Perceived and Real Environmental Impacts of Phosphorus

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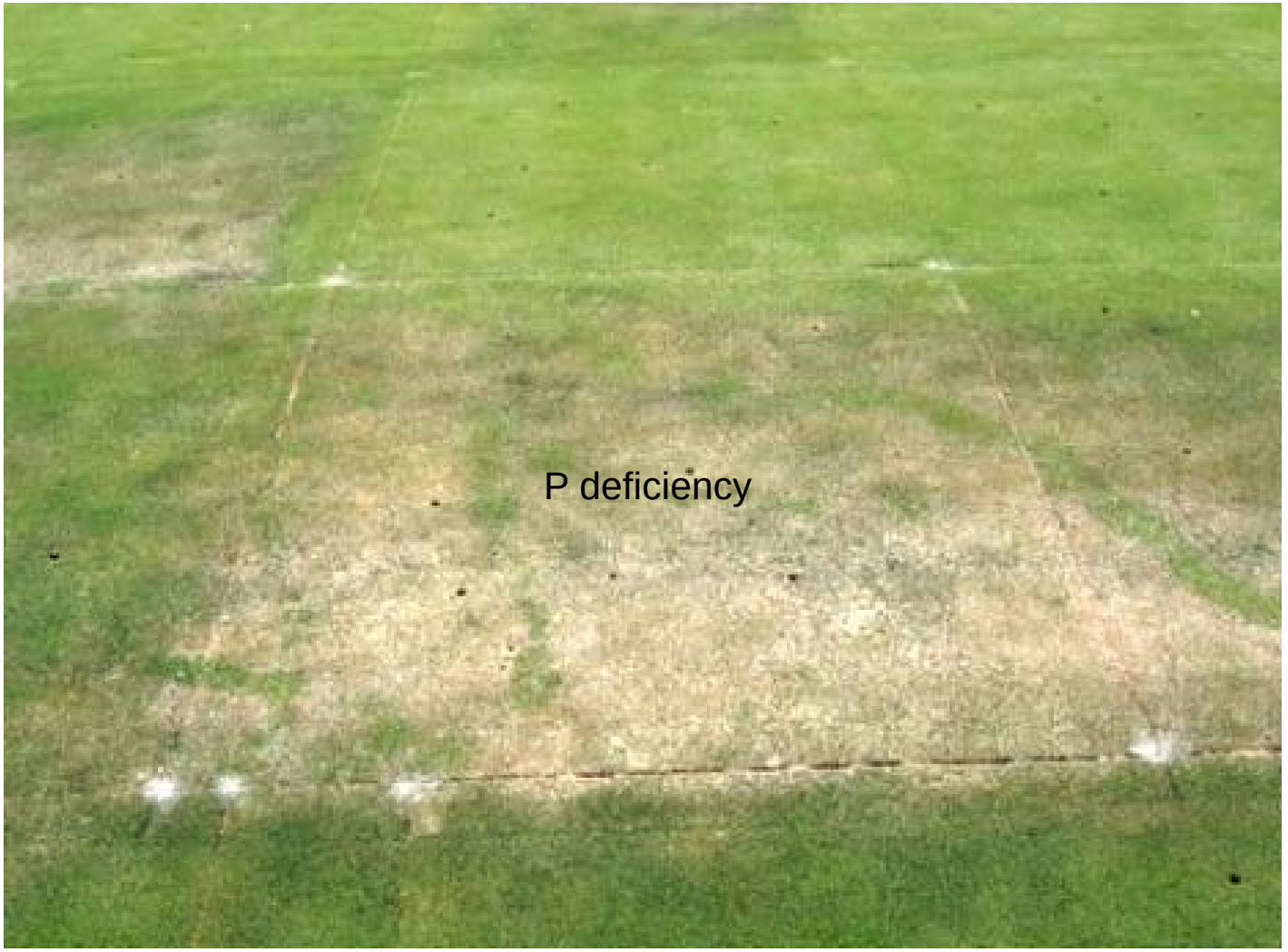
Phosphorus

- Macronutrient – along with N & P, typically applied in larger quantities than other nutrients
- Use a soil test to determine adequate levels in soil
- Percent in dry turfgrass leaf tissue - 0.25 - 0.60% (Mills and Jones, 1996)

Why you need P:

- ADP and ATP – energy transformations in plants.
- Essential part of DNA.
- Root development, especially lateral and fibrous roots.
- Crop maturity – flowering, fruiting, seed formation.
- Straw strength in cereal crops.



From D. Soldat, University of WI, creeping bentgrass

P deficiency - corn

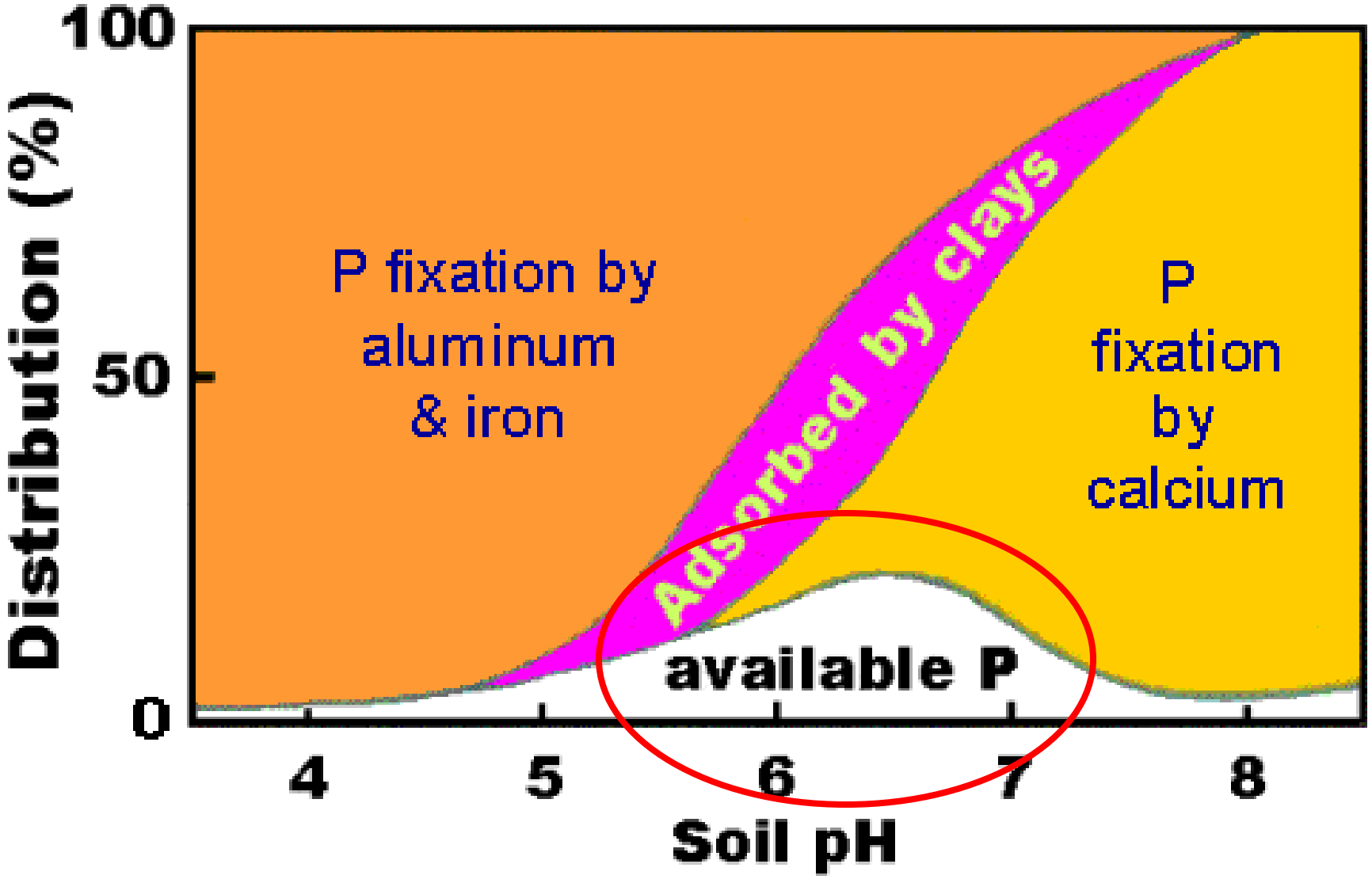
Where Do You Need P?
Phosphorus in the Soil

- total P in soil is low (~1/10th of N and 1/20th of K)
- most of the native P is not available to plants – insoluble
- over time, P added to soil (ex: fertilizer) is fixed, and becomes unavailable to plants
- environmental influences, such as grass species, soil type, rainfall, temperatures and use of the area all determine nutrient needs
- there is both organic and inorganic soil P

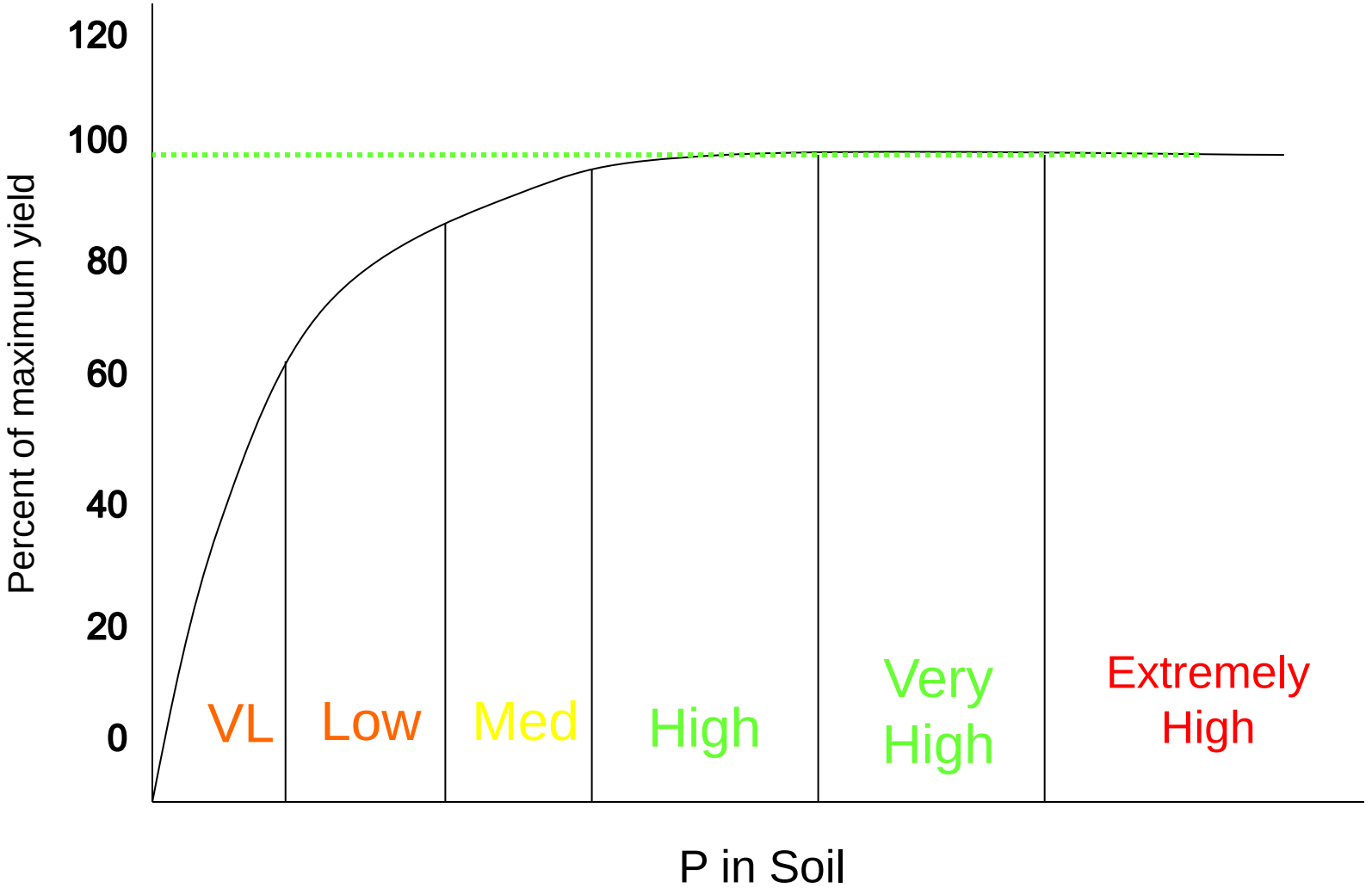
Inorganic P in the Soil

- Two big groups: 1) Calcium phosphates, and 2) Iron and Aluminum phosphates.
- The P that a turfgrass plant can use ($H_2PO_4^-$) is a very small portion of the total P.
- When fertilizer P is added, turfgrasses have an uptake efficiency of around 10 to 40%, with the remaining fertilizer P fixed into unavailable forms

Where Inorganic P is in the Soil…..

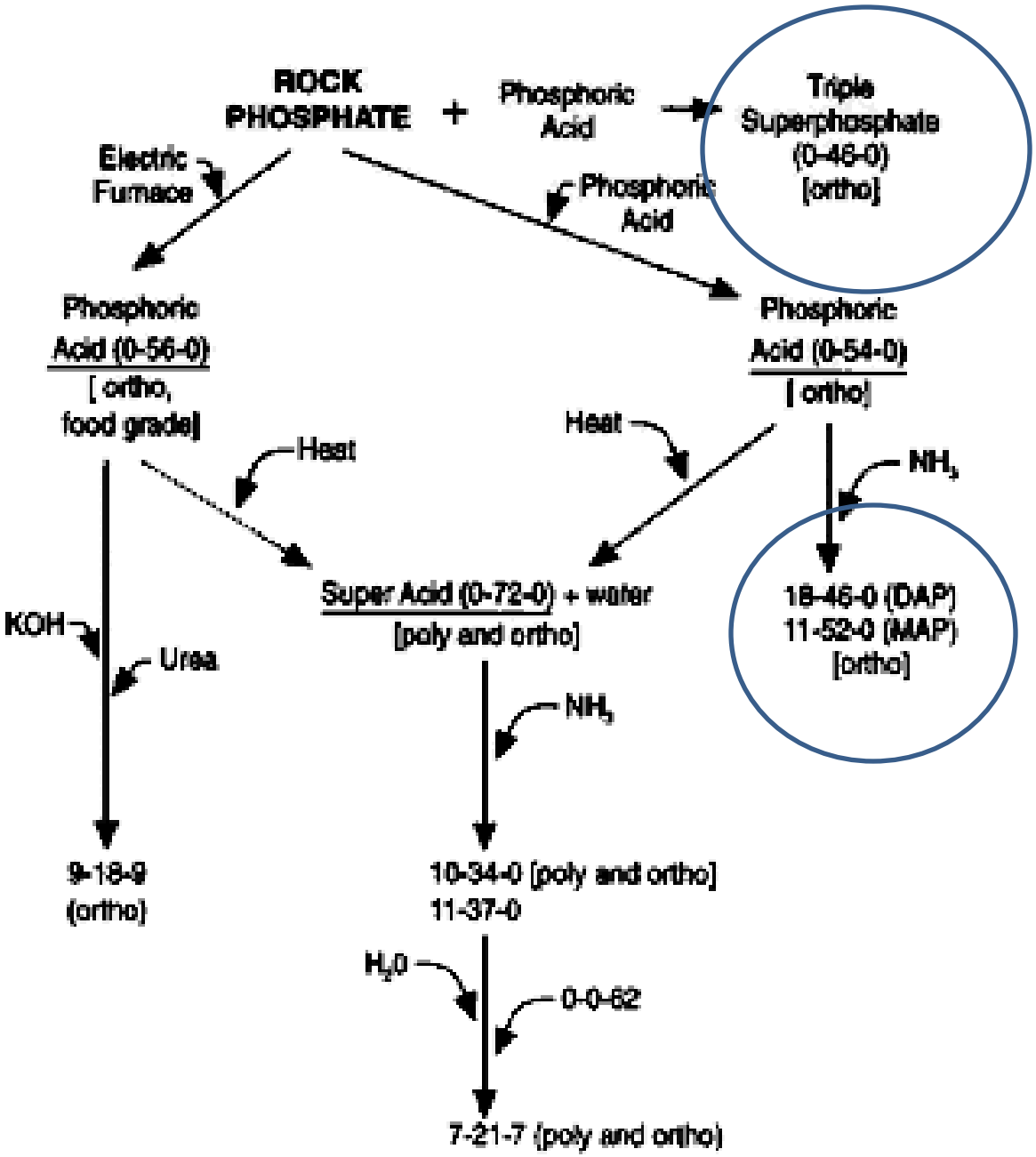


How that Affects P Fertilizer Recommendations…..



P Fertilizer Sources

- Triple super phosphate (TSP) – 0-44-0
- Diammonium phosphate
- Monoammonium phosphate
- Rock phosphate – not a soluble source of P


ROCK PHOSPHATE
+
Phosphoric Acid
Triple Superphosphate (0-46-0) [ortho]
Electric Furnace
Phosphoric Acid
Phosphoric Acid (0-56-0) [ortho, food grade]
Phosphoric Acid (0-54-0) [ortho]
Heat
Heat
NH3
KOH
Urea
Super Acid (0-72-0) + water [poly and ortho]
18-46-0 (DAP)
11-52-0 (MAP)
[ortho]
NH3
9-18-9 (ortho)
10-34-0 [poly and ortho]
11-37-0
H2O
0-0-62
7-21-7 (poly and ortho)

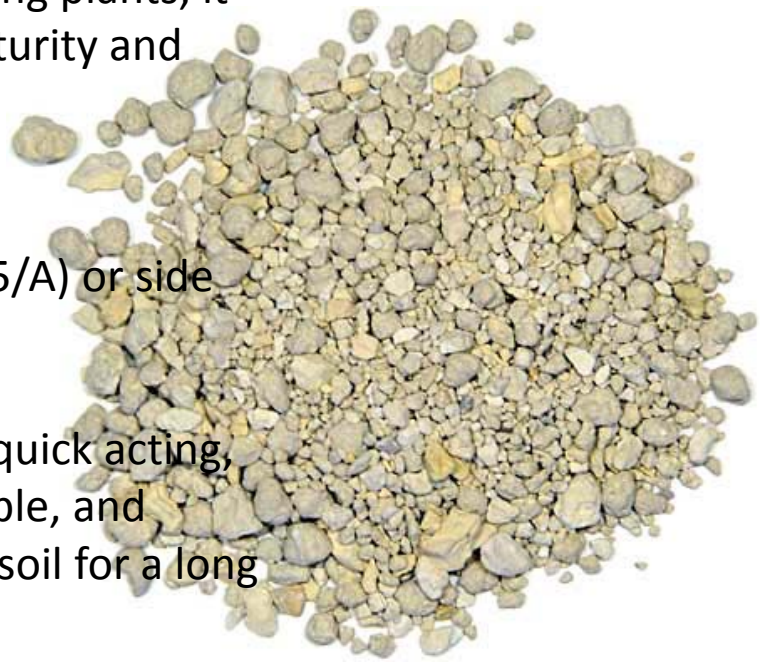
ROCK PHOSPHATE

Calphos™ is a natural, untreated Soft Rock Phosphate (0-3-0) with colloidal clay containing valuable trace minerals in addition to phosphorus. Since phosphorus is lacking in most soils, applications are a must for superior results. Contains a minimum of 3% available (and a minimum of 20% total) phosphoric acid (P_2O_5) and 20% Calcium (Ca). OMRI Listed for use in organic production.

Once applied, Calphos™ remains in the soil until used by the plants - will not leach. Ideal for fruiting and flowering plants, it stimulates strong root formation, hastens crop maturity and encourages earthworms and soil bacteria.

DIRECTIONS FOR USE:
Broadcast 50 lbs. per 1,000 square feet (65 lb P_2O_5/A) or side dress around existing plants.

Note: Because of its natural fineness, Calphos™ is quick acting, like superphosphate. Because it is relatively insoluble, and therefore not subject to leaching, it will last in the soil for a long time.



Example P Soil-Test Recommendations…..

LAB No.	SENDER'S SAMPLE DESIGNATION	CROP TO BE GROWN	SOIL* GROUP	SOIL TEST RESULTS					RECOMMENDATIONS			
				pH**	Phosphorus P***	Potassium K***	Magnesium Mg***	Calcium Ca***	LIME-STONE	N	P_2O_5	K_2O
					Pounds per acre				Tons/acre	Pounds per acre		
14208	NEW S 201 SEE COMMENT 59	GOLF GREEN	1	7.0	H 100	M 62	H 61	1010	0.0	400	0	130
14209	NEW S 202 SEE COMMENT 55	GOLF GREEN	1	6.9	VH 141	M 94	H 84	440	0.0	400	0	80
14210	NEW S 203 SEE COMMENT 62	GOLF GREEN	1	6.1	M 27	M 70	H 59	580	0.0	400	130	110
14211	NEW S 301 SEE COMMENT 62	GOLF GREEN	1	6.2	M 32	M 97	H 56	620	0.0	400	120	80
14212	NEW S 302 SEE COMMENT 55	GOLF GREEN	1	6.7	VH 157	M 116	H 123	480	0.0	400	0	50
14213	NEW S 303 SEE COMMENT 55	GOLF GREEN	1	6.7	VH 115	M 81	H 83	640	0.0	400	0	100
14214	NEW S 401 SEE COMMENT 56	GOLF GREEN	1	6.9	VH 105	L 57	H 87	740	0.0	400	0	130
14215	NEW S 402	GOLF GREEN	1	6.4	L 19	M 71	H 57	560	0.0	400	150	110

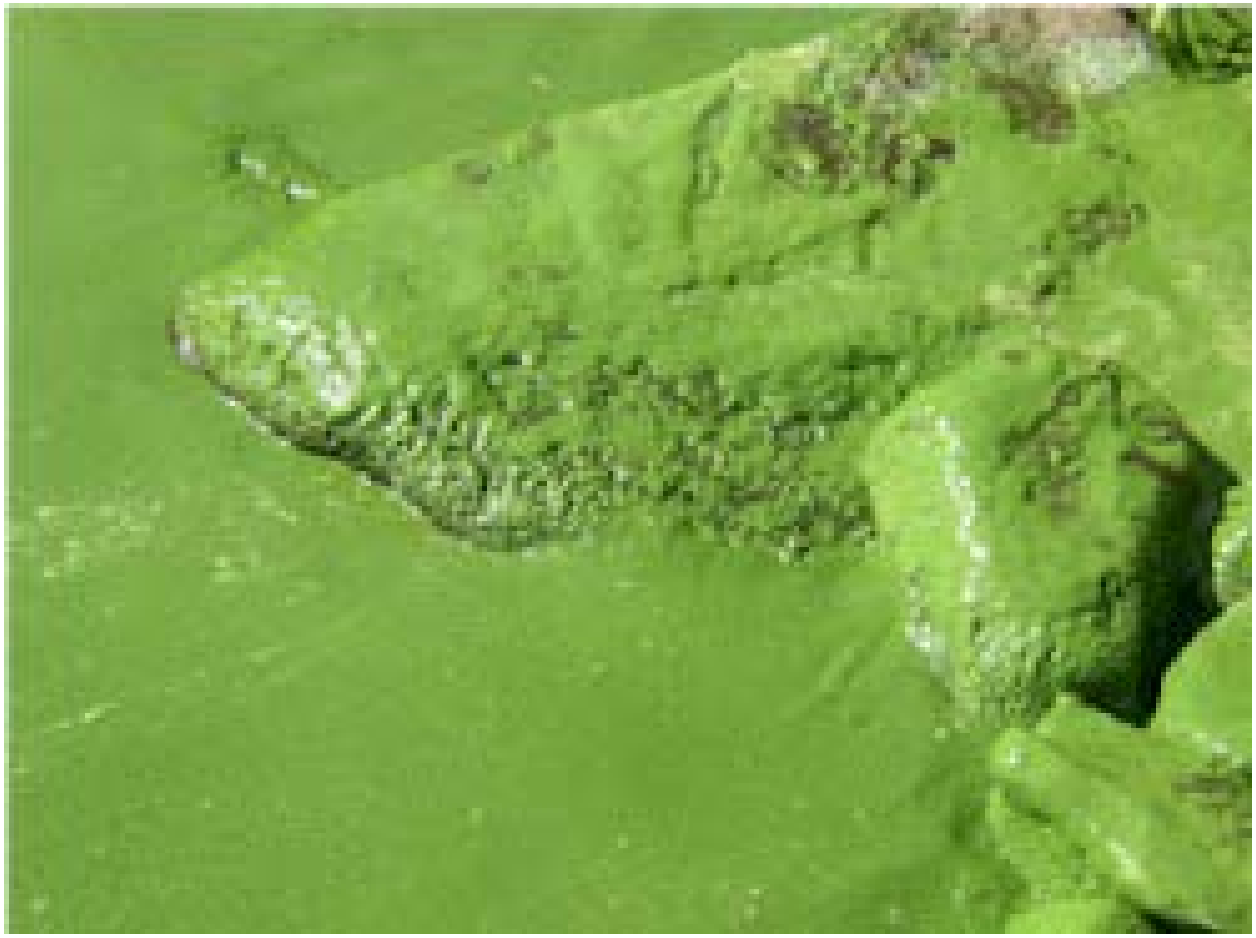
1. Sandy soils (CEC < 4.6 $cmol_c kg^{-1}$)
2. Loams & Light clays (CEC = 4.6-9.0 $cmol_c kg^{-1}$)
3. Clays and soils high in organic matter(CEC > 9.0 $cmol_c kg^{-1}$)
4. Clays of the Blackbelt(CEC > 9.0 $cmol_c kg^{-1}$)

* 7.4 or higher - Alkaline 6.6-7.3 - Neutral 6.5 or lower - Acid 5.5 or lower - Strongly Acid

** Extractable nutrients in pounds per acre

What happens when your soil-test P gets too high?

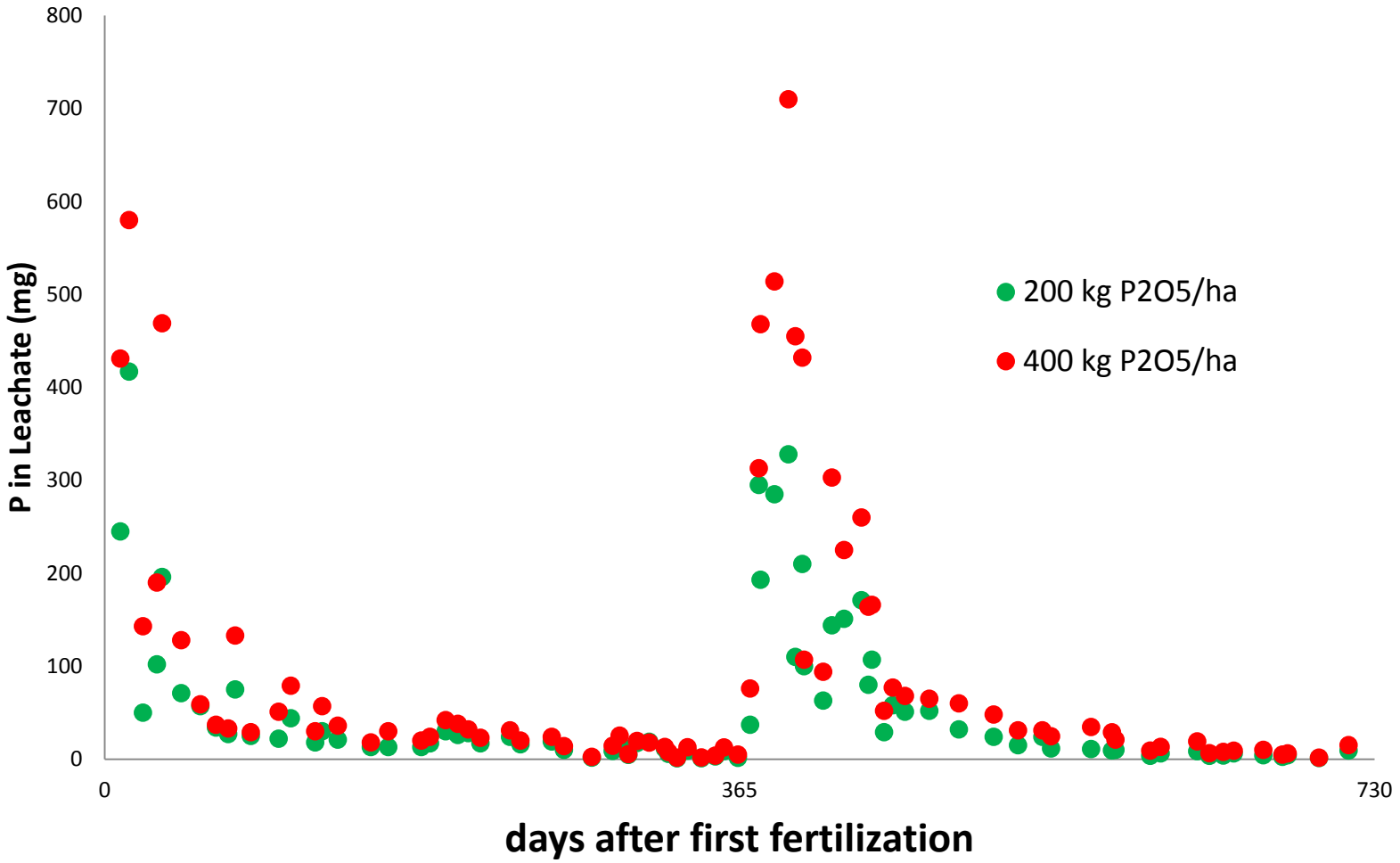
Loss of P in Runoff……



Forms of P in Water – Boring, but it matters

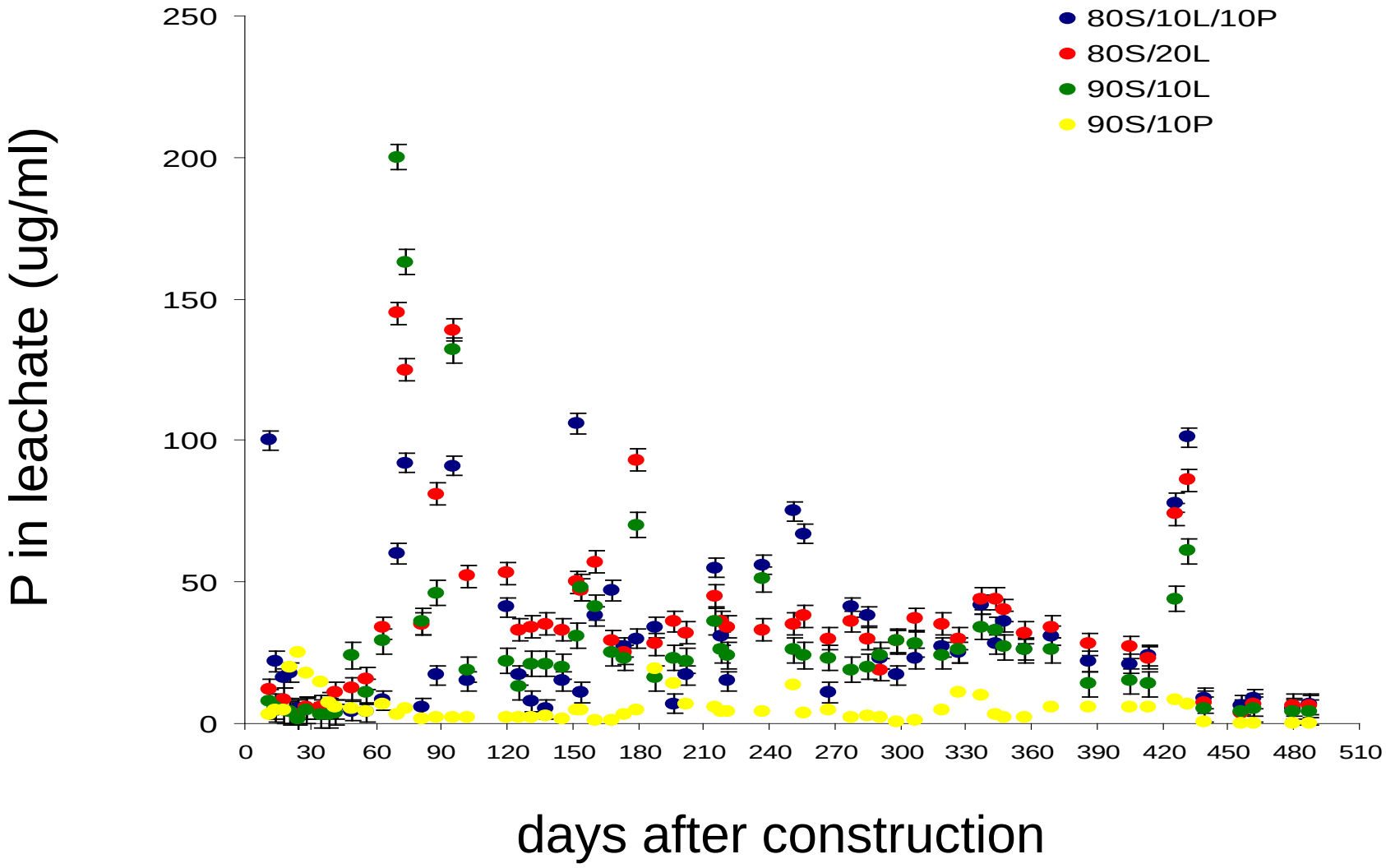
- Soluble P – P dissolved in water, typically a filtered sample.
- Total P – P in water plus that attached to sediment (runoff not filtered).
- Orthophosphate – soluble P (may also be called dissolved or reactive P)
- Bioavailable P - dissolved and particulate P
- EPA water quality threshold is 0.1 mg L^{-1}.

Phosphorus in Leachate as Affected by P Rate



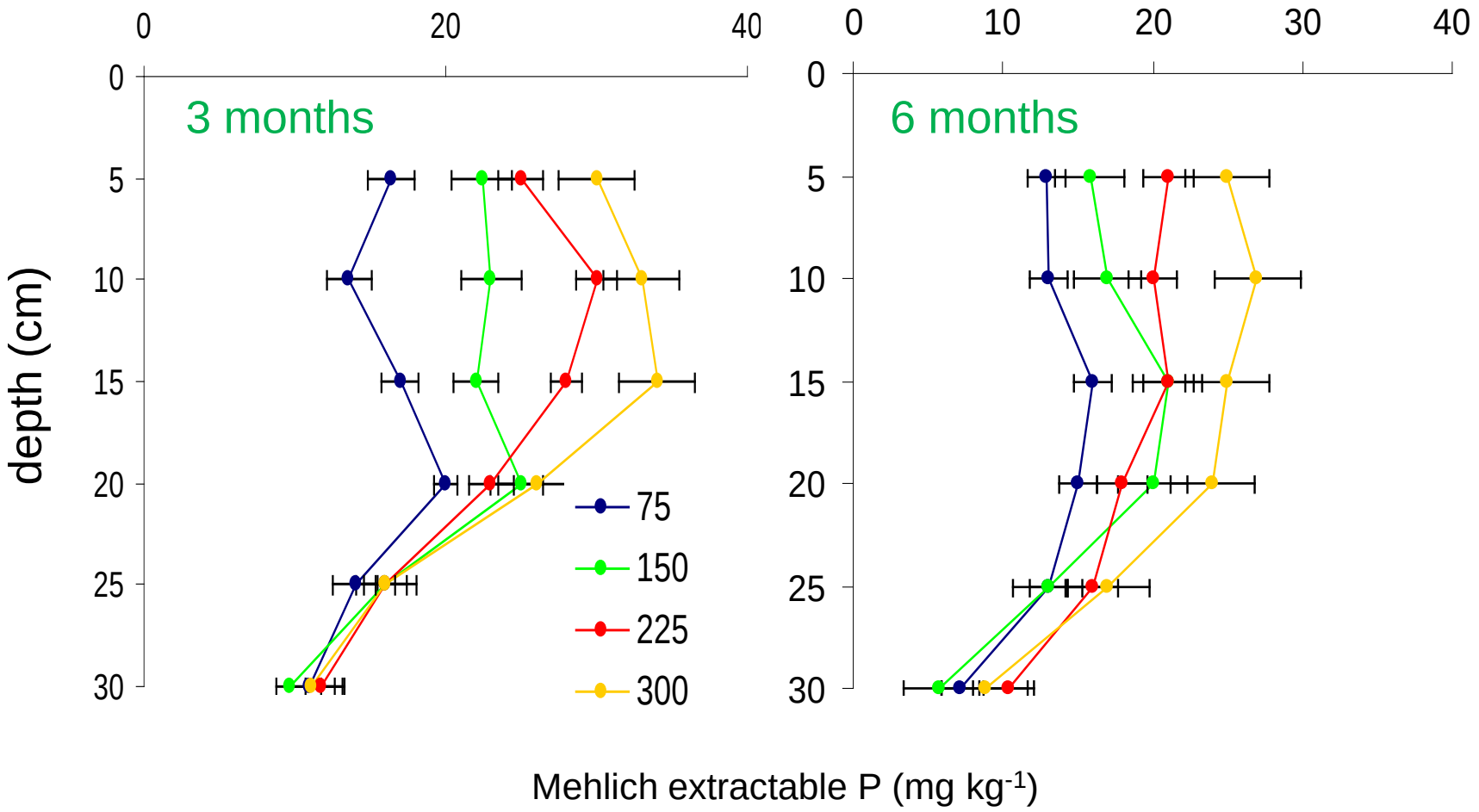
What happens when your soil-test P gets too high?

Loss of P as leachate in very sandy soils…



Fertilizer Evaluation

Soil-test P in sand-based putting greens, AU Club



Shapiro et al., 1974

- Study conducted on health of lakes in TCMA
- Street sweeping reduces P concentration in runoff

Time of Year	Storm Drain TP Conc
Feb. to mid-June	0.587 mg/L
Mid-June to mid-Oct.	0.256 mg/L
Oct. after leaf fall	1.095 mg/L

Barten and Jahnke, 1997

- Concluded phosphorus runoff to surface water bodies was from applied P fertilizer
  - Not from landscape vegetation
- Sampled from May to October
  - 70-90% of annual runoff occurs from Dec-March
- Did not measure runoff water volumes
  - Assumed 10% volume of runoff
  - Assumed all lawns have same runoff volume
- Other research: mean annual runoff ~ 1.1%

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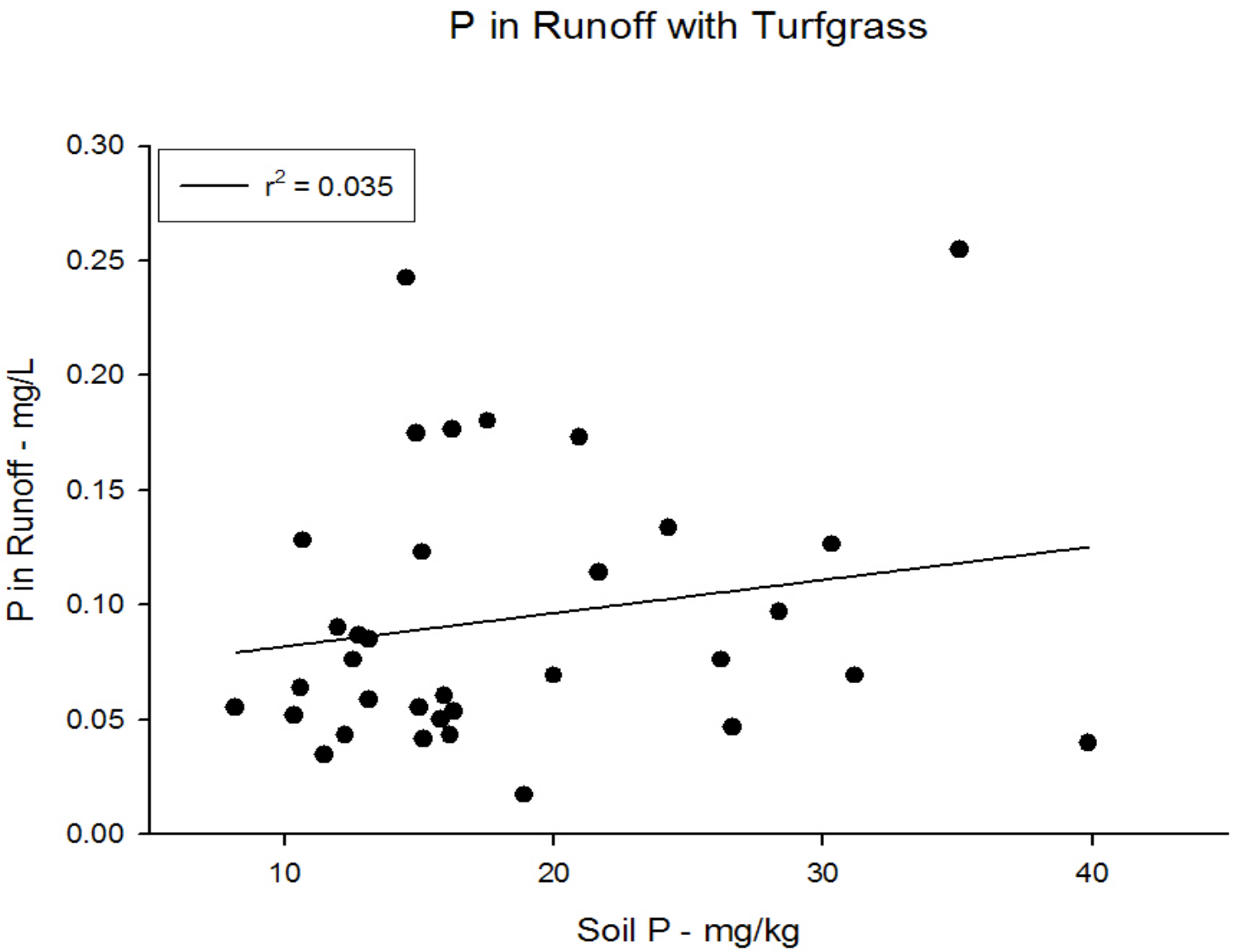
Kussow, 2001

- Annual losses of P in runoff water was 0.26 lb/A
  - 81% of P collected was in runoff when soil was frozen (0.05 lb/A during growing season)
- Small but consistent release of P into urban surface water from vegetation regardless of whether fertilizer is applied
  - Agrees with Shuman et al, 1994
- Healthy turf reduces water runoff volume and particulate P bound to soil

Soil P level and P runoff with turf (sandy loam, 4 yr old turf- Kbg /p. ryegrass , Soldat PhD Thesis, 2007)



Phosphorus Runoff and Landscape use: Agriculture

Land Use	Soluble P	Particulate P
	--------- lb. P/A/year --------	
Fallow	0.10	33.2
Conven. Corn	0.27	13.5
No-till Corn	0.98	1.9
Hay	0.39	0.02

Sources: Sharpley and Menzel, 1987; Rehm, et al., 1997.

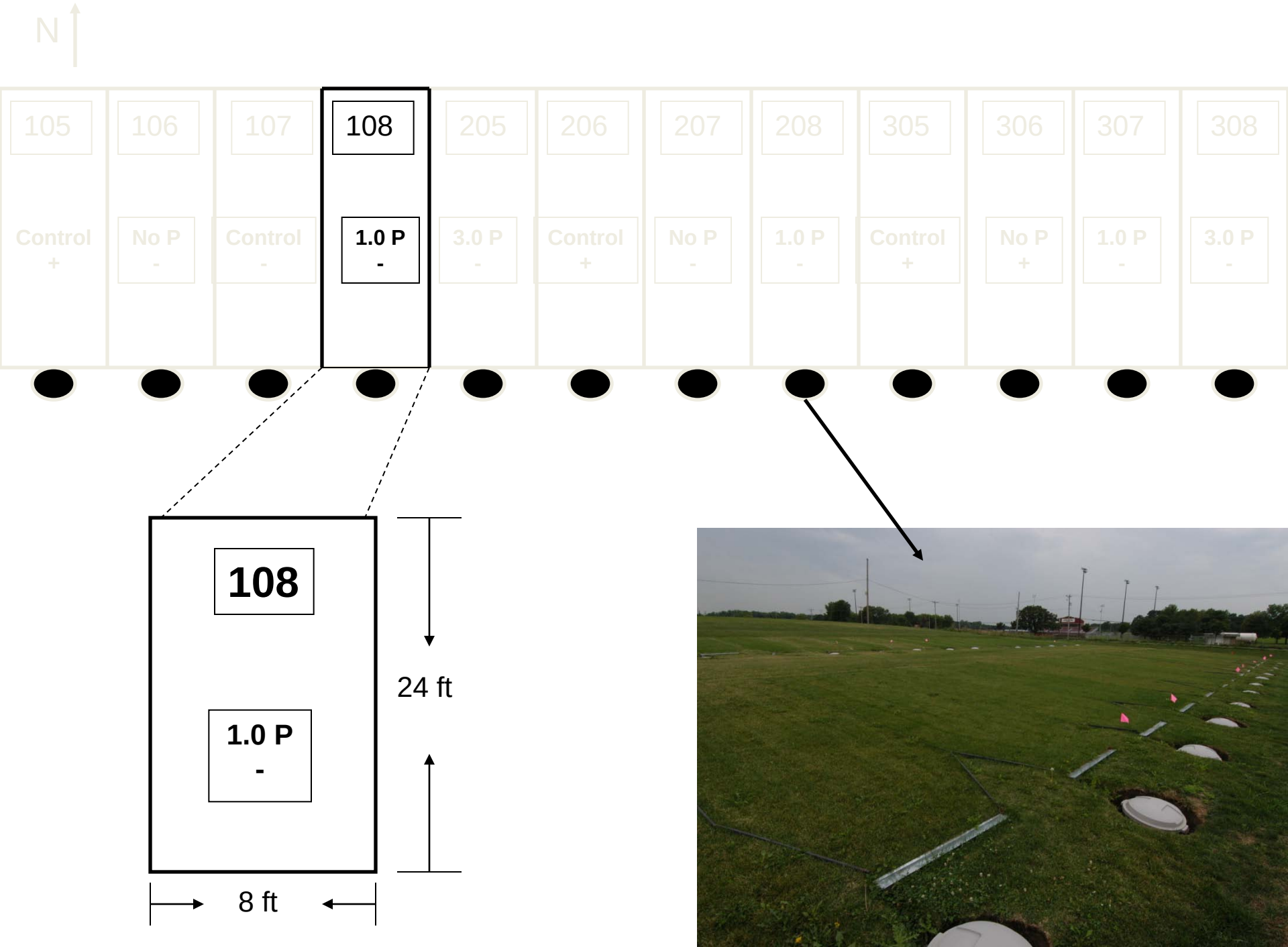
MN RESEARCH OBJECTIVES

- Evaluate the effect of grass clipping management and fertilizer inputs on P runoff from homelawns
- Improve the current understanding of chemical transport with runoff from fairway turf
- Evaluate the ability of management practices to mitigate chemical transport with rainfall runoff
- Quantify the transport of snow-mold fungicides and late-fall fertilizer with rainfall and snowmelt runoff

Turf Plots: Home Lawn

- Constructed and maintained as a home lawn
  - Compacted the soil, installed and irrigation system, sod
- Plot size: 8 ft wide x 24 ft long, 5 % slope (1% within field site)
- Turfgrass species: Kentucky bluegrass
- Managed at various levels of homelawns

  (3 in height of cut)


N
105
106
107
108
205
206
207
208
305
306
307
308
Control
+
No P
-
Control
-
1.0 P
-
3.0 P
-
Control
+
No P
-
1.0 P
-
Control
+
No P
+
1.0 P
-
3.0 P
-
108
1.0 P
-
24 ft
8 ft

N

105	106	107	108	205	206	207	208	305	306	307	308
Control +	No P -	Control -	1.0 P -	3.0 P -	Control +	No P -	1.0 P -	Control +	No P +	1.0 P -	3.0 P -

Turf Plots: Home Lawn

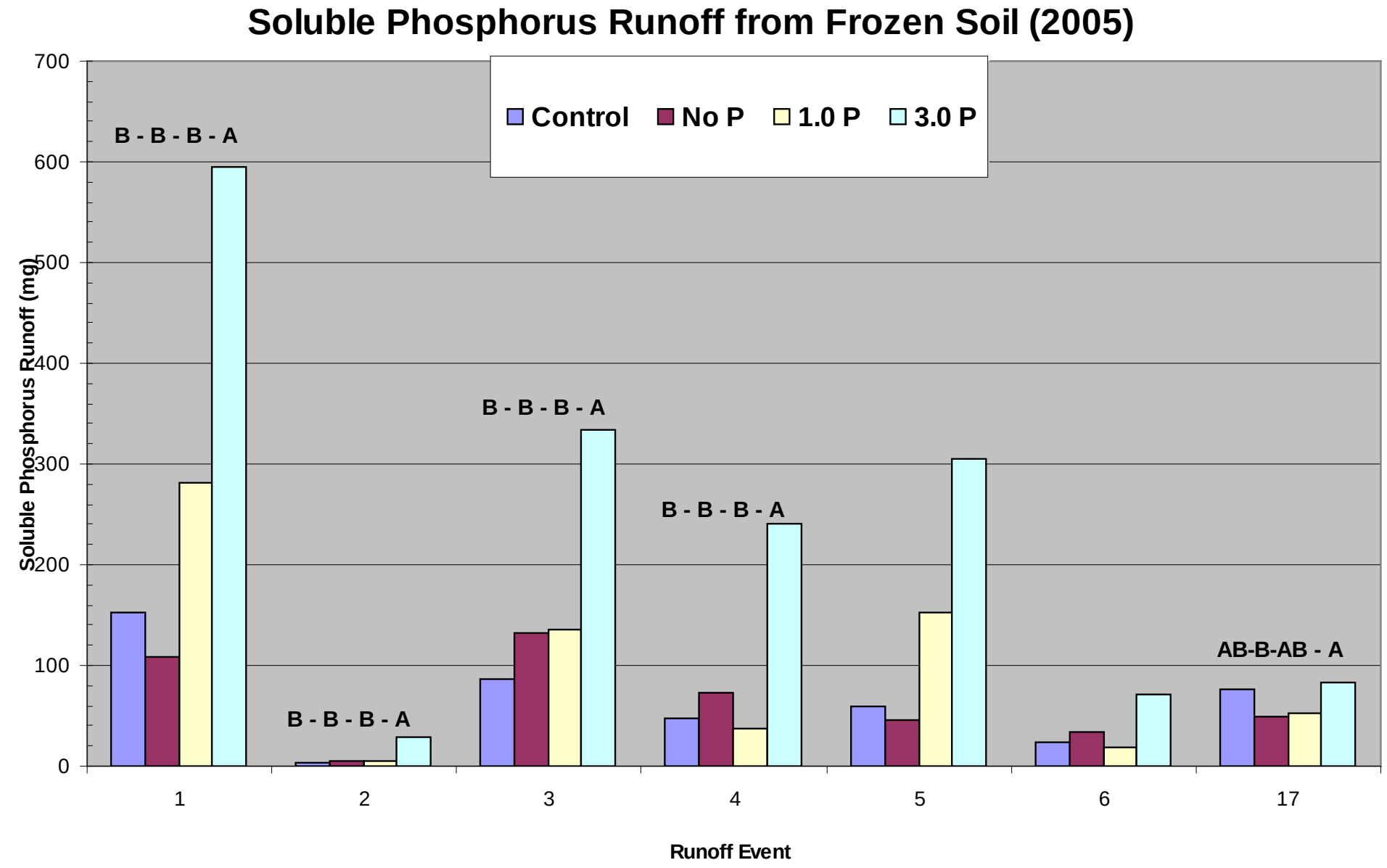
2005

1. no fertilizer
2. no phosphorus (N and K)
3. complete (1 lb P_2O_5)
4. complete (3 lbs P_2O_5)

2006 - 2009

1. no fertilizer
2. no phosphorus (N and K)
3. complete (0.33 lb P_2O_5)
4. complete (1 lb P_2O_5)

Runoff Results


Soluble Phosphorus Runoff from Frozen Soil (2005)
Control
No P
1.0 P
3.0 P
B - B - B - A
B - B - B - A
B - B - B - A
B - B - B - A
AB-B-AB - A
Soluble Phosphorus Runoff (mg)
0
100
200
300
400
500
600
700
1
2
3
4
5
6
17
Runoff Event

P runoff: 5 yrs of data

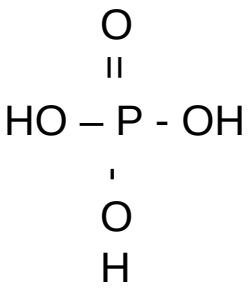
- [TP] and [RP] in runoff, soil test P and tissue [P] increased linearly with increasing P fertilizer application rate
- 86% of P runoff when soil was frozen
- 78% of runoff depth when soil frozen
- ~72% of runoff P was RP
- TP runoff ranged from 0.002 to 0.03 lbs per 1000 ft^2
- P runoff can be reduced without affecting turf quality by not applying P fertilizer when soil test P levels are high
- Properly fertilized turf can reduce P runoff

Runoff of P – Some Conclusions

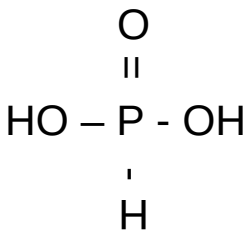
- Bare soil/thin turf – prone for greater loss via P-sediment erosion.
- Greater P losses if irrigation/rainfall follows immediately after application.
- Majority of P in runoff occurred in snowmelt.
- Inclusion of buffer strips significantly reduces P in runoff.

Phosphites?

Phosphate



Phosphite



- Phosphite has one less O than phosphate.
- It is more soluble than phosphate, making leaf and root uptake more efficient.
- Phosphite is slowly converted to phosphate (3 to 4 months) (soil or foliage applied).
- Phosphite has proven fungicidal properties, breaks down very slowly in soil to plant available forms of P.
- Thus, cannot replace P fertilizers (phosphate).

Phosphite as a Fungicide

- Annual crops – initially is a poor source of P for short cycle crops.
- However, when crops are planted into previously phosphite fertilized soil do as well as those in phosphate-fertilized soil.
- Phosphite inhibits *Phytophthora* and *Pythium* (Aliette (Fosetyl-Al)).
- Since trademark patent expired many phosphite products have entered the market, with many advertised and registered as fertilizers.
- Many are some type of potassium phosphite.
- Growing evidence that foliar application (fruit crops, nut crops) has positive benefits beyond that of a fungicide.

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Nitrogen Fertilizers – sorting them out

- Soluble, Quick-release fertilizers
- Slow-release or Controlled release fertilizers
  - Synthetic
  - Natural organic

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Nitrogen Fertilizers – sorting them out

Soluble, quick – release fertilizers

- » Examples: urea, ammonium sulfate

  Ammonium nitrate (also calcium or potassium nitrate)
- » Inexpensive
- » Rapid plant response
- » Short-lived

Ammonium sulfate 2 weeks after application

Flush of growth – collect clippings

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Nitrogen Fertilizers – sorting them out

Slow release or controlled release fertilizers

- More expensive
- Slower initial response
  - Limit flush of growth
- Greater longevity
- Reduced potential for loss (leaching, runoff, volatilization, denitrification

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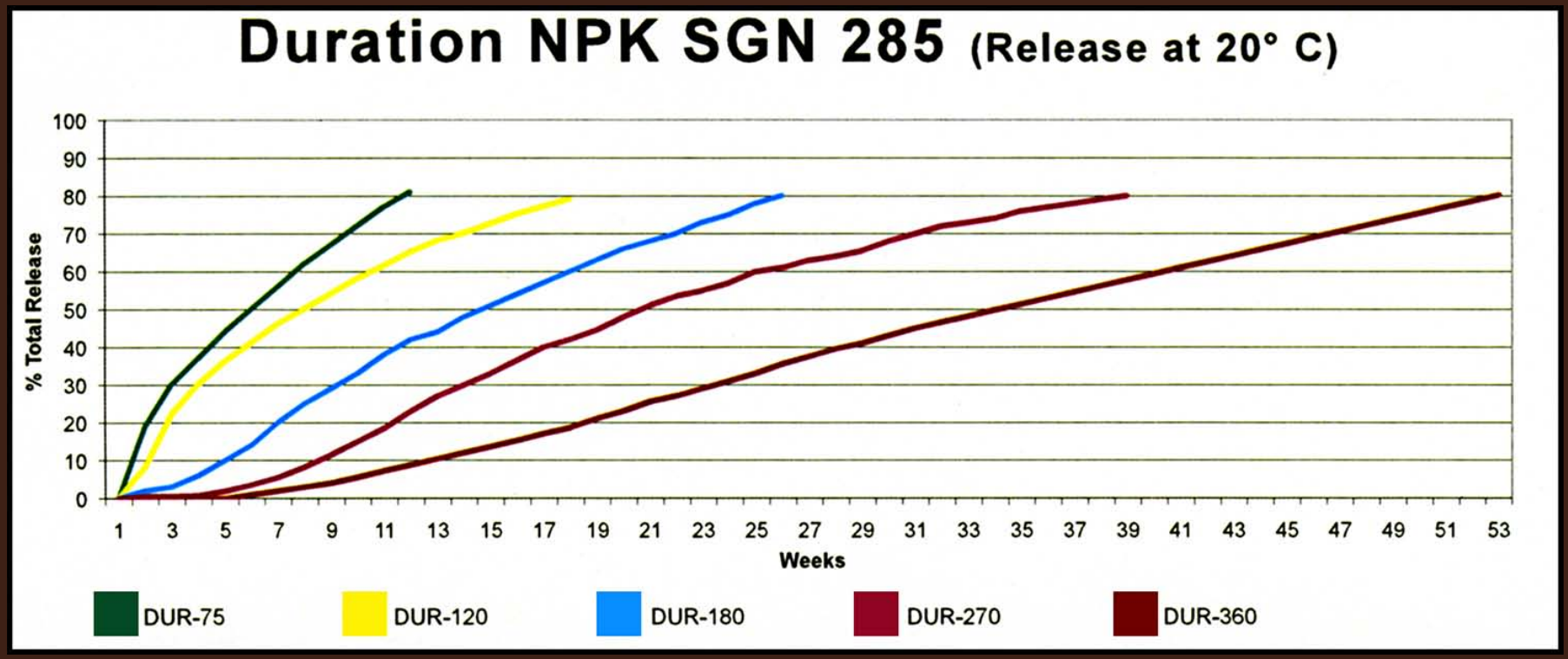
Nitrogen Fertilizers – sorting them out

- Slow-Release - Synthetic fertilizers
  - » Release based on soil moisture
    - Sulfur coated urea (SCU)
    - Polymer coated sulfur coated urea (PCSCU)
      - Poly-S, TriKote, XCU, PolyPlus
    - Polymer coated urea (PCU)
      - PolyOn, Duration, Apex (nursery & Ghouse), ESN (crops)
    - IBDU (isobutylidene diurea)

PCU longevity of release



Source: Agrium AT

Nitrogen Fertilizers – sorting them out

- Slow Release - Natural Organic Fertilizers
  - » Release based on soil temperature
    - Feather meal, blood meal, poultry waste, poultry manure, fish meal, soybean meal, biosolids, bone meal
    - Not all constituents are organic – nitrate of soda, potassium sulfate
  - » Relatively high in P (narrow N:P ratio)

Nitrogen Fertilizers – sorting them out

- Slow Release - Natural Organic Fertilizers
  - » May enhance soil microbial community
  - » N release may be less than from synthetic fertilizers
    - Recalcitrant substrates
    - Compensate?

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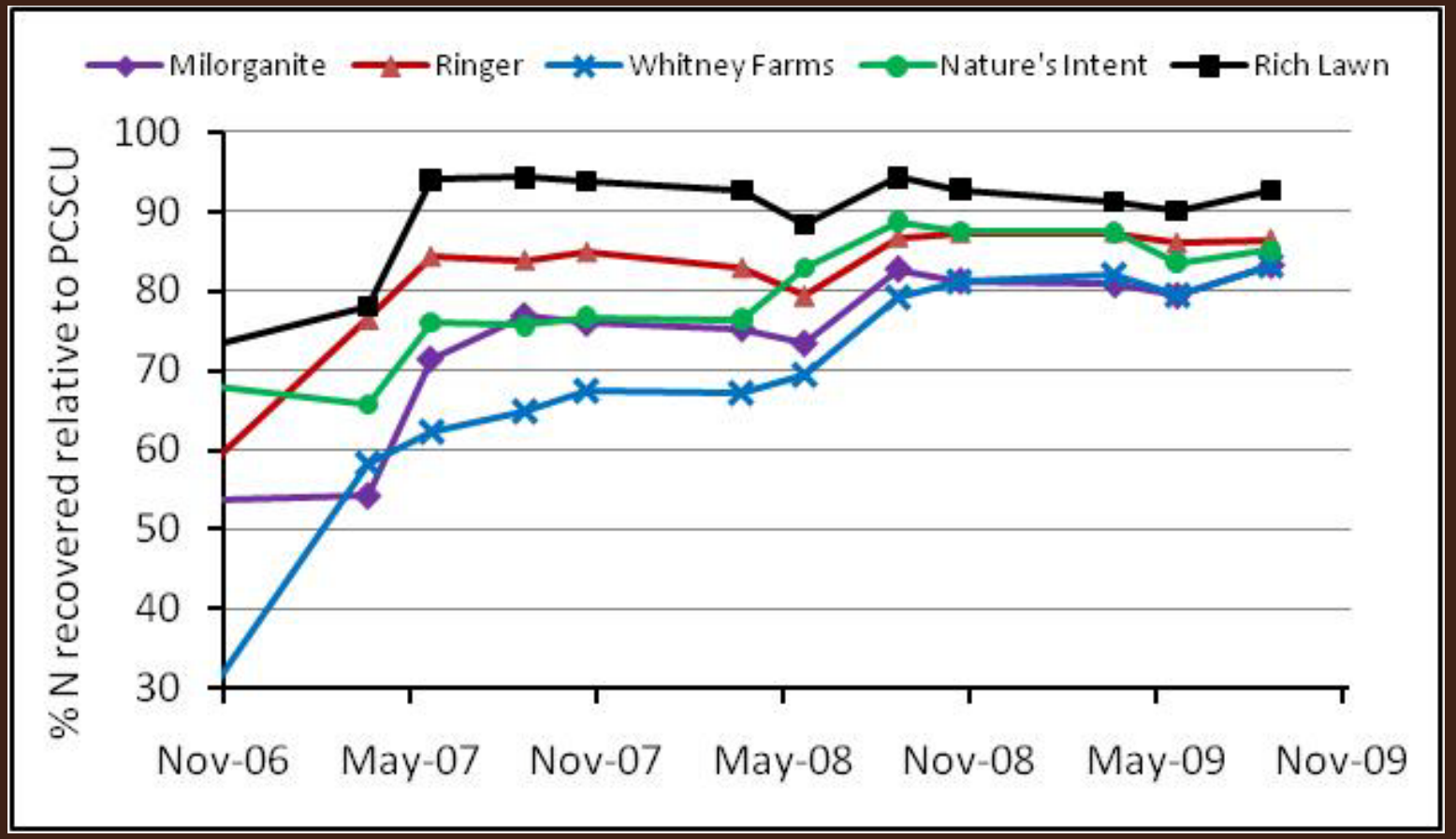
N Uptake from Natural Organics



4 lbs N / 1000 sq ft / yr for 3 yrs

Lower potential for leaching, runoff

Table 1. Sources and amounts of N applied and the amounts of NO_3^-, NH_4^+, and total N lost from the greens expressed as a percentage of the applied N.

Mix and forms of N lost	N Source, application rate (kg ha^{-1}) and dates of application				
	NH_4NO_3 163 2-16-73	Ureaformaldehyde 244 6-6-73	12-12-12 146 7-26-73	Milorganite 146 10-17-73	IBDU 146 6-20-74
	% applied N				
Sand (90-0-10)					
NO_3^-	21.9 a†	0.2 b	9.5 b	7.7 b	0.9 b
NH_4^+	0.8 c	1.3 b	0.8 c	2.0 a	0.6 c
Total	22.7 a	1.5 b	10.3 b	9.7 b	1.4 b
Mixtures					
85-5-10					
80-10-10					
NO_3^-	21.7 a	0.3 c	8.7 b	2.4 c	0.7 c
NH_4^+	1.3 a	1.3 a	0.6 b	1.3 a	0.3 c
Total	23.0 a	1.6 c	9.3 b	2.8 c	1.0 c
Soil 0-100-0					
NO_3^-	8.6 a	0.1 b	0.6 b	0.5 b	0.1 b
NH_4^+	1.2 a	0.9 a	0.2 a	1.2 a	0.1 a
Total	9.8 a	1.0 b	0.8 b	1.7 b	0.2 b

† Values in a given row followed by similar letters do not differ at the 5% level of significance.

Brown et al., 1982

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NO_3^-	21.9 a†	0.2 b	9.5 b	7.7 b	0.9 b
NH_4^+	0.8 c	1.3 b	0.8 c	2.0 a	0.6 c
Total	22.7 a	1.5 b	10.3 b	9.7 b	1.4 b
Mixtures 85-5-10 80-10-10					
NO_3^-	21.7 a	0.3 c	8.7 b	2.4 c	0.7 c
NH_4^+	1.3 a	1.3 a	0.6 b	1.3 a	0.3 c
Total	23.0 a	1.6 c	9.3 b	2.8 c	1.0 c
Soil 0-100-0					
NO_3^-	8.6 a	0.1 b	0.6 b	0.5 b	0.1 b
NH_4^+	1.2 a	0.9 a	0.2 a	1.2 a	0.1 a
Total	9.8 a	1.0 b	0.8 b	1.7 b	0.2 b

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Brown et al., 1982

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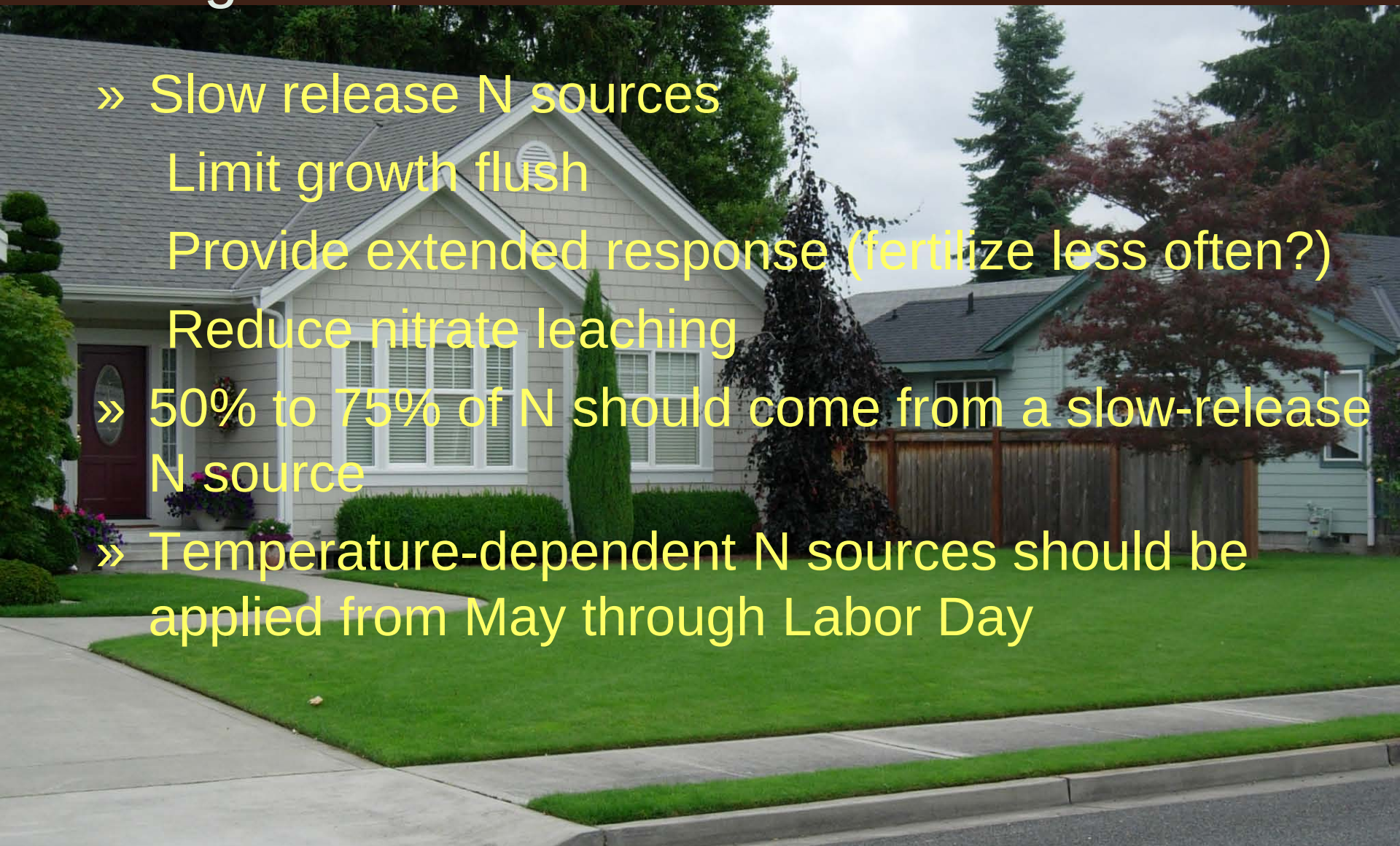
Nitrogen Fertilizer Use Recommendations



- Slow release N sources
  - Limit growth flush
  - Provide extended response (fertilize less often?)
  - Reduce nitrate leaching
- 50% to 75% of N should come from a slow-release N source
- Temperature-dependent N sources should be applied from May through Labor Day

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Use a Balanced Fertility Program

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Fertility Program

- Run a soil test before applying any nutrients. (Every 3 yrs.)
  Test for: N, P, K, Ca, Mg, pH, % O.M.

- What ever source is used **do not apply more than ½ lb. of quickly available N per app.**

A new turf area will most likely need nutrients, while an established area will require much less as nutrients have built up over time.

Timing of Applications: Refer to local area recommendations. Do not apply
nutrients when ground is frozen.

Use a slow release product. Do not apply organic fertilizers when soil temperatures are lower than 50 F.

Returning or recycling grass clippings will put nutrients in soil.

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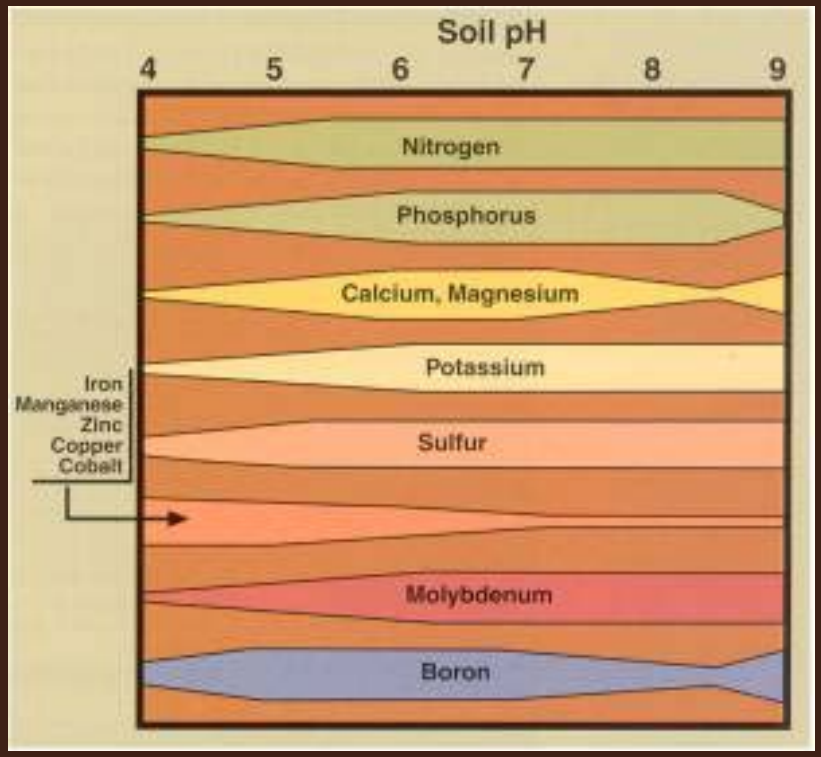
Soil Levels of Nutrients for Turfgrasses in the Pacific Northwest

Nutrient	Soil Level
P	Bray P_1 – 20-30 Sodium Acetate 5-8 ppm
K	250 ppm
Ca	3-5 meq/100 g soil, 600-1000 ppm
Mg	1-3 meq/100 g soil, 200-600 ppm
S	25 ppm SO_4-S
Fe	25-50 ppm
Cu	1.6 - 3 ppm
Zn	6.1- 8 ppm
Mn	30-50 ppm
B	1.3 - 3 ppm
Mo	0.2 - 0.4 ppm



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Athletic Field Fertility Program (Soil Tests Are Required)

- Many athletic fields are sand-based to lengthen time of year for play.
- Sand encourages drainage and less compaction, but does not hold nutrients in high amounts. Usually mix in known amount of organic matter (5 to 15% by volume) after testing soil texture combinations in a soil testing lab.
- Due to high use and necessity for quick recoveries for use, a fertility program using slow release products throughout the year may total as much as 8 lbs. N/1000 sq.ft./year. Timing of applications are similar to lawns, but on a more frequent basis to encourage recovery.
- Overseeding and topdressing are also an important IPM practice to keep the athletic fields safe for player use.

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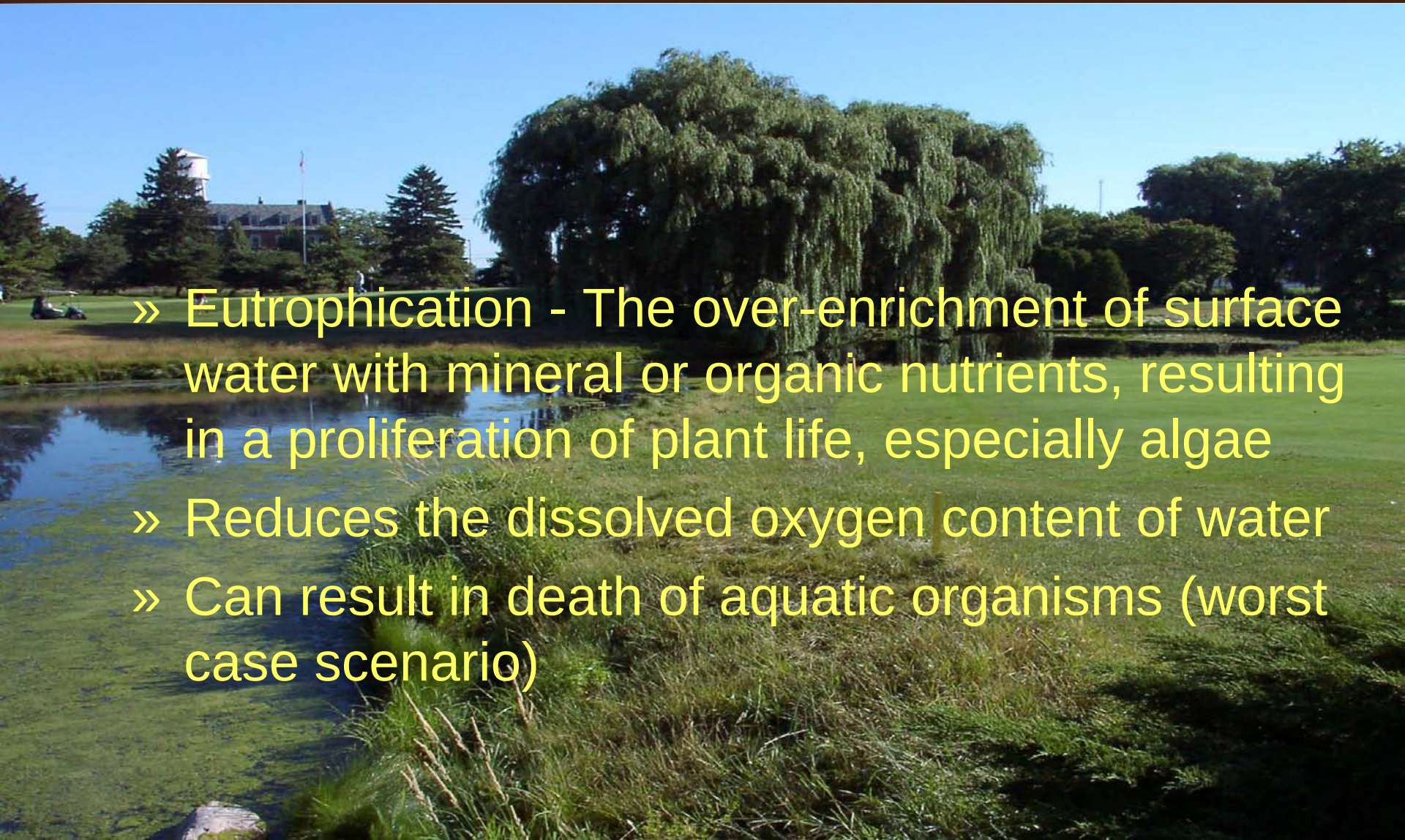
Phosphorus – Environmental Concerns



- Eutrophication - The over-enrichment of surface water with mineral or organic nutrients, resulting in a proliferation of plant life, especially algae
- Reduces the dissolved oxygen content of water
- Can result in death of aquatic organisms (worst case scenario)

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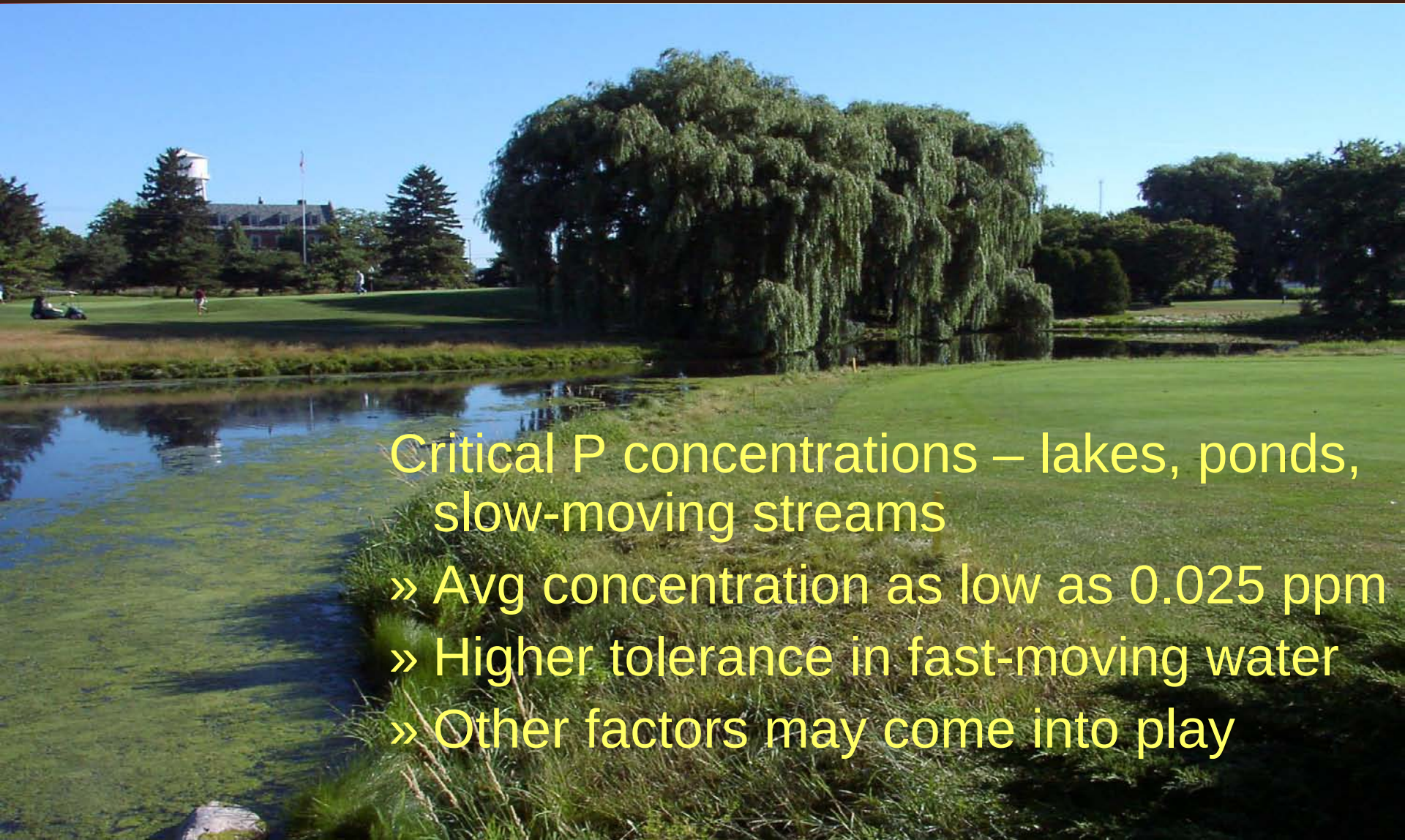
Phosphorus – Environmental Concerns



Critical P concentrations – lakes, ponds, slow-moving streams

» Avg concentration as low as 0.025 ppm

» Higher tolerance in fast-moving water

» Other factors may come into play

Runoff depth (volume), Ithaca, NY

- Fertilized lawn reduced runoff volume

Shallowest soil

Deepest soil

Table II. Runoff Depths for each Block and Land Use in the Watershed

Land Use	*Block I*	*Block II*	*Block III*
		(mm)	
Urban Barren	7.76a[a]	3.82b	0.51e
High Maintenance	2.90b	1.74d	0.36e
Forested	4.53c	4.45b	0.26e

[a] Land uses with the same letter are not significantly different as determined by a FPLSD at $\alpha \leq 0.05$.

Easton and Petrovic, 2008

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Phosphorus runoff, Ithaca, NY

- Lower dissolved P runoff from fertilized turf on 2 of 3 sites
- Lower particulate P runoff on all sites

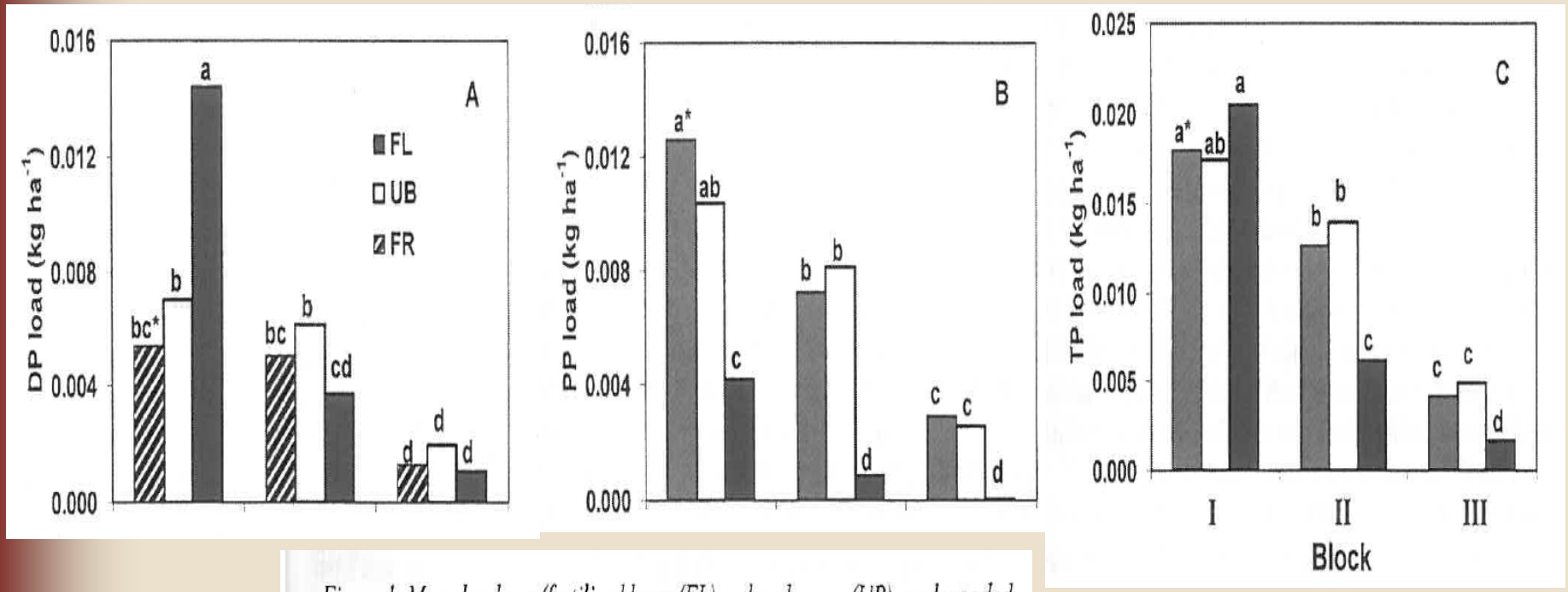

*Figure 1. Mean land use (fertilized lawn (FL), urban barren (UB), and wooded (FR)) dissolved P (A), particulate P (B), and total P (C) losses by block for all 98 runoff events. *Land uses with the same letter are not significantly different as determined by a FPLSD at $\alpha \leq 0.05$.*

Easton and Petrovic, 2008

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Natural Organic Transition Study 1 Year Application Summary

Product	Soil lb. N/M/yr	Sand lb. N/M/yr	Soil/Sand lb. $P_2 O_5$/M/yr
NatureSafe 1X 8-3-5	3	5	1.13
NatureSafe 1.5X 8-3-5	3	5	1.69
SoundGro 1X 5-4-0	3	5	2.40
SoundGro 1.5X 5-4-0	3	5	3.60
PCSCU 38-0-0-11	3	5	0.75

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Puyallup, WA, Soil Study P Data

There was no significant difference between treatments for Total Soil P

Average Total Soil P in Plots = 1137mg/kg

Control Samples: Total P = 1005 mg/kg Bray P = 18 mg/kg

Multiple pairwise comparisons using the Dunn's procedure for Bray or Available P/ Two-tailed test:

Sample	Frequency	Sum of ranks	Mean of ranks	P (mg/kg)	Groups	
BRAY P | PCSCU 38-0-0-11	4	19.000	4.750	19.5	A	
BRAY P | NatureSafe 1.5X 8-3-5	4	26.000	6.500	21.3	A	B
BRAY P | NatureSafe 1X 8-3-5	4	33.000	8.250	22.8	A	B
BRAY P | SoundGro 1X 5-4-0	4	63.000	15.750	35.0	A	B
BRAY P | SoundGro 1.5X 5-4-0	4	69.000	17.250	38.5		B

Bonferri corrected significance level = 0.005

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Puyallup, WA, Sand Study P Data

There was no significant difference between treatments for Total Sand P

Average Total Sand Plot P = 280 mg/kg

Control Samples: Total P = 294 mg/kg Bray P = 16 mg/kg

Multiple pairwise comparisons using the Dunn's procedure / Two-tailed test:

Sample	Freq.	Sum of ranks	Mean of ranks	P (mg/kg)	Groups	
Bray P |PCSCU	4	15.5	3.875	23.5	A	
Bray P |NatureSafe 1X	4	31.0	7.750	27.3	A	B
Bray P |NatureSafe 1.5X	4	31.5	7.875	28.0	A	B
Bray P |SoundGro 1X	4	63.5	15.875	66.3		B
Bray P |SoundGro 1.5X	4	68.5	17.125	75.3		B

Bonferri corrected significance level = 0.005

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Phosphorus runoff, recommendations

- Healthy turf reduces runoff
- Although P runoff from turf can occur, typical low rates of fertilizer P are unlikely to contribute significantly
- Research in MN, WI shows majority of P runoff occurs from frozen soils
- Apply P based on soil test results
- Fall may not be the best time to apply P

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Which turfgrass diseases might be linked to lack of P ?

- Microdochium Patch
- Red Thread
- Necrotic Ring Spot
- Take-all Patch

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Phosphorus legislation in WA

- Bill passed house in WA on Feb. 28, 2011.
- Under consideration in Senate
- Not based on best available science
- Language states that:
  - P is not required to grow healthy turf
  - lawn fertilizers contribute significantly to P loading
- Restricts fertilizer P application to lawns
  - exceptions for establishment, soil test results
- Requires clean-up from impermeable surfaces
- Does not exempt natural organic fertilizers

So??

- Link between plant stress, disease and fertility is hard to pick apart so that separate effects can be studied.
- Seeing responses unrelated to the fungicidal benefits (often in fruit crops).
- Phosphite toxicity is described in the literature, when applied at fertilizer rates in annual crops.
- Watch rates.

How to Handle a Site with High Soil Test P

- Don’t fertilizer with P.
- Remove clippings to ‘mine’ P from the site.
- Don’t let the site get bare – P in runoff is our biggest environmental issue.

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We All Live Here And Need To Make Educated Choices