PLANT-SOIL INTERACTIONS

ADAM THOMS
IOWA STATE UNIVERSITY
March 2, 2023

INTERPRETATION IS THE KEY

- CHEMICAL TESTS CONSISTENT
- INTERPRETATION VARIES

BASIC PRINCIPLES AND TERMINOLOGY

REPORT NO.	809629	I.D. NO.	95635	DATE REC'D.	07-Dec-93	DATE REPORTED	08-Dec-93	SAMPLE WILL BE KEPT UNTIL	07-Jan-94	LABORATORY NUMBER	

Scotts ProTurf

Soil Analysis

Conducted by

HARRIS LABORATORIES INC.

THIS ANALYSIS RUN FOR:

RANDY CARPENTAR
MEADOWS FARMS GC
4300 FLAT RUN RD
LOCUST GROVE VA 22508

THIS ANALYSIS REQUESTED BY:

Robert Herring
7303 Native Dancer Dr
Midlothian VA 231126170
PH804-739-1050 77L

ALL NUTRIENT RESULTS EXPRESSED IN PPM

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

CODING INFORMATION

	Sample Description	Composite Information	Plant Variety	Sample Nature
1	GRN11		GART	
2	GRN12		GART	

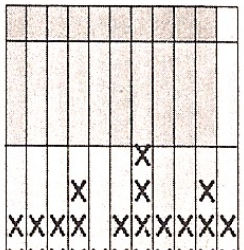
VERY HIGH

HIGH

EXCESSIVE

VERY HIGH

HIGH



FIRST THREE LINES FILLED WITH INFORMATION

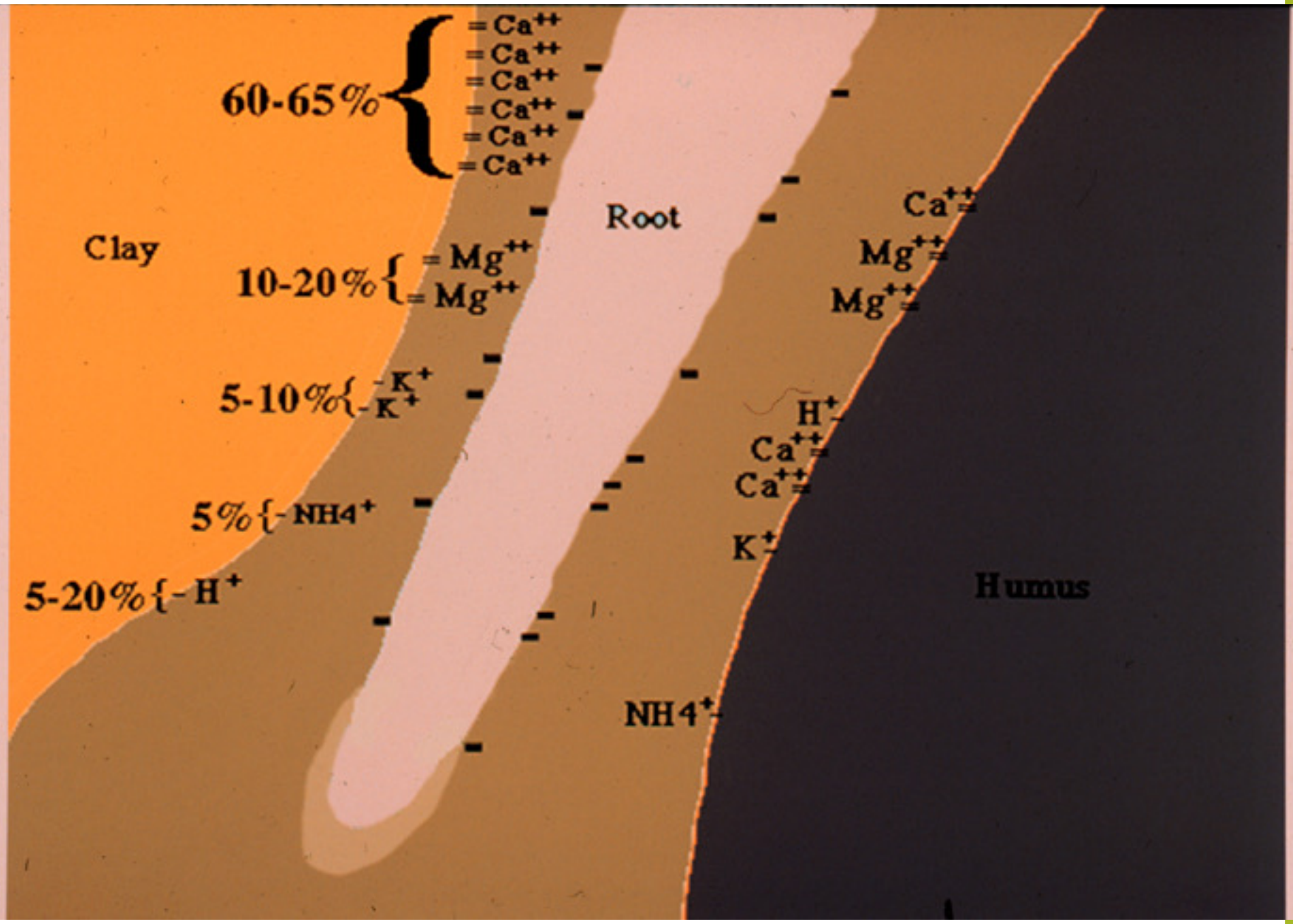
CEC

pH

BUFFER pH

CATION EXCHANGE CAPACITY (CEC)

THE ABILITY TO EXCHANGE CATIONS


60-65%
= Ca++
= Ca++
= Ca++
= Ca++
= Ca++
= Ca++
Clay
Root
Humus
10-20%
= Mg++
= Mg++
5-10%
-K+
-K+
5%
-NH4+
5-20%
-H+
Ca++=
Mg++=
Mg++=
H+-
Ca++=
Ca++=
K+-
NH4+-

CATION EXCHANGE CAPACITY

1 milliequivalent (meq)

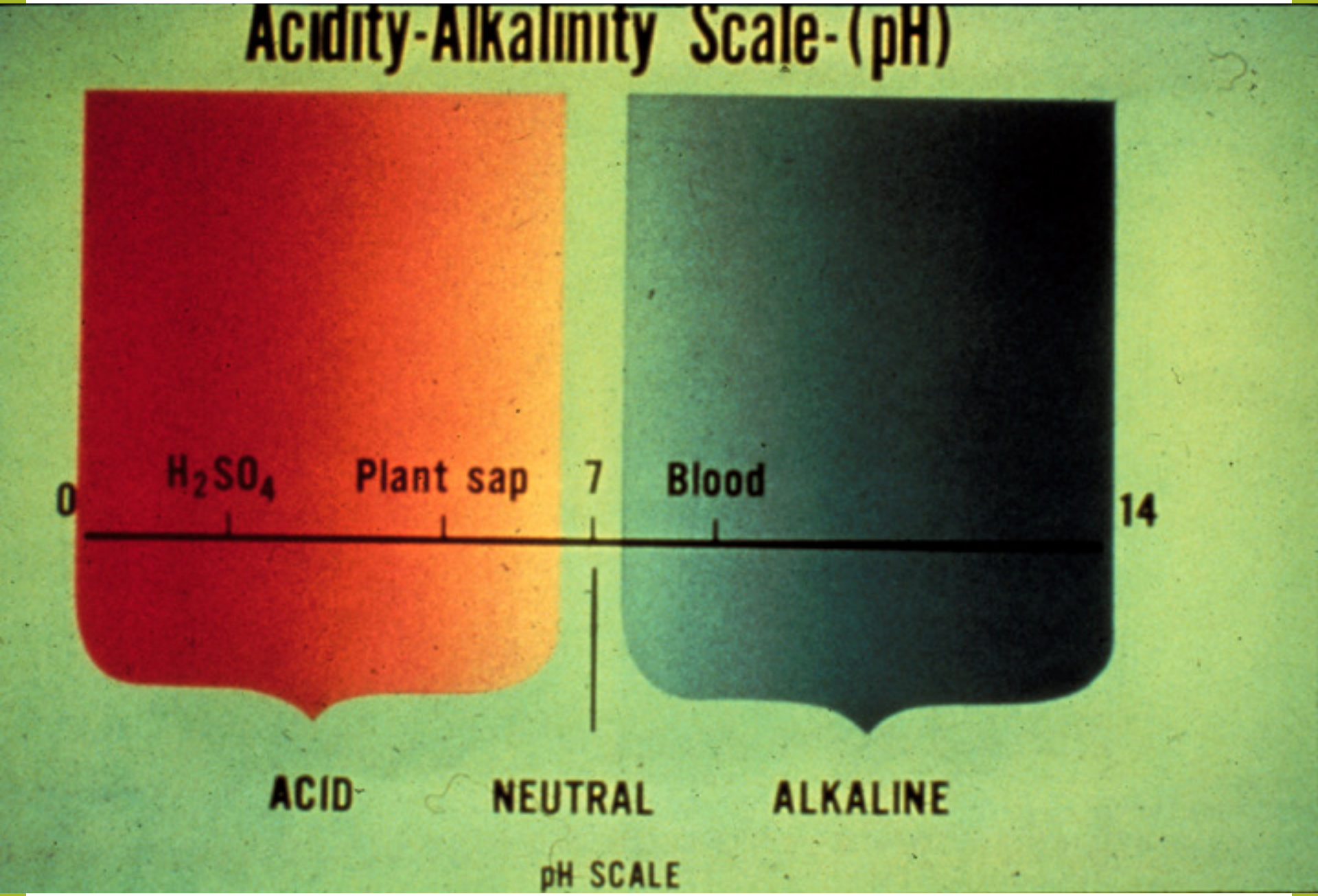
6.02×10^{20}

602,000,000,000,000,000,000

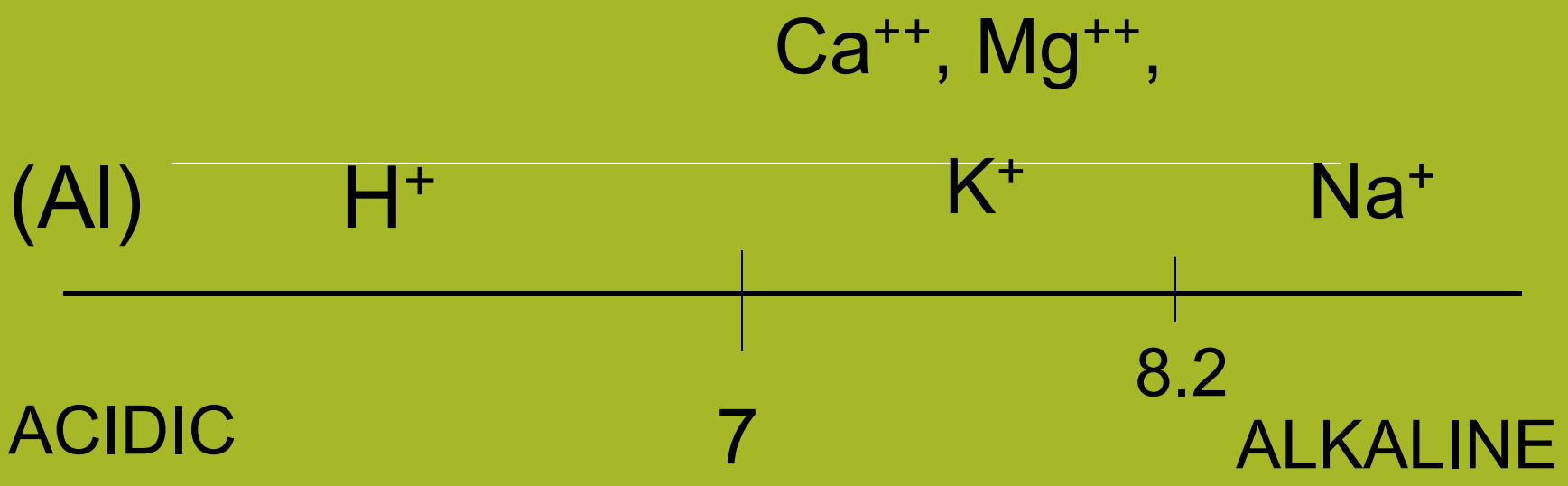
CATION EXCHANGE CAPACITY

SOIL TYPE	meq/100g
SAND	<1 - 8
CLAY	80 - 120
ORGANIC MATTER	150 – 500
CLAY LOAM SOIL	25 – 30
SAND-BASED FIELD	<1 - 14

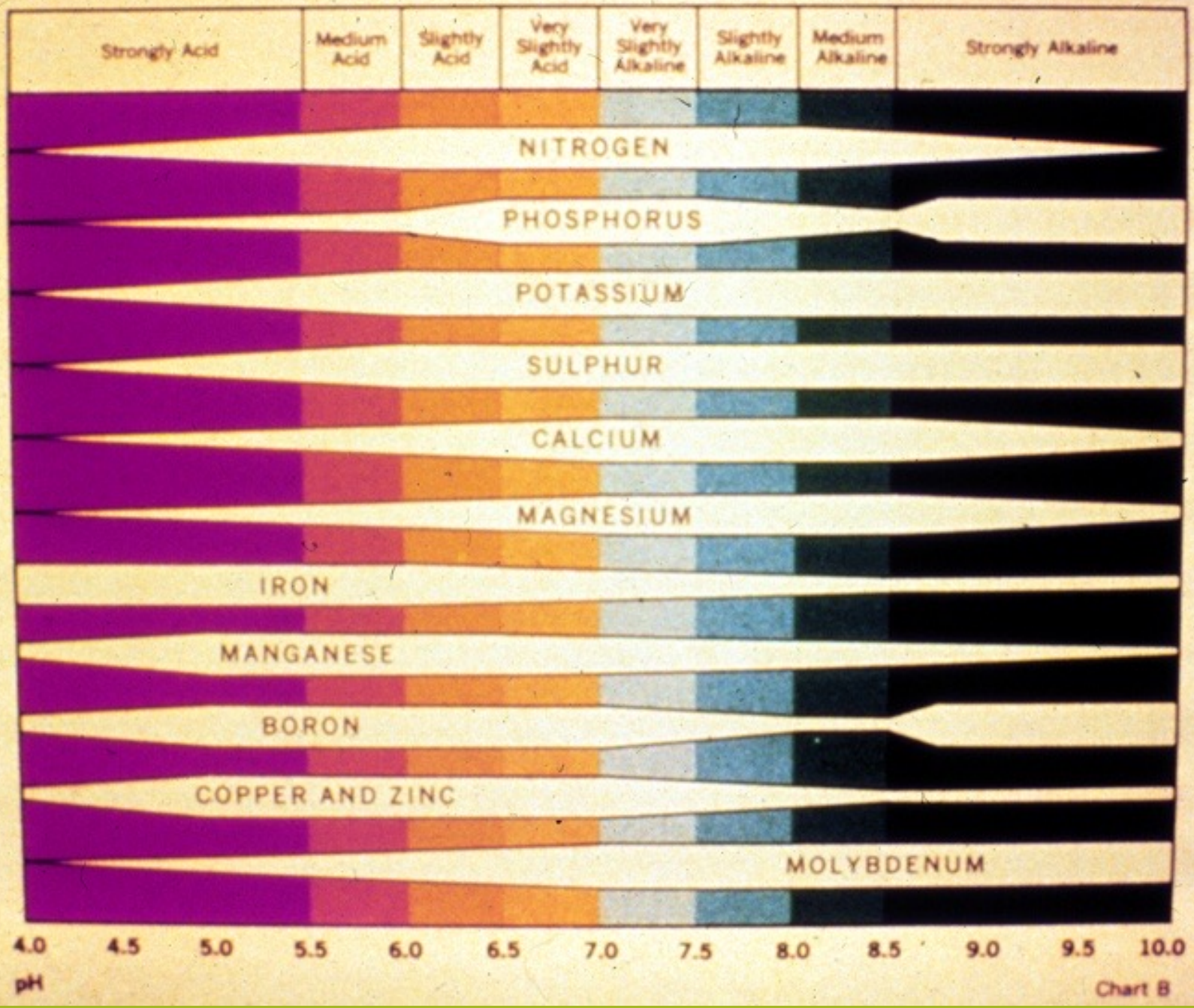
PH


Acidity-Alkalinity Scale-(pH)
0
H_2SO_4
Plant sap
7
Blood
14
ACID
NEUTRAL
ALKALINE
pH SCALE

PH



HOW SOIL pH AFFECTS AVAILABILITY OF PLANT NUTRIENTS



LIME

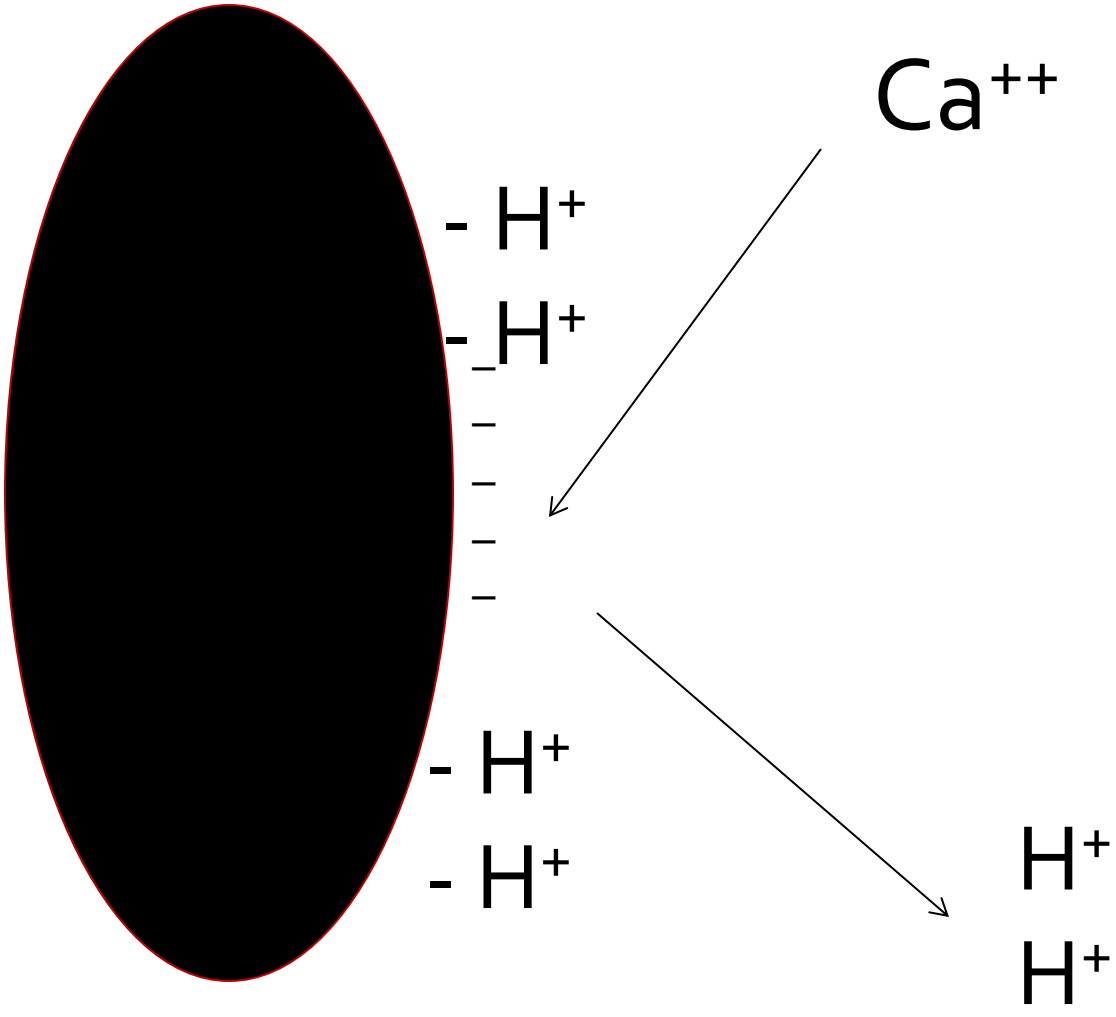
CALCIUM CARBONATE

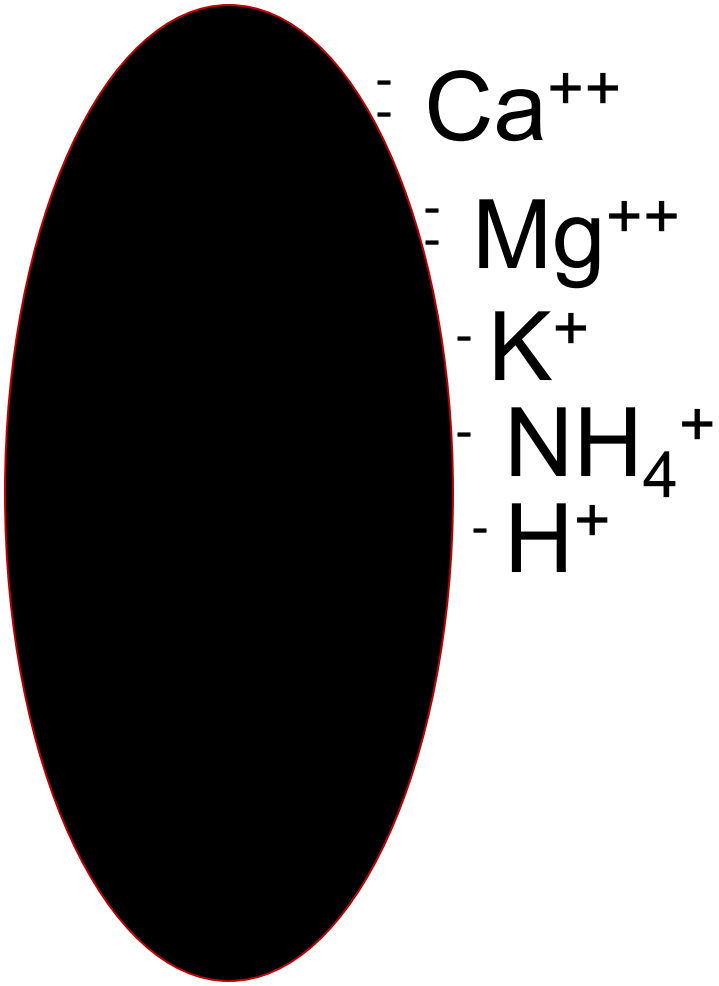
$CaCO_3$

LIME

RAISES

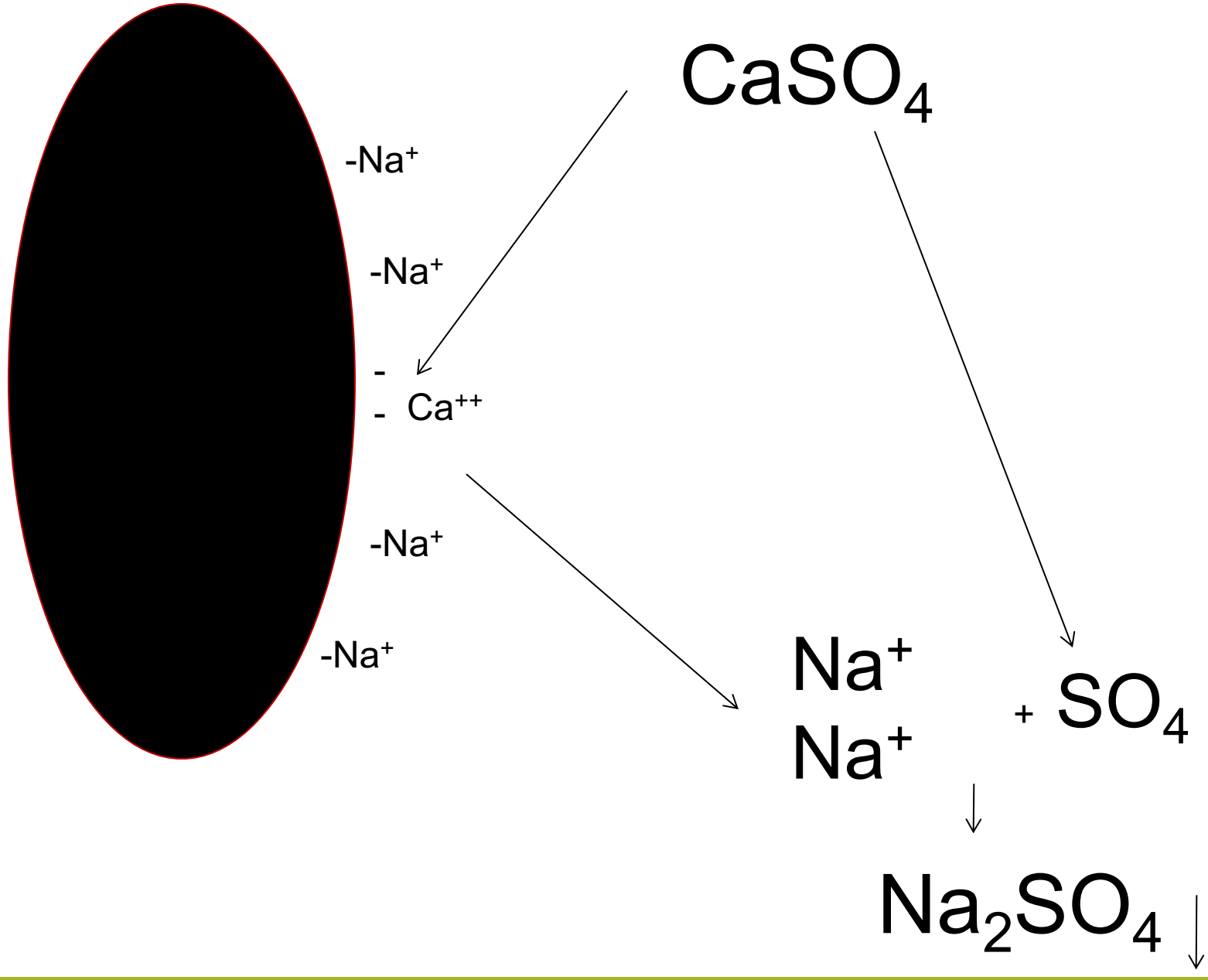
PH


Ca++
- H+
- H+
- H+
- H+
H+
H+


- Ca^{++}
- Mg^{++}
- K^{+}
- NH_4^{+}
- H^{+}

GYPSUM

$CaSO_4$


$CaSO_4$
$-Na^+$
$-Na^+$
$-$
$-\ Ca^{++}$
$-Na^+$
$-Na^+$
Na^+
Na^+
$+\ SO_4$
Na_2SO_4

SOIL TESTING

17 ESSENTIAL ELEMENTS

- CARBON C
- HYDROGEN H
- OXYGEN O
- PHOSPHORUS P
- POTASSIUM K
- NITROGEN N
- SULFUR S
- CALCIUM Ca
- IRON Fe
- MAGNESIUM Mg
- BORON B
- MANGANESE Mn
- COPPER Cu
- ZINC Zn
- MOLYBDENUM Mo
- CHLORINE Cl
- NICKEL Ni

17 ESSENTIAL ELEMENTS

- CARBON C
- HYDROGEN H
- OXYGEN O
- PHOSPHORUS P
- POTASSIUM K
- NITROGEN N
- SULFUR S
- CALCIUM C
- IRON Fe
- MAGNESIUM Mg
- BORON B
- MANGANESE Mn
- COPPER Cu
- ZINC Zn
- MOLYBDENUM Mo
- CHLORINE Cl
- NICKEL Ni

17 ESSENTIAL ELEMENTS

- CARBON C
- HYDROGEN H
- OXYGEN O
- PHOSPHORUS P
- POTASSIUM K
- NITROGEN N
- SULFUR S
- CALCIUM Ca
- IRON Fe
- MAGNESIUM Mg
- BORON B
- MANGANESE Mn
- COPPER Cu
- ZINC Zn
- MOLYBDENUM Mo
- CHLORINE Cl
- NICKEL Ni

MACRONUTRIENTS

- 1000 mg/kg or more
- C, H, O, N, P, K, S, Mg, AND Ca

MICRONUTRIENTS

- Less than 100 mg/kg
- Mo, Cu, Zn, Mn, B, Fe, Cl, and Ni

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 TESTING

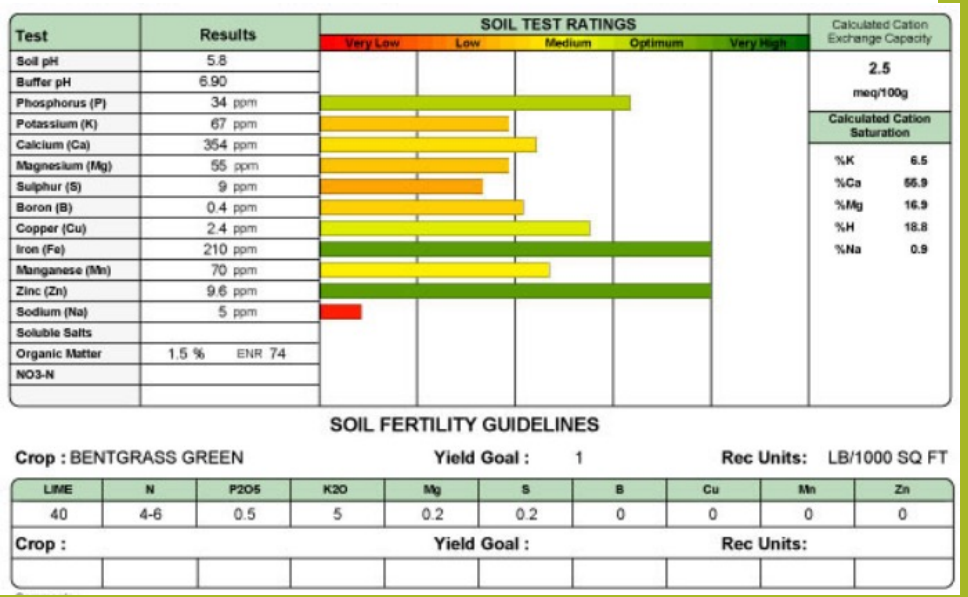
SLAN--sufficiency level of available nutrients

BCSR--basic cation saturation ratio

MLSN minimum level for sustainable nutrition

SLAN

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



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	66.9
%Mg	16.9
%H	18.8
%Na	0.9

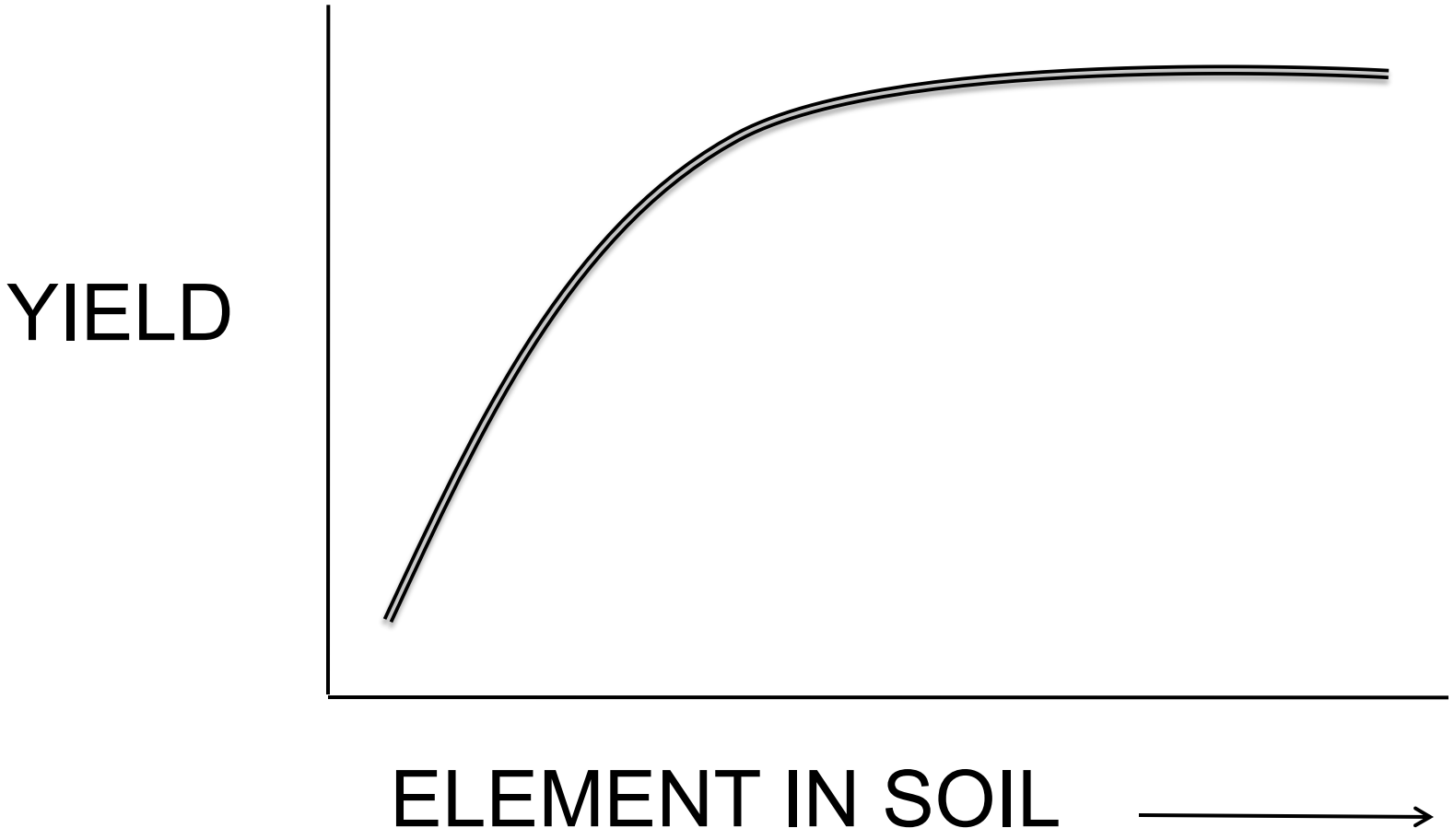
SOIL FERTILITY GUIDELINES

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:

YIELD CURVE



BCSR

Basic Cation Saturation Ratio

- Based on an ideal ratio of cations on exchange sites
- Newer method
- Less research
- Private labs
- Tends to overestimate
- Do not use for turfgrass

Minimum Level for Sustainable Nutrition

- Developed recently by PACE Turf and Asian Turfgrass Center
  - Dr. Larry Stowell and Dr. Micah Woods
- 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”

Why Use MLSN?

- Focus on sustainability
- Reduce inputs
- Reduce maintenance costs
  - (or redirect costs, more on this later)
- Maintain expected turf performance
- Show reception to environmental concerns
- Plant health and soil health

Minimum Level for Sustainable Nutrition

- **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

Nutrient	Tissue ppm	Ratio:N
N	40,000	1
P	5,000	0.125
K	20,000	0.5
Ca	4,000	0.1
Mg	2,000	0.05

This gives us a nutrient use ratio:

N:P:K → 8:1:4

MLSN

- Good start, Going in the right direction
- Basically SLAN for turf based on turf quality
- Turf quality not always the best guide
- MSLN 6 YEARS, SLAN >86 YRS

HOW ABOUT PASTE EXTRACT?

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

Paste Extract Tests

- Should be used with standard soil tests every time
- Expect low extraction values for fertility
- Bicarbonates will show up (they dissolve easily in water)- they don't cause structure problems or sealing in the soil
- Data is lacking between turf quality and soluble nutrients

THE USEFULNESS OF A SOIL TEST DEPENDS ON PROPER INTERPRETATION

LABS TEND TO OVERESTIMATE HOW MUCH P IS NEEDED AND UNDERESTIMATE HOW MUCH K IS NEEDED

PHOSPHORUS P

FUNCTION

- ENERGY TRANSFER
- STARCH DECOMPOSITION
- GENETIC MATERIAL
  - GRASSES ARE VERY EFFICIENT USERS OF P

PHOSPHORUS (BRAY P1)

PPM		LB/A	KG/HA
0 - 5	VERY LOW	0 - 10	0 - 11
6 - 10	LOW	12 - 20	13 - 22
10 - 20	ADEQUATE	20 - 40	22 - 45
20 - +	HIGH	40 - +	45 - +

PHOSPHORUS

P SUFFICIENCY LEVEL BY EXTRACTANT(CARROW)

	ppm P			
	Very low	Low	Medium	High
BRAY P1	0-4	5-15	16-30	>31
MEHLICH III	0-12	13-26	27-54	>55
OLSEN	0-6	7-12	13-28	>29

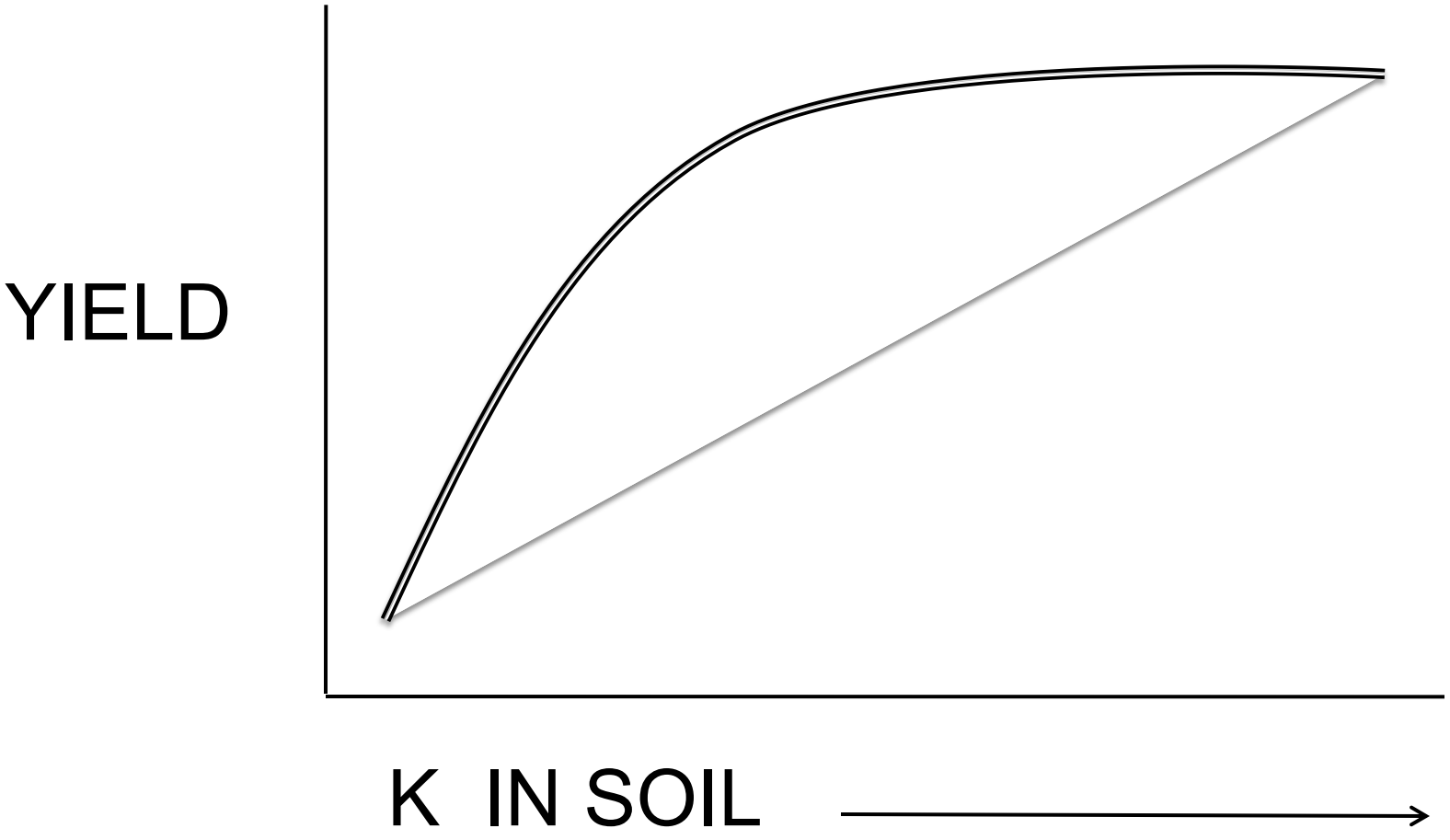
NUMBERS VARY SOMEWHAT FROM LAB TO LAB.

POTASSIUM K

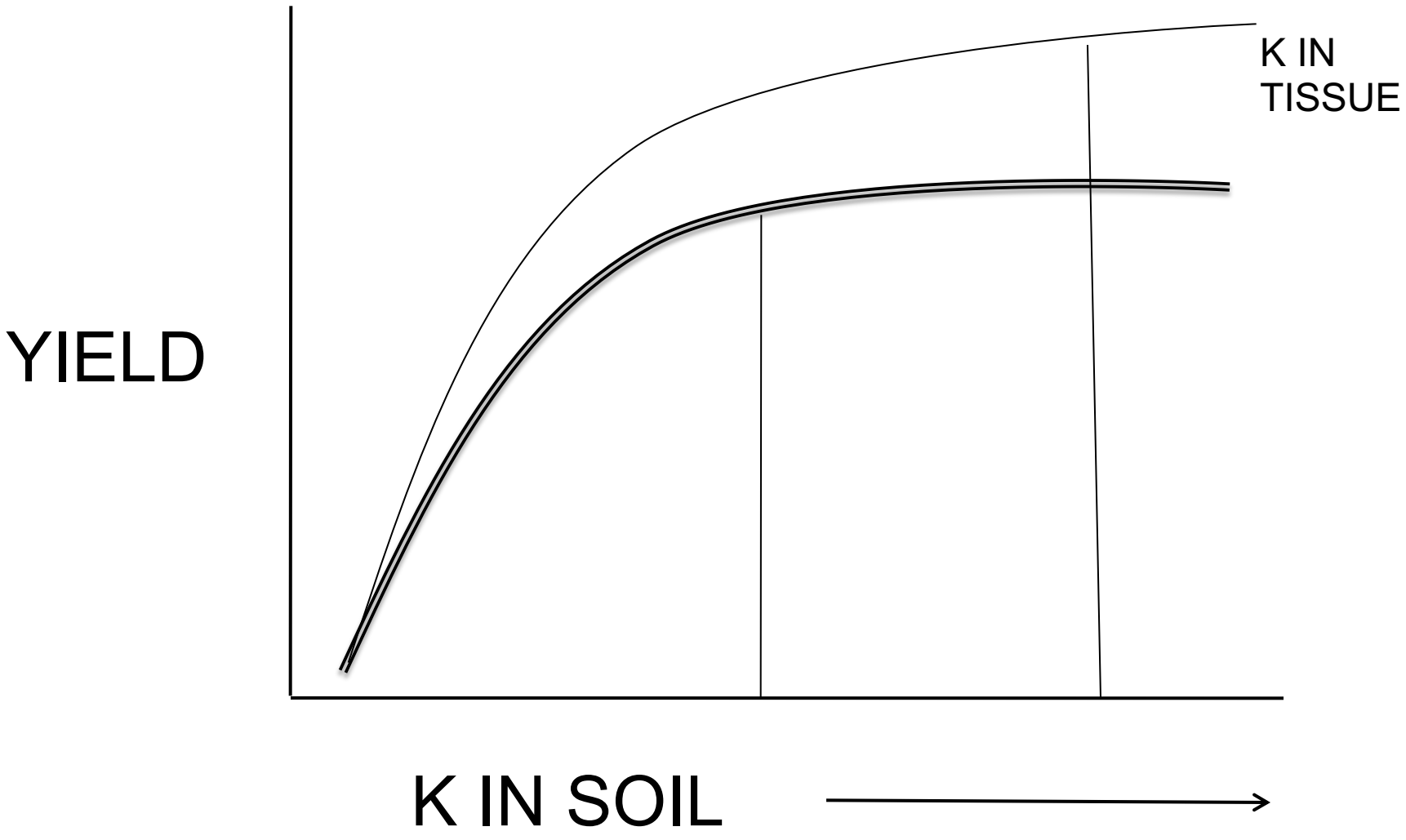
- MYSTERY ELEMENT
- NOT A PART OF BIOCHEMICALS
- ACTS AS COFACTER
- STOMATAL CONTROL

STRESS

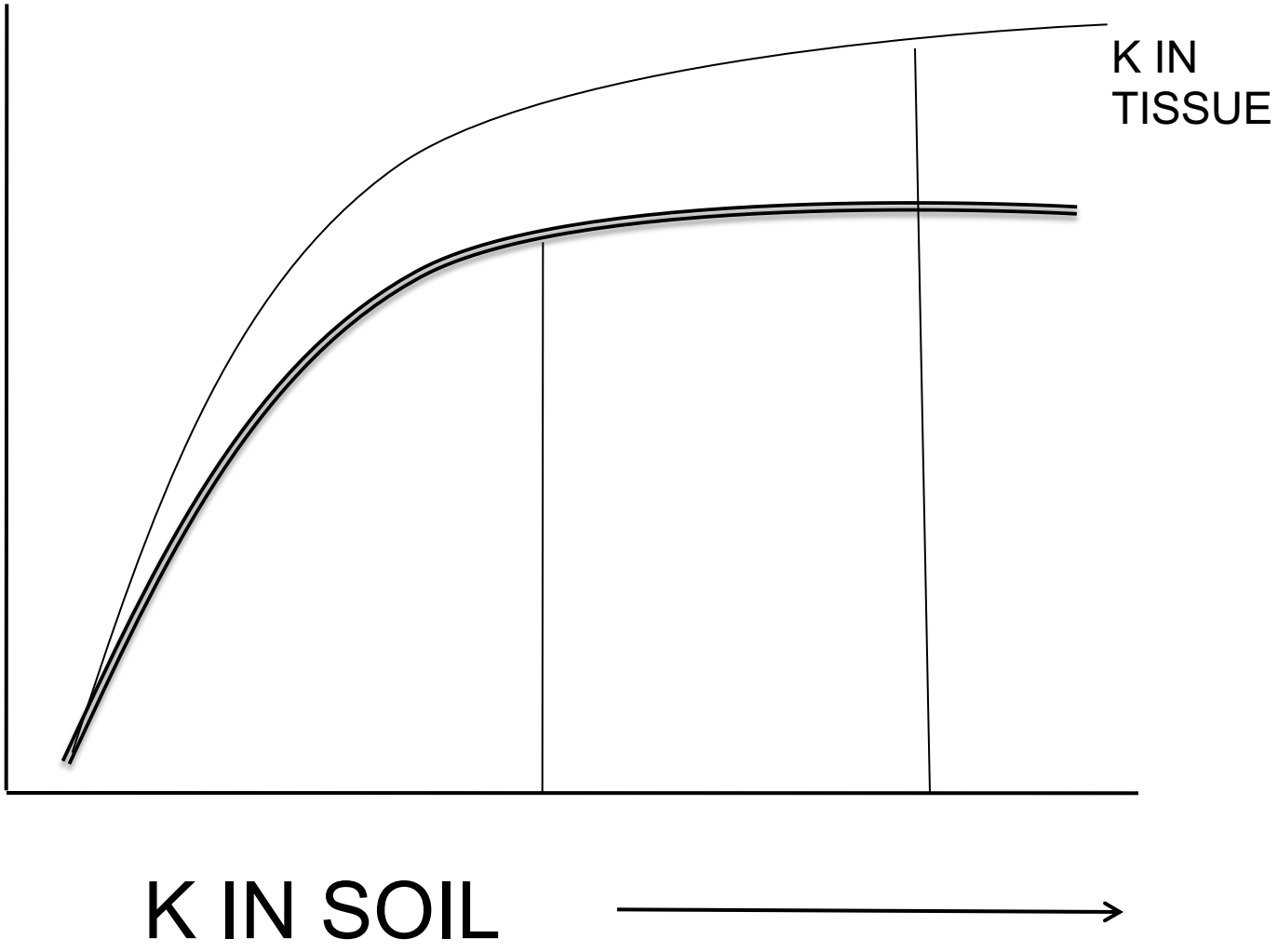
POTASSIUM RESPONSE



LUXURY CONSUMPTION



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- +

RECOMMENDATIONS

- Maintain potassium within sufficiency range:
  - Soil K ppm = 100 to 250 lb/acre or 50 to 125 (Mehlich-III)
  - Tissue K = 2 to 3%

- If a deficiency in soil K exists, potassium can be applied biweekly at 0.2 to 0.3 lbs K_2O/ 1000-sq ft to build up soil K
- To maintain soil K level, potassium can be applied biweekly at 0.1 lbs K_2O/ 1000-sq ft

HOW ABOUT Ca, Mg, S and the MICRONUTRIENTS?

CALCIUM (Ca)

- 0.30 TO 1.25 % IN TISSUE
- YOUNGER LEAVES TURN REDDISH-BROWN
- FADES TO RED
- LOW pH CONDITIONS
- LIMING SOLVES PROBLEMS

MAGNESIUM (Mg)

- 0.15 to 0.50 % in tissue
- > 0.15 % in tissue deficient
- Soil test levels varies with CEC
  - Less than 4 meq
    - Mehlich 1 (30 to 60 ppm)
    - Mehlich 2 (70 to 140 ppm)
    - Ammonium acetate (80-140 ppm)
  - Higher CEC
    - Double the numbers (Carrow 2001)

SULFUR (S)

- 0.10 TO 0.50 % IN TISSUE
- YELLOWING OF YOUNGER LEAVES
- SLOW GROWTH
- RARE IN MOST OF U.S. BECAUSE OF HIGH SULFUR COAL
  - 12 to 15 lb/ac in Midwest
- MAY SEE IT IN RARE SITUATIONS

IRON (Fe)

- COFACTOR FOR CHLOROPHYLL FORMATION
- SYMPTOM - CHLOROSIS
- HIGH pH
- MOST COMMON OF ALL MICRONUTRIENT DEFICIENCIES

IRON (Fe)

- 100 to 500 ppm in tissue
- Soil tests inaccurate
- Very small amounts applied to tissue (0.3 to 0.5 lb Fe/ac)

SUMMER INDUCED CHLOROSIS

- David Devetter, MS Student
- Develops during high temperature periods
- Not observed in spring and fall
- Usually on sand, also can be on soil
- It is an iron problem

OUR OBSERVATIONS

- Summer-induced iron chlorosis
  - Appears from late July to early September
  - Goes away if left untreated
  - Bentgrass and bluegrass
  - Widespread
    - Multiple countries
    - Golf courses
    - Sports fields
    - Home lawns

* While common on sand soils it is present in finer textured soils as well

Chlorosis

Conclusions

- Summer-induced chlorosis was caused by an iron deficiency
- Soil temperature may play a role in summer-induced iron chlorosis
- Summer-induced iron chlorosis can be treated with iron fertilization
- Higher rates of iron lead to more color recovery
- Treating before symptoms occur does not work
- Control of chlorosis depends on timing of iron fertilization

MANGANESE

- Activator of at least 35 plant enzymes
- Formation of chlorophyll
- Root growth
- Cofactor for lignin formation
- 20 to 500 ppm in tissue
- Soil tests misleading

MANGANESE

- YELLOWING SIMILAR TO IRON DEFICIENCY
- VEINS REMAIN GREEN - TIPS MAY REMAIN GREEN
- LEAVES DROP (lignin)

ZINC (Zn)

- Catalyst of enzymes
- Regulates gene expression
- Membrane function
- Stress management
  - Saturation
  - High temperature
- 20 to 55 ppm in tissue sufficient
- 15 to 20 ppm deficient

COPPER (Cu)

- Catalyst in photosynthesis and resp.
- Carbohydrate formation
- Lignin formation
- 5 to 38 ppm in tissue
- Deficiencies in high pH soils (rare)

COPPER (Cu)

MIKE FAUST MS PROJECT ‘98 TO ‘99

- 0 to 600 ppm Cu
- Cu reduced Bentgrass rooting at 200 ppm and above. Approximately 50% reduction at 600 ppm

BORON (B)

Membrane and cell wall formation

Sugar transport, carbohydrate metabolism

Respiration

Little needed (5 to 10 ppm in tissue)

Deficiencies rare

Very narrow range between deficiency and toxicity

Sewage effluent (1 to 2 ppm can be toxic)

MOLYBDENUM (Mo)

- Enzyme reactions
- Sulfur metabolism
- Function of P in plant
- 0.1 to 1 ppm in tissue
- Deficiency
  - older leaves pale green
- Toxicity by mines in mountains

Chlorine (Cl)
Nickel (Ni)

SUMMARY

USING SOIL TESTS TO DEVELOP A FERTILITY PROGRAM

THINGS TO BE AWARE OF

Turfgrass Rooting Response to Humic Fertilizers

- Objective
  - Determine if the addition of humic substances to fertilizers benefits turfgrass rooting

Materials & Methods

- Greenhouse Study
- Rooting Tubes
  - 45° angle
- CRD – 4 reps
- Repeated in time
- Kentucky Bluegrass
- Bermudagrass

Materials & Methods

Treatment	Application Rate
22-0-4 Synthetic Fert. w/ Black Gypsum	1#N/M
PCHCU 2.5%	1#N/M
Urea + Humic DG (HDG)	1#N/M + 0.9#/M
18-24-12 Starter Fert. + HDG	1#N/M + 0.9#/M
18-24-12 Starter Fert.	1#N/M
Uflexx	1#N/M
Urea	1#N/M
Non-treated	-

- KBG 56 d interval
- BG 28 d interval
- Harvest 120 d after seeding

Data Collection

Syn. + BG

PCHCU

Urea + HDG

Starter + HDG

Starter

Uflexx

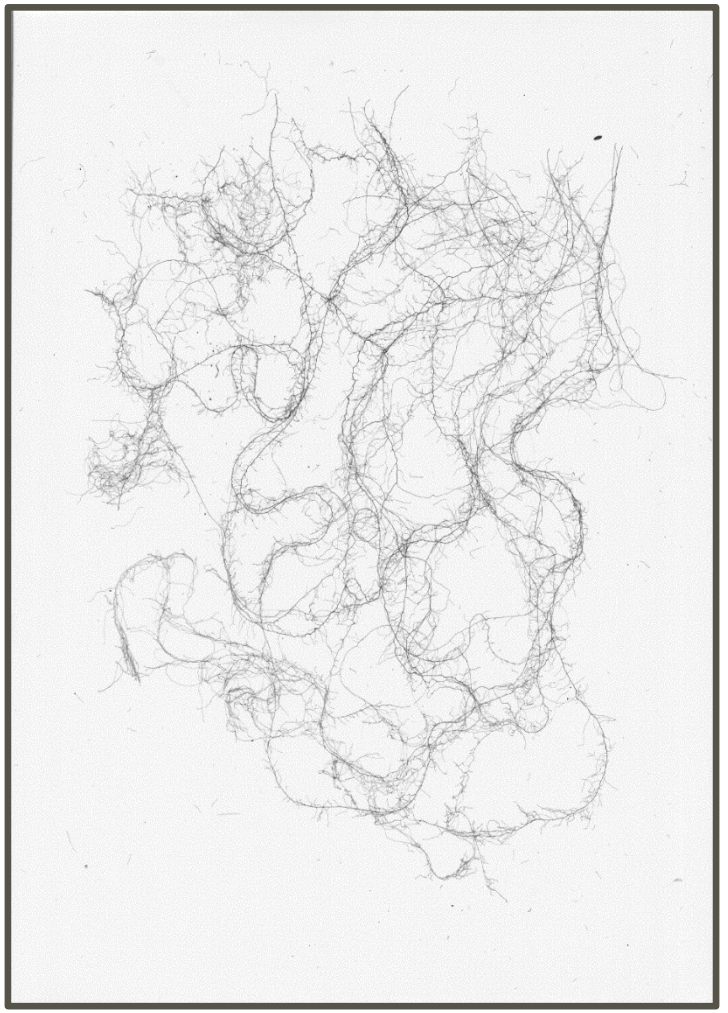
Urea

Non-treated

- Visual root and shoot length
- Longest root and shoot length

Data Collection

- WinRHIZO
  - Total root length
  - Root surface area
  - Root volume
- Root and shoot biomass



Kentucky Bluegrass

Treatment	Nutrient Analysis	Longest Root	Total Root Length	Root Surface Area	Root Volume	Root Biomass
		cm	cm	cm^2	cm^3	g
Synthetic Fert. w/ Black Gypsum	22-0-4, 30% gypsum, 4.7% HA	44.0	2884	150	0.62	0.09
PCHCU	45-0-0.2, 2% HA	47.7	3572	184	0.75	0.10
Urea + HDG	46-0-0 + 70% HA	44.2	3117	154	0.61	0.08
Starter Fert.+ HDG	18-24-12 + 70% HA	53.3	5508	333	1.61	0.25
Starter Fert.	18-24-12	54.2	5334	327	1.61	0.24
Uflexx	46-0-0	39.9	2145	103	0.39	0.06
Urea	46-0-0	42.3	2601	130	0.51	0.07
Non-treated	No added nutrients	39.7	1704	85	0.34	0.05
	$LSD_{0.05}$	6.1	495	33	0.20	0.04

Kentucky Bluegrass

Treatment	Nutrient Analysis	Longest Root	Total Root Length	Root Surface Area	Root Volume	Root Biomass
		cm	cm	cm^2	cm^3	g
Synthetic Fert. w/ Black Gypsum	22-0-4, 30% gypsum, 4.7% HA	44.0	2884	150	0.62	0.09
PCHCU	45-0-0.2, 2% HA	47.7	3572	184	0.75	0.10
Urea + HDG	46-0-0 + 70% HA	44.2	3117	154	0.61	0.08
Starter Fert.+ HDG	18-24-12 + 70% HA	53.3	5508	333	1.61	0.25
Starter Fert.	18-24-12	54.2	5334	327	1.61	0.24
Uflexx	46-0-0	39.9	2145	103	0.39	0.06
Urea	46-0-0	42.3	2601	130	0.51	0.07
Non-treated	No added nutrients	39.7	1704	85	0.34	0.05
	$LSD_{0.05}$	6.1	495	33	0.20	0.04

Conclusions

- Starter fertilizer
  - Phosphorus (P)
  - Humic substances no added benefit
- Absence of starter fertilizer, humic substances increased KBG rooting
  - P limitations or bans
- Future research
  - Timing
  - Species and cultivars

Soil Health Response to Humic Fertilizers

- Objectives
  - Evaluate the effects of the addition of humic substances to fertilizers on turfgrass soil health
    - Microbes, structure, and chemical properties
  - Evaluate reduced rates of nitrogen w/humic substances on turfgrass color and quality

Materials & Methods

- Randomized Complete Block
- Granular applications
  - Scotts Box
- Native Soil – Kentucky Bluegrass, sports field height
- USGA – Creeping Bentgrass

Materials & Methods – Native Soil

Treatment	Application Rate	Application Timing
22-0-4 w/BG	1#N/M	April, May, Sept., Oct.
PCHCU	1#N/M	April, May, Sept., Oct.
PCHCU	0.75#N/M	April, May, Sept., Oct.
Urea + HDG	0.75#N/M+0.92#HDG/M	April, May, Sept., Oct.
Urea + HDG	0.5#N/M+0.92#HDG/M	April, May, Sept., Oct.
Urea	1#N/M	April, May, Sept., Oct.
Uflexx	1#N/M	April, May, Sept., Oct.
HDG	0.92#HDG/M	April, May, Sept., Oct.
Non-treated	-	-

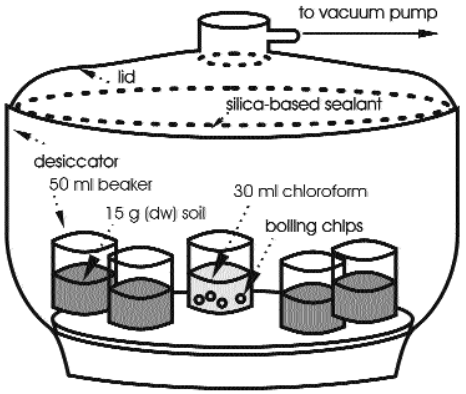
Data Collection

- Visual Quality
- Digital image analysis
  - Percent green cover
  - Dark green color index (DGCI)
- Soil water content (TDR)
- Soil compaction (Soil Penetrator)
- Clippings

Data Collection

- Soil test
  - Nutrient concentrations
  - pH
  - CEC
  - Organic matter
- Soil microbial biomass
- Potential mineralizable carbon
- Potential net N mineralization

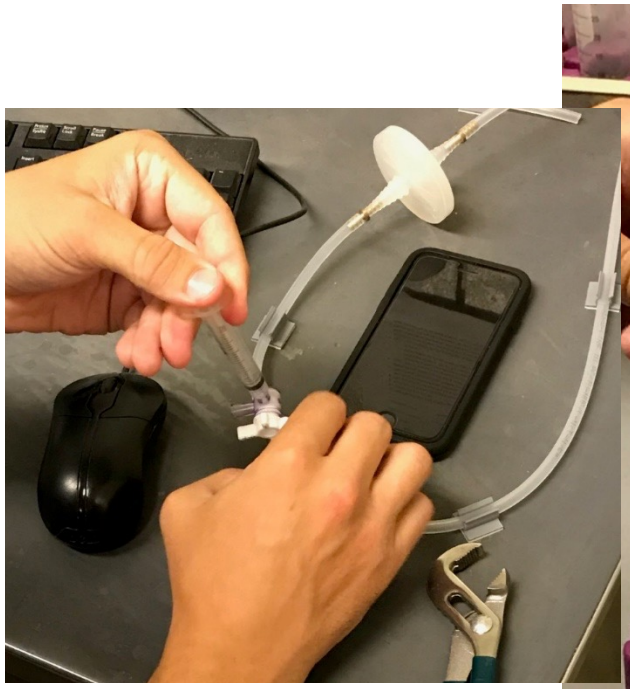
Soil Microbial Biomass



- Chloroform fumigation
  - Burst cell walls
- Soil extractions
  - Fumigated and non-fumigated
- Microbial biomass C & N
  - Fumigated – non-fumigated

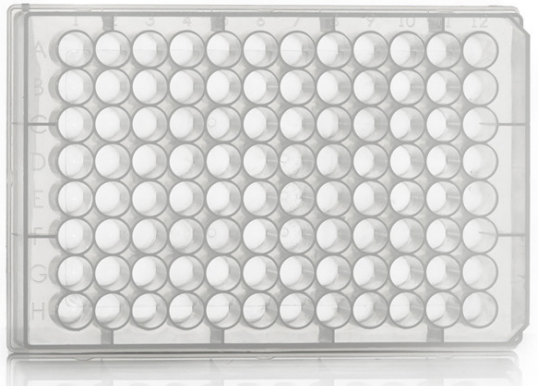
Potential Mineralizable Carbon

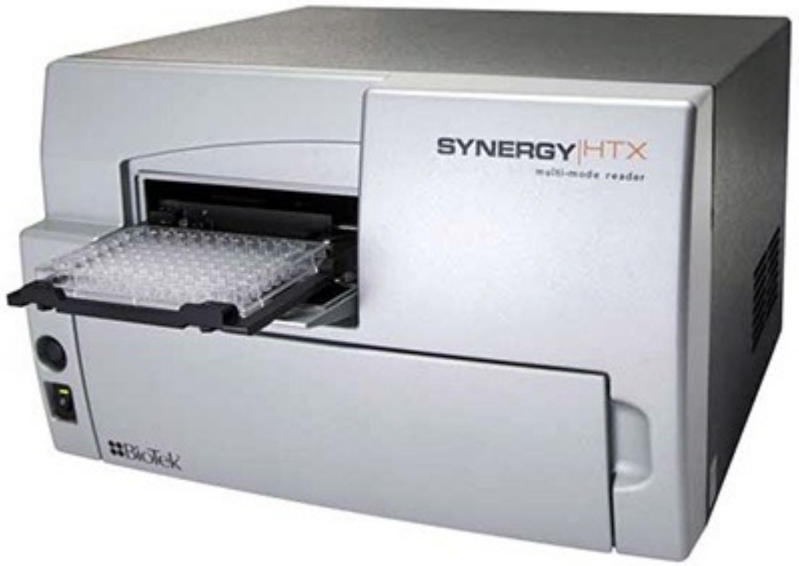
- 2 week soil incubation
- Measure CO_2
  - 1, 2, 3, 5, 7, 10, 14 days after start
- Indicator of soil biological activity



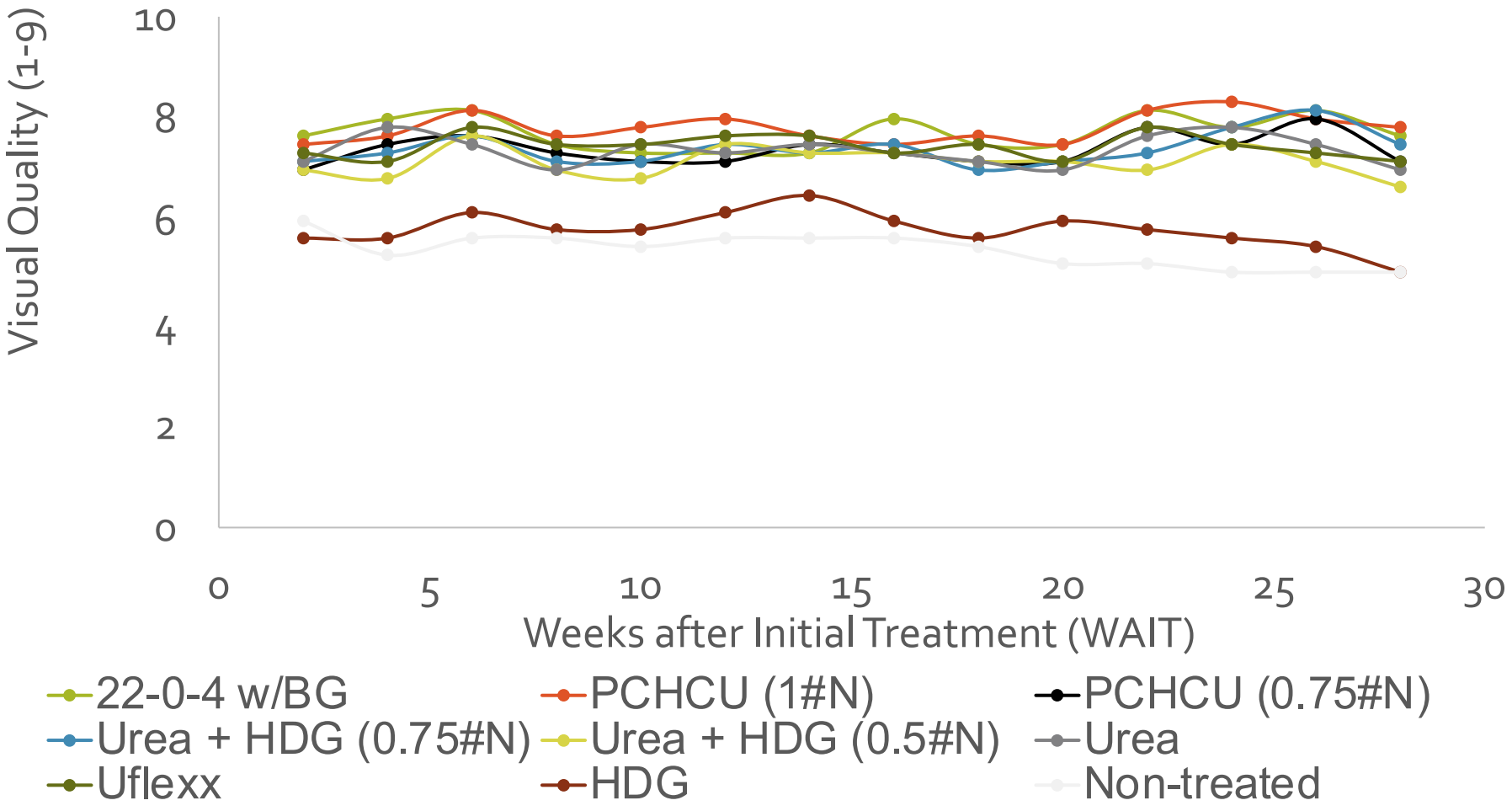
Potential Net N Mineralization

- 2 week soil incubation
- Soil extraction
  - Before and after incubation
- Measure NO_3 & NH_4 concentrations
- Net N mineralization
  - After incubation – before incubation

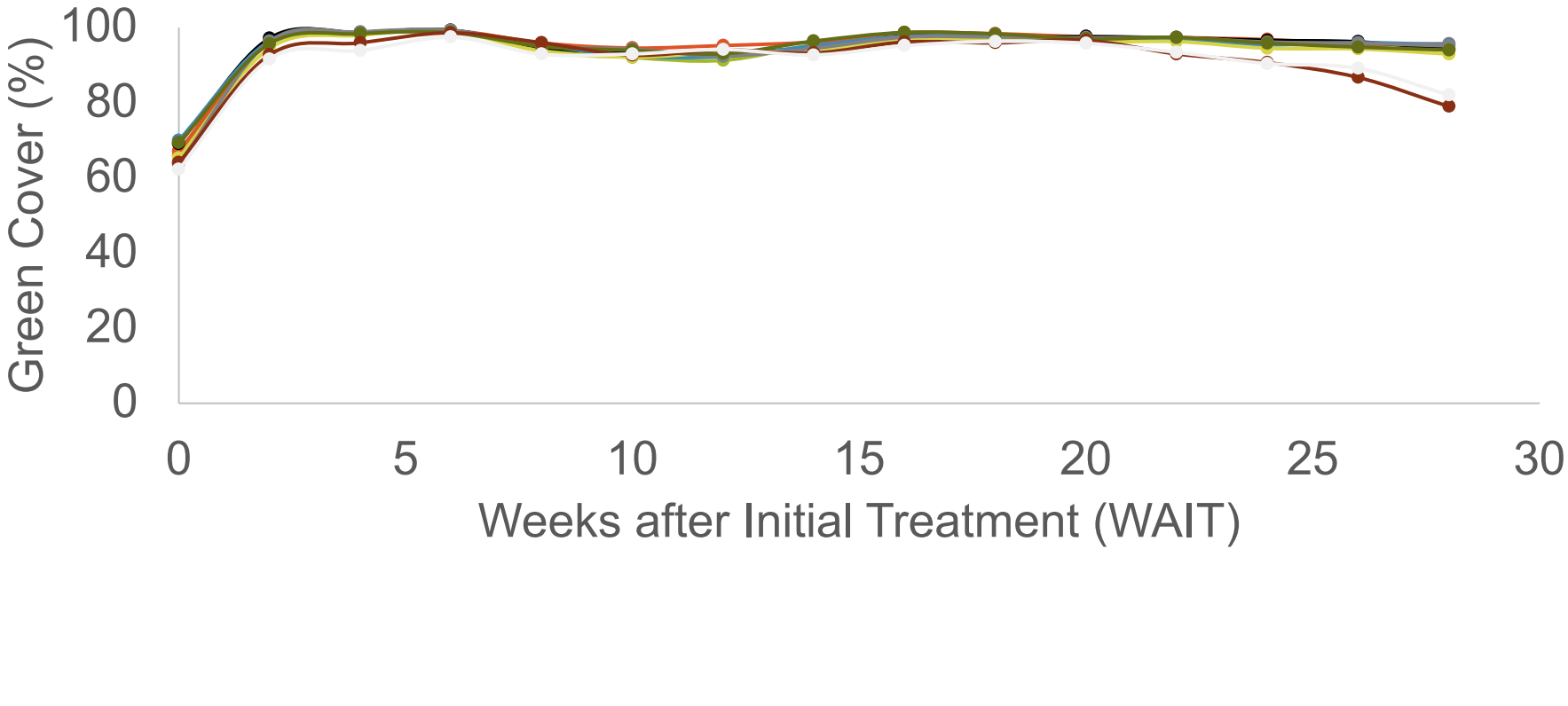




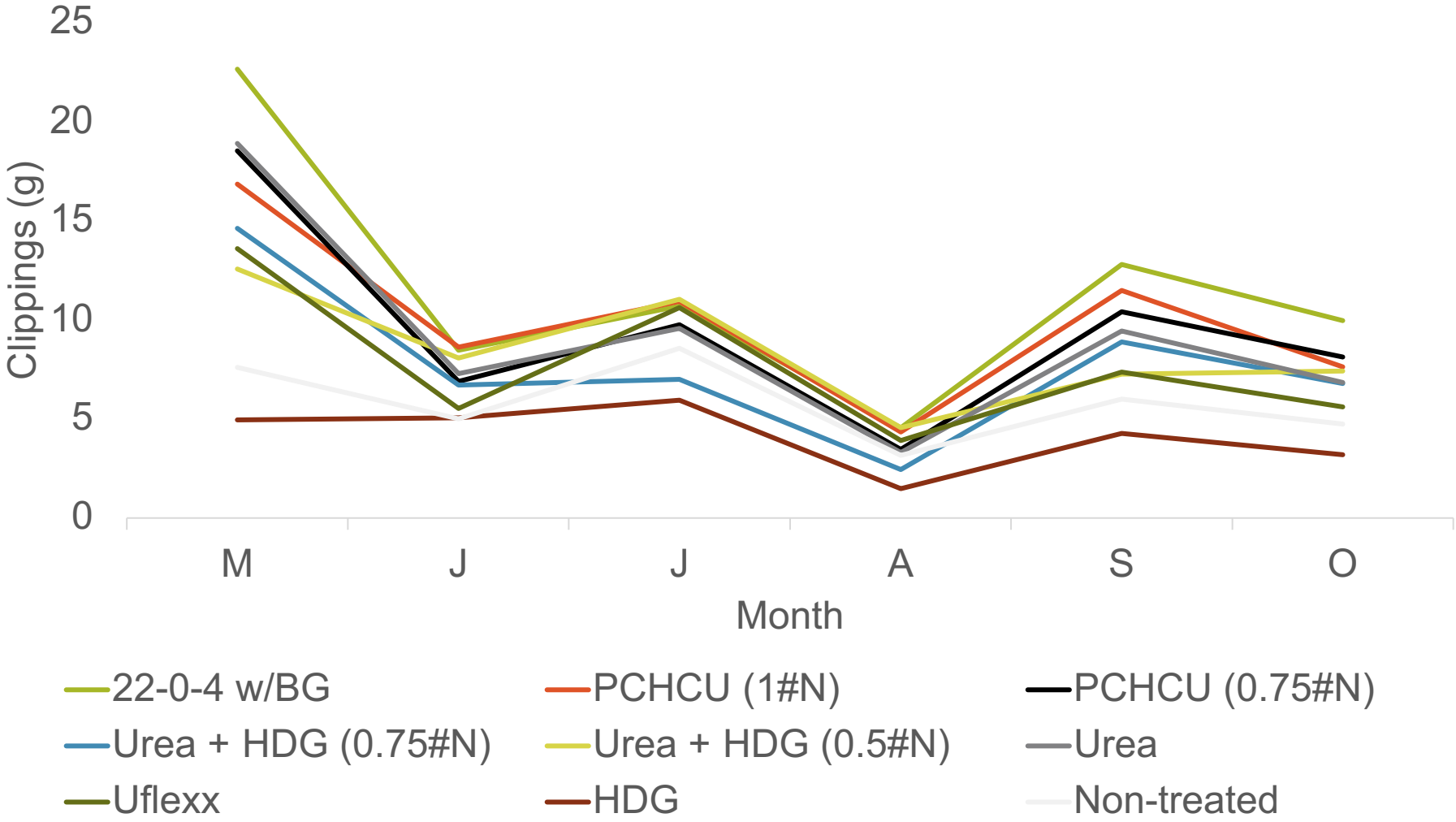
Visual Quality – Native Soil



Percent Green Cover – Native Soil



Clippings – Native Soil



Soil Test – Native Soil

Treatment	Sulfur Conc.	pH	CEC	Organic Matter
	mg kg^{-1}		$cmol_c\ kg^{-1}$	%
22-0-4 w/BG	7.5	6.9	16.8	4.5
PCHCU (1#N)	4.8	7.0	16.2	4.5
PCHCU (0.75#N)	4.8	7.0	16.1	4.6
Urea + HDG (0.75#N)	4.9	6.9	15.9	4.2
Urea + HDG (0.5#N)	4.9	7.0	16.0	4.3
Urea	4.8	6.9	16.7	4.3
Uflexx	4.7	7.1	16.3	4.3
HDG	5.0	7.0	16.4	4.3
Non-treated	5.0	7.0	15.9	4.3
$LSD_{0.05}$	0.8	NS	NS	NS

Microbial Biomass – Native Soil

Treatment	Application Rate	Microbial Biomass Carbon	Microbial Biomass Nitrogen
		mg kg^{-1}	mg kg^{-1}
22-0-4 w/BG	1#N/M	493.0	79.7
PCHCU	1#N/M	546.4	88.9
PCHCU	0.75#N/M	506.7	82.4
Urea + HDG	0.75#N + 0.92#HDG/M	481.3	98.2
Urea + HDG	0.5#N + 0.92#HDG/M	508.9	83.0
Urea	1#N/M	510.5	85.2
Uflexx	1#N/M	507.5	80.2
HDG	0.92#HDG/M	520.8	82.2
Non-treated	-	523.5	90.1
	$LSD_{0.05}$	61.7	NS

Potential C & N Mineralization – Native Soil

Treatment	Application Rate	Potential C Mineralization	Potential N Mineralization
		mg kg^{-1}	mg kg^{-1}
22-0-4 w/BG	1#N/M	416.0	13.2
PCHCU	1#N/M	394.0	14.0
PCHCU	0.75#N/M	324.4	12.4
Urea + HDG	0.75#N + 0.92#HDG/M	237.4	11.1
Urea + HDG	0.5#N + 0.92#HDG/M	243.0	10.9
Urea	1#N/M	304.2	13.3
Uflexx	1#N/M	388.4	14.0
HDG	0.92#HDG/M	315.4	11.8
Non-treated	-	234.9	8.8
	$LSD_{0.05}$	142.0	3.4

Conclusions – Native Soil

- PCHCU (0.75#N) and urea + HDG (0.75#N and 0.5#N) resulted in equivalent visual quality and green cover compared to full rates (1#N)
- Reduced rates had less clippings collected on average, but maintained acceptable quality
- 22-0-4 w/BG, PCHCU (1#N), and Uflexx increased soil biological activity (increased CO_2 production)
- 22-0-4 w/BG, PCHCU (1#N and 0.75#N), Uflexx and urea increased the N supply power of the soil

QUESTIONS?

athoms@iastate.edu

515-294-1957 office

@ThomsTurf