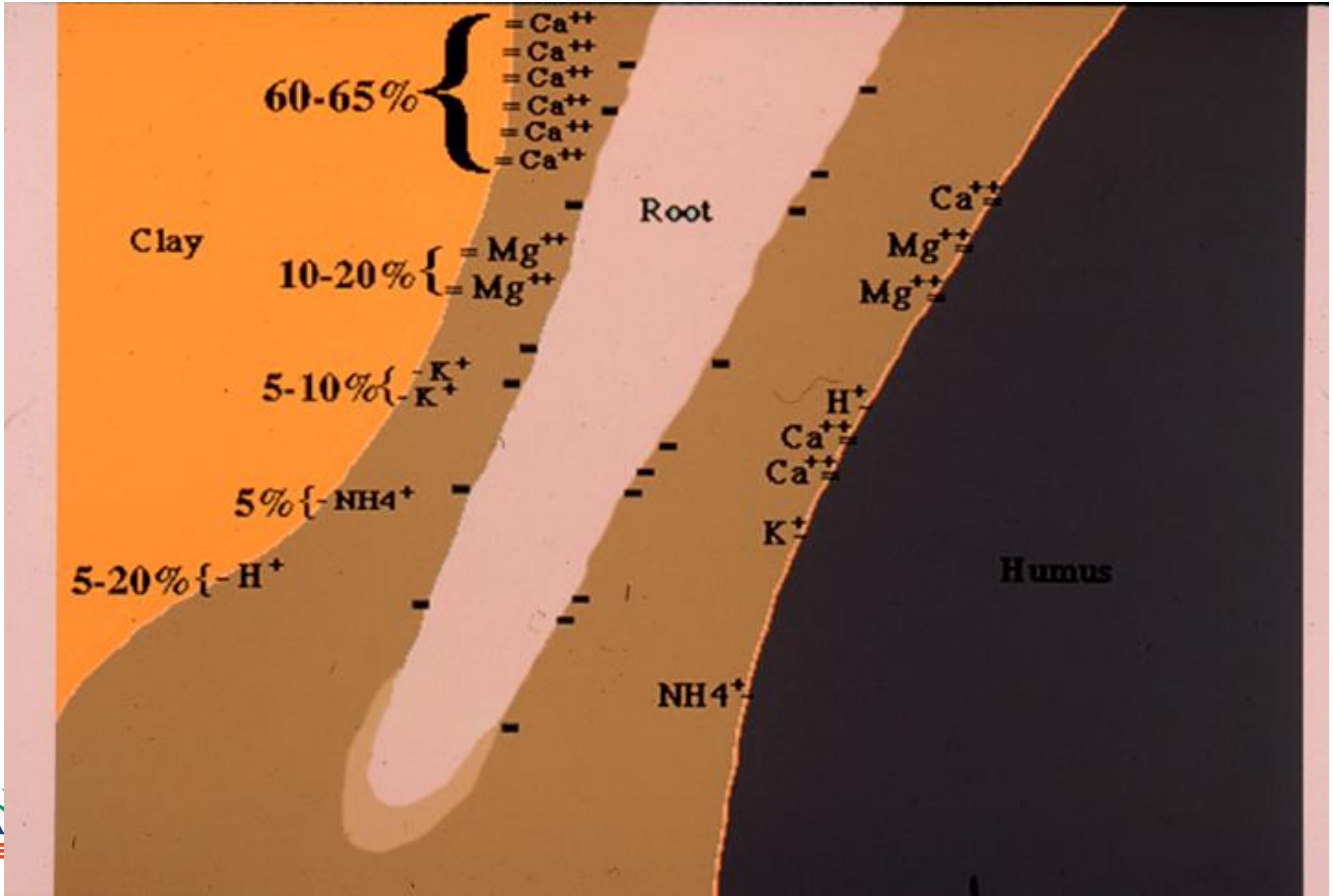
CEC



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CEC of Clays and Humus

Clay or Humus	CEC meq/100 g
Kaolinite (south)	5-15
Illite	10-45
Vermiculite	60-150
Montmorillonite	60-150
Humus (well decomposed)	140-200
Roots	10-30

CEC of Soils

Soil Texture	CEC meq/100 g
Sand	2-4
Sandy	2-12
Loam	7-16
Silt loam	10-25
Clay, clay loam	20-50

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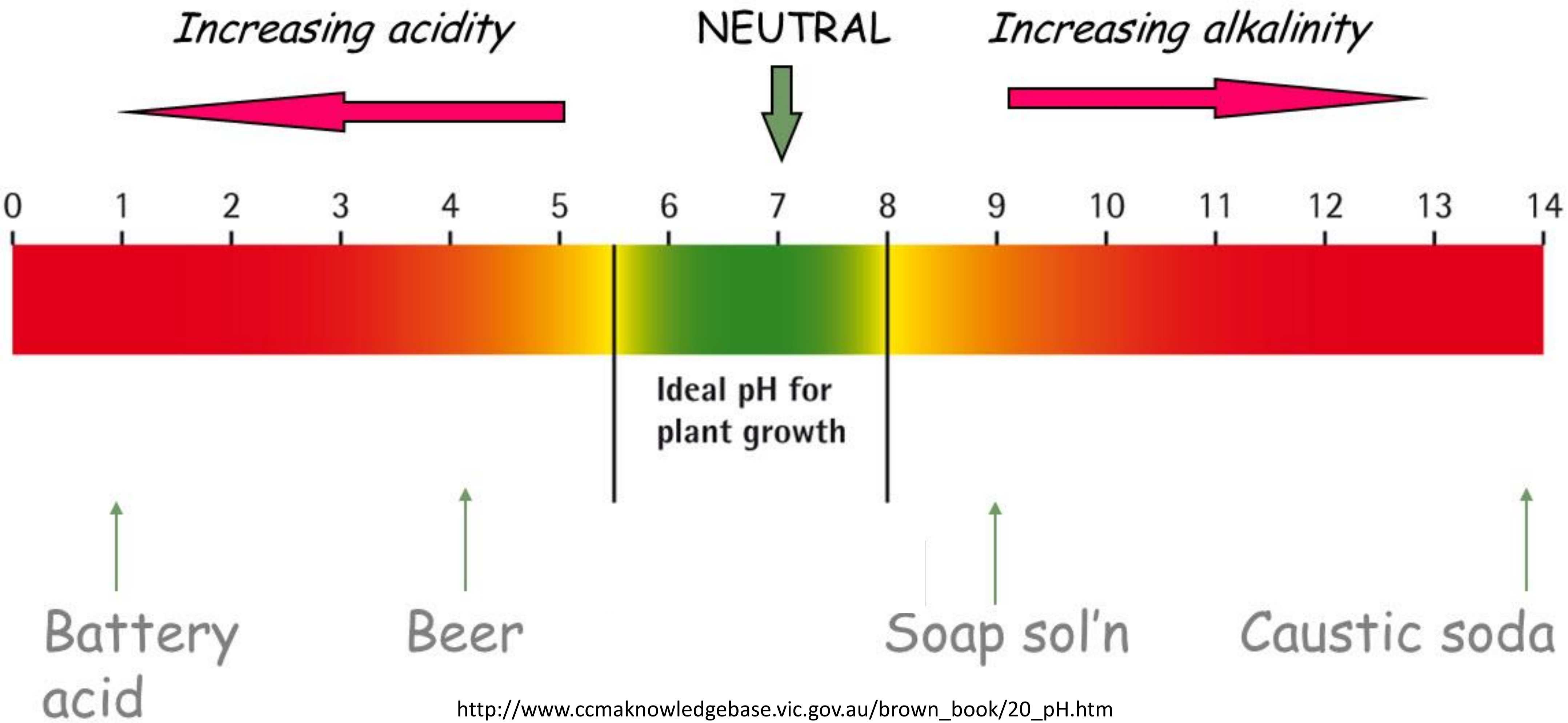
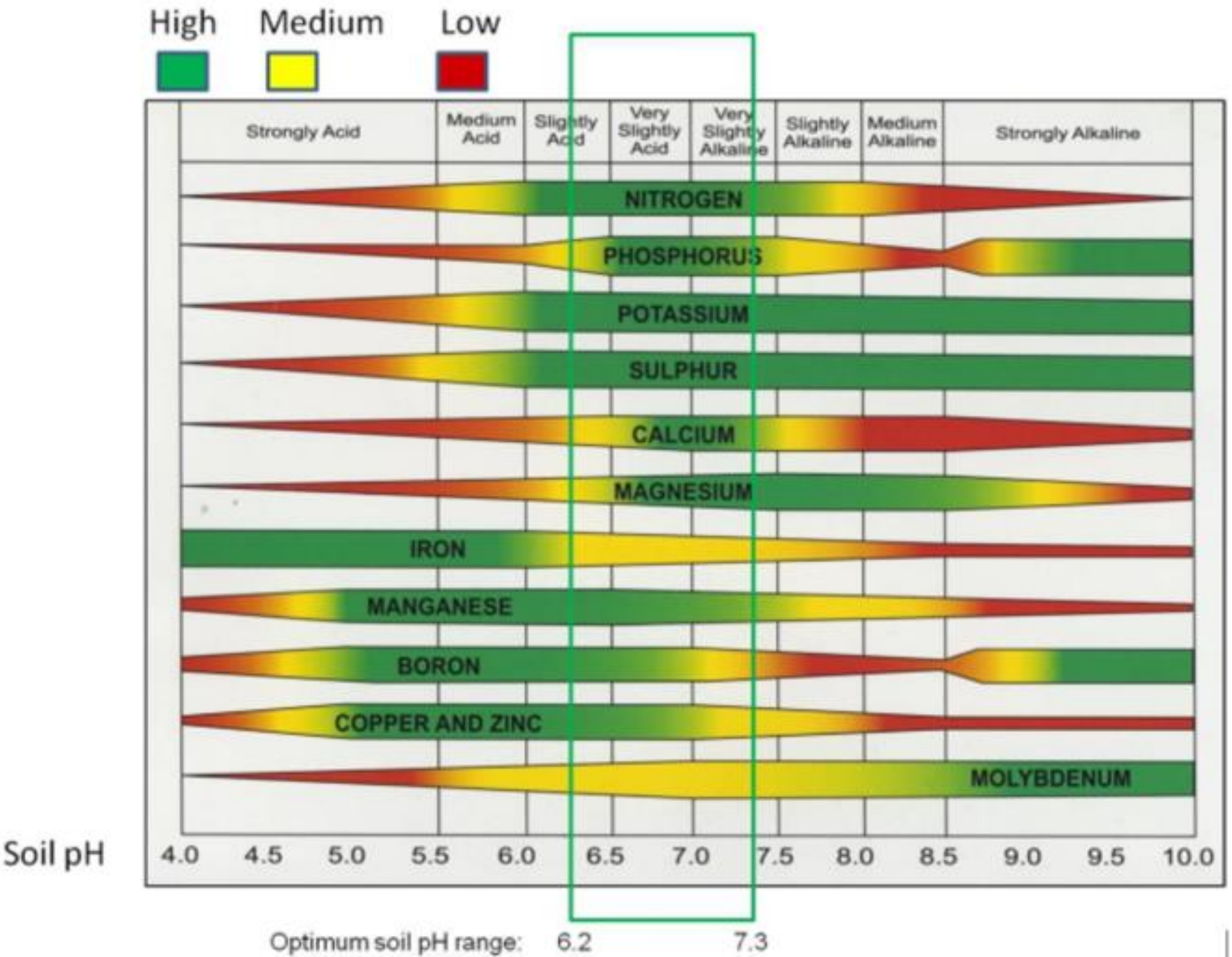
Soil pH - what is it?

- measure of the acidity or alkalinity of a soil
- concentration of hydrogen ions (H+) in the soil solution



http://www.ccmaknowledgebase.vic.gov.au/brown_book/20_pH.htm

How soil pH affects availability of plant nutrients



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https://ucanr.edu/sites/Salinity/Salinity_Management/Effect_of_salinity_on_soil_properties/Effect_of_pH_sodicity_and_salinity_on_soil_fertility_/

Front Yard – Struggling to Survive

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Back Yard – Not too Bad

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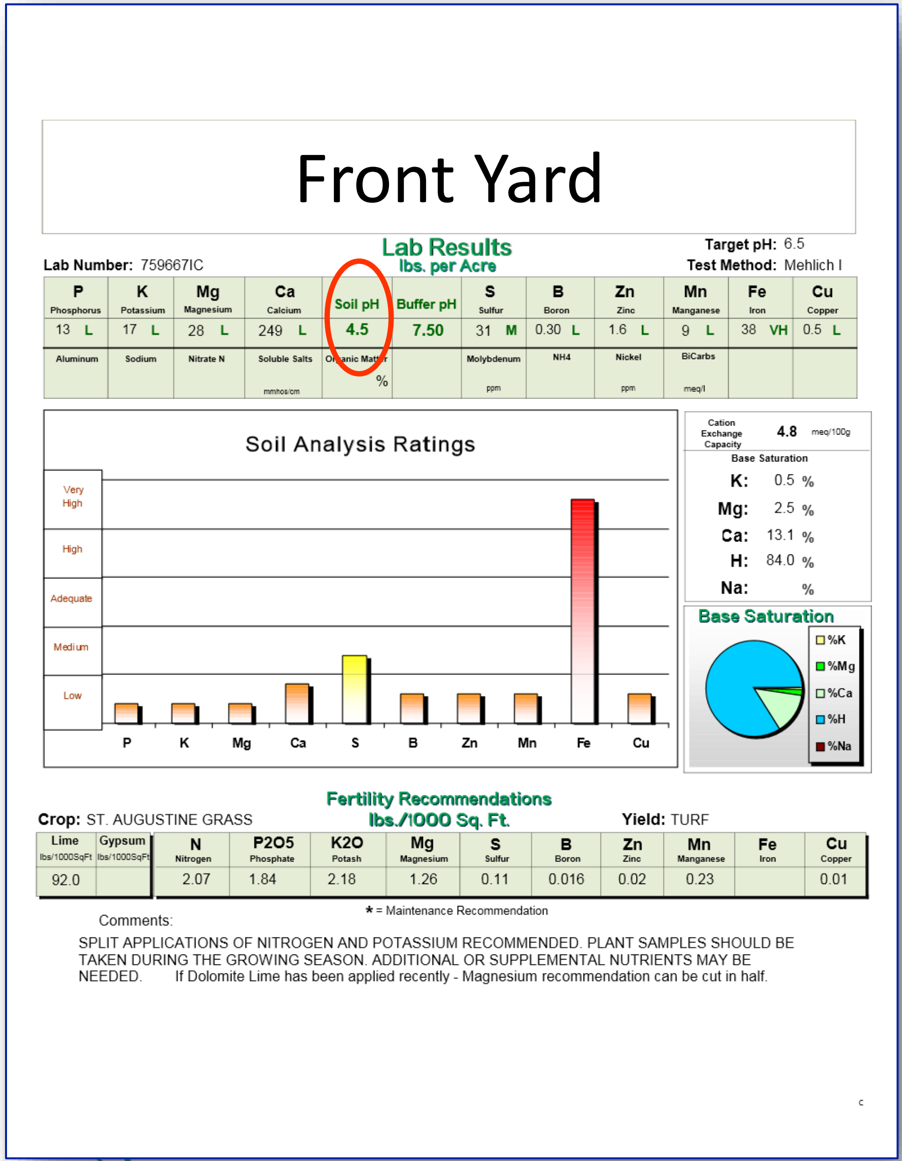


Front Yard

Lab Results lbs. per Acre

Lab Number: 759667IC

Target pH: 6.5
Test Method: Mehlich I

P Phosphorus	K Potassium	Mg Magnesium	Ca Calcium	Soil pH	Buffer pH	S Sulfur	B Boron	Zn Zinc	Mn Manganese	Fe Iron	Cu Copper
13 L	17 L	28 L	249 L	4.5	7.50	31 M	0.30 L	1.6 L	9 L	38 VH	0.5 L
Aluminum	Sodium	Nitrate N	Soluble Salts mmhos/cm	Organic Matter %		Molybdenum ppm	NH4	Nickel ppm	BiCarbs meq/l		

Cation Exchange Capacity: 4.8 meq/100g

Base Saturation

K:	0.5	%
Mg:	2.5	%
Ca:	13.1	%
H:	84.0	%
Na:		%

Fertility Recommendations lbs./1000 Sq. Ft.

Crop: ST. AUGUSTINE GRASS **Yield:** TURF

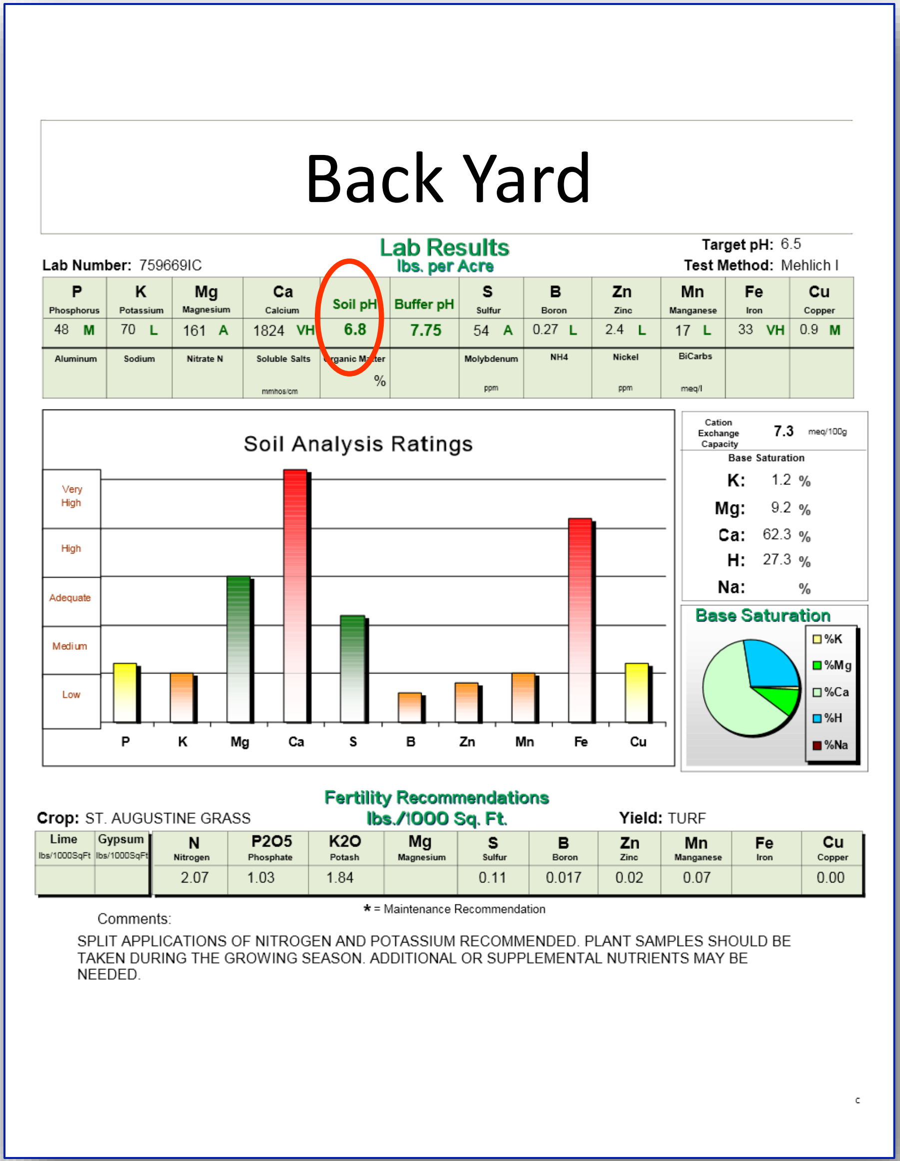
Lime lbs/1000SqFt	Gypsum lbs/1000SqFt	N Nitrogen	P2O5 Phosphate	K2O Potash	Mg Magnesium	S Sulfur	B Boron	Zn Zinc	Mn Manganese	Fe Iron	Cu Copper
92.0		2.07	1.84	2.18	1.26	0.11	0.016	0.02	0.23		0.01

* = Maintenance Recommendation

Comments:

SPLIT APPLICATIONS OF NITROGEN AND POTASSIUM RECOMMENDED. PLANT SAMPLES SHOULD BE TAKEN DURING THE GROWING SEASON. ADDITIONAL OR SUPPLEMENTAL NUTRIENTS MAY BE NEEDED. If Dolomite Lime has been applied recently - Magnesium recommendation can be cut in half.

c



Back Yard

Lab Results lbs. per Acre

Lab Number: 759669IC

Target pH: 6.5
Test Method: Mehlich I

P Phosphorus	K Potassium	Mg Magnesium	Ca Calcium	Soil pH	Buffer pH	S Sulfur	B Boron	Zn Zinc	Mn Manganese	Fe Iron	Cu Copper
48 M	70 L	161 A	1824 VH	6.8	7.75	54 A	0.27 L	2.4 L	17 L	33 VH	0.9 M
Aluminum	Sodium	Nitrate N	Soluble Salts mmhos/cm	Organic Matter %		Molybdenum ppm	NH4	Nickel ppm	BiCarbs meq/l		

Cation Exchange Capacity: 7.3 meq/100g

Base Saturation

K:	1.2	%
Mg:	9.2	%
Ca:	62.3	%
H:	27.3	%
Na:		%

Fertility Recommendations lbs./1000 Sq. Ft.

Crop: ST. AUGUSTINE GRASS **Yield:** TURF

Lime lbs/1000SqFt	Gypsum lbs/1000SqFt	N Nitrogen	P2O5 Phosphate	K2O Potash	Mg Magnesium	S Sulfur	B Boron	Zn Zinc	Mn Manganese	Fe Iron	Cu Copper
		2.07	1.03	1.84		0.11	0.017	0.02	0.07		0.00

* = Maintenance Recommendation

Comments:

SPLIT APPLICATIONS OF NITROGEN AND POTASSIUM RECOMMENDED. PLANT SAMPLES SHOULD BE TAKEN DURING THE GROWING SEASON. ADDITIONAL OR SUPPLEMENTAL NUTRIENTS MAY BE NEEDED.

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Lime ($CaCO_3$) Raises pH

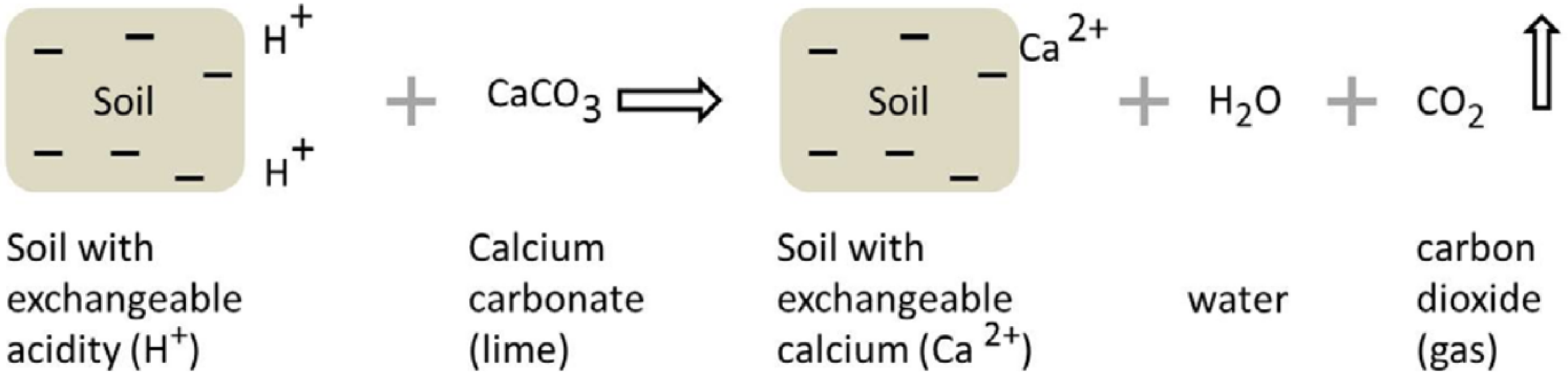

Figure 3.—Soil acidity reacts with lime to form water and carbon dioxide. The carbon dioxide gas is lost to the atmosphere. This chemical reaction continues until all of the lime has reacted. Figure by Dan Sullivan.

https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/em9057.pdf

Salinity and Sodicity

The salt-affected soils occur in the arid and semiarid regions where evapo-transpiration greatly exceeds precipitation. The accumulated ions causing salinity or alkalinity include sodium, potassium, magnesium, calcium, chlorides, carbonates and bicarbonates. The salt-affected soils can be primarily classified as saline soil and sodic soil.

S. No.	Characteristics	Saline (Alkaline)	Saline – Sodic	Sodic (Alkali)
1.	pH	< 8.5	> 8.5	> 8.5
2.	EC	> 4.0 dSm^{-1}	> 4.0 dSm^{-1}	< 4.0 dSm^{-1}
3.	Salt Concentration	> 0.2 %	> 0.2 %	< 0.2 %
4.	ESP%*	< 15.0%	> 15.0%	> 15.0%
5.	SAR**	< 13.0	> 15.0	> 15.0
6.	Dominant Cation	Ca^{2+}, Mg^{2+}, K^{+}	Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}	Na^{+}
7.	Dominant Anion	Cl^{-}, SO_4^{2-}, NO_3^{-}	Cl^{-}, SO_4^{2-}, NO_3^{-}, CO_3^{2-}, HCO_3^{-}	CO_3^{2-}, HCO_3^{-}
8.	Soil Structure (Soil particles)	Flocculated	Flocculated	De flocculated
9.	Infiltration	Good	God	Poor
10.	Drainage	Good	God	Poor
11.	Nomenclature	Solenchalk (White alkali)	-	Solentz (Black alkali)

* Exchangeable Sodium Percentage (ESP)

$$ESP = \frac{\text{Exchangeable } Na^{+} \text{ (in milli equi./100 g Soil)}}{\text{Total CEC (in milli equi./100 g Soil)}} \text{ X } 100$$

** Sodium Adsorption Ratio (SAR)

$$SAR = \frac{[Na^{+}]}{\sqrt{[Ca^{2+}] + [Mg^{2+}] / 2}}$$

EC

ESP

SAR

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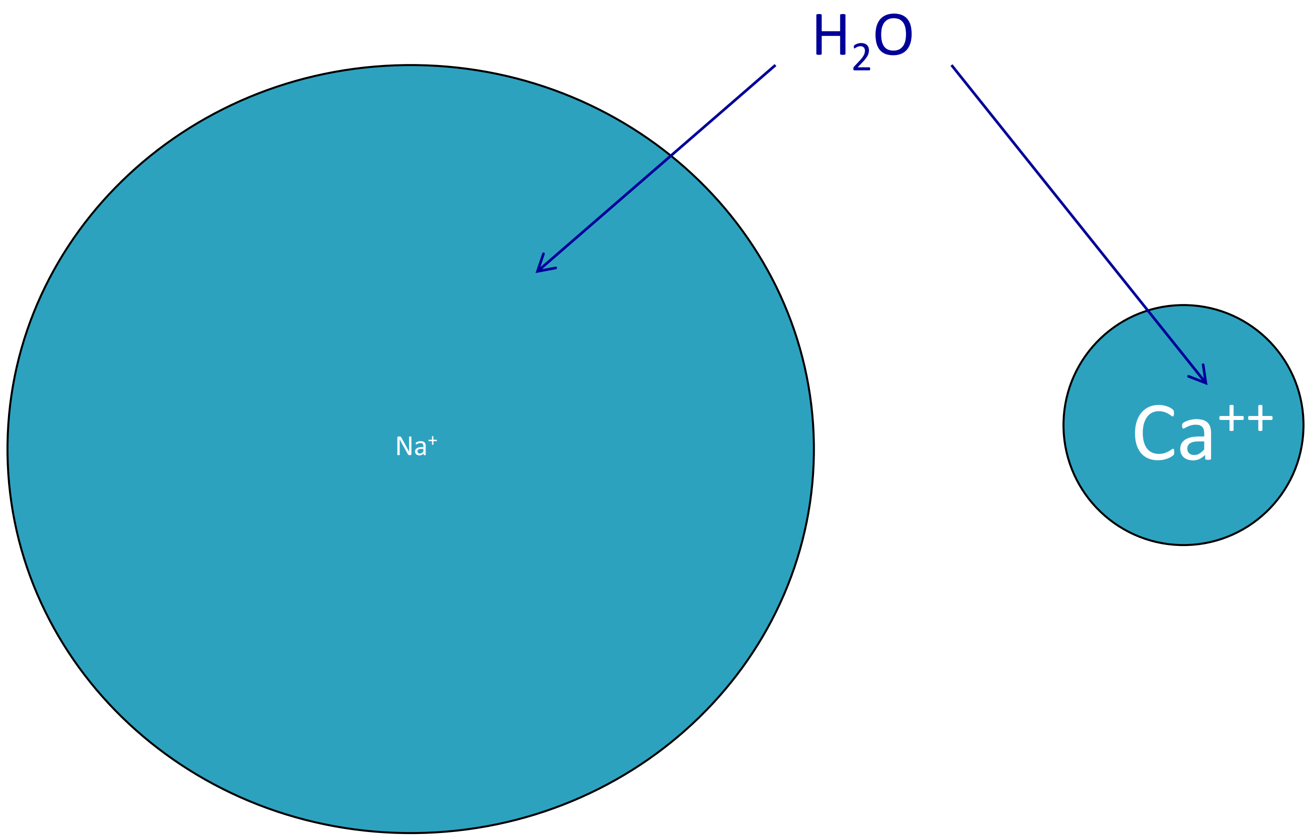
http://www.jnkvv.org/PDF/02042020114958Pro.%20Soil-Book%20chapters%2006%20to%2008%20-%20Dr.%20R.K.%20Thakur.pdf

Sodium (Na)

- Not an essential element
- Naturally occurring
- Sewage effluent
- Can damage plants
- Monovalent (1^+)
- Large hydrated size
- Can damage soil structure

Hydrated size



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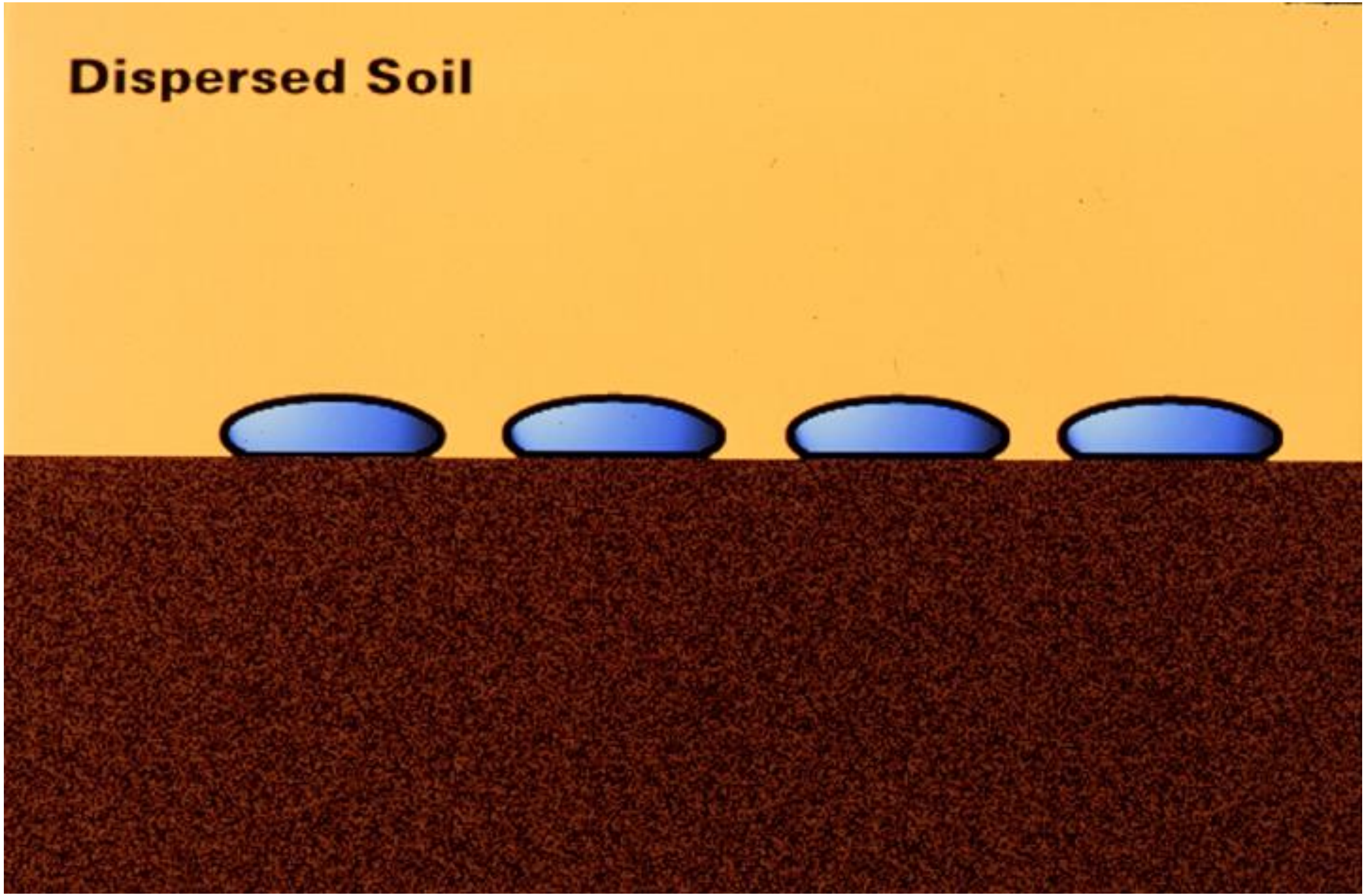
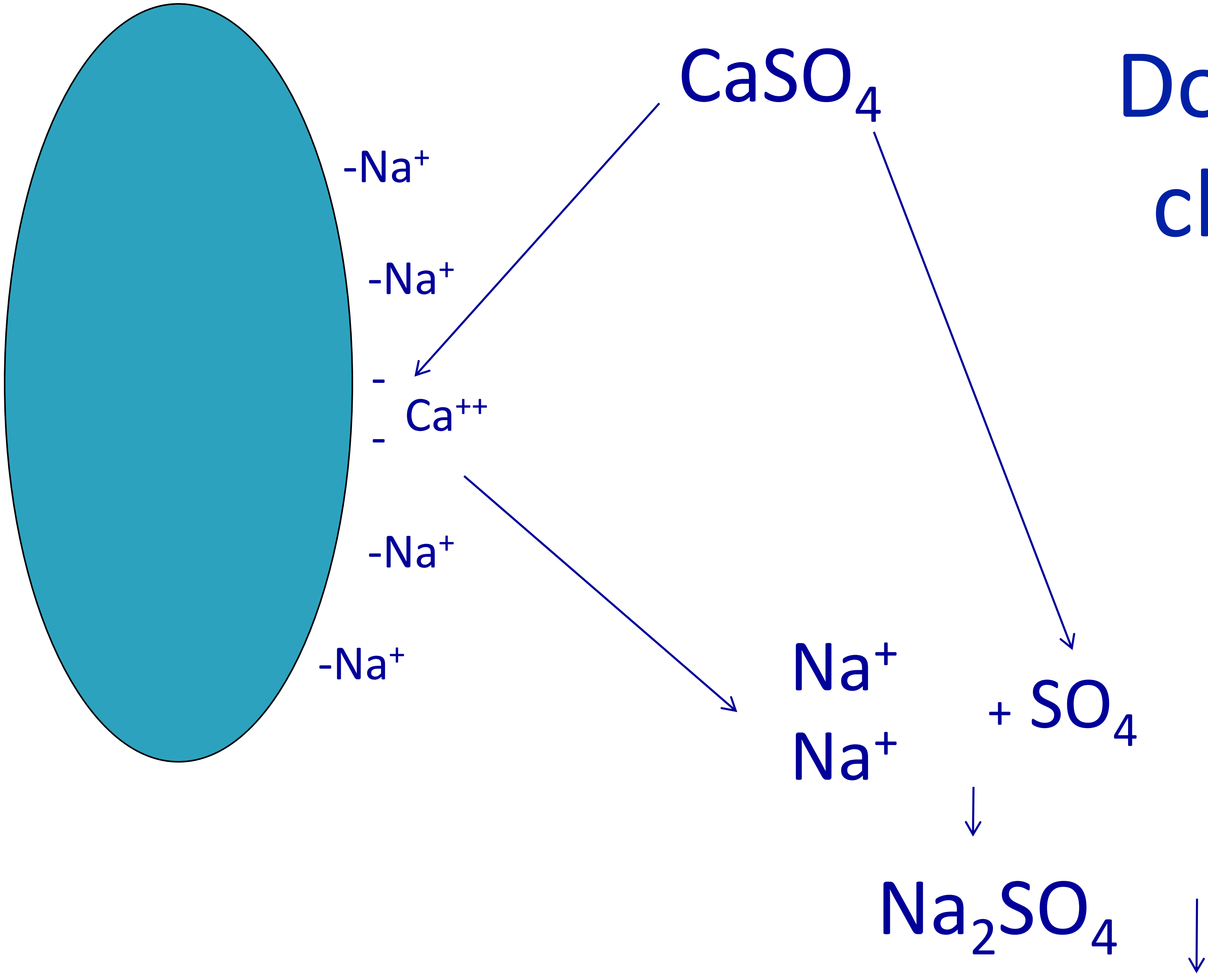
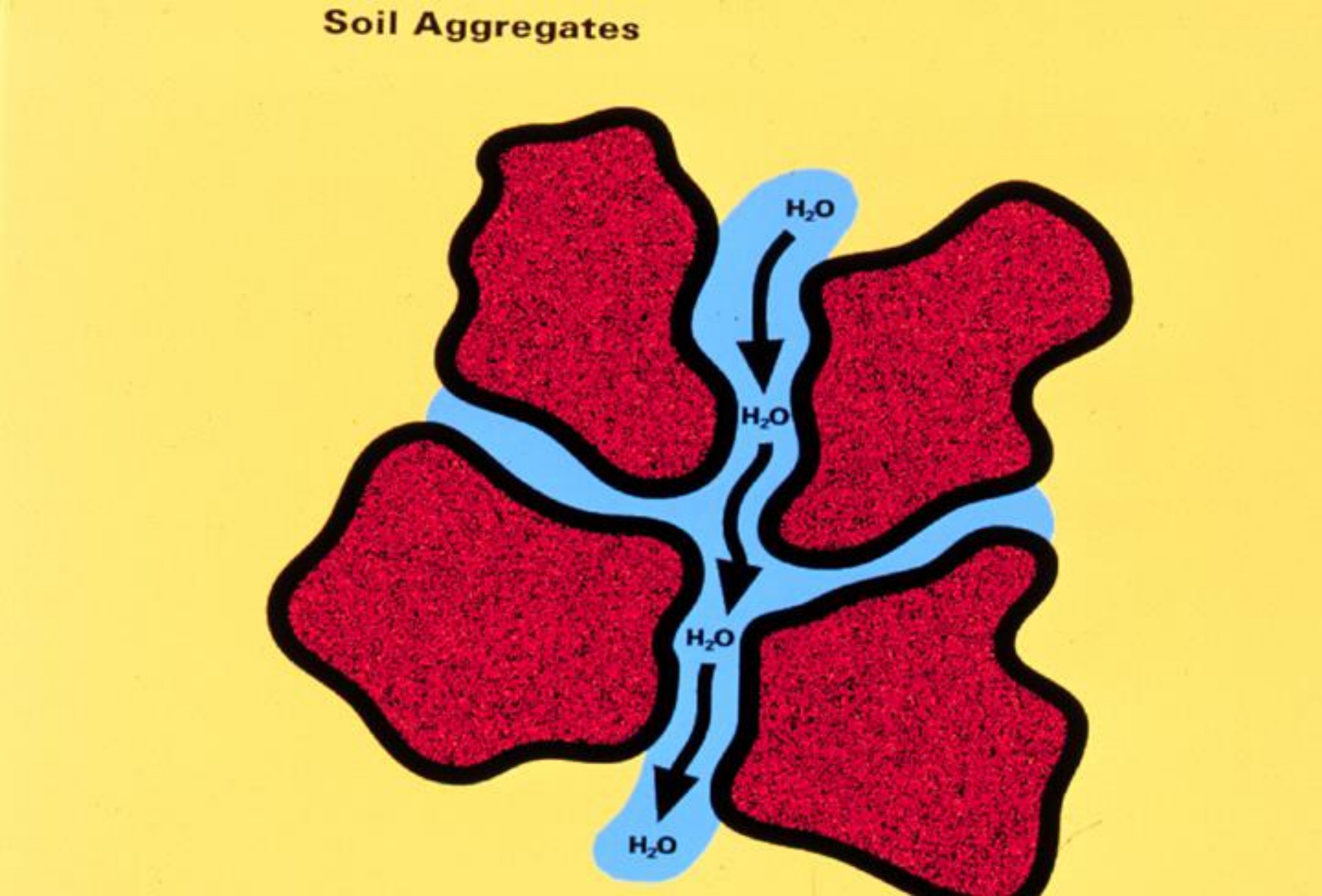

Dispersed Soil

Gypsum



Does not change pH


Soil Aggregates
H2O
H2O
H2O
H2O

Soil testing

- Paste extract
- SLAN – sufficiency level of available nutrients
- BCSR – basic cation saturation ratio
- MLSN – minimum level for sustainable nutrition

Paste Extract Tests

- Water-soluble test for short term results
- Tells what nutrients are soluble in soil
- Factors influencing paste tests
  - Weather (amount of rain), irrigation, poor water quality, high bicarbonate levels, recent fertilizer applications, topdressing, etc.
- Great tool for accessing soil salinity and pH

Paste Extract Tests

- Should be used with standard soil tests every time
- Expect low extraction values for fertility
- Data is lacking between turf quality and soluble nutrients
- **Soil electrical conductivity (EC) – amount of salts**
- **pH**

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Saturated Paste Report

			Green	Green	Green
Sample Location			Green	Green	Green
Sample ID			3	5	10
Lab Number			104735	104736	104737
Water Used			H2O prov	H2O prov	H2O prov
pH			7.2	7.2	7.1
Soluble Salts		ppm	242	249	223
Chloride (Cl)		ppm	42	32	29
Bicarbonate (HCO3)		ppm	195	215	176
ANIONS	SULFUR	ppm	6.31	6.68	6.08
ANIONS	PHOSPHORUS	ppm	3.4	1.97	1.27
SOLUBLE CATIONS	CALCIUM	ppm	46.42	52.53	47.33
SOLUBLE CATIONS	CALCIUM	meq/l	2.32	2.63	2.37
SOLUBLE CATIONS	MAGNESIUM	ppm	7.89	8.68	7.86
SOLUBLE CATIONS	MAGNESIUM	meq/l	0.66	0.72	0.65
SOLUBLE CATIONS	POTASSIUM:	ppm	16.36	8.96	7.85
SOLUBLE CATIONS	POTASSIUM:	meq/l	0.42	0.23	0.20
SOLUBLE CATIONS	SODIUM	ppm	8.77	7.05	6.27
SOLUBLE CATIONS	SODIUM	meq/l	0.38	0.31	0.27
PERCENT	Calcium		61.32	67.53	67.67
PERCENT	Magnesium		17.38	18.60	18.72
PERCENT	Potassium		11.23	5.98	5.83
PERCENT	Sodium		10.08	7.89	7.79
TRACE ELEMENTS	Boron (p.p.m.)		0.04	0.05	0.03
TRACE ELEMENTS	Iron (p.p.m.)		0.57	0.31	0.47
TRACE ELEMENTS	Manganese (p.p.m.)		0.03	< 0.02	< 0.02
TRACE ELEMENTS	Copper (p.p.m.)		< 0.02	< 0.02	< 0.02
TRACE ELEMENTS	Zinc (p.p.m.)		< 0.02	< 0.02	< 0.02
TRACE ELEMENTS	Aluminum (p.p.m.)		1.14	0.69	0.93

Soil Report

Sample Location			Green	Green	Green
Sample ID			3	5	10
Lab Number			248	249	250
Sample Depth in inches			6	6	6
Total Exchange Capacity (M. E.)			10.95	13.13	11.10
pH of Soil Sample			7.8	7.8	7.8
Organic Matter, Percent			0.91	1.08	0.76
ANIONS	SULFUR:	p.p.m.	8	10	10
ANIONS	Mehlich III Phosphorous:	as (P_2O_5) lbs / acre	455	414	437
EXCHANGEABLE CATIONS	CALCIUM: lbs / acre	Desired Value	2977	3571	3019
EXCHANGEABLE CATIONS	CALCIUM: lbs / acre	Value Found	3743	4604	3773
EXCHANGEABLE CATIONS	CALCIUM: lbs / acre	Deficit			
EXCHANGEABLE CATIONS	MAGNESIUM: lbs / acre	Desired Value	315	378	319
EXCHANGEABLE CATIONS	MAGNESIUM: lbs / acre	Value Found	213	207	215
EXCHANGEABLE CATIONS	MAGNESIUM: lbs / acre	Deficit	-102	-171	-104
EXCHANGEABLE CATIONS	POTASSIUM: lbs / acre	Desired Value	341	409	346
EXCHANGEABLE CATIONS	POTASSIUM: lbs / acre	Value Found	186	149	221
EXCHANGEABLE CATIONS	POTASSIUM: lbs / acre	Deficit	-155	-260	-125
EXCHANGEABLE CATIONS	SODIUM:	lbs / acre	32	44	43
BASE SATURATION %	Calcium (60 to 70%)		85.48	87.66	84.96
BASE SATURATION %	Magnesium (10 to 20%)		8.11	6.57	8.07
BASE SATURATION %	Potassium (2 to 5%)		2.18	1.45	2.55
BASE SATURATION %	Sodium (.5 to 3%)		0.64	0.73	0.85
BASE SATURATION %	Other Bases (Variable)		3.60	3.60	3.60
BASE SATURATION %	Exchangable Hydrogen (10 to 15%)		0.00	0.00	0.00
EMENTS	Boron (p.p.m.)		0.24	0.32	0.26
EMENTS	Iron (p.p.m.)		98	93	94
EMENTS	Manganese (p.p.m.)		47	57	49

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SLAN

Sufficiency level of available nutrients

- Oldest method
- 80 Years + Research
- Interpretation varies with crop, soil type, climate, etc.

Test	Results	SOIL TEST RATINGS (Very Low / Low / Medium / Optimum / Very High)
Soil pH	5.8	
Buffer pH	6.90	
Phosphorus (P)	34 ppm	
Potassium (K)	67 ppm	
Calcium (Ca)	354 ppm	
Magnesium (Mg)	55 ppm	
Sulphur (S)	9 ppm	
Boron (B)	0.4 ppm	
Copper (Cu)	2.4 ppm	
Iron (Fe)	210 ppm	
Manganese (Mn)	70 ppm	
Zinc (Zn)	9.6 ppm	
Sodium (Na)	5 ppm	
Soluble Salts		
Organic Matter	1.5 % ENR 74	
NO3-N		

Calculated Cation Exchange Capacity: 2.5 meq/100g

Calculated Cation Saturation	
%K	6.5
%Ca	56.9
%Mg	16.9
%H	18.8
%Na	0.9

SOIL FERTILITY GUIDELINES

Crop : BENTGRASS GREEN Yield Goal : 1 Rec Units: LB/1000 SQ FT

LIME	N	P2O5	K2O	Mg	S	B	Cu	Mn	Zn
40	4-6	0.5	5	0.2	0.2	0	0	0	0

Crop : Yield Goal : Rec Units:

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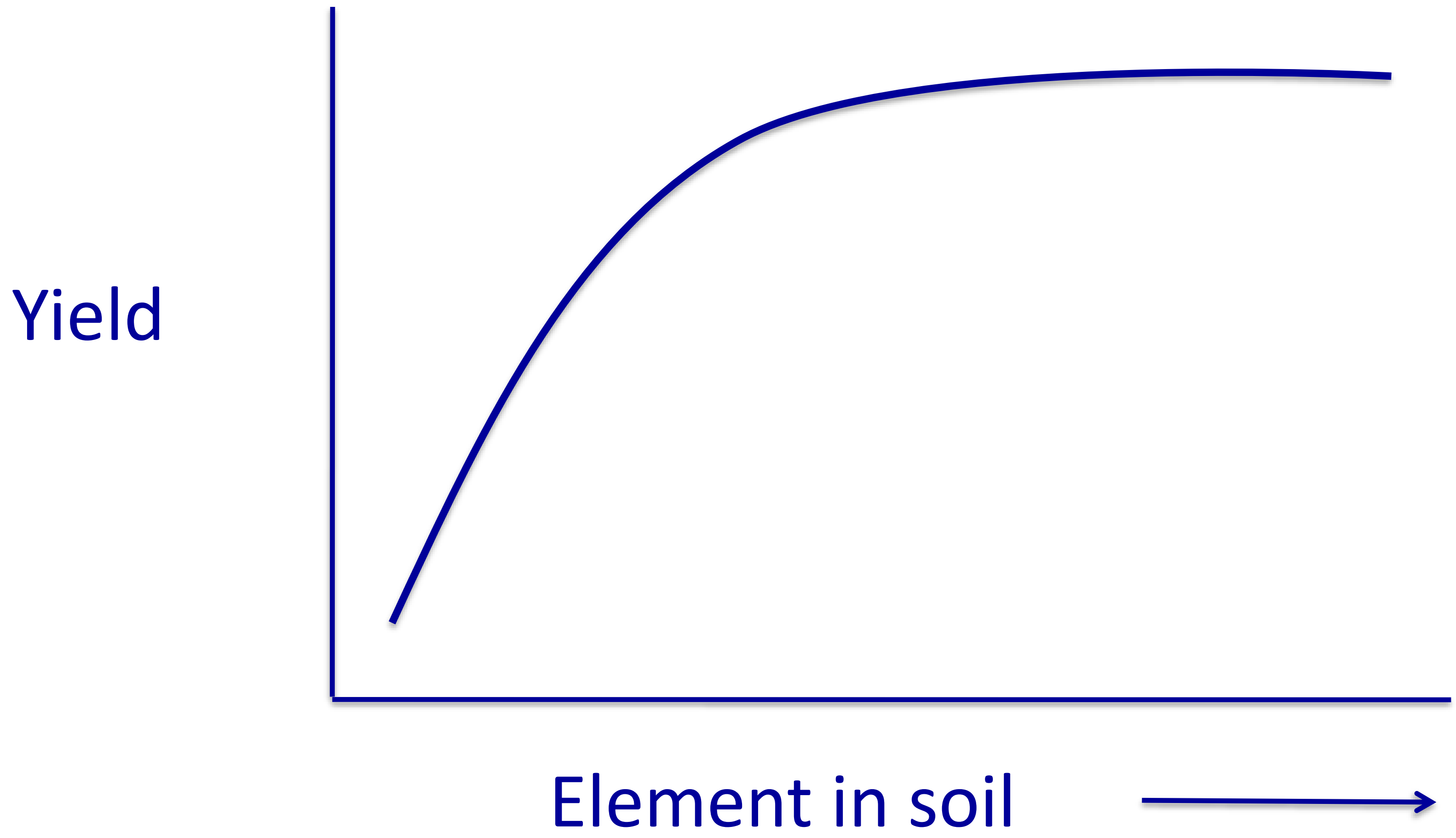
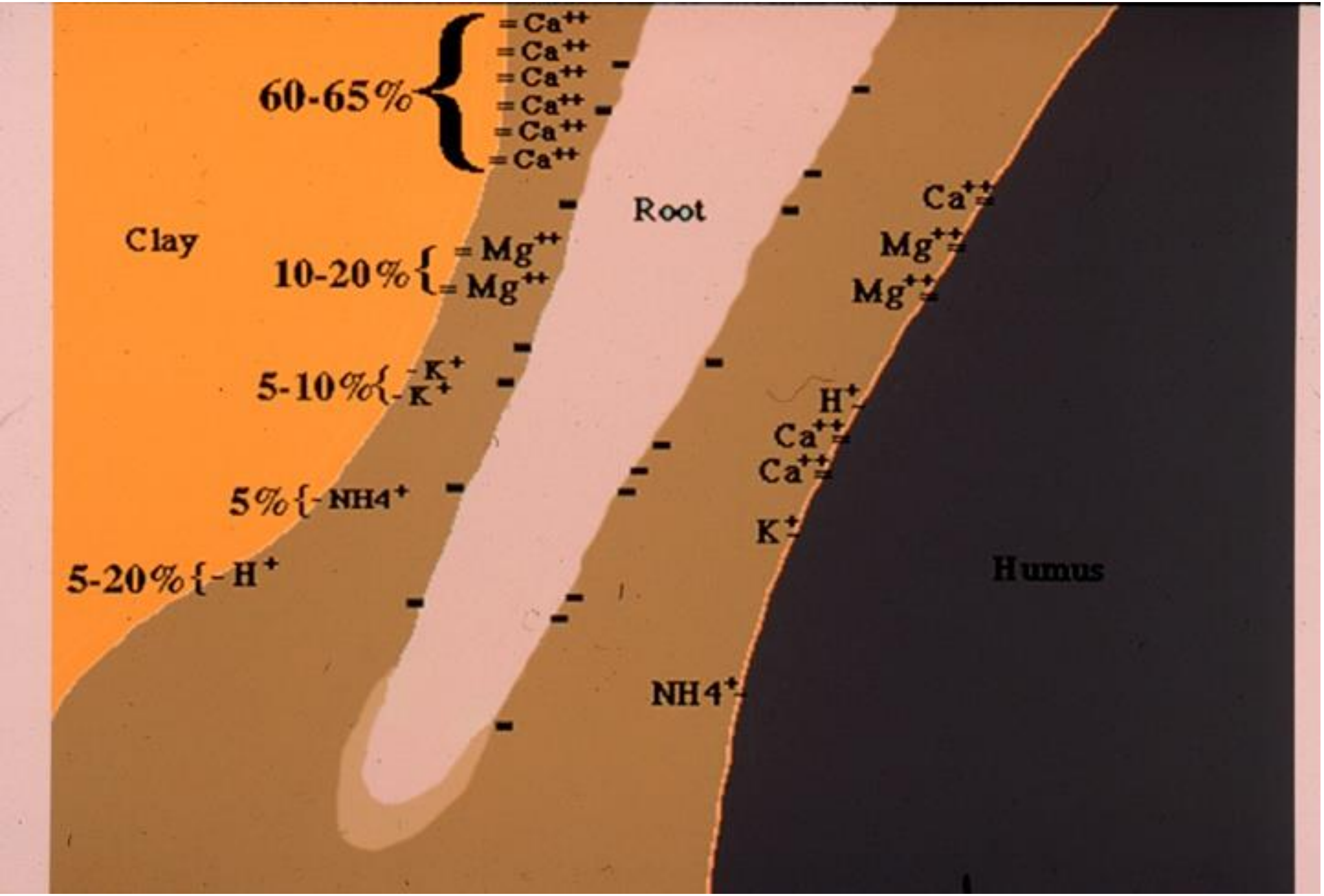
Yield Curve



BCSR

Basic Cation Saturation Ratio

- Based on an ideal ratio of cations on exchange sites
- Newer method
- Less research
- Do not use for turfgrass



- Problem – ratio of cations
- Nutrient deficiency may exist

MLSN

Minimum level for sustainable nutrition

- Replacement for SLAN
- **Set minimum required for optimal turf growth**
  - Baseline soil nutrient concentrations
    - Keep soil levels above this value
  - Gives minimum values instead of a range
  - Tells how much to apply
  - Incorporates turf “growth potential”

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Why Use MLSN?

- Focus on sustainability
- Reduce inputs
- Reduce maintenance costs
- Maintain expected turf performance
- Show reception to environmental concerns
- Plant health and soil health

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MLSN

- Apply all nutrients at ratio determined by MLSN
- Why a ratio? Nutrient uptake driven by nitrogen
- Only apply what the plant can use
  - Amount determined by clipping nutrient content

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

This gives us a nutrient use ratio:

N:P:K → 8:1:4

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https://www.paceturf.org/PTRI/Documents/Haines_Stowell_MLSN_GP.pdf

MLSN

Estimate from growth One can collect the clippings, express them as a mass, and calculate the quantity of nutrients in that mass of clippings. Clipping volume is a rapid way to estimate the mass. For every 1 L of clippings m^{-2}, expect a dry mass of 63 g. Then, calculate nutrient content by considering the elements in healthy turf. I typically use these numbers.

Element	% in dry leaves			
	Agrostis & Poa	*Cynodon*	*Paspalum*	*Festuca*
N	4	3	3	3
K	2	2	3	1.5
P	0.5	0.5	0.5	0.5
Ca	0.5	0.5	0.5	0.5
Mg	0.2	0.2	0.2	0.2
S	0.2	0.2	0.2	0.2

If you know that your turf contains different concentrations of nutrients than shown in this table, please make the adjustments to fit your site.

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http://files.asianturfgrass.com/mlsn_cheat_sheet.pdf

Reference

September, 2014

Minimum Levels for Sustainable Nutrition Soil Guidelines

The Minimum Level for Sustainable Nutrition (MLSN) Guideline is a new, more sustainable approach to managing soil nutrient levels that can help you to decrease fertilizer inputs and costs, while still maintaining desired turf quality and playability levels. The MLSN guidelines were developed in a joint project between PACE Turf and the Asian Turfgrass Center. All soil analyses were conducted at Brookside Laboratories, New Bremen, OH.

	MLSN Soil Guideline
pH	>5.5
Potassium (K ppm)	37
Phosphorus (P ppm)	21
Calcium (Ca ppm)	331
Magnesium (Mg ppm)	47
Sulfur as sulfate (S ppm)	7

Nitrogen requirements are best determined based on **turf growth potential**, which incorporates site-specific weather and turf type to calculate nitrogen demand (Gelernter and Stowell, 2005. Golf Course Management, p. 108-113, March, 2005).

How the guidelines were developed

From a database of over 17,000 soil samples, we selected 3,721 that were classified as having:

- not poor performing turfgrass
- pH 5.5 - 8.5: to avoid aluminum toxicity at pH less than 5.5, and to avoid alkalinity hazard at pH greater than 8.5

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https://www.paceturf.org/PTRI/Documents/1202_ref.pdf

MLSN Positives

- Adaptive to future research
  - Turf nutrient understanding will evolve
- Adaptive to site and climate
- Reduce/redirect costs
- Maintain high quality
- Environmentally responsible

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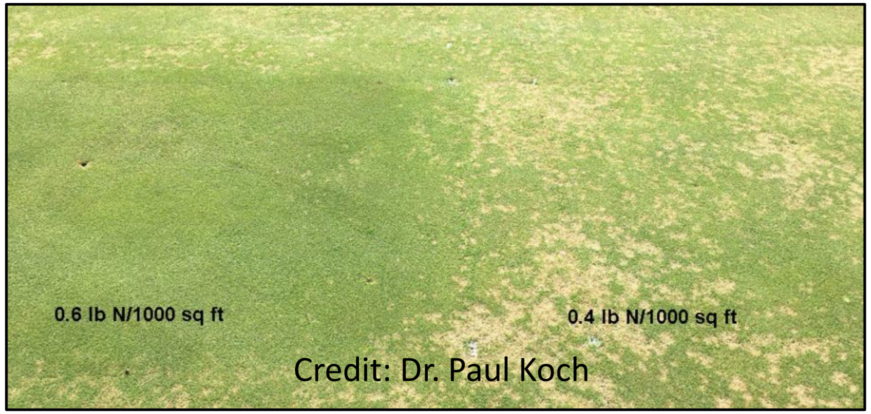
MLSN Limitations

- Good start, right direction
- Basically, SLAN for turf based on turf quality
- Turf quality not always the best guide
- Disease control
  - Diseases reduced by N
    - Dollar spot, rust, red thread



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Tissue Testing

- Estimate of nutritional status at time of sampling
- Nutrient deficiencies can be detected before visual symptoms
- Precision turfgrass fertilization program?

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Tissue Sampling

- Clipping collection
  - No sand or fertilizer contamination
- Do not collect immediately following fertilization, liming, topdressing, or pesticide application
- Paper bag not plastic
- Dry if possible

Reference Ranges

Table 1. Nutrient ranges for warm-season turfgrass species.*

	Bermudagrass	Centipedegrass	Seashore Paspalum	St. Augustinegrass	Zoysiagrass
			%		
N	2.30–5.00	1.5–2.9	2.80–3.50	1.90–3.00	2.04–2.36
P	0.15–0.50	0.18–0.26	0.30–0.60	0.20–0.50	0.19–0.22
K	1.00–4.00	1.12–2.50	2.00–4.00	2.50–4.00	1.05–1.27
Ca	0.35–1.00	0.50–1.15	0.25–1.50	0.30–0.50	0.44–0.56
Mg	0.13–0.50	0.12–0.21	0.25–0.60	0.15–0.25	0.13–0.15
S	0.15–0.50	0.20–0.38	0.20–0.60	0.18–0.33	0.32–0.37
			ppm		
Fe	50–500	102–221	50–500	50–300	188–318
Mn	25–300	35–75	50–300	40–250	25–34
Zn	20–250	17–40	20–250	20–100	36–55
Cu	5–50	2–7	5–50	10–20	2–4
B	6–30	5–10	5–60	5–10	6–11
Mo	0.10–1.20	0.14–0.30	0.5–1.0	0.15–0.5	0.12–0.30

*Bryson et al. (2014)

https://edis.ifas.ufl.edu/pdf/EP/EP53900.pdf

Soil Test Units

- Units may vary with test
  - lb/A, parts per million (ppm)
- Sampling depth matters
  - ppm x 2 = lb/A (6-inch sampling depth)
  - ppm = lb/A (3-inch sampling depth)
- CEC: meq = $cmol_c\ kg^{-1}$

The usefulness of a soil test depends on proper interpretation

Nitrogen (N)

- For the most part, nitrogen controls the growth of turfgrass
  - Component of chlorophyll, proteins, amino acids, enzymes, and numerous other plant substances
- Nitrogen greatly enhances shoot growth
- Stimulates thatch accumulation
- Disease activity
- For a quality stress-tolerant turf, it must be routinely applied
- Potential environmental implications

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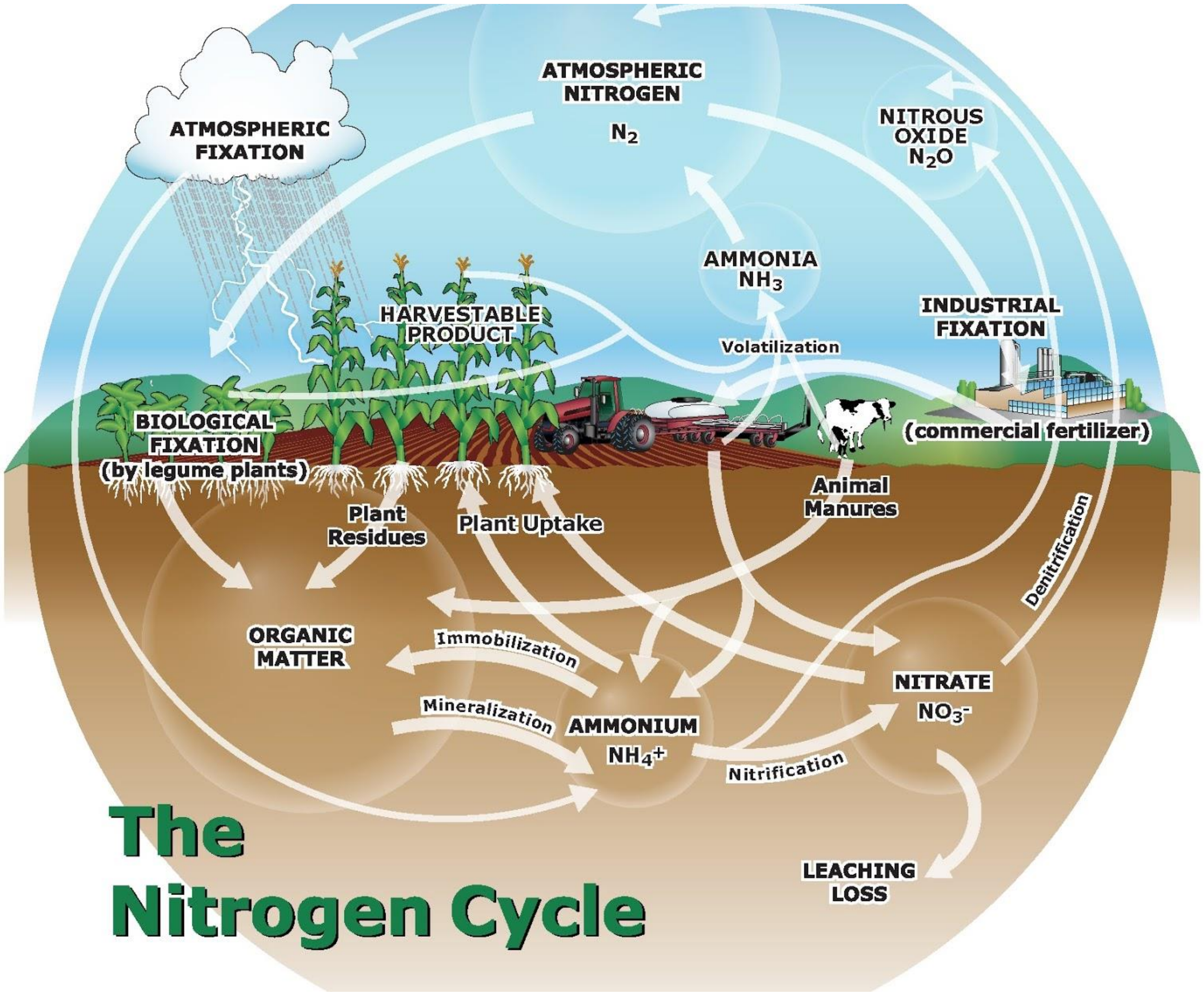
Testing for N?



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https://blog-crop-news.extension.umn.edu/2017/05/how-nitrogen-cycle-affects-fall-n.html

Ana-Lync Golf

Nutrient Evaluation

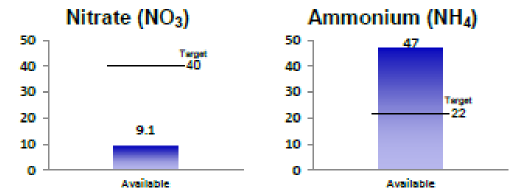
Testing Performed by Harris Labs, Lincoln, Nebraska

Distributor:	Trigon Turf Sciences/Tremblay	Date:	January 17, 2018
Client:	DEERING BAY	Info Sheet #:	896183
	CORAL GABLES, FL 33158	Sample IDs:	GRN17
		Lab IDs:	BF64380

PHYSICALITY & GENERAL INFORMATION

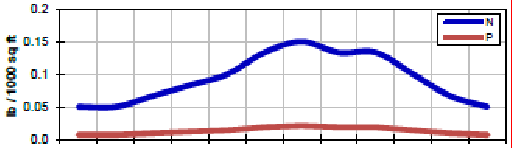
OM%:	1.1	pH:	7.8
CEC:	5.5	Sat. Index:	0.62
ENR:	1.1	EC:	1.2
EPR:	0.16		

NITROGEN

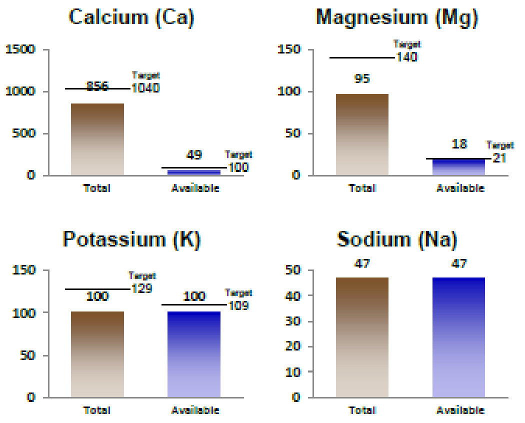


N & P Release

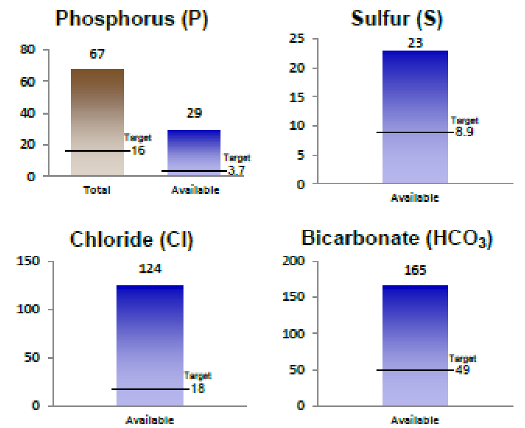
Estimated Nutrient Release By Month (0-4" Depth)



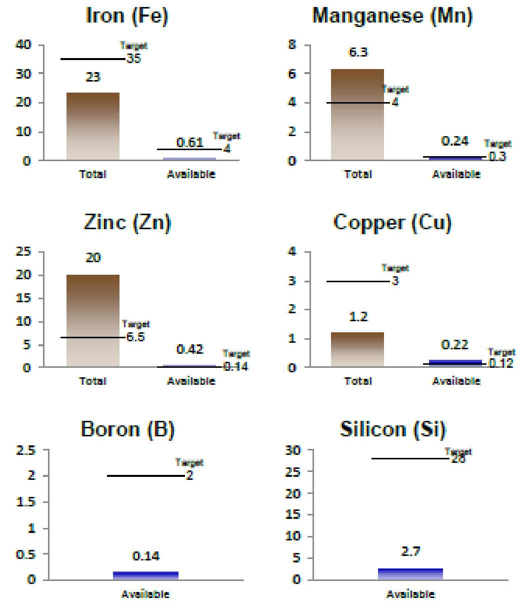
BASE CATIONS



ANIONS



MICRONUTRIENTS



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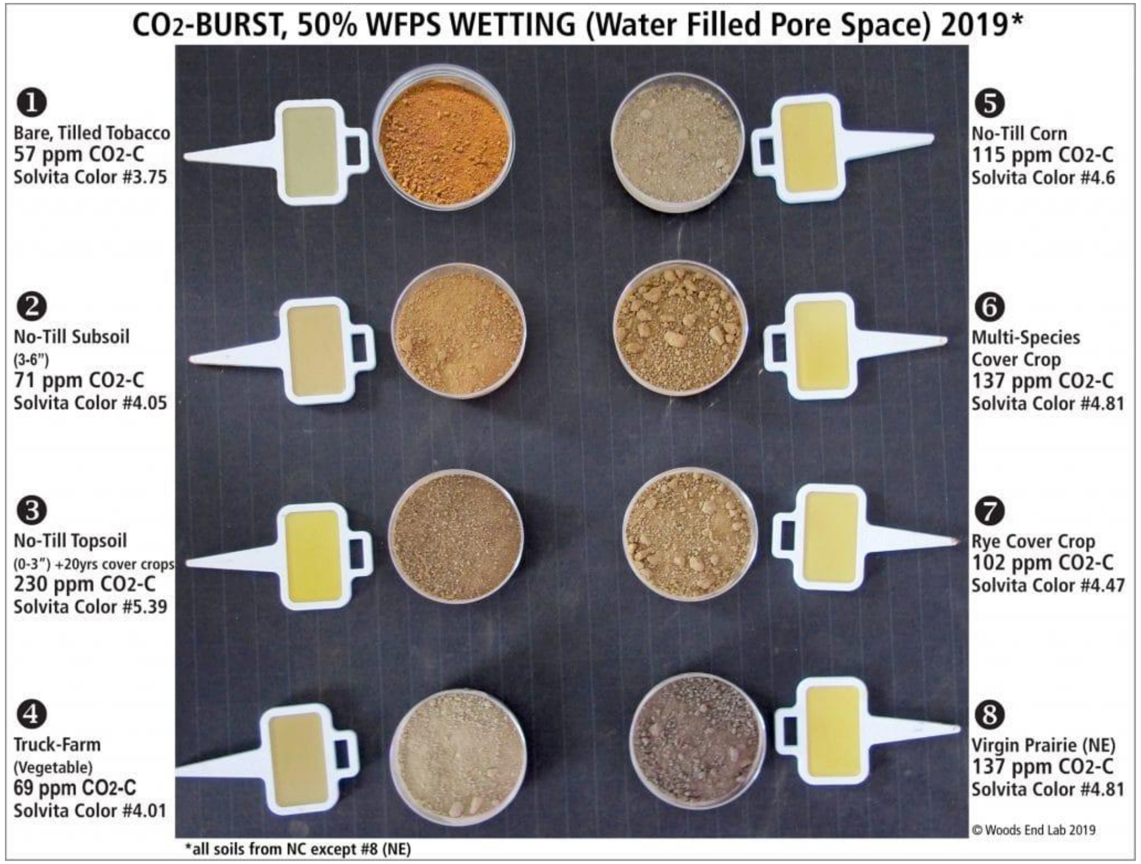
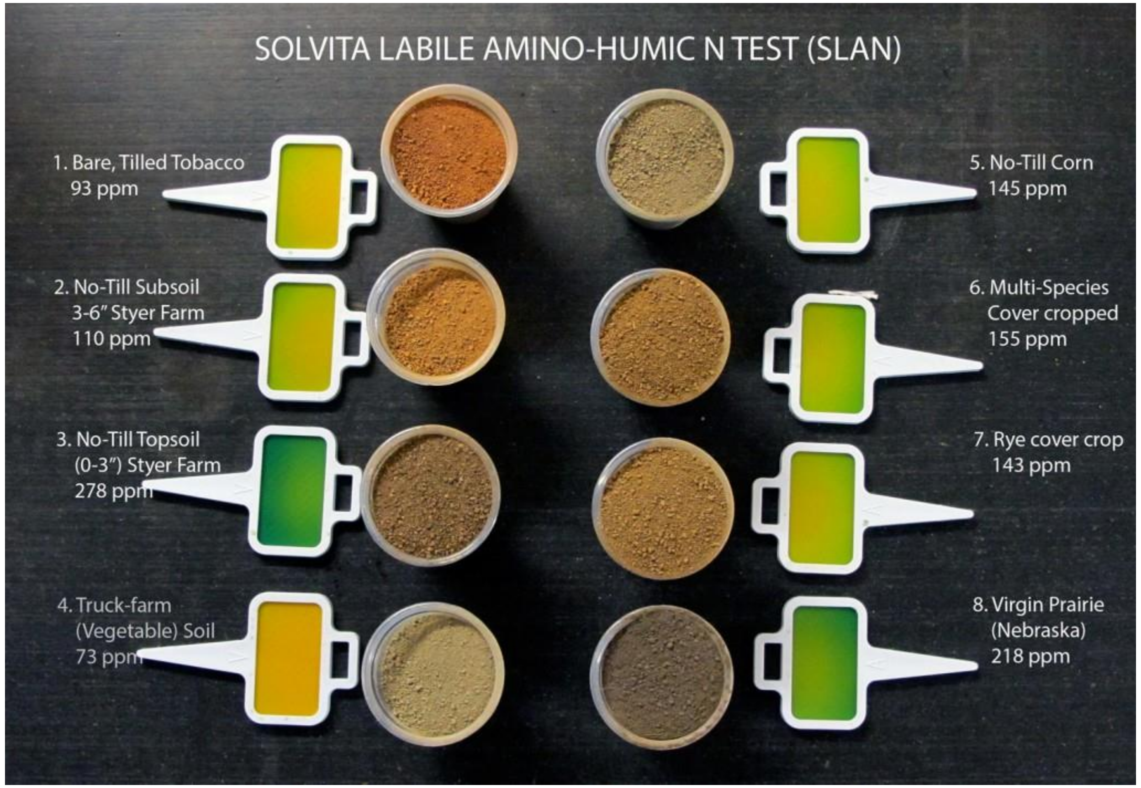
Solvita



https://solvita.com/co2-burst/



https://solvita.com/slan/

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Nitrogen (N) Recommendations

- Use crop response for N rates
- IFAS Recommendations

Table 1. Fertilization Guidelines for Established Turfgrass Lawns			
	Nitrogen Recommendations (lbs 1,000 ft^{-2} $year^{-1}$)[1, 2]		
	North Florida	Central Florida	South Florida
Bahiagrass	1.0 – 3.0	1.0 – 3.0	1.0 – 4.0
Bermudagrass	3.0 – 5.0	4.0 – 6.0	5.0 – 7.0
Centipedegrass	0.4 – 2.0	0.4 – 3.0	0.4 – 3.0
St. Augustinegrass	2.0 – 4.0	2.0 – 5.0	4.0 – 6.0
Zoysiagrass	2.0 – 3.0	2.0 – 4.0	2.5 – 4.5

[1]Because homeowner preferences for lawn quality and maintenance level will vary; we recommend a range of fertility rates for each grass and location. Additionally, effects within a localized region (i.e., micro-environmental influences -- such as shade, drought, soil conditions, and irrigation) will necessitate that a range of fertility rates be used.

[2]These recommendations assume that grass clippings are left on the lawn.

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https://edis.ifas.ufl.edu/pdf/EP/EP35300.pdf

Phosphorus (P)

- Component of energy molecules - ATP and ADP
  - Store and transfer available energy within the plant
- Structural constituent in a number of biochemicals such as phospholipids, phosoproteins, nucleic acids, sugar phosphates, nucleotides, and coenzymes
- Deficiency symptoms
  - Initially dark green
  - Purple discoloration

PHOSPHORUS

- P required in greater amounts during establishment of turf
- P fertilization should be based on soil test results
- MLSN: 21 ppm
- **Florida: 10 ppm**

P Sufficiency Level by Extractant (Carrow)				
	ppm P			
	Very low	Low	Medium	High
Bray	0-4	5-15	16-30	>31
Mehlich	0-12	13-26	27-54	>55
Olsen	0-6	7-12	13-28	>29
Numbers vary somewhat from lab to lab.				

Potassium (K)

- Required for activation of many enzymes
- Most important inorganic solute in the vacuole involved with osmoregulation and, thereby, water regulation in plants
- Used in carbohydrate, amino acid, and protein synthesis
- Stress tolerance

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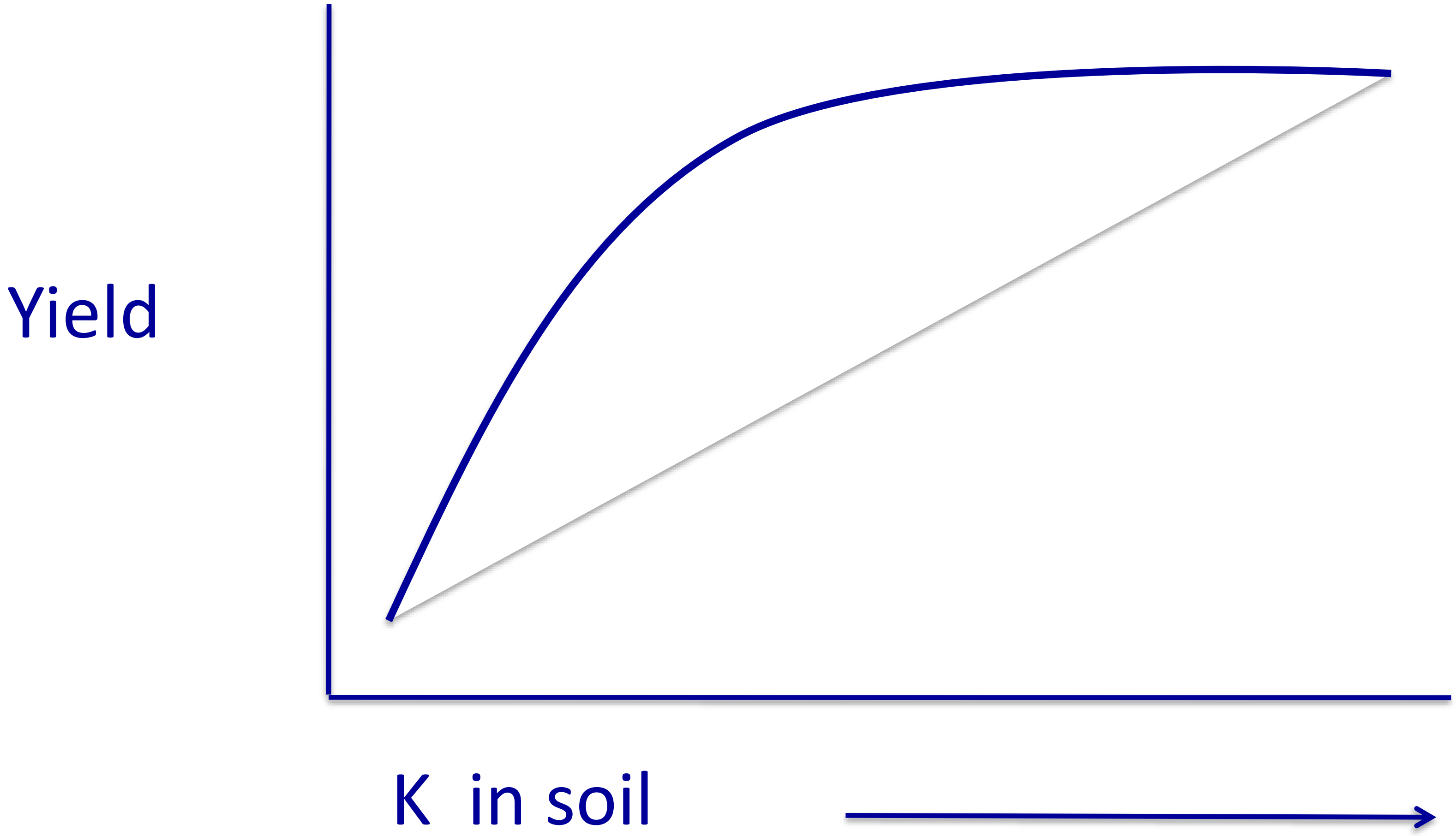
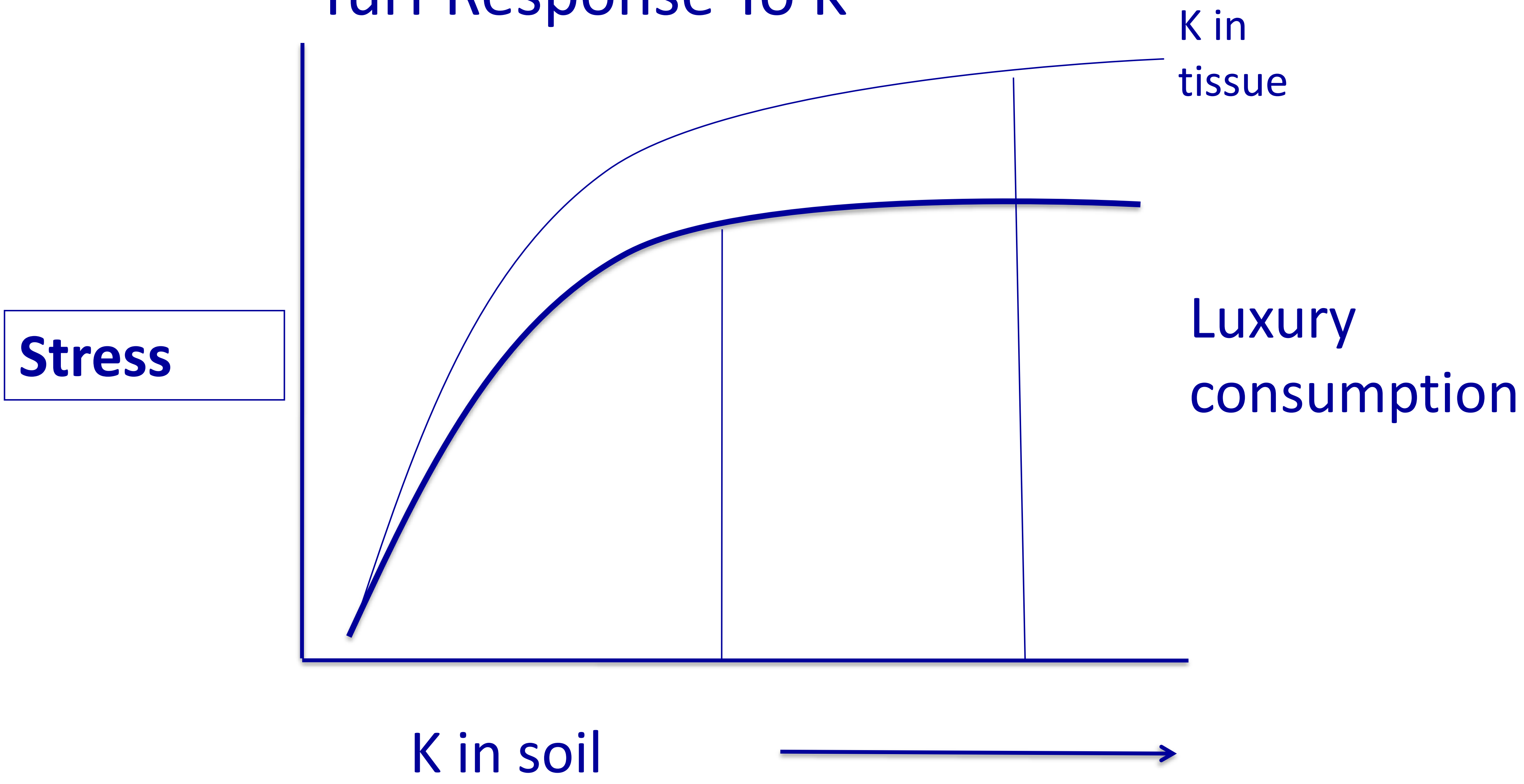
Potassium (K) Nutrition

- Many ignore potassium fertilization because there is no obvious visual or growth response from applications
  - Deficiencies lead to:
    - Increased wilting
    - Winter desiccation
    - Reduced drought tolerance
    - Reduced wear tolerance
    - Increased disease susceptibility

Potassium Response



Turf Response To K



Potassium

PPM		LB/A	KG/HA
0 - 40	Very Low	0-80	0-90
41 – 175	Low	81-350	91-392
175 -250	Adequate	350-500	392-560
250- +	High	500-+	560-+

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Recommendations

- Maintain potassium within sufficiency range:
  - Soil K = 100 to 250 lb/acre or 50 to 125 ppm (37 ppm MLSN)
  - Tissue K = 1 to 4 %
- Florida: No nutrient response curve

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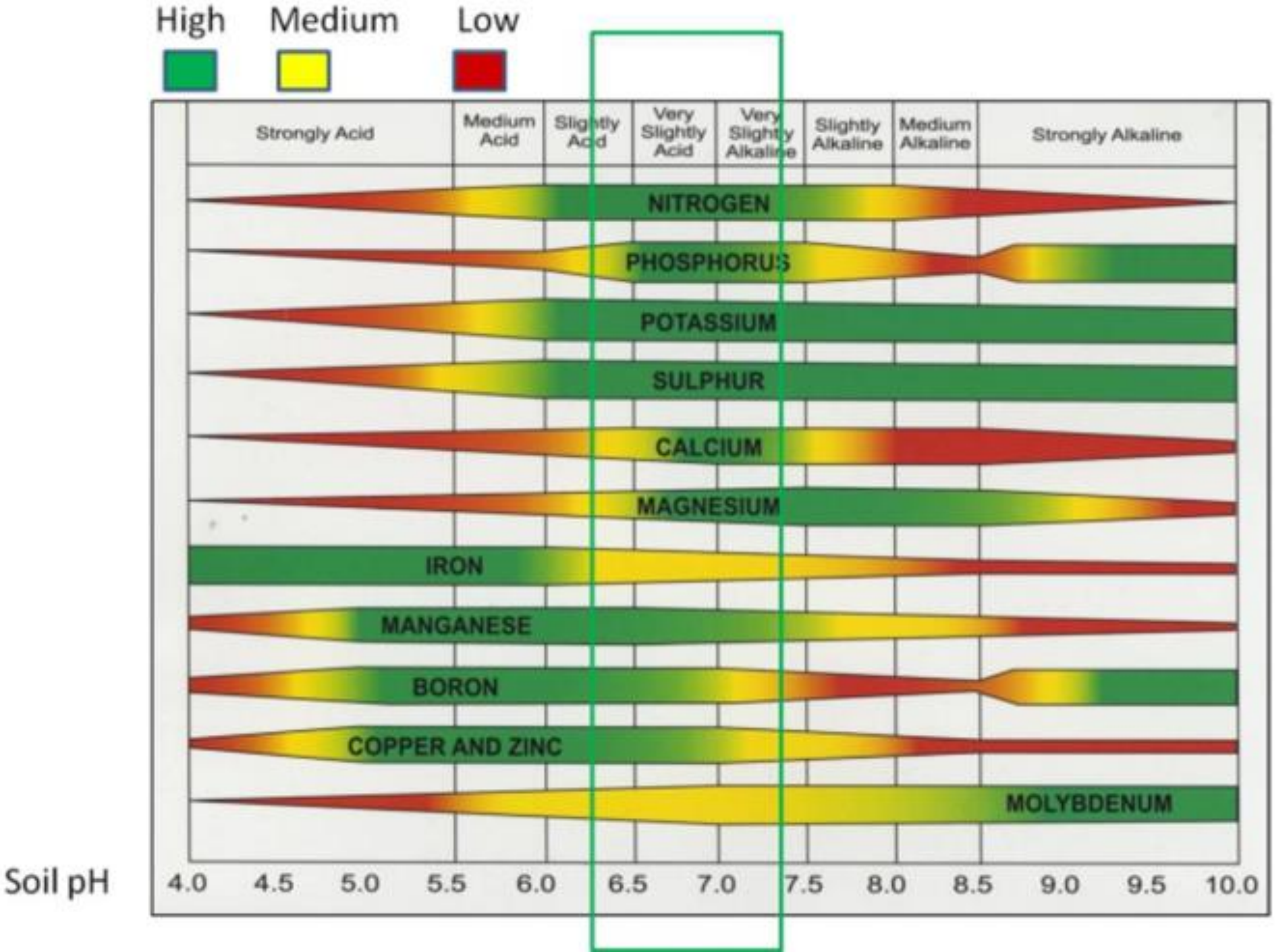
Ca, Mg, S, and the micronutrients



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https://ucanr.edu/sites/Salinity/Salinity_Management/Effect_of_salinity_on_soil_properties/Effect_of_pH_sodicity_and_salinity_on_soil_fertility_/

Calcium (Ca)

- Cell wall formation, cell division, osmotic balance, membrane stabilization
- Younger leaves turn reddish-brown, fades to red
- Low pH conditions
- Liming solves problem
- MLSN: 331 ppm (Soil test issues?)
- 0.25 to 1.5 % in tissue

Soil Testing Problems

- Problems Identified with Soil Test Procedures – CEC
- May be using inappropriate methods
  - Many using Ammonium Acetate (NH_4OAc)
  - NH_4OAc will dissolve calcium carbonate
  - Increases the amount of measured Ca
  - Increases the estimated CEC

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Magnesium (Mg)

- Center of chlorophyll
- Symptom – Chlorosis
- Low pH & Low CEC
- 0.12 to 0.60 % in tissue
- MLSN: 47 ppm
- **Florida: 20 ppm**

- Soil test levels varies with CEC
  - Less than 4 meq
    - Mehlich (30 to 140 ppm)
    - Ammonium acetate (80-140 ppm)
  - Higher CEC
    - Double the numbers (Carrow 2001)

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Sulfur (S)

- May see it in rare situations
- Rare in most of U.S. because of high sulfur coal
- Yellowing of younger leaves
- Slow growth
- MLSN: 7 ppm
- 0.15 to 0.60 % in tissue

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Iron (Fe)

- Cofactor for chlorophyll formation
- Symptom - chlorosis
- Most common of all micronutrient deficiencies
- High pH
- Soil tests inaccurate
- 50 to 500 ppm in tissue
- Very small amounts applied to tissue (foliar application)

Iron in the Soil

Applied

$$Fe^{3+} + 3H_2O = Fe(OH)_3 + 3^{H+}$$

Precipitates

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Manganese (Mn)

- Activator of at least 35 plant enzymes, formation of chlorophyll and lignin, root growth
- Yellowing like iron deficiency, veins remain green
  - Tips may remain green
- Leaves drop (lignin)
- Soil tests misleading
- 25 to 300 ppm in tissue

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Zinc (Zn)

- Catalyst of enzymes, regulates gene expression, membrane function
- Stress management
- Deficiency rare
- 17 to 250 ppm in tissue

Copper (Cu)

- Catalyst in photosynthesis and respiration, carbohydrate formation, lignin formation
- Deficiencies in high pH soils (rare)
- 2 to 50 ppm in tissue

Boron (B)

- Membrane and cell wall formation, sugar transport, carbohydrate metabolism
- Deficiencies rare
- Little needed (5 to 60 ppm in tissue)
- Very narrow range between deficiency and toxicity

Molybdenum (Mo)

- Enzyme reactions, sulfur metabolism
- Deficiency
- older leaves pale green
- 0.1 to 1 ppm in tissue

Summary

Use soil and tissue tests to develop a fertility program

Turfgrass Growth

Turf growth occurs through process of photosynthesis

Plants manufacture food from sunlight and turn it into carbon materials they use for growth.

Plants maintain some of this carbon as storage for use in spring green-up, recovery from stress, etc.

Our management practices (fertilization, irrigation, mowing) influence turfgrass growth.

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Nutrition and Fertilization BMPs

- The goal of a proper nutrient management plan should be to apply the minimum necessary nutrients to achieve an acceptable quality and apply these nutrients in a manner that maximizes their plant uptake

Inputs:

- Fertilization
- Atmospheric Deposition
- Deposition of Organic Residues

Plant-Available Nutrient Pool

Outputs:

- Clipping Removal
- Gaseous Loss
- Conversion to Unavailable Forms
- Leaching/Runoff Loss

Basic Questions to Ask When Developing a Fertilizer Program

- What fertilizer analysis and source is best?
  - Soil and tissue tests
- What rate of this fertilizer should be used?
  - Soil and tissue tests
- What timing and frequency will provide optimum results?

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Seven Steps To Developing a Fertilizer Program

- Determine annual N needs; Consider length of growing season
- Set approximates dates and rates of N application
- Select appropriate N carrier(s)
- Determine needs for P_2O_5, K_2O, other nutrients, lime, etc.
- Consider other factors (ease of application, price, etc.)
- Plan the program, set up a table showing dates, carriers, rates, etc.
- Adjust program as needed for weather, disease, traffic, etc.

Micronutrients

- Fertilizer application of these nutrients may not be necessary where sufficient quantities exist in the soil or are supplied as small impurities in other fertilizers
  - Soil testing should provide the basis for determining a micronutrient fertility program

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Fertilizer

- Micronutrients should be applied via foliar application
  - Fe – the only micronutrient to produce a response in every trial
  - Mn – rarely produces a response
  - Mg – almost never produces a response

  - No other micronutrients should be applied unless you have documented a response

Tissue Test Reference Ranges

Table 1. Nutrient ranges for warm-season turfgrass species.*

	Bermudagrass	Centipedegrass	Seashore Paspalum	St. Augustinegrass	Zoysiagrass
			%		
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K	1.00–4.00	1.12–2.50	2.00–4.00	2.50–4.00	1.05–1.27
Ca	0.35–1.00	0.50–1.15	0.25–1.50	0.30–0.50	0.44–0.56
Mg	0.13–0.50	0.12–0.21	0.25–0.60	0.15–0.25	0.13–0.15
S	0.15–0.50	0.20–0.38	0.20–0.60	0.18–0.33	0.32–0.37
			ppm		
Fe	50–500	102–221	50–500	50–300	188–318
Mn	25–300	35–75	50–300	40–250	25–34
Zn	20–250	17–40	20–250	20–100	36–55
Cu	5–50	2–7	5–50	10–20	2–4
B	6–30	5–10	5–60	5–10	6–11
Mo	0.10–1.20	0.14–0.30	0.5–1.0	0.15–0.5	0.12–0.30

*Bryson et al. (2014)

https://edis.ifas.ufl.edu/pdf/EP/EP53900.pdf

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https://www.paceturf.org/PTRI/Documents/1202_ref.pdf

Florida

- **P: 10 ppm**
- **Mg: 20 ppm**

https://edis.ifas.ufl.edu/pdf/SS/SS31700.pdf

Fertilizer Recommendations

Table 1. N, P, K, and Mg recommendations for golf putting greens, tee boxes, fairways, roughs, and athletic fields.

Grass Use	Grass Type	Location	Target pH	N[N]	P_2O_5[P]			K_2O[K]			Mg[Mg]
					L	M	H	L	M	H	<20 mg/kg
				lb/1000 sq ft/yr							
Greens	Bermuda	North[x]	6.5	8.0	0.2	0.1	0	4.5	3	0	2
		South	6.5	12.0	0.4	0.2	0	6	4	0	2
	Cool Season	North	6.5	4.0	0.5	0.2	0	1	0.5	0	1
		South	6.5	3.0	0.4	0.2	0	1	0.5	0	1
Tees	Bermuda	North	6.5	6.0	0.2	0.1	0	3	2	0	2
		South	6.5	8.0	0.3	0.1	0	4	3	0	2
	Cool Season	North	6.5	3.0	0.5	0.2	0	1	0.5	0	1
		South	6.5	2.0	0.4	0.2	0	0.5	0.2	0	1
Fairways	Bermuda	North	6.5	4.0	0.2	0.1	0	1	0.5	0	1
		South	6.5	5.0	0.2	0.1	0	1.2	0.6	0	1
	Cool Season	North	6.5	2.0	0.2	0.1	0	0.5	0.2	0	0.5
		South	6.5	1.0	0.1	0.1	0	0.2	0.1	0	0.5
Roughs	Bermuda	North	6.5	2	0.2	0.1	0	0.5	0.2	0	1
		South	6.5	2.5	0.2	0.1	0	0.5	0.2	0	1
Athletic Fields	Bermuda	North	6.5	3.0	0.5	0.1	0	2	1	0	1
		South	6.5	5.0	0.5	0.2	0	3	2	0	1
	Cool Season	North	6.5	2.0	0.5	0.2	0	1	1	0	1
		South	6.5	2.0	0.5	0.2	0	1	1	0	1

https://edis.ifas.ufl.edu/pdf/SS/SS40400.pdf

Questions?

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352-273-4791