Phosphorus Fertilization in High Yield Crops

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Grateful Acknowledgements

- Neil Hansen, BYU
- My students and staff
- Tyler J. Hopkins, Sci-Scapes, Inc.

So, why do we bother fertilizing?

Phosphorus (P) is an essential nutrient.

- Only nitrogen (N) surpasses this nutrient in global fertilizer need.

“Those that fail to learn from history are doomed to repeat it.” -Winston Churchill

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CELEBRATING THE 350TH ANNIVERSARY OF DISCOVERING PHOSPHORUS—FOR BETTER OR WORSE

Phosphorus Management in High-Yield Systems

Bryan G. Hopkins* and Neil C. Hansen

Hopkins, B.G. 2020. **Developments in the use of fertilizers**. *In* Rengel, Z. *(ed.) Achieving Sustainable Crop Nutrition*. Ch. 19: 555-588. Cambridge, UK: Burleigh Dodds Science Publishing. *(ISBN: 978 1 78676 312 9; www.bdspublishing.com)*

Hopkins, B.G. 2015. **Phosphorus in plant nutrition**. *In* D.J. Pilbeam and A.V. Barker (*ed.*) *Plant Nutrition Handbook*. 2^{nd} ed., Ch. 3: 65-126. Boca Raton, FL: CRC Press, Taylor & Francis Group.

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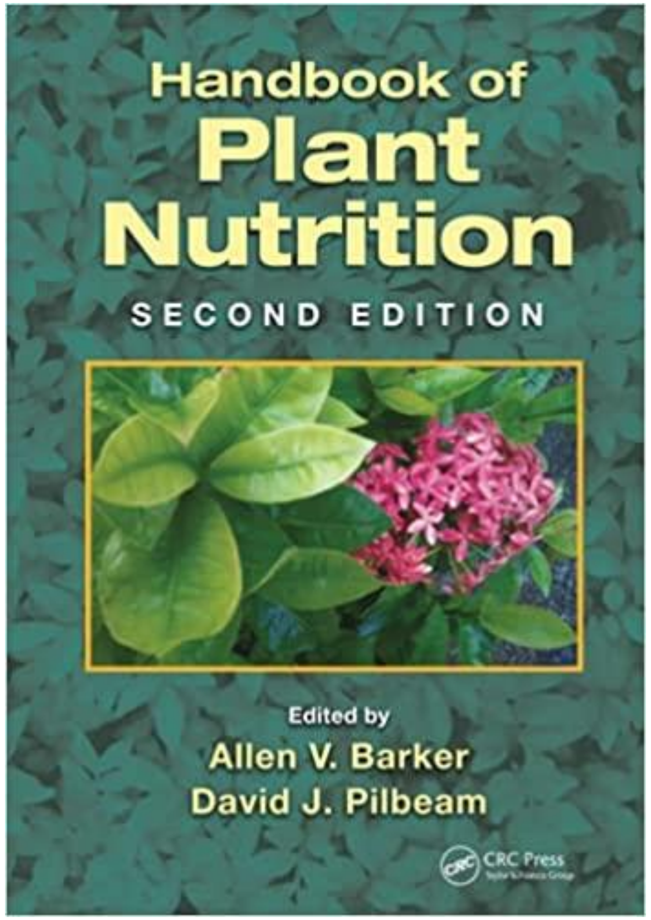
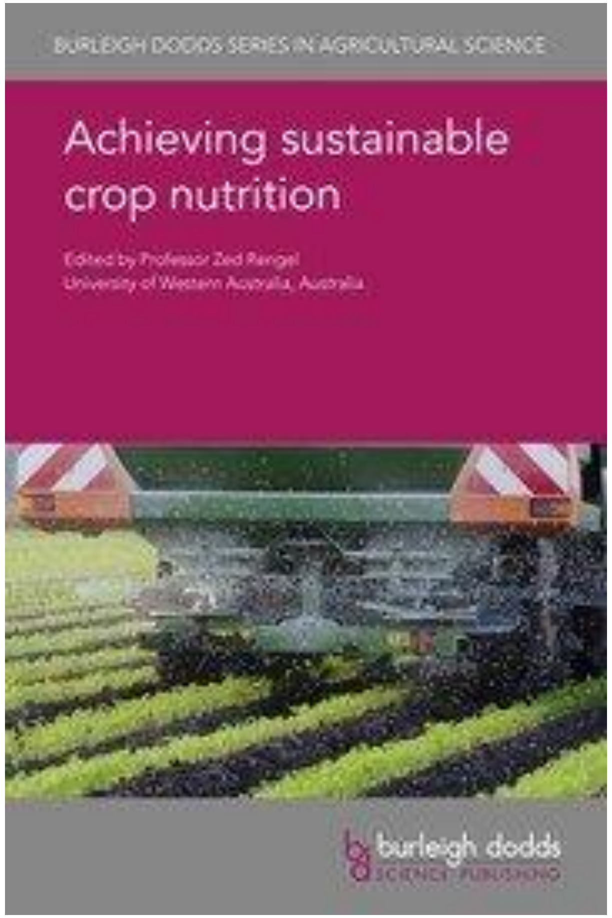
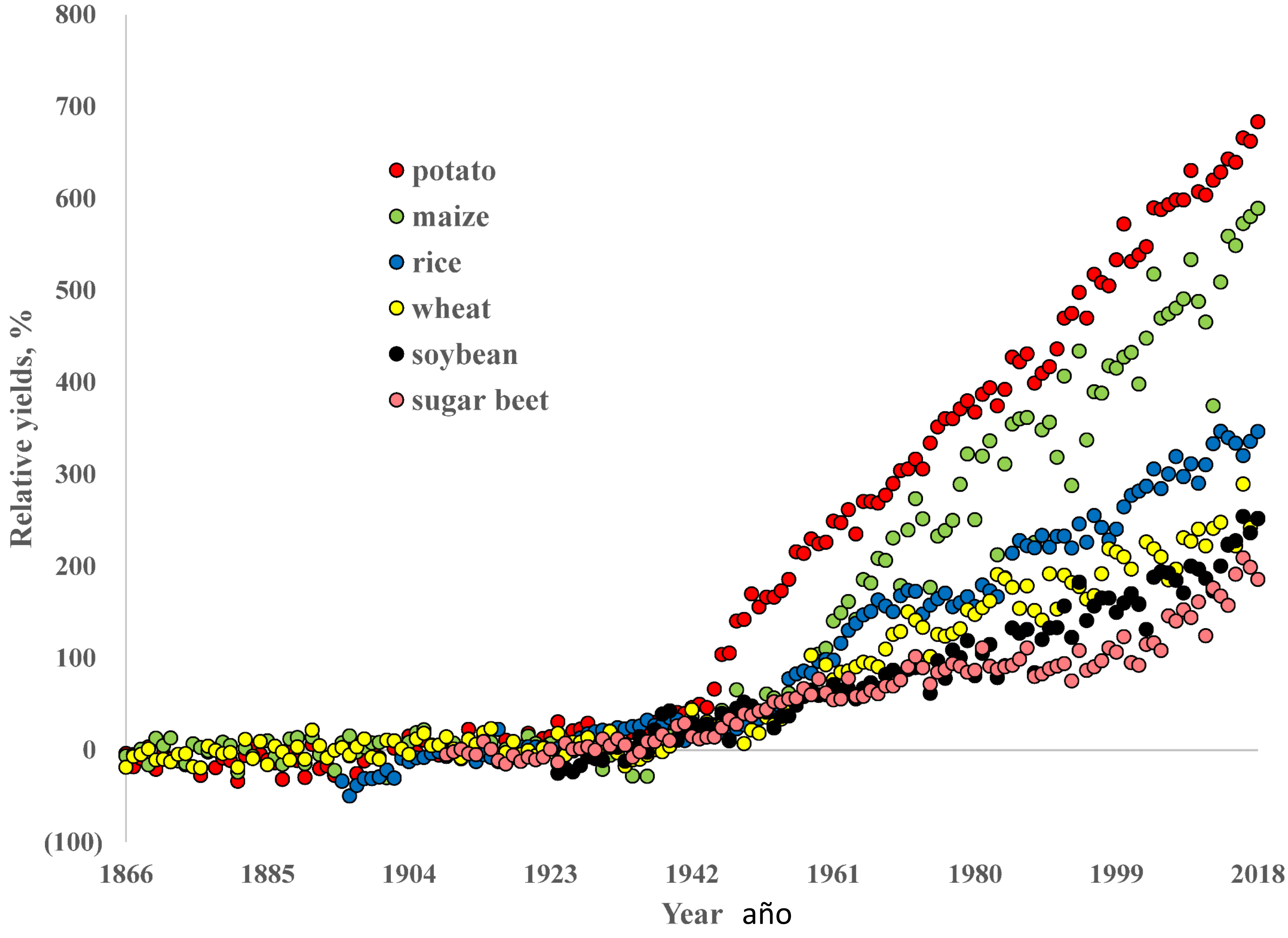




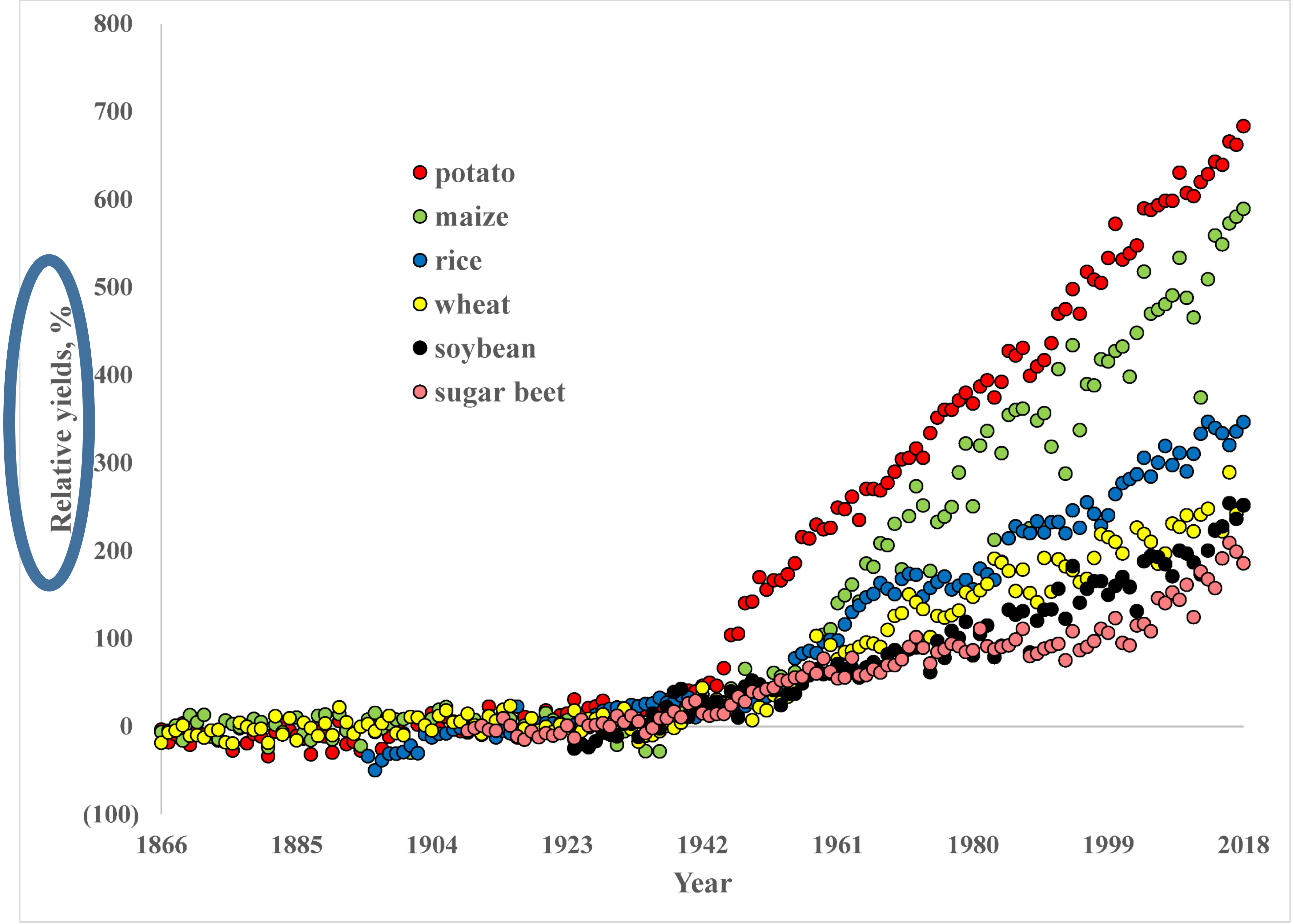
Core Ideas

- History of P fertilization illuminates traditional soil P management and needed changes.
- Recalibration of STP and P fertilizer recommendations are needed to match increasing yield and rates of P uptake.
- Environmental concerns and diminishing P supply necessitate improvement in P use efficiency.
- Placement and timing are improved through understanding of variable rooting patterns.
- Enhanced efficiency P fertilizers can be effective if applied correctly.

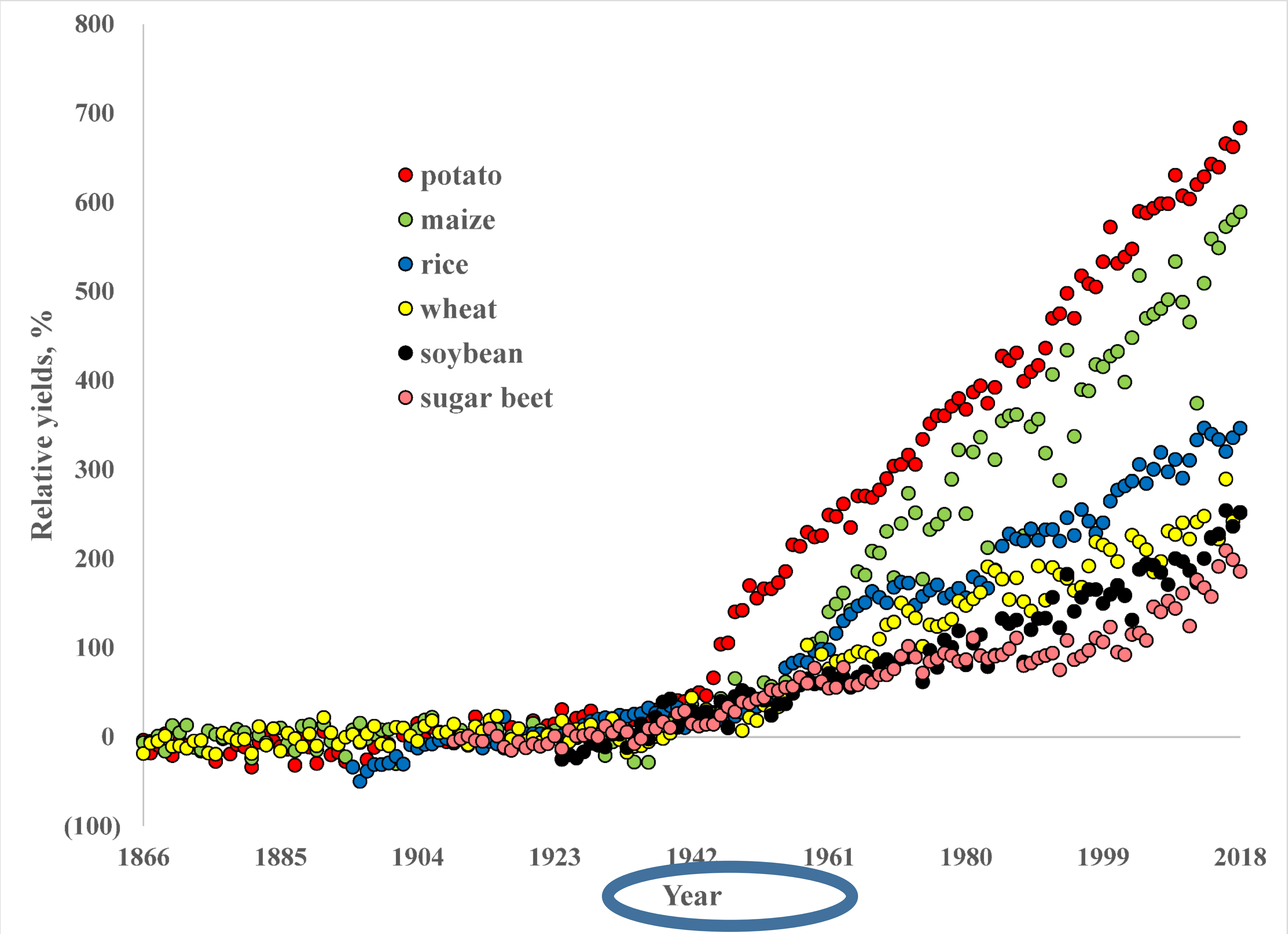


800
700
600
500
400
300
200
100
0
(100)
Relative yields, %
potato
maize
rice
wheat
soybean
sugar beet
1866
1885
1904
1923
1942
1961
1980
1999
2018
Year año

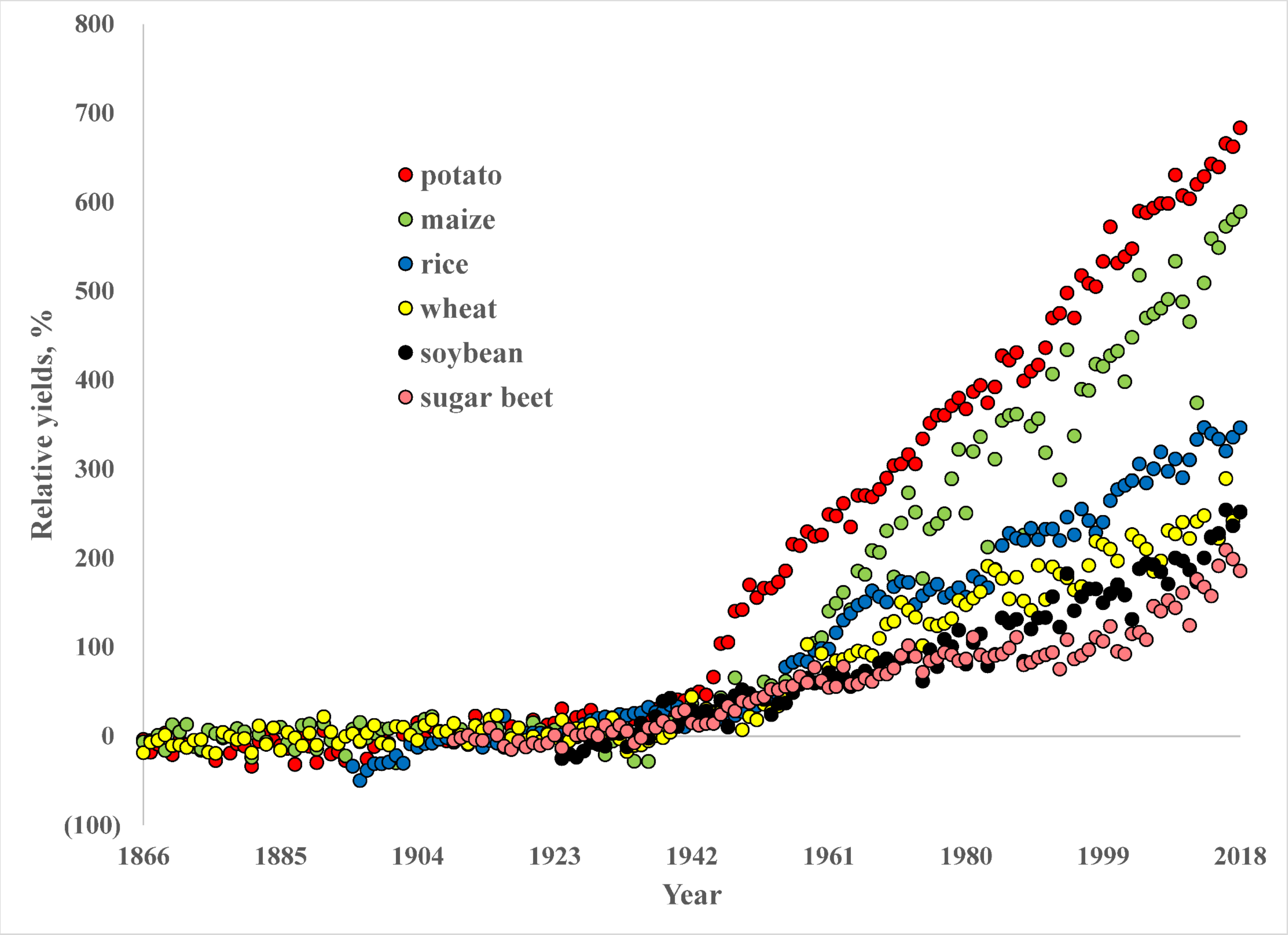
Relative yield = yield relative to the yields 1866-1923.



Crop yields were stagnant until after World War II with the beginning of the Green Revolution.



We know that these and other crops have much more yield potential than we are currently at and, thus, we predict continued increase in yields.



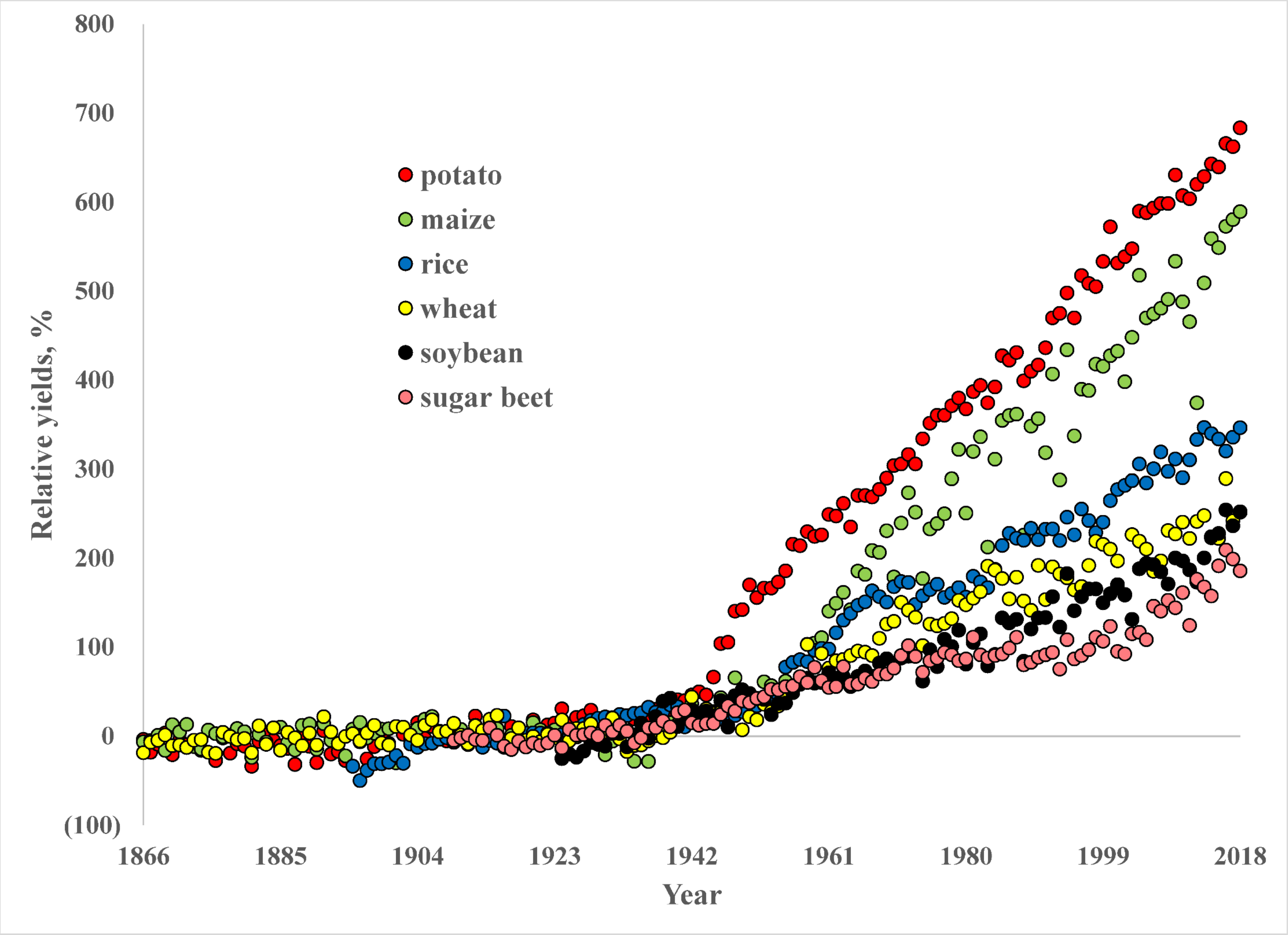
Why a Green Revolution?

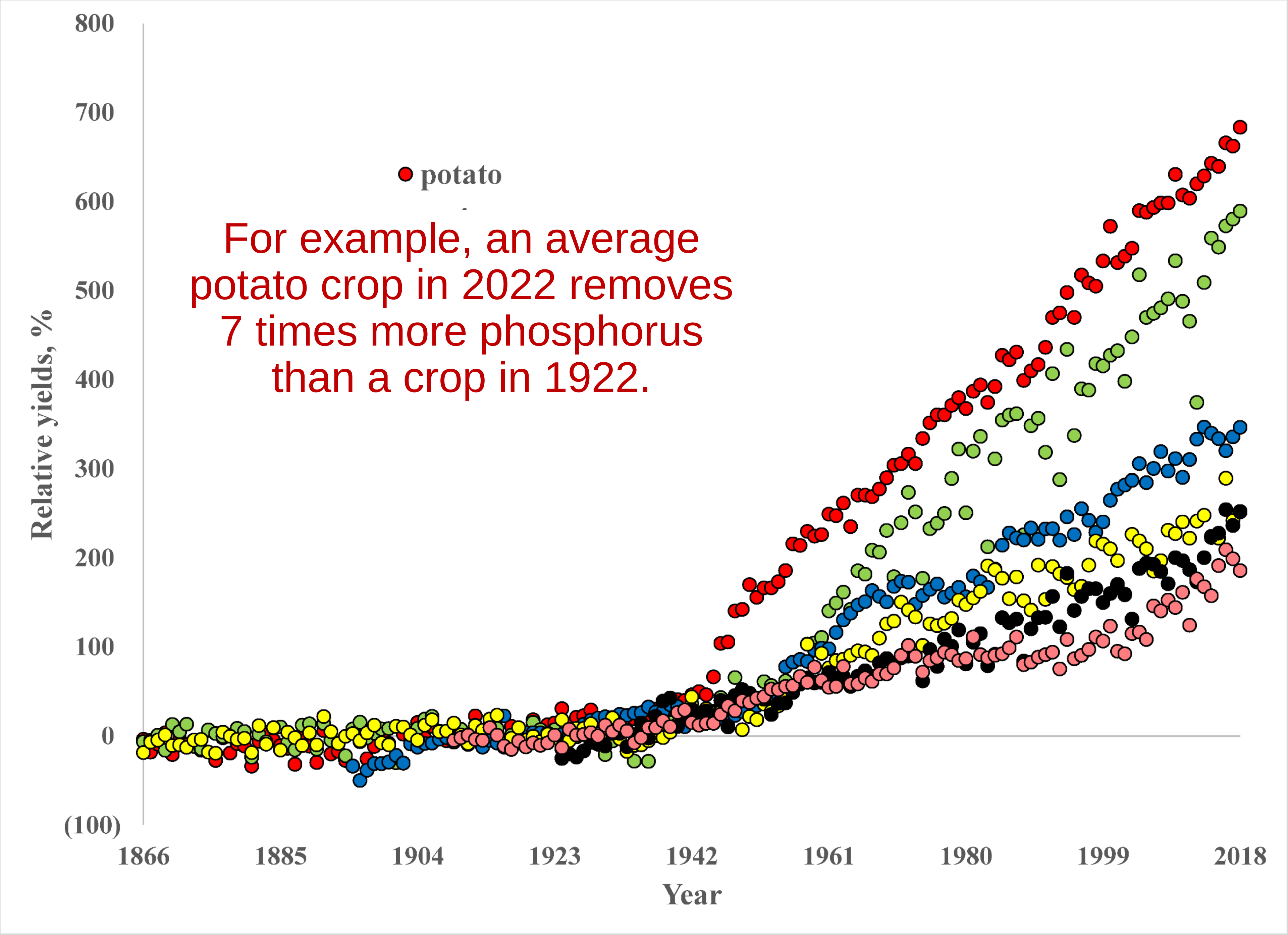
- Soil Analysis Based Fertilization
- Pesticides
- Irrigation
- Breeding & Genetics
- Mechanization
- Technology
- Transportation
- Research and Education

Plants growing natively don’t require fertilizer because they grow relatively slowly and have evolved to require relatively less nutrients.

Crops have been bred to grow relatively rapidly and to have relatively high nutrient requirements.

The steady increases in yields also requires continual increases in nutrient needs.



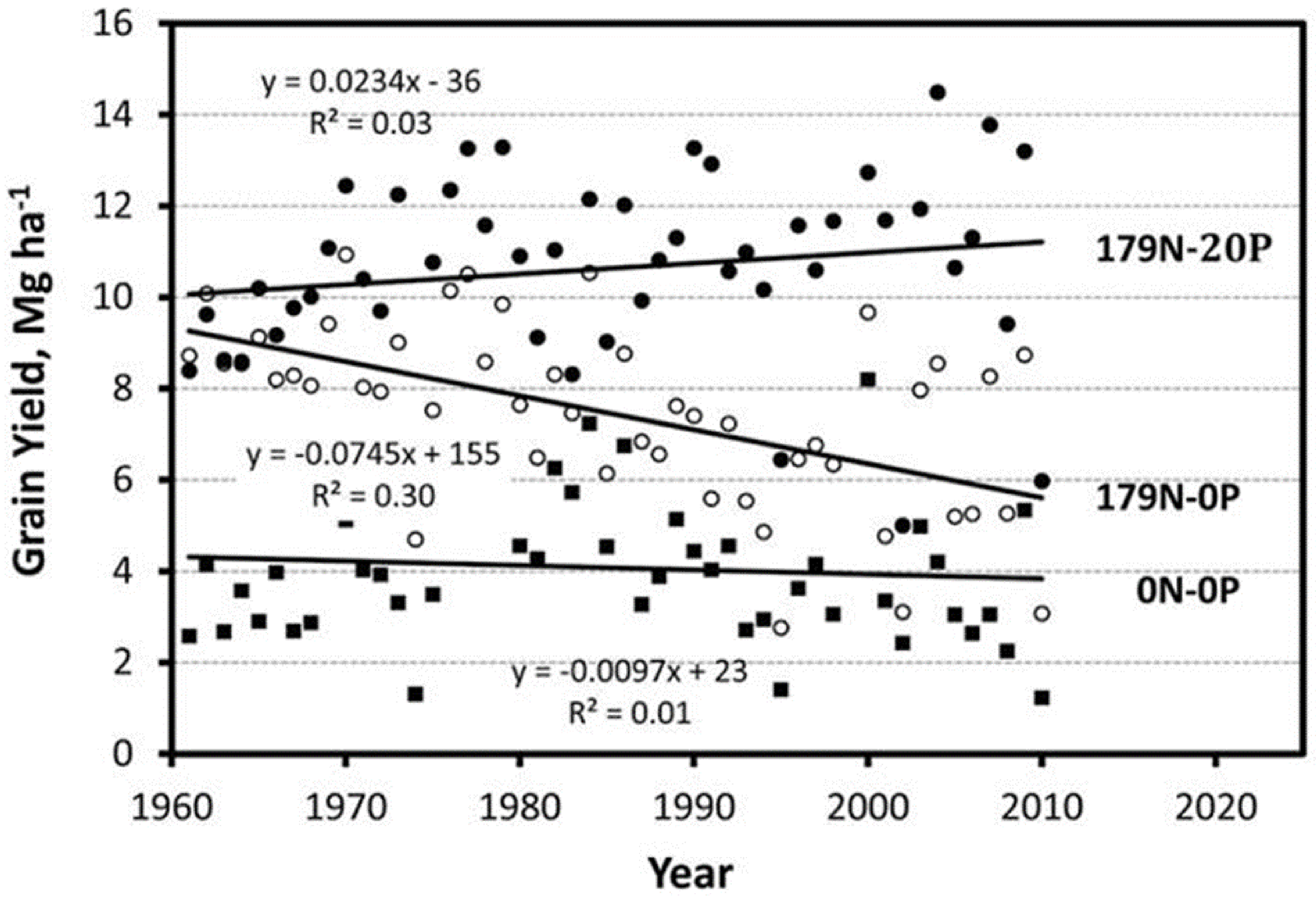


potato
For example, an average potato crop in 2022 removes 7 times more phosphorus than a crop in 1922.
Relative yields, %
800
700
600
500
400
300
200
100
0
(100)
1866
1885
1904
1923
1942
1961
1980
1999
2018
Year

	NRC P, %DM	CVAS P, %DM
Forages		
Alfalfa hay, immature	.31	.34
Alfalfa hay, mature	.28	
Grass hay, immature	.34	.27
Grass hay, mature	.26	
Barley silage	.30	.36
Corn silage	.26	.23
Rye silage	.42	.42
Pasture, intensively managed	.44	
Grains		
Barley	.39	
Corn	.30	.28
Protein Meals		
Cottonseed meal	1.15	1.08
Peanut meal	.64	
Soybean meal	.70	.69
Fish meal	3.05	2.68
Whole Seeds		
Cottonseeds	.60	.63
Soybeans	.60	.58

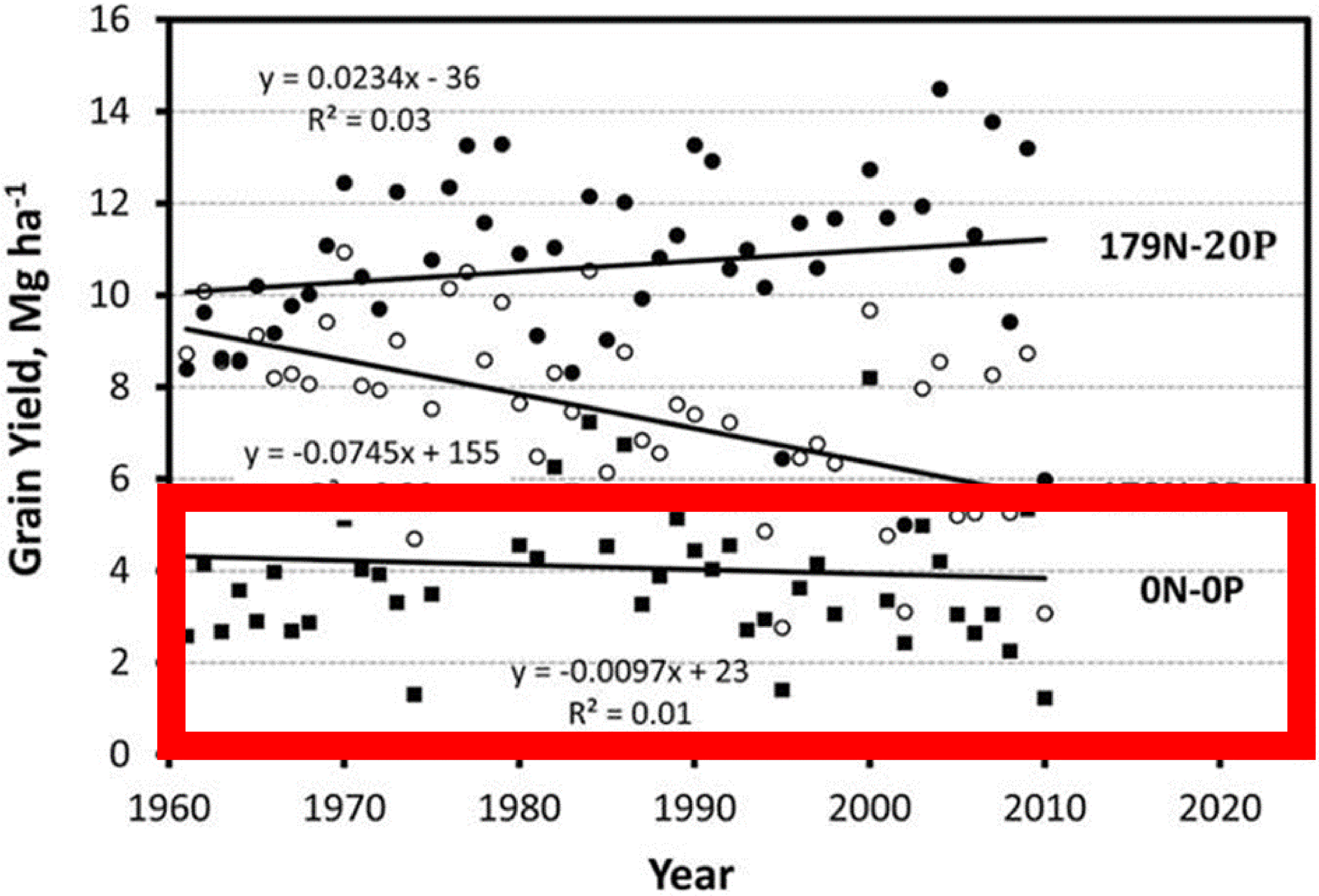
This is the amount of phosphorus in various crops. These values remain approximately constant at low and high yields.

As yields increase, the management techniques for nutrients, including phosphorus, may no longer be sufficient.

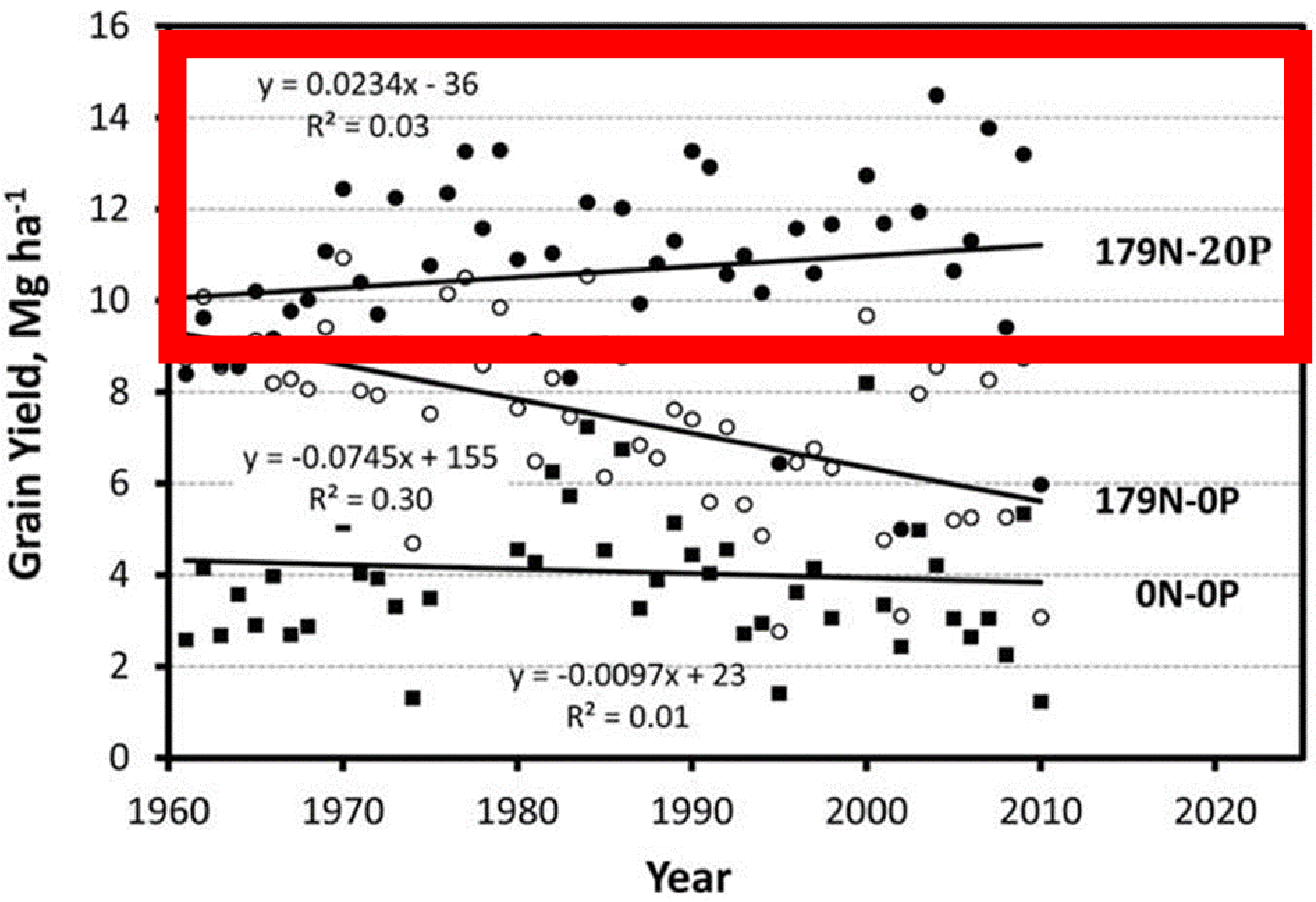


Corn grain yield for a 50 year fertilizer trial.

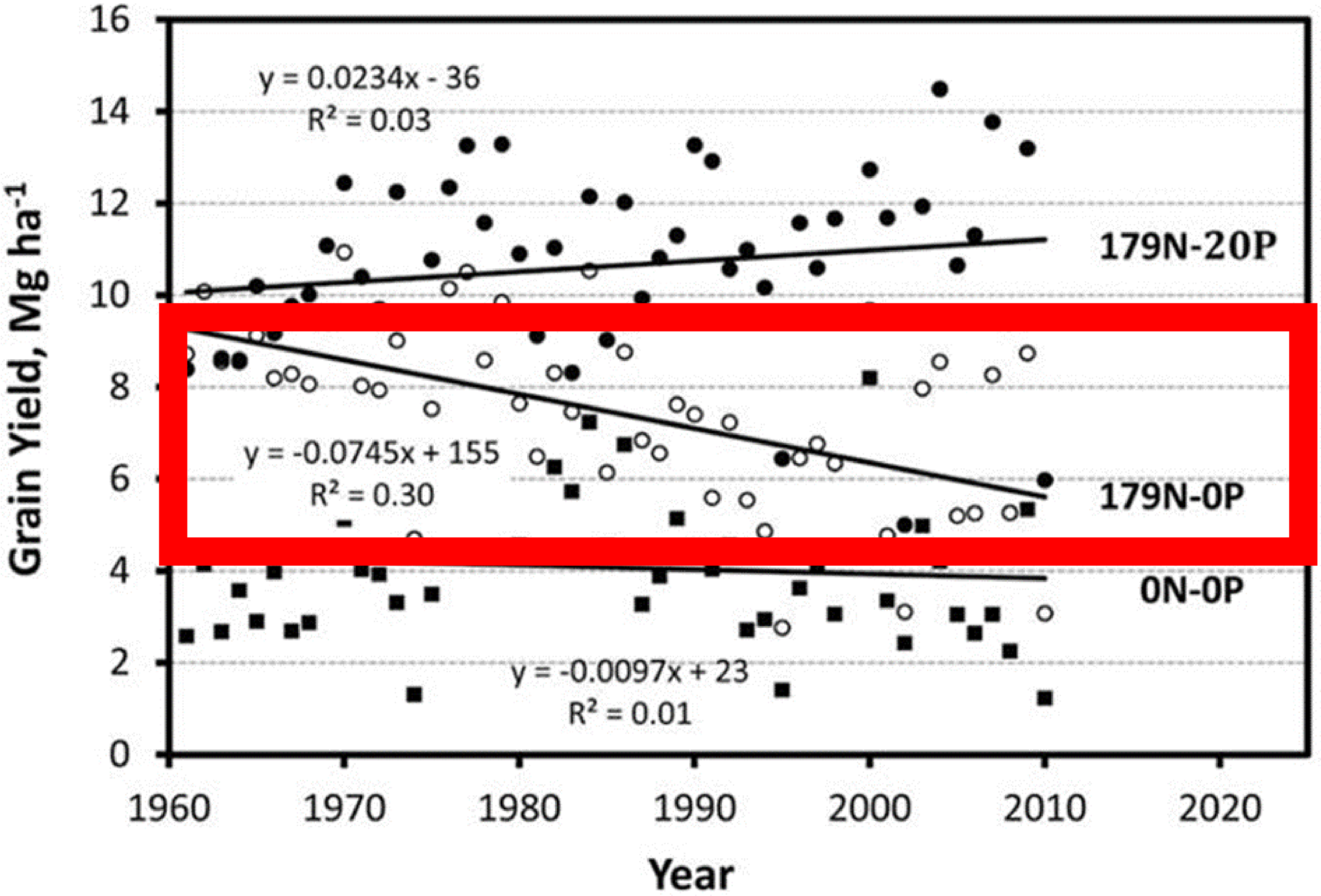
Schlegel, A.J., and Havlin, J.L. 2017. Corn yield and grain nutrient uptake from 50 years of nitrogen and phosphorus fertilization. Agron. J. 109:335-342. doi:10.2134/agronj2016.05.0294



Untreated control with the symbol ■ never fertilized (0 nitrogen and 0 phosphorus) has base yields that the soil system can support without fertilizer, with a slight downward trend.

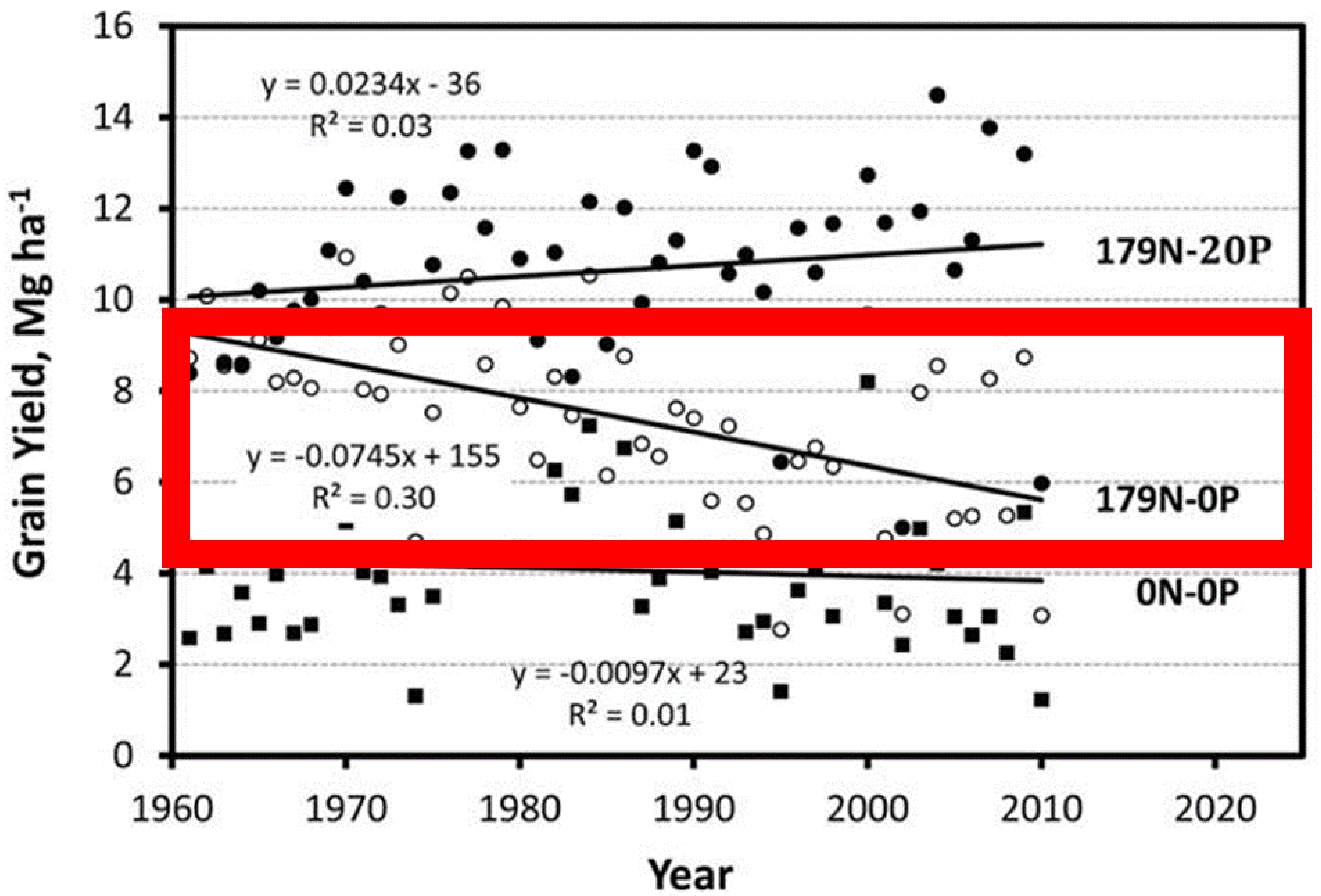


Fertilized with N & P with symbol - ● fertilized prior to the start of the study and receiving fertilizer (179 N & 20 P) has elevated yields enhanced by fertilization, with a slight upward trend.

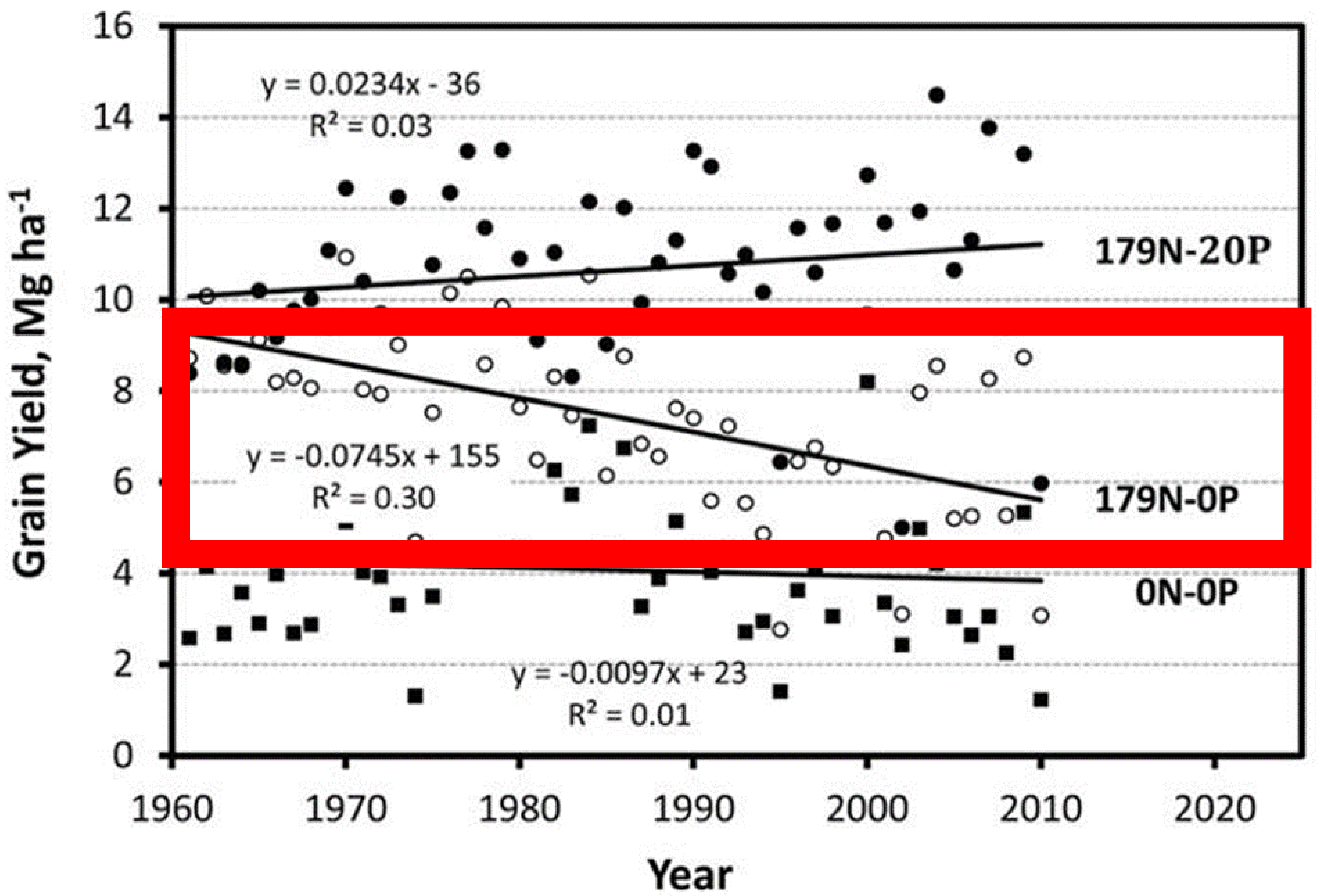


Nitrogen only fertilization with the symbol ○ fertilized prior to the start of the study and receiving fertilizer (179 N but no phosphorus) has elevated yields enhanced by fertilization at the beginning of the trial, but with a significant downward trend.

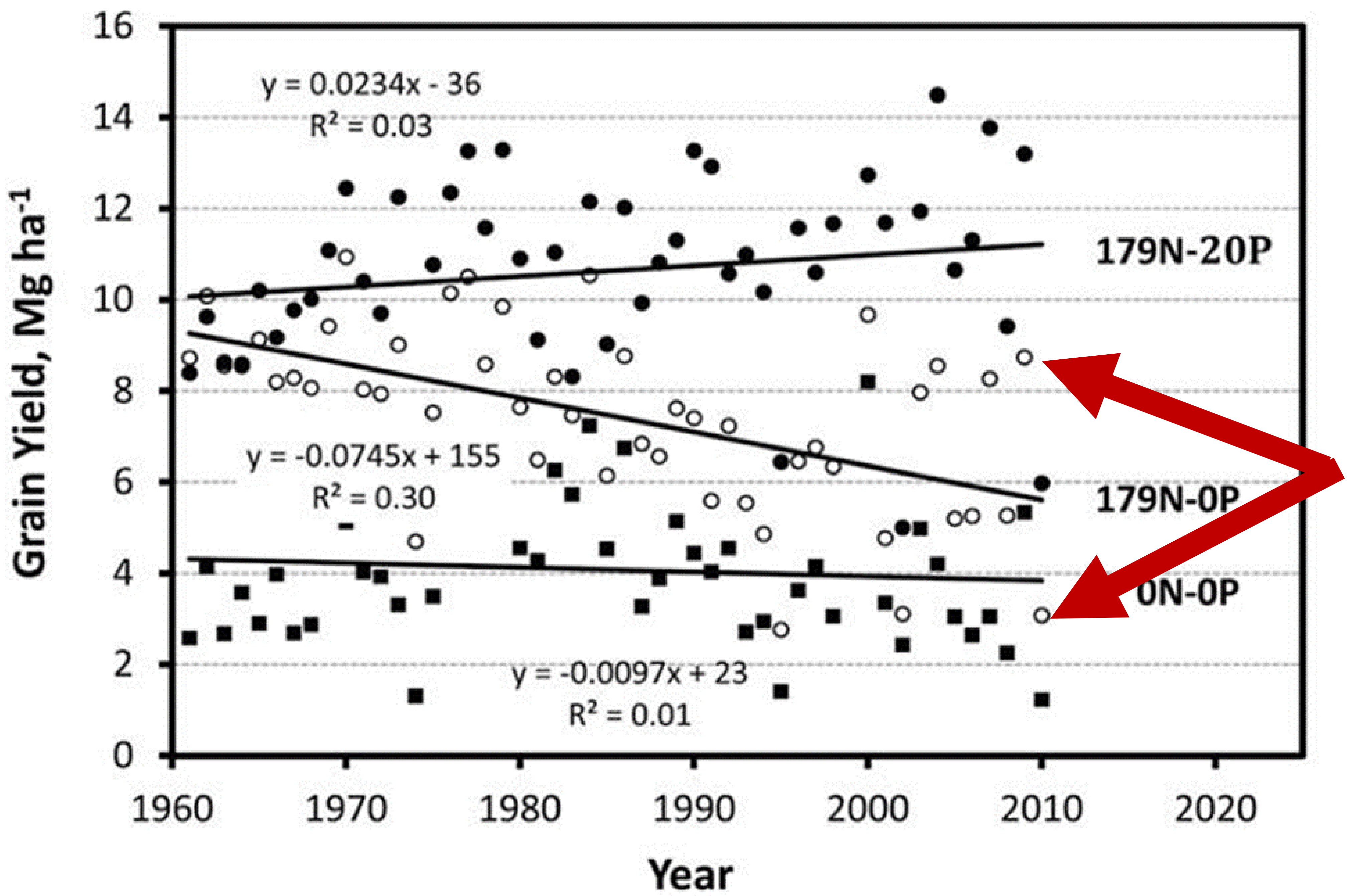
○



Residual P does impact future year crops, but its supply is not endless.



Notice that it takes a few years before problems become serious.



Also notice the scatter in the data. For example, see the last two years of the trial with large differences.

Cropping systems are outpacing fertilizer recommendations.

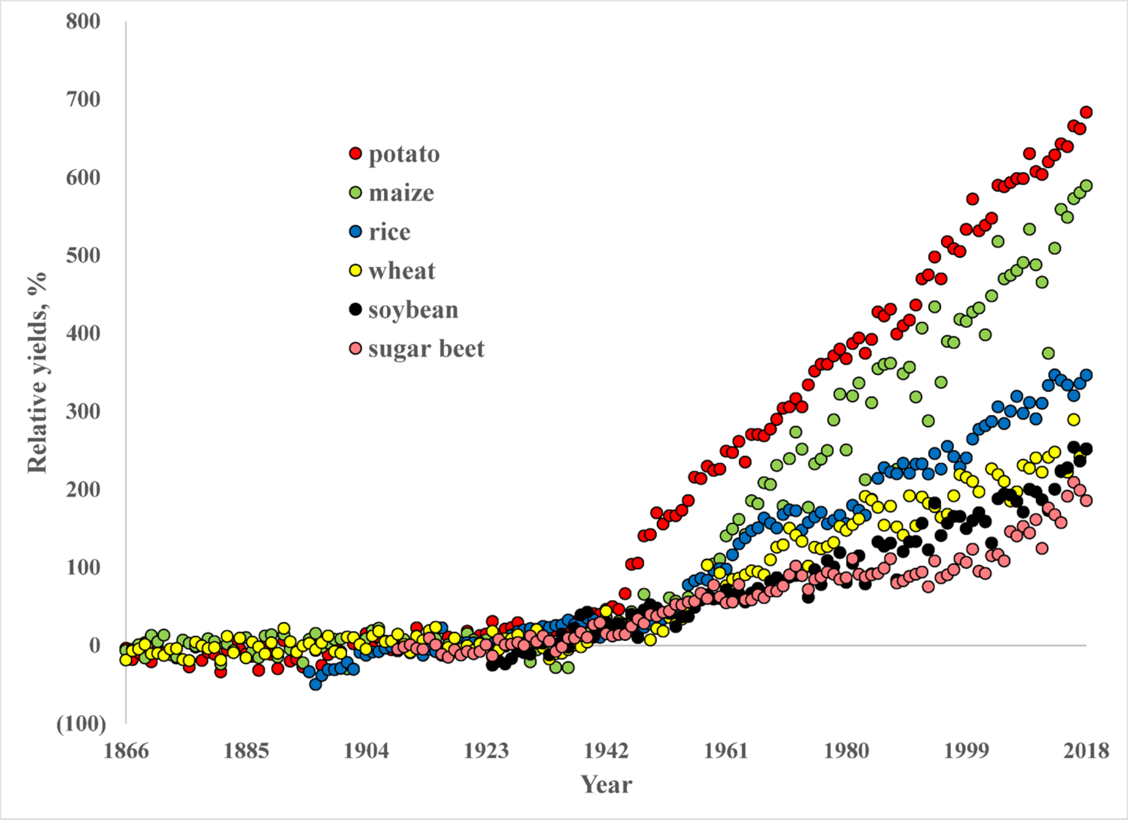


Table 2. Phosphorus uptake (International Plant Nutrition Institute, 2014), average crop yields (Lazicki et al., 2016; USDA-NASS, 2019, averaged across 2007–2016), P removal at average yields (USDA-NASS, 2019), leaf P concentrations (Bryson et al., 2014), and P concentrations in the harvested portion (Lardy and Schafer, 2014; USDA-ARS, 2019; USDA-NRCS, 2019) for eight key species.

	Uptake	Yield	Removal		Leaves	Harvested portion
	kg P Mg^{-1}	Mg ha^{-1}	kg P Mg^{-1}	kg P ha^{-1}	%	%
Potato	0.92	46.9	0.56	26	0.20–0.50	0.04
Maize	4.19	10.1	2.70	27	0.25–0.50	0.21
Rice	3.67	8.2	2.54	21	0.10–0.18	0.10
Wheat	5.24	3.1	3.83	12	0.20–0.50	0.42
Soybean	7.86	3.1	6.48	20	0.25–0.50	0.70
Sugar beet	0.61	64.6	0.45	29	0.45–1.10	0.24
Onion	0.21	56.6	0.14	8	0.35–0.50	0.03
Apple	0.25	34.8	0.04	2	0.10–0.40	0.01

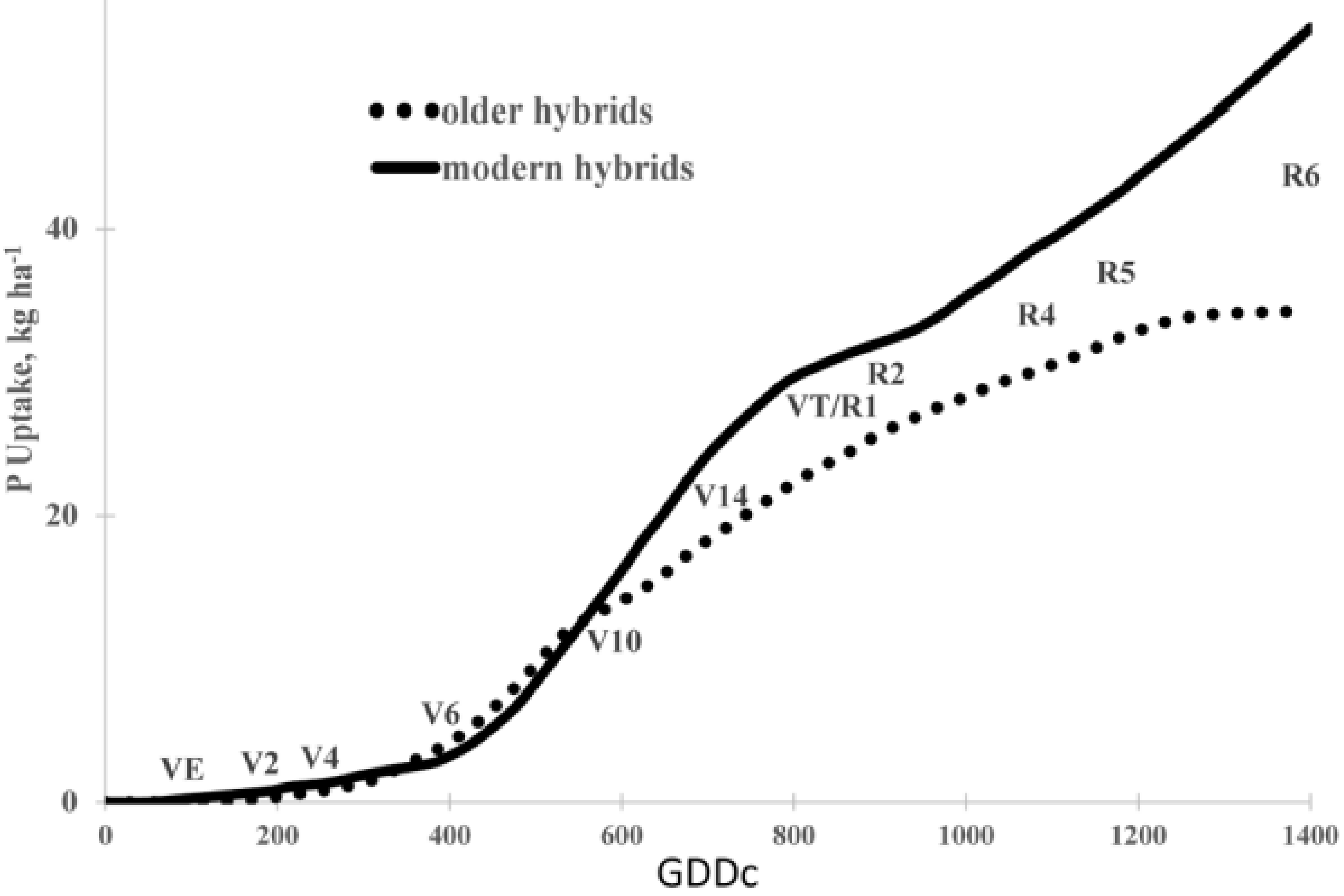
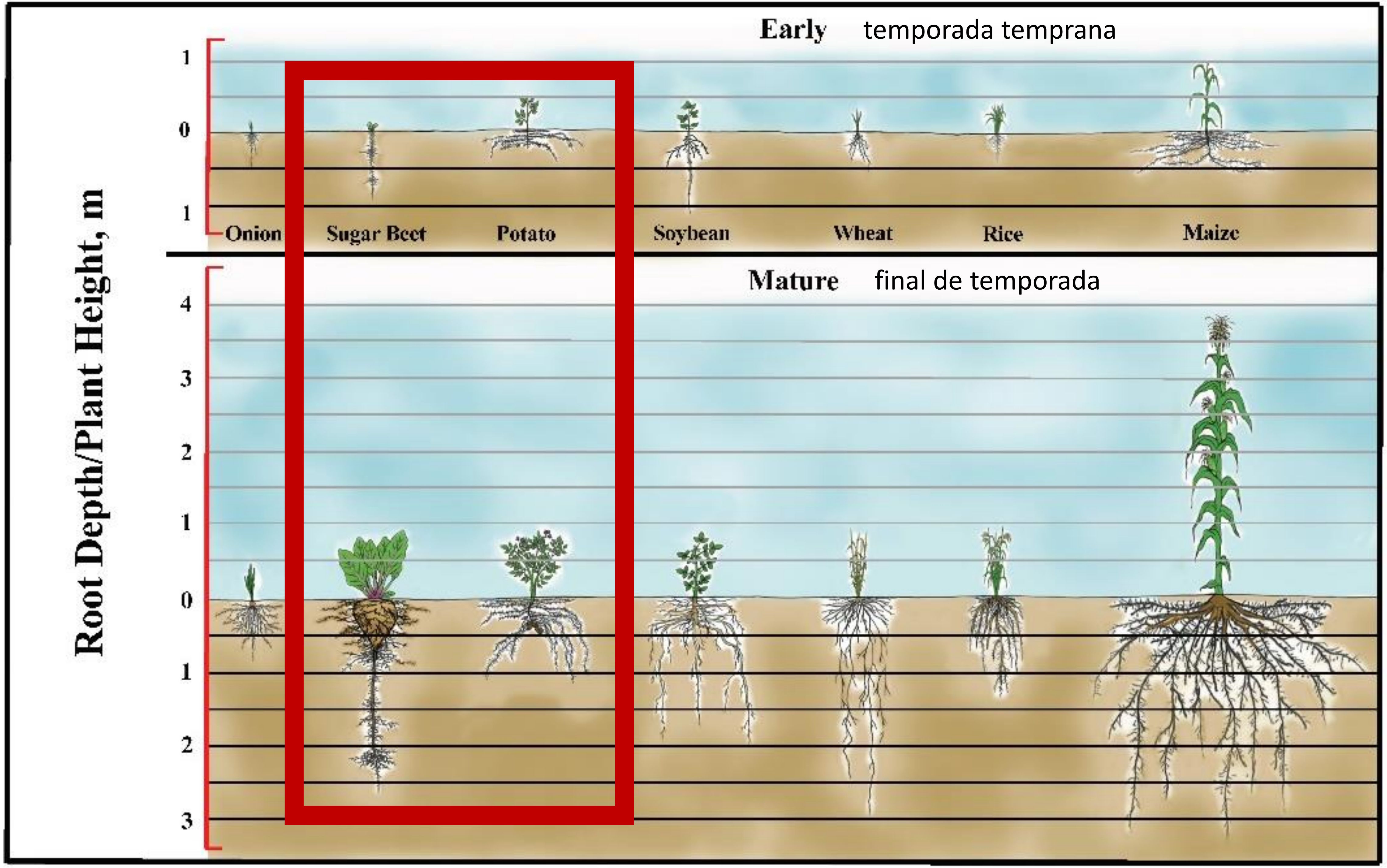


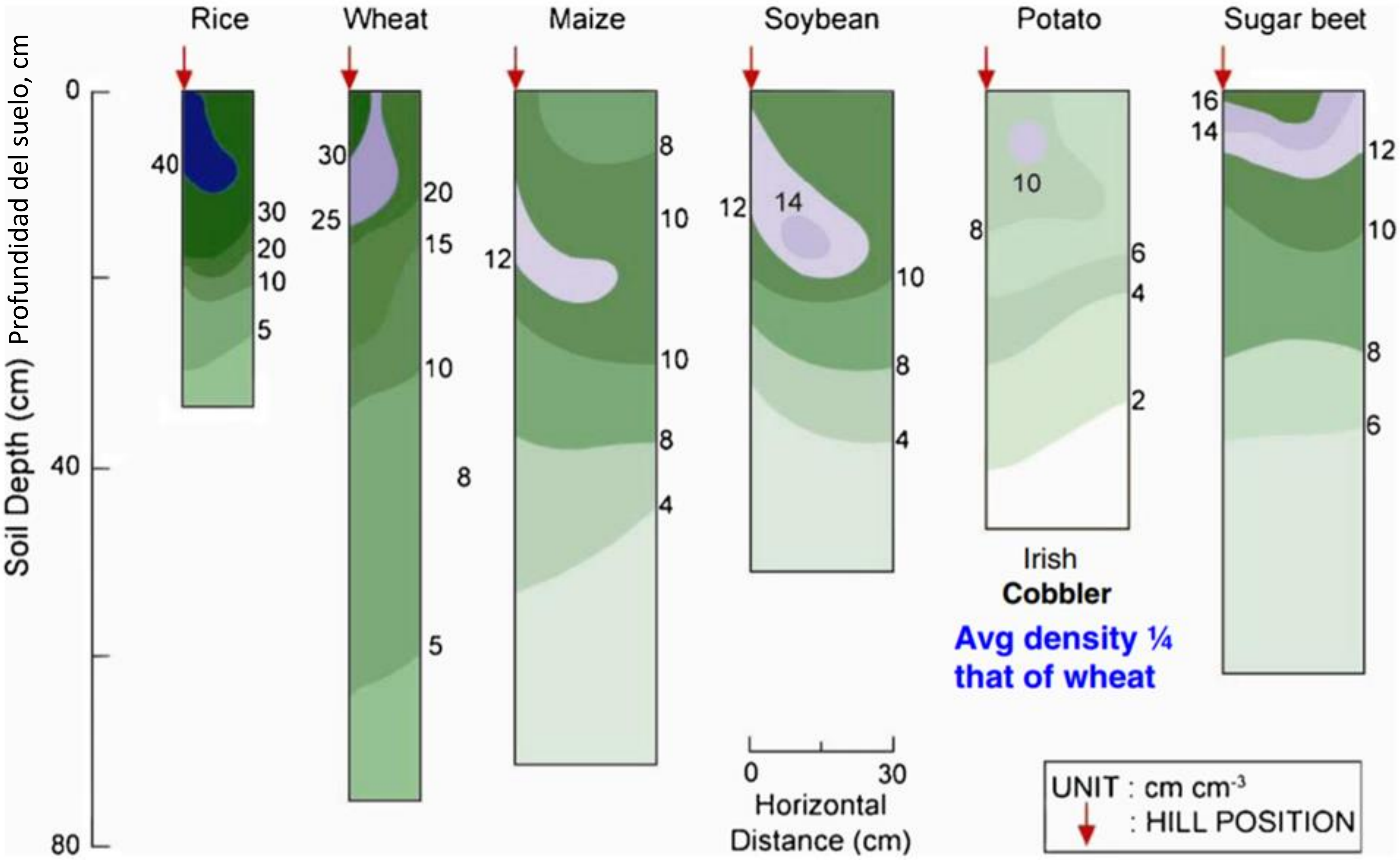
Fig. 3. Estimated cumulative P uptake for maize as a function of growing degree days (GDDc) for maize growth with vegetative (V) and reproductive (R) stages shown for "modern hybrids" (adapted from Bender et al., 2013a) and "older hybrids" (adapted from Ritchie et al., 1997).

Meeting Increased Phosphorus Demands

Exceptional Yields Require Exceptional Management

- Spatially Precise Technologies
- Variable Root Access to Phosphorus


Early
temporada temprana
Root Depth/Plant Height, m
1
0
1
Onion
Sugar Beet
Potato
Soybean
Wheat
Rice
Maize
Mature
final de temporada
4
3
2
1
0
1
2
3



Rooting depth and density impact uptake of nutrients, such as P, with limited mobility in the soil.

Iwama, K. 2008. Physiology of the potato: new insights into root system and repercussions for crop management. Potato Res. 51:333–353. doi.org/10.1007/s11540-008-9120-3

We can’t effectively manage nutrients if we don’t have a basic understanding of their behavior in the soil.

Opposite of nitrogen (N), phosphorus (P) chemistry is dominated mostly by its very poor solubility.

"Don't eat rocks."

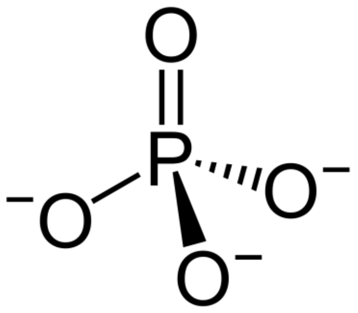
Plants can't effectively take up nutrients in solid form

Plants “drink” their nutrients

- Nutrients need to be dissolved in soil solution.

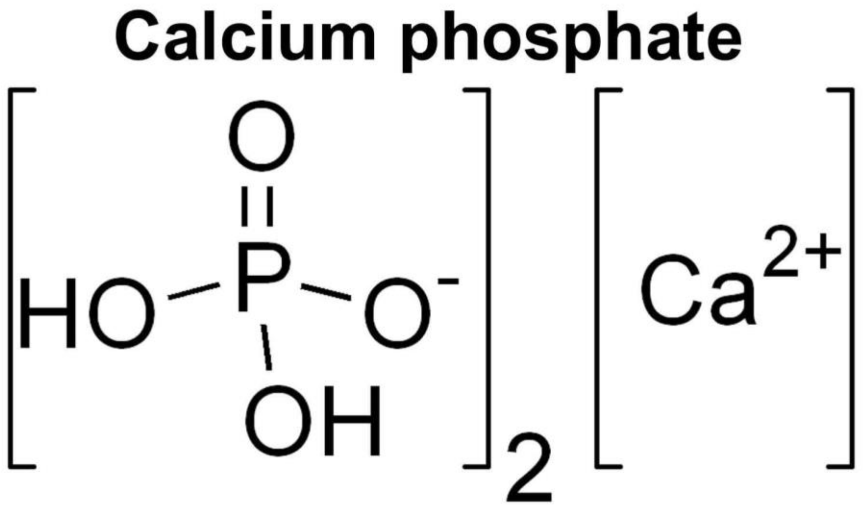
Phosphorus in Soil

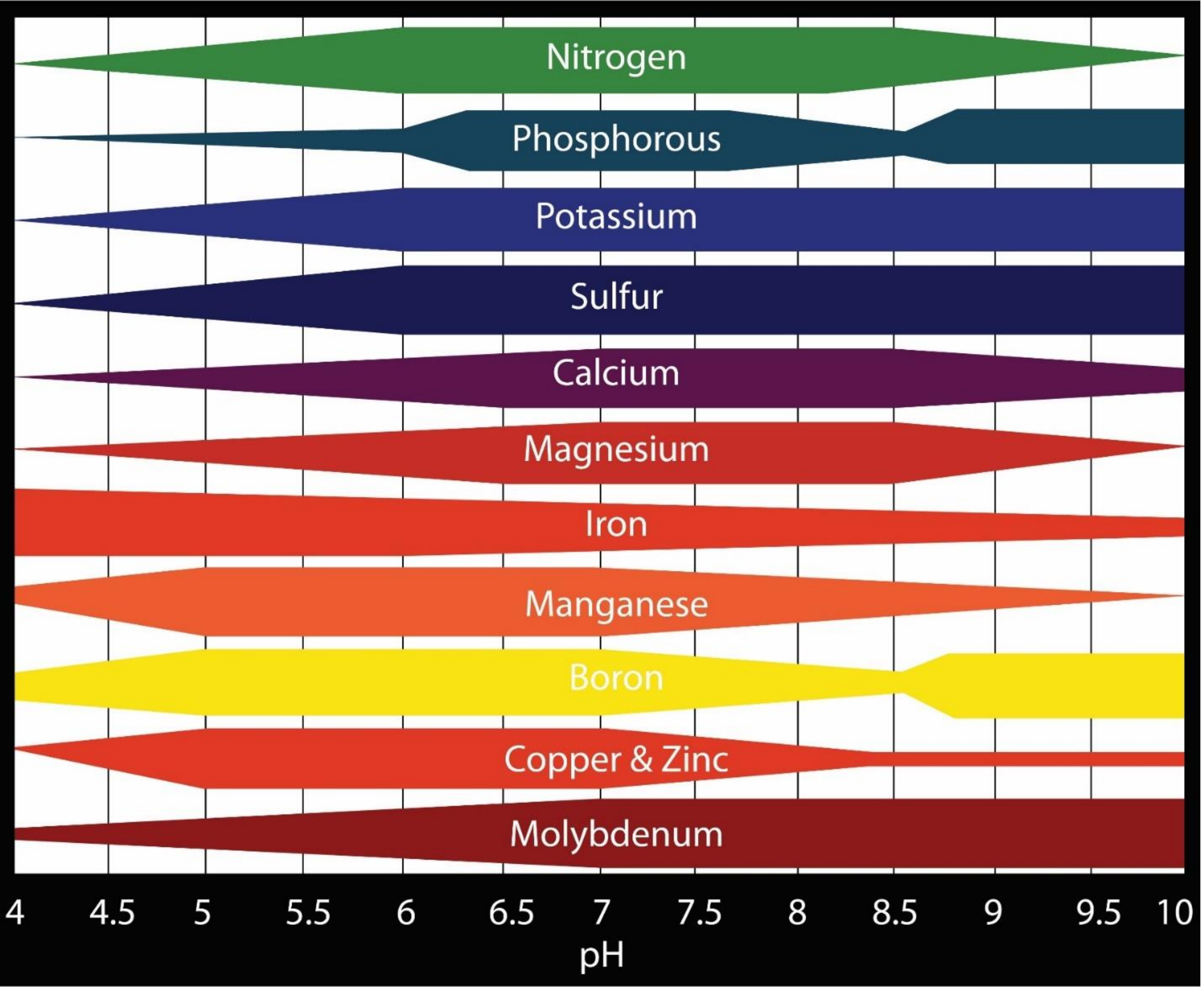
- Ions [phosphate ion (PO_4^{3-})] are dissolved in soil solution.



Phosphorus in Soil

- Ions can react with other oppositely charged ions and form precipitates, which don't readily leach or interact with the CEC.





Soil pH impacts nutrient availability

Adapted from:
Truog, Emil. 1947. The Liming of Soils. In: USDA Yearbook of Agriculture 1943-1947. pp. 569-570

Likelihood of Nutrient Deficiency as a Function of Soil pH

ACID (pH = 0-7)

deficiency risk increases at pH <6

NEUTRAL (pH = 7)

optimum at pH 6-7

ALKALINE (pH = 7-14)

deficiency risk increases at pH >7

Decreased Mineralization & Decomposition

Nitrogen
Sulfur
Molybdenum

Poor Solubility

Phosphorus

Hydrogen Competition (Leaching)

Potassium
Calcium
Magnesium

Volatilization (Ammonia)

Nitrogen

Poor Solubility

Phosphorus
Zinc
Manganese
Iron
Copper
Boron

Hopkins, B.G. and N.C. Hansen. 20xx. Adapting conventions to improve phosphorus use efficiency in high yield environments. *Journal of Environmental Quality.* (submitted in March 2019)

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Calcium
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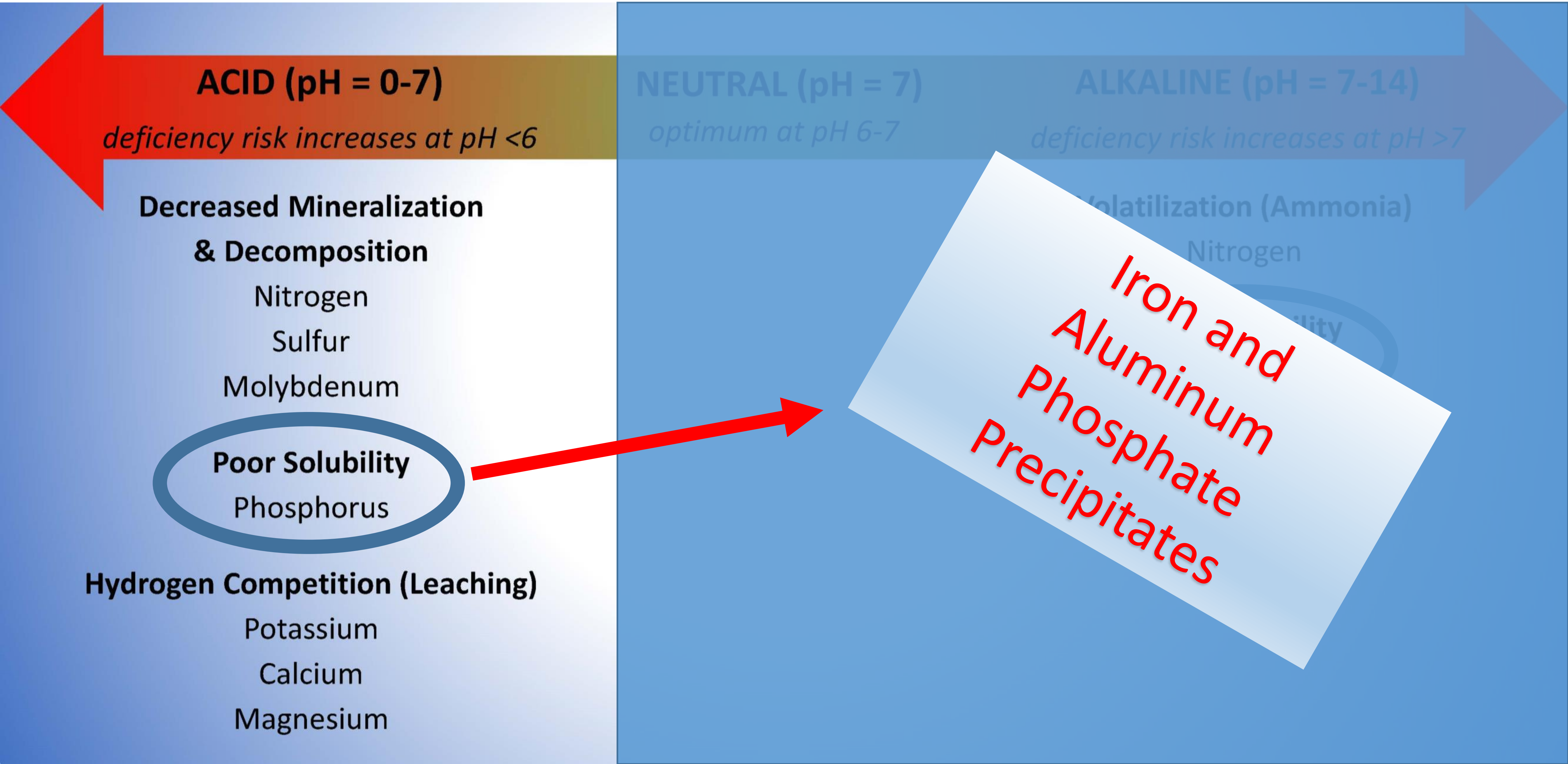
Volatilization (Ammonia)

Nitrogen

Poor Solubility

Phosphorus
Zinc
Manganese
Iron
Copper
Boron

Phosphorus is highly reactive in forming precipitates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Decreased Mineralization
& Decomposition
Nitrogen
Sulfur
Molybdenum
Poor Solubility
Phosphorus
Hydrogen Competition (Leaching)
Potassium
Calcium
Magnesium
Nitrogen
Iron and
Aluminum
Phosphate
Precipitates

ACID (pH = 0-7)

deficiency risk increases at pH <

NEUTRAL (pH = 7)

optimum at pH 6-7

ALKALINE (pH = 7-14)

deficiency risk increases at pH >7

Decreased Minerali

& Decom

Hydrogen Co

(Leaching)

Po

ium

Calcium

Magnesium

Calcium and Magnesium Phosphate Precipitates

Volatilization (Ammonia)

Nitrogen

Poor Solubility

Phosphorus

Zinc

Manganese

Iron

Copper

Boron

Most P is in solid form

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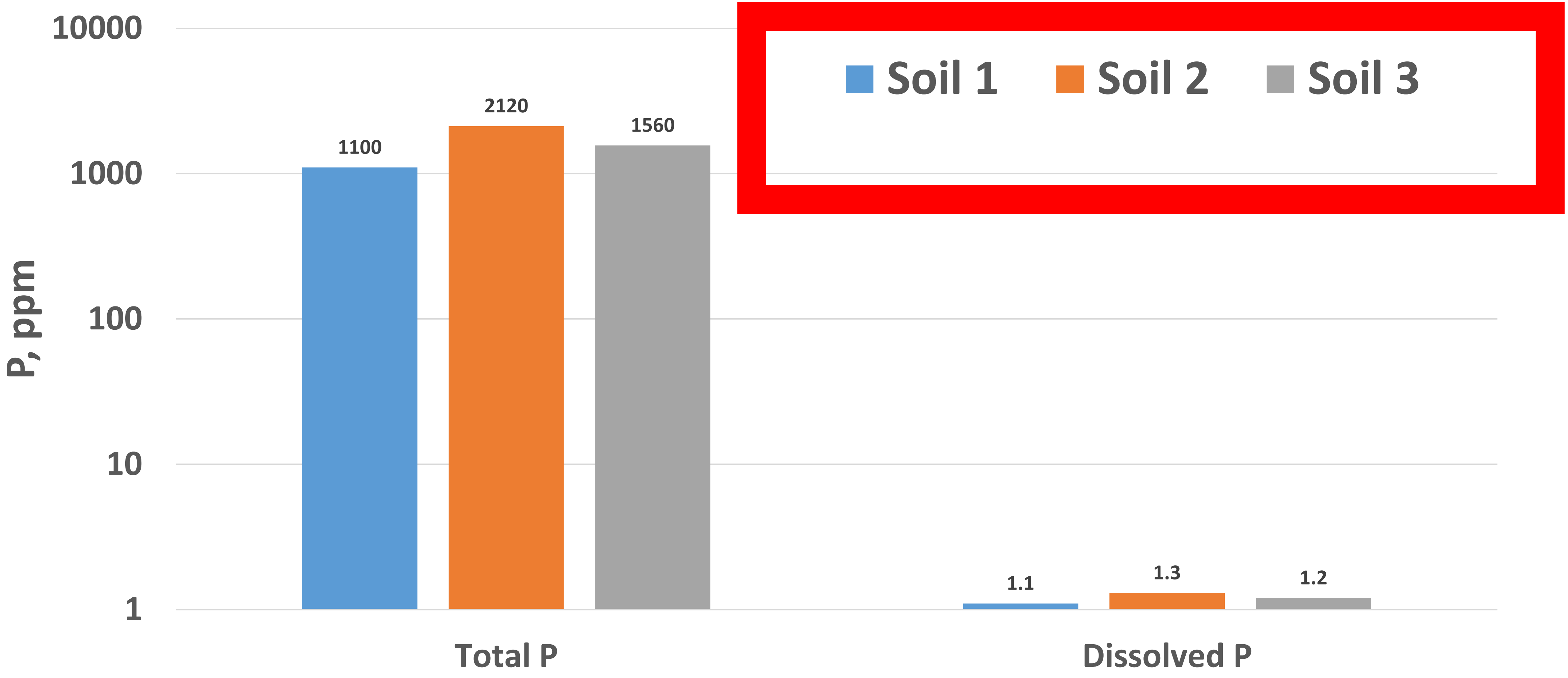
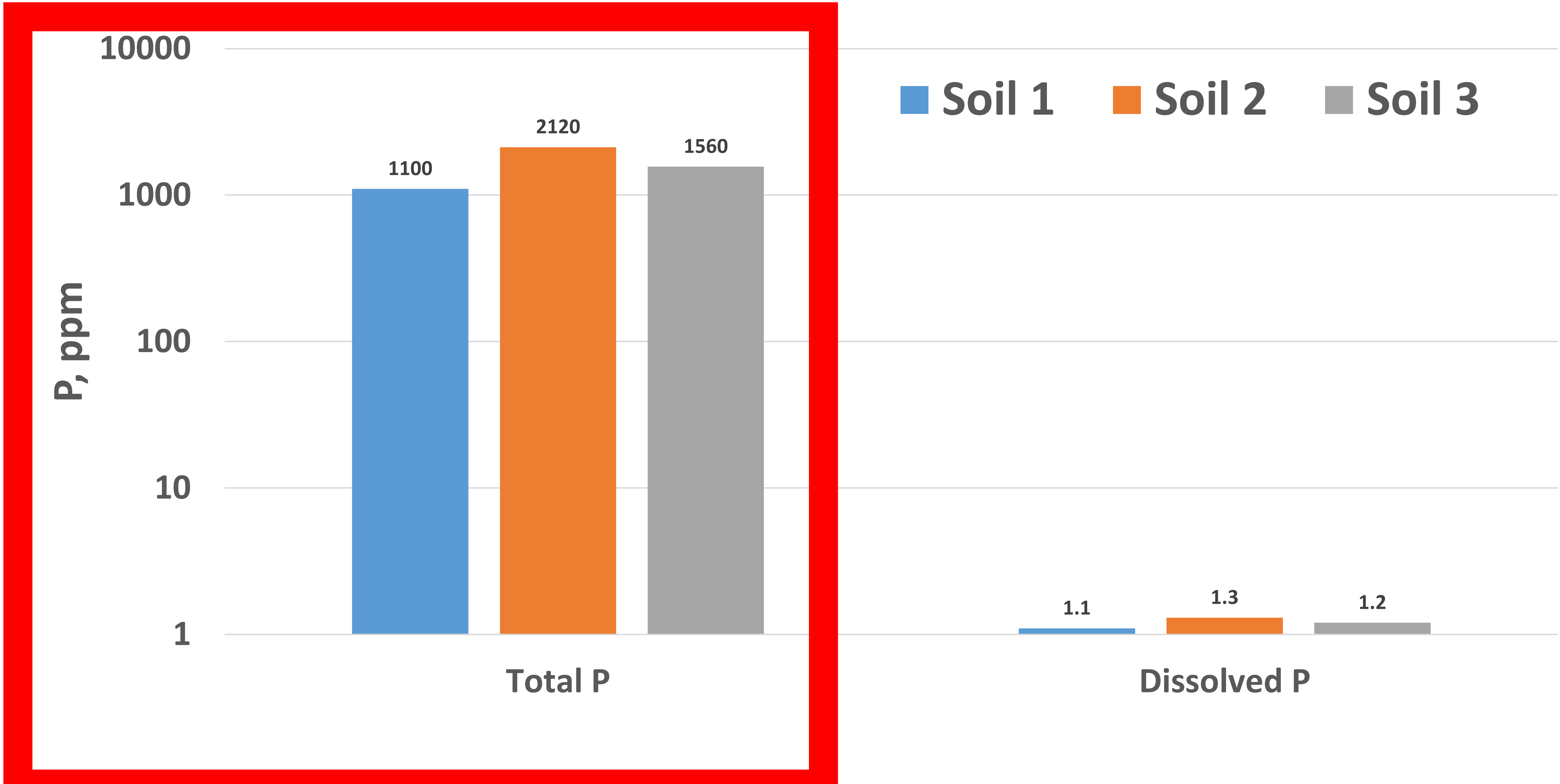
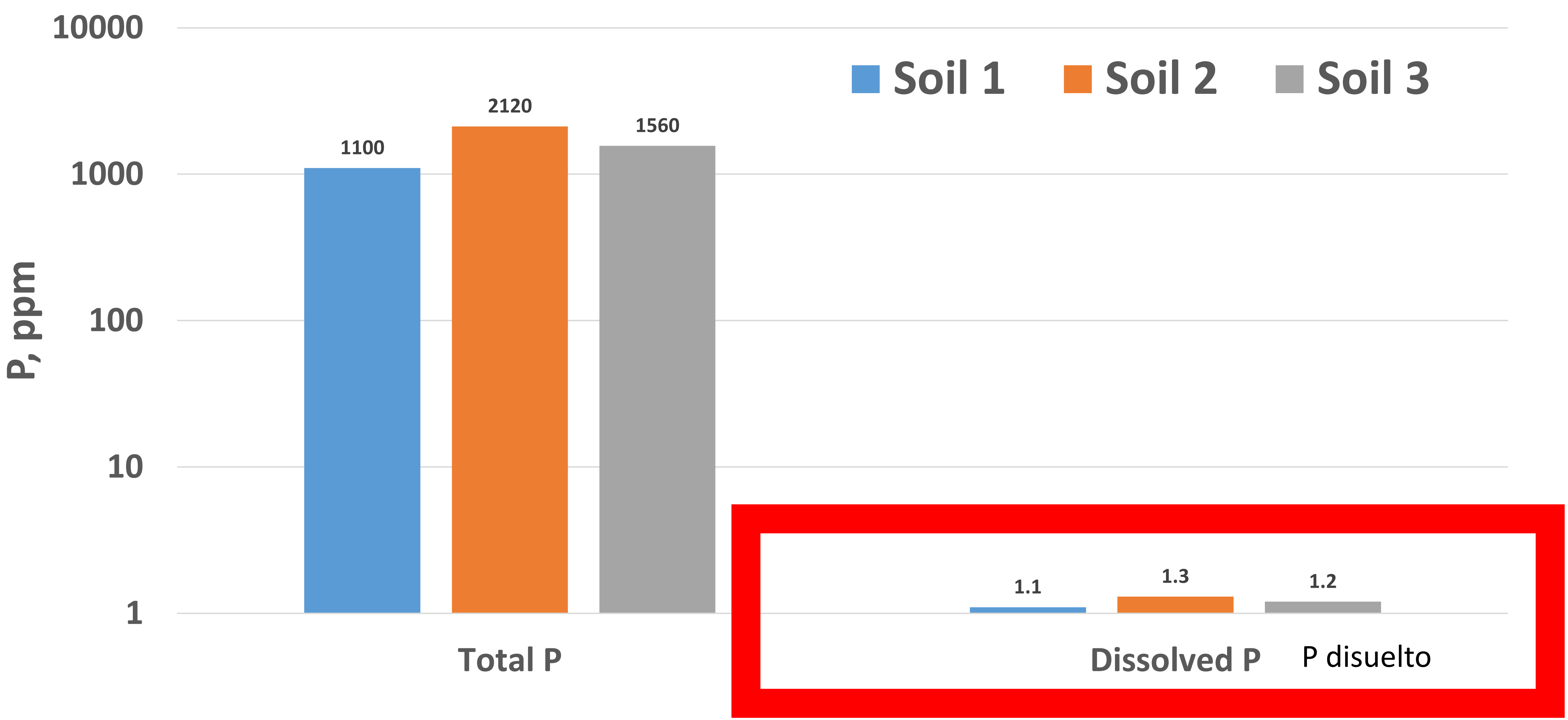


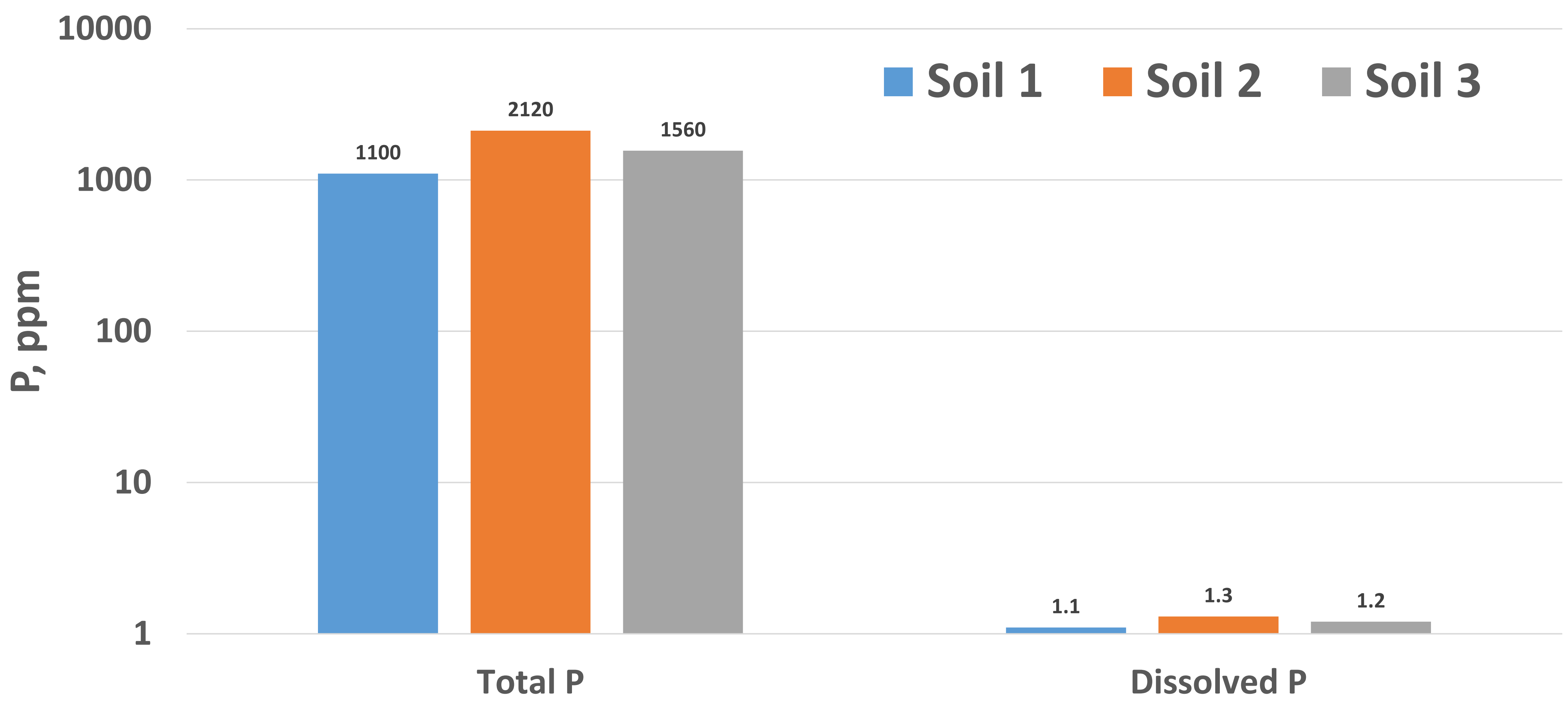
Most P is in solid form



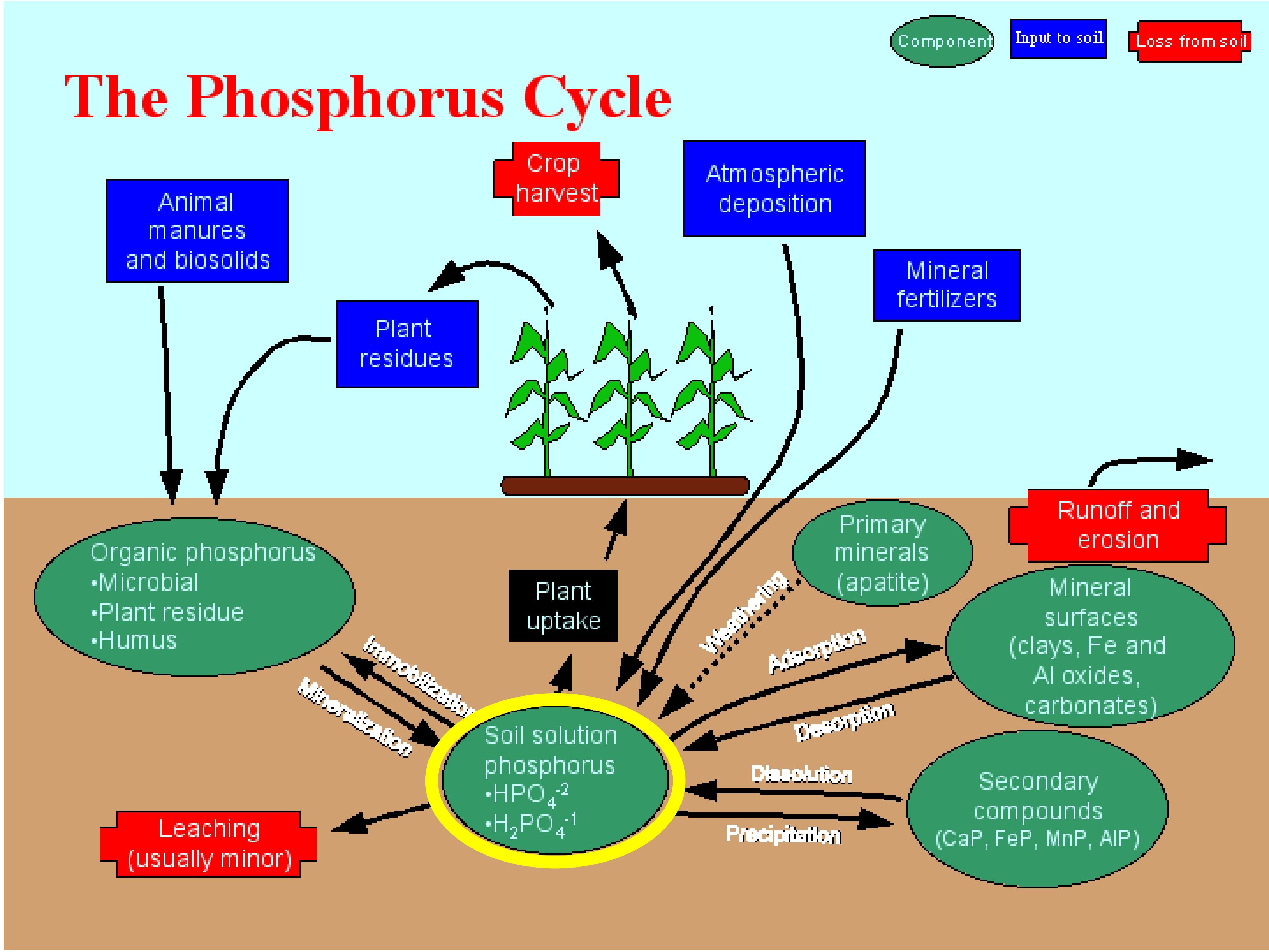
Most P is in solid form



Is it a problem if most P is in a solid form?

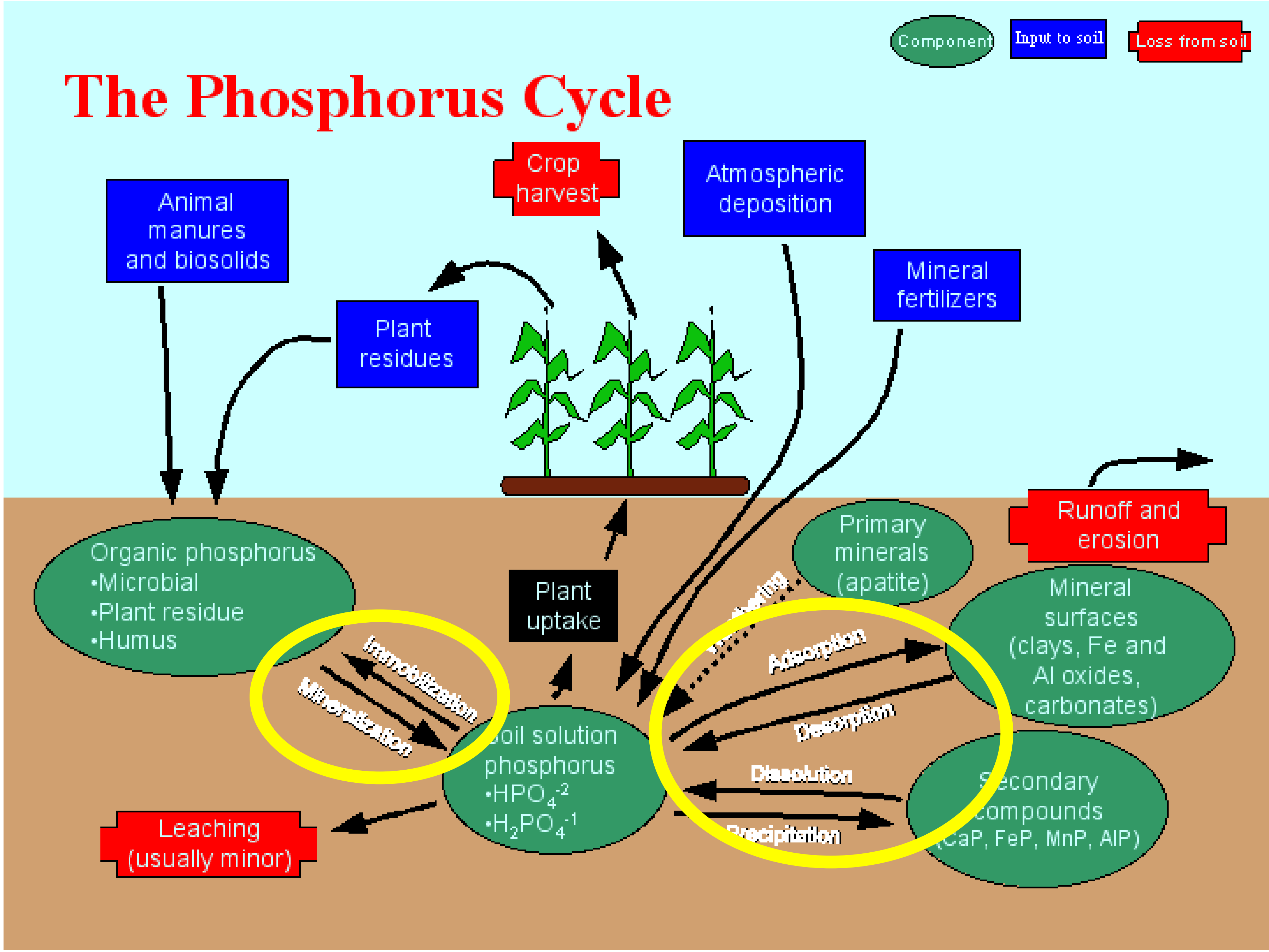


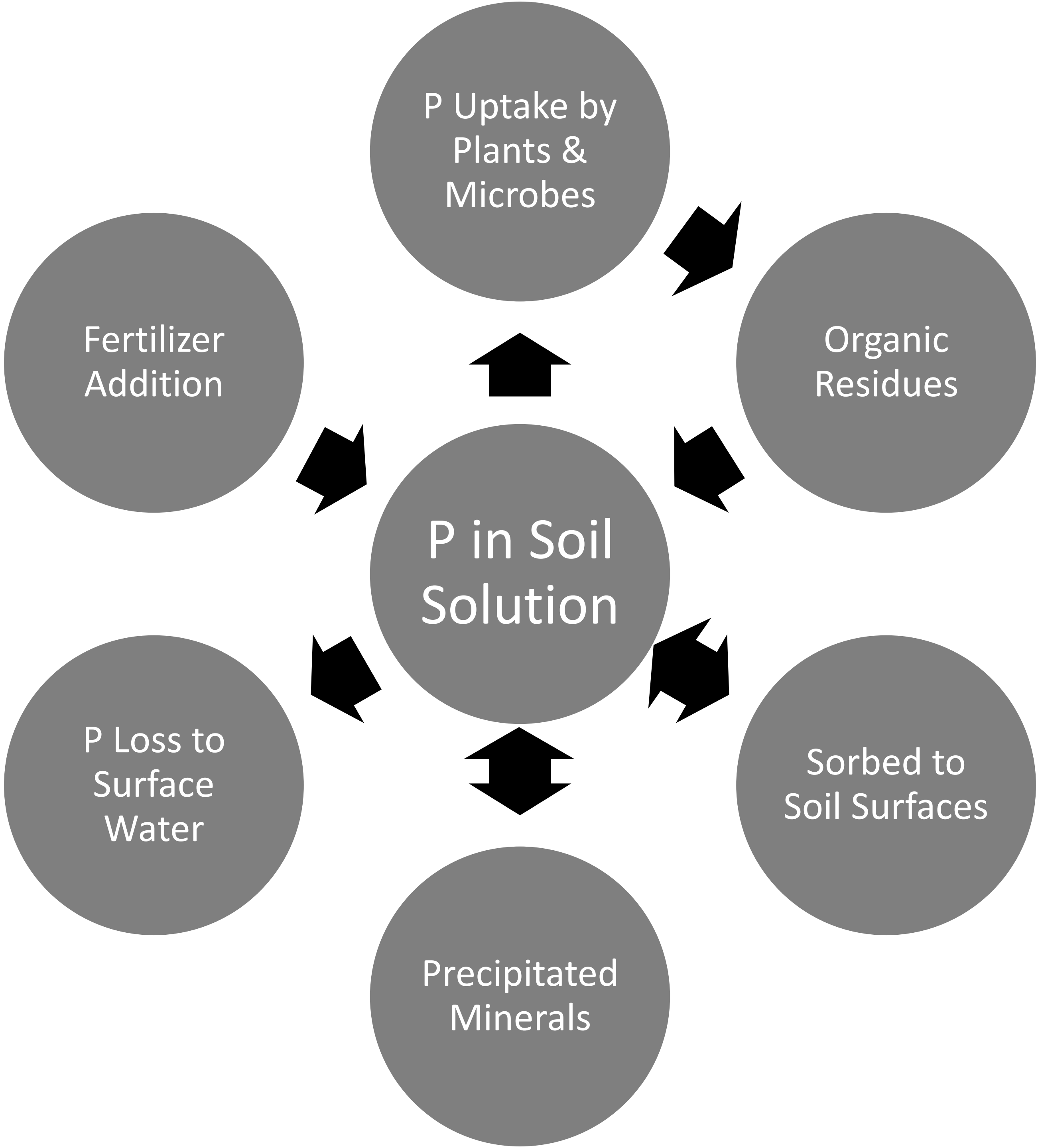
Equilibrium Chemistry



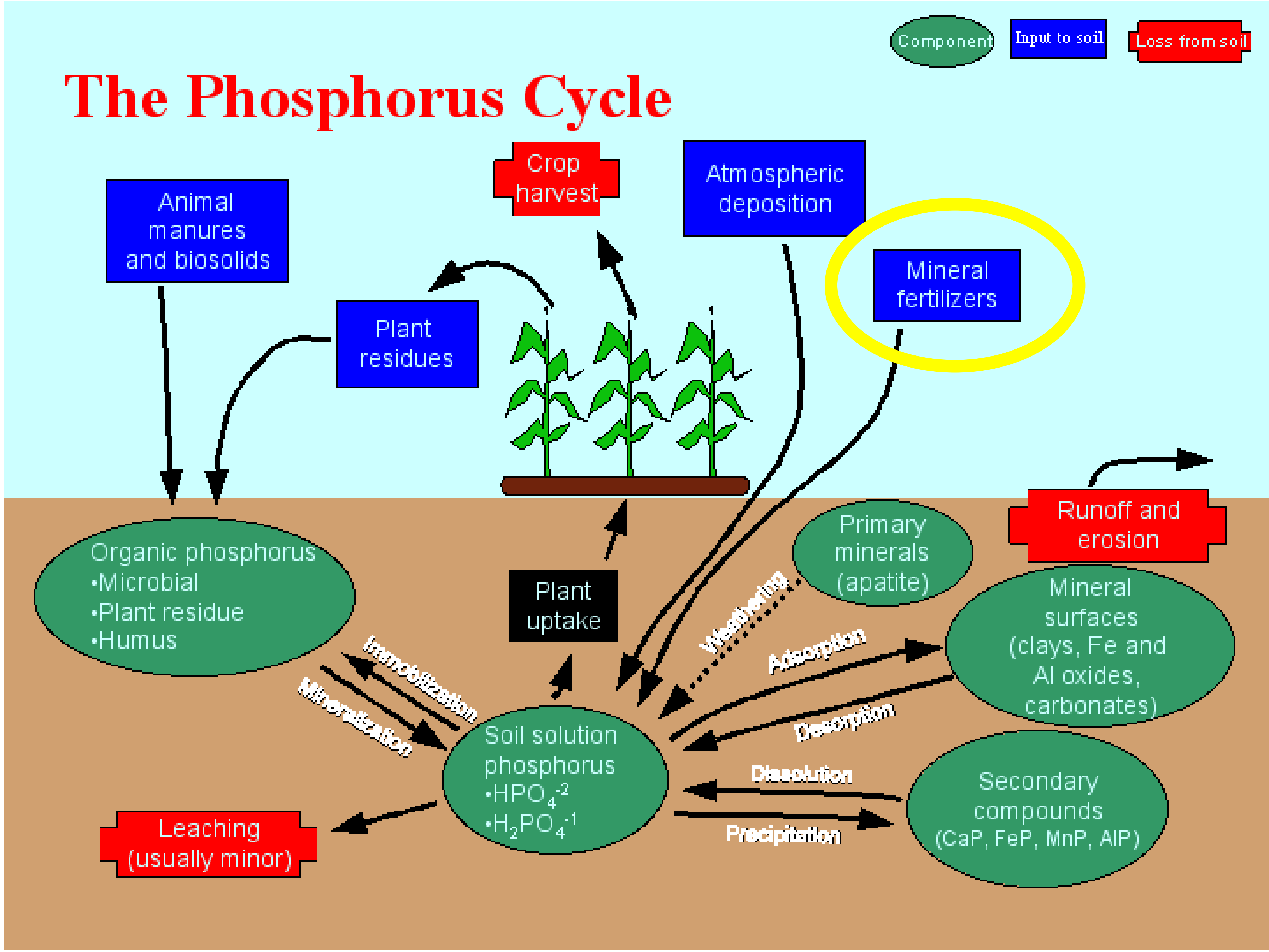
International Plant Nutrition Institute

Notice the arrows are going both directions between the soil solution P and the solid forms.

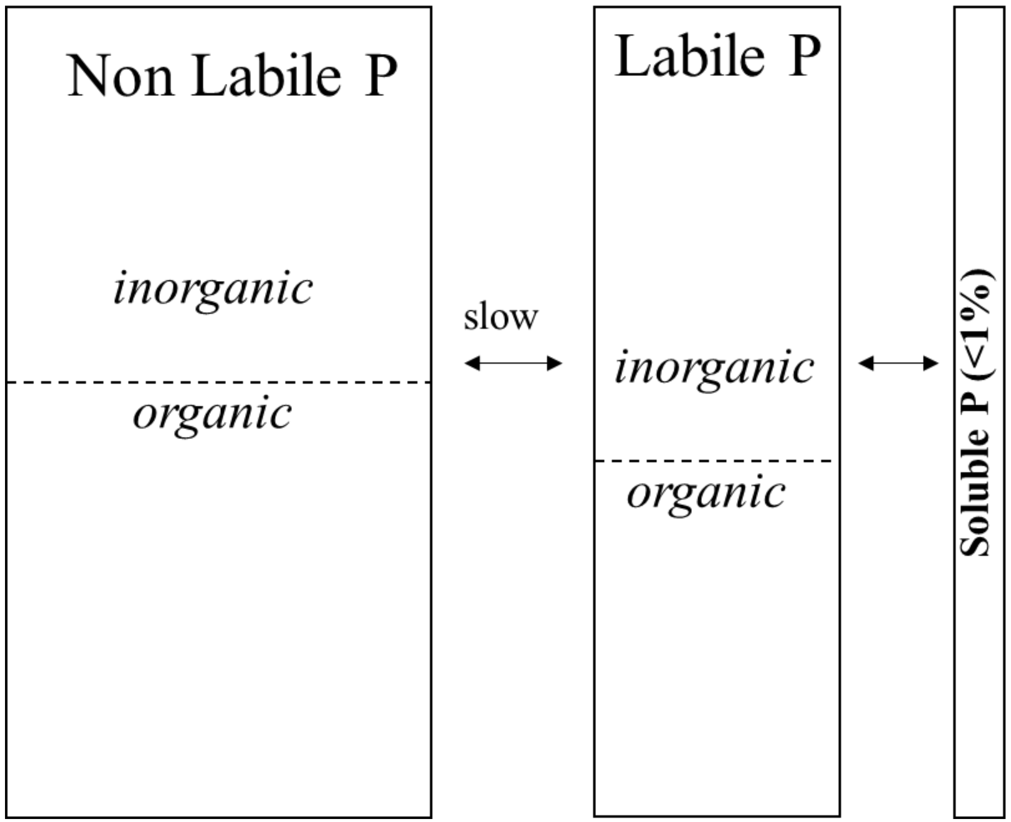



P Uptake by Plants & Microbes
Organic Residues
Fertilizer Addition
P in Soil Solution
P Loss to Surface Water
Sorbed to Soil Surfaces
Precipitated Minerals

Fertilizer P typically dissolves rapidly, but most of it precipitates (fixation).



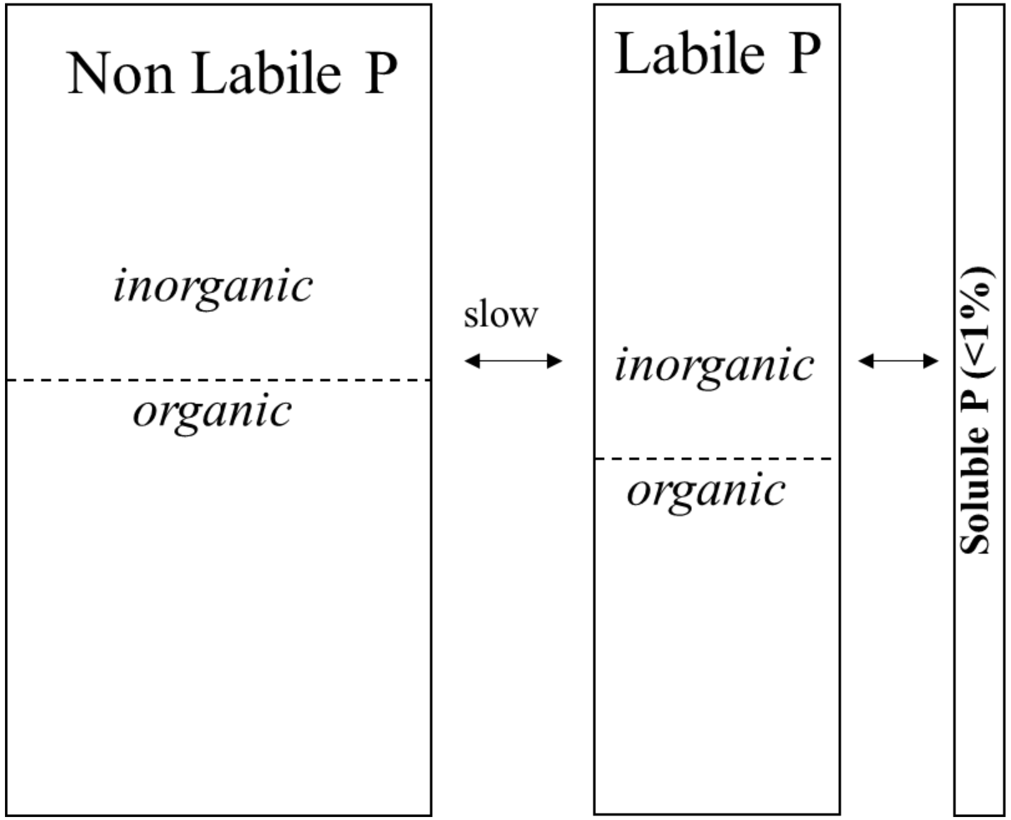
Phosphorus in the soil



Soil Total Phosphorus

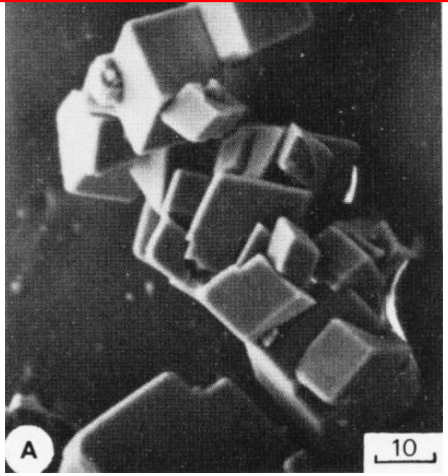
- Determined in the laboratory by a harsh chemical extraction
- Ranges 200-5000 mg/kg   Average ~ 500 mg/kg
  (~2,000 lbs/ac)

Phosphorus in the soil

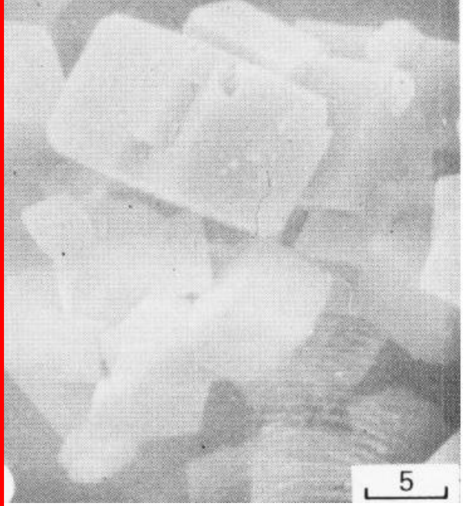


Soil Soluble Phosphorus

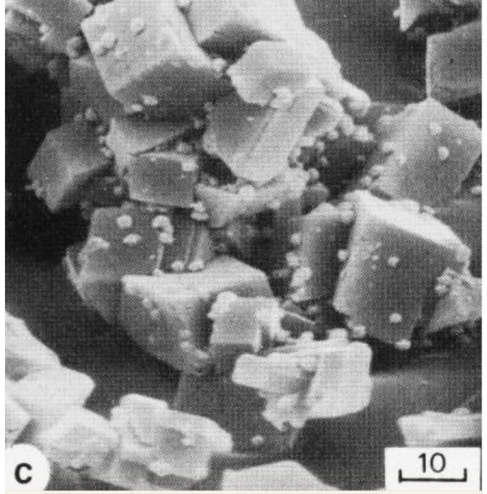
- Plants take P from solution
- Average soil solution concentration ~ 0.05 ppm (< 1 lb/ac)



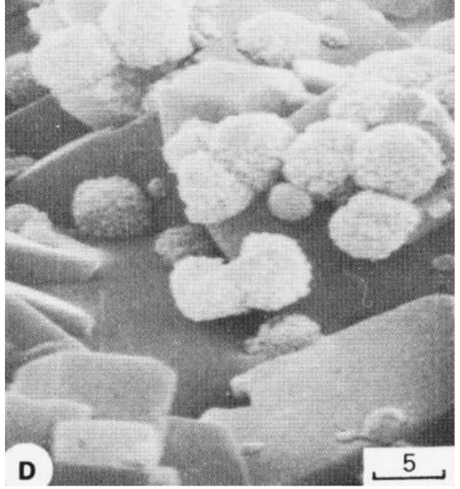
No P on calcite



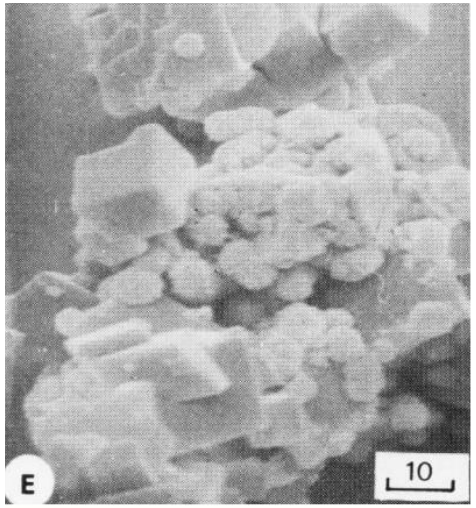
10 ppm



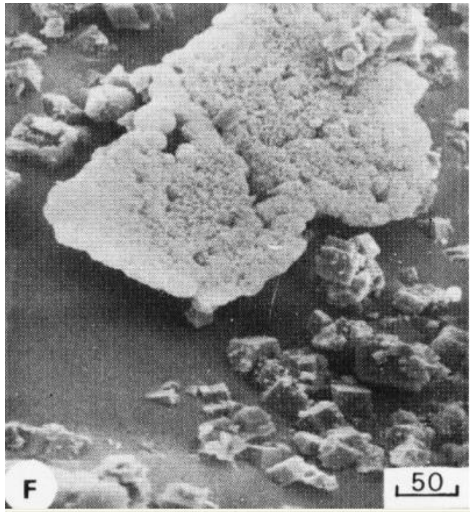
25 ppm



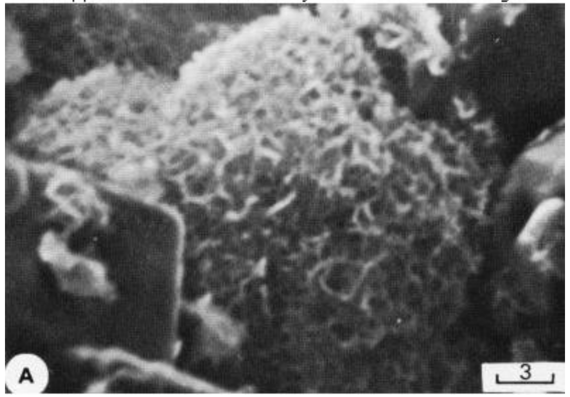
50 ppm



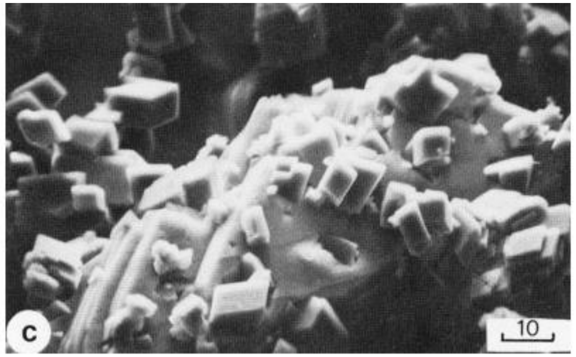
100 ppm



500 ppm

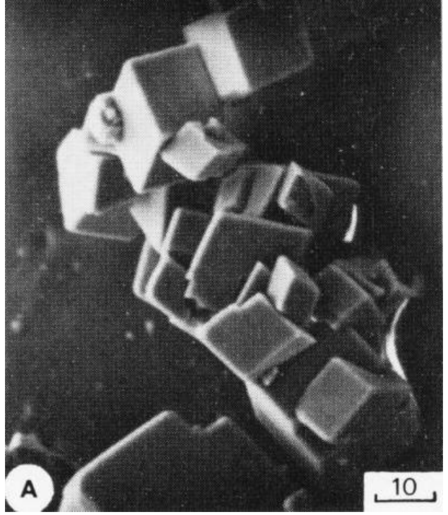


500 ppm on calcite after 10 days

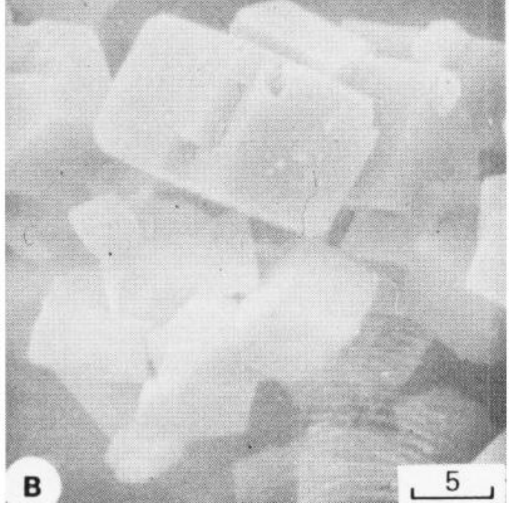


Large Ca P crystal

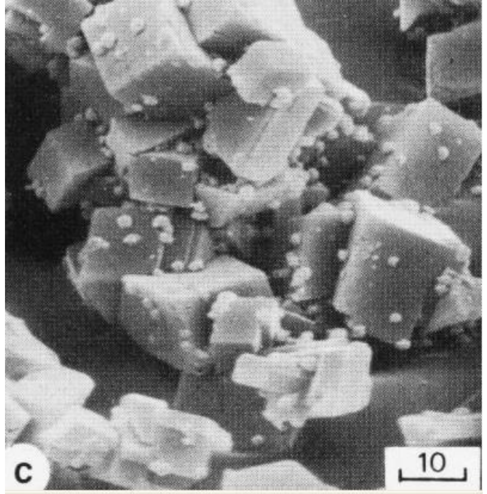
Freeman and Rowell, 1981. J. Soil Sci. 32:75-84



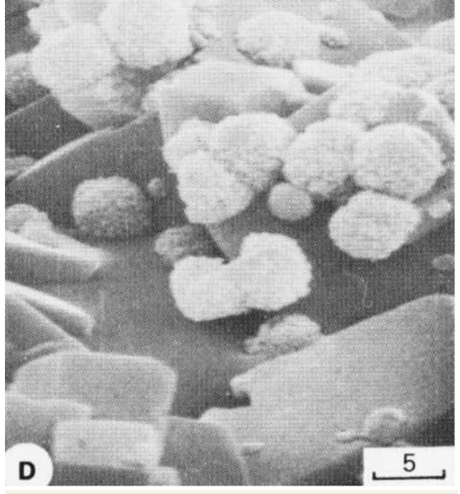
No P on calcite



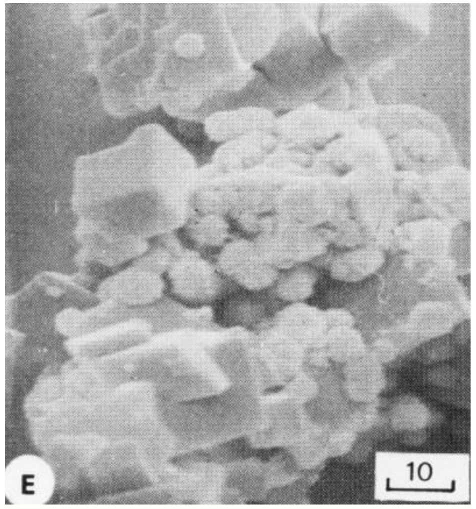
10 ppm



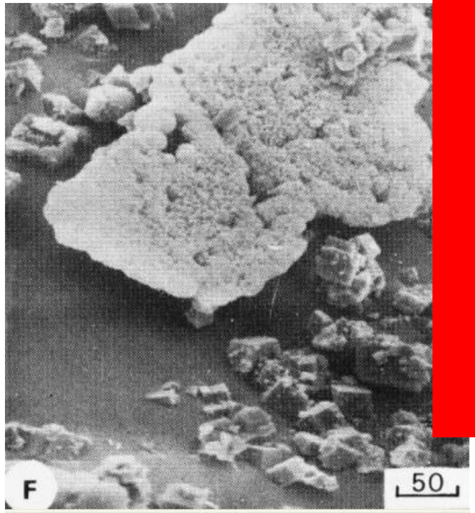
25 ppm



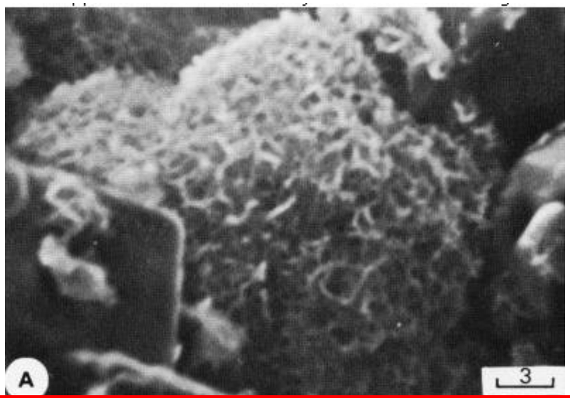
50 ppm



100 ppm

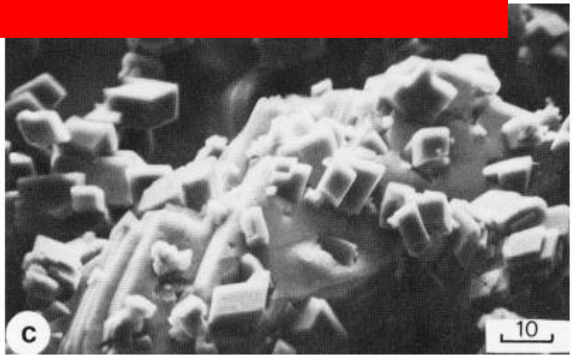


500 ppm



500 ppm on calcite after 10 days

Large Ca P crystal

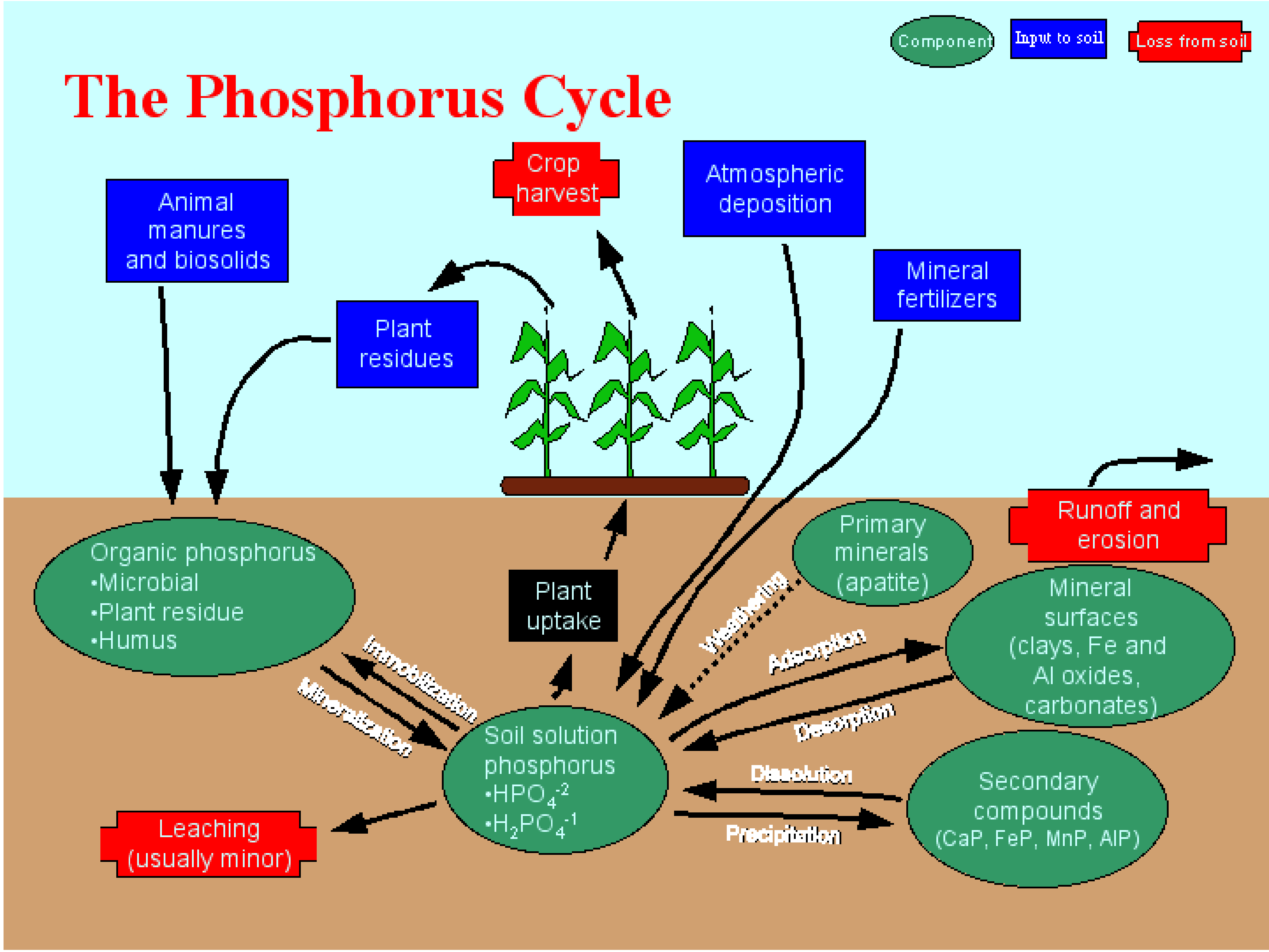


Freeman and Rowell, 1981. J. Soil Sci. 32:75-84

Is precipitated fertilizer P “lost”?

Is precipitated fertilizer P “lost”?

No!



How Does Equilibrium Chemistry Work?

1. Plants take up P
2. Soil solution P concentration decreases
3. Rate of P mineralization (dissolution) from minerals increases
4. Rate of P dissolution decreases once equilibrium is reached

What determines if there is a P deficiency?

Plants take up P

Soil solution P concentration decreases

Rate of P mineralization (dissolution) from minerals increases

Rate of P dissolution decreases once equilibrium is reached

Demand and Supply

1. **Plants take up P**
2. **Soil solution P concentration decreases**
3. **Rate of P mineralization (dissolution) from minerals increases**
4. **Rate of P dissolution decreases once equilibrium is reached**

Stunted plants with slower row closure on this eroded hillside with P deficient calcareous soil.

Photo taken by B.G. Hopkins of field near St. Anthony, ID

- 4Rs
  - The Right
    - Rate
    - Timing
    - Placement
    - Source

Modernizing Proven Practices

- Soil Test Phosphorus Critical Levels
- Foundational Management Practices

Phosphorus Best Management Practices

- Select appropriate solid and/or liquid sources with high availability of P to plants.
- Account for degradation rates of crop residues and animal wastes, especially in cool soils.
- Account for the possible value, synergy, and/or toxicity of accompanying nutrients and other chemicals in the fertilizer blend.
- Avoid unwanted precipitation or caking or clumping during handling.
- Correct and/or account for soil pH and other chemical properties of soil and their interaction with fertilizers.
- Use appropriate P fertilizer rates based on scientific and/or on-farm studies (P response and/or omission plots) specific to the P source, soil, and cropping system.
- Use tissue analysis to evaluate fertilizer effectiveness with, if needed, rescue applications of P appropriate for the cropping system, followed by adjustments in preplant fertilization in future years.
- Evaluate root growth and vascular system health to determine the effectiveness of this aspect of the P supply system for the plant.

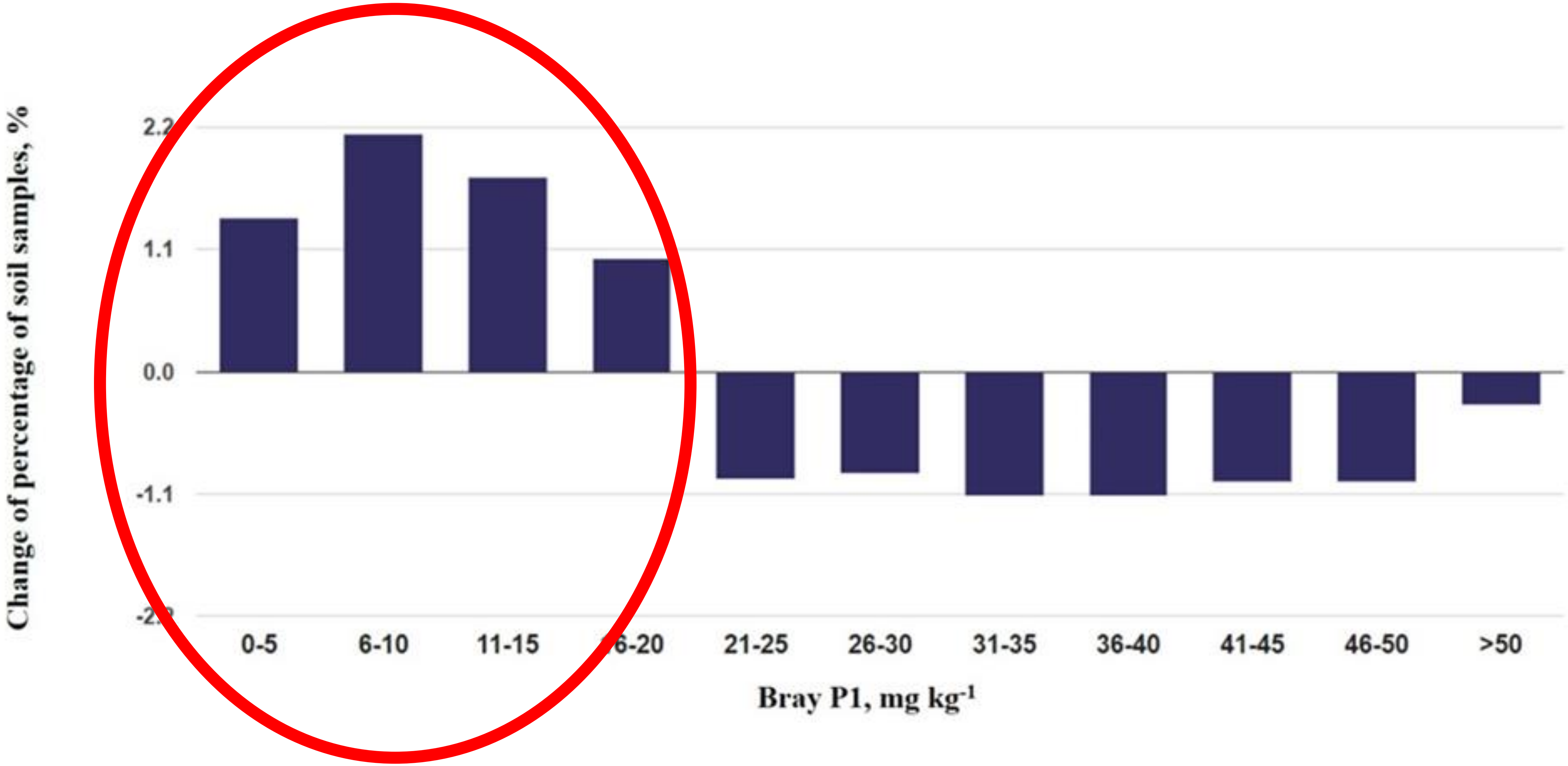
4Rs

- Right Rate
- Right Placement
- Right Timing
- Right Source

Right Rate

- Good Soil Sample
- Accurate Soil Test

Soils in the deficient category are increasing in percentage

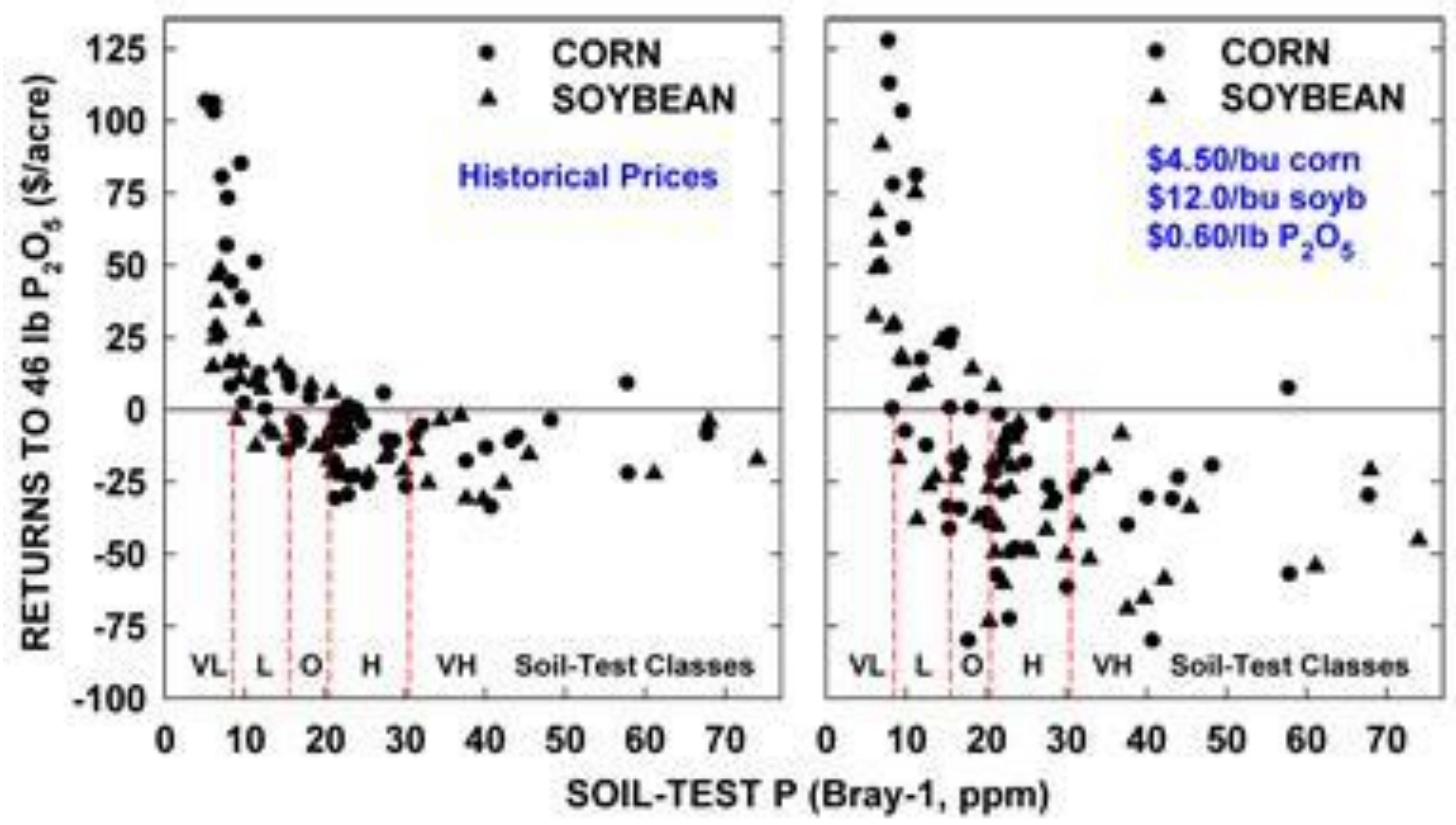


IPNI Soil Test Summary

Right Rate

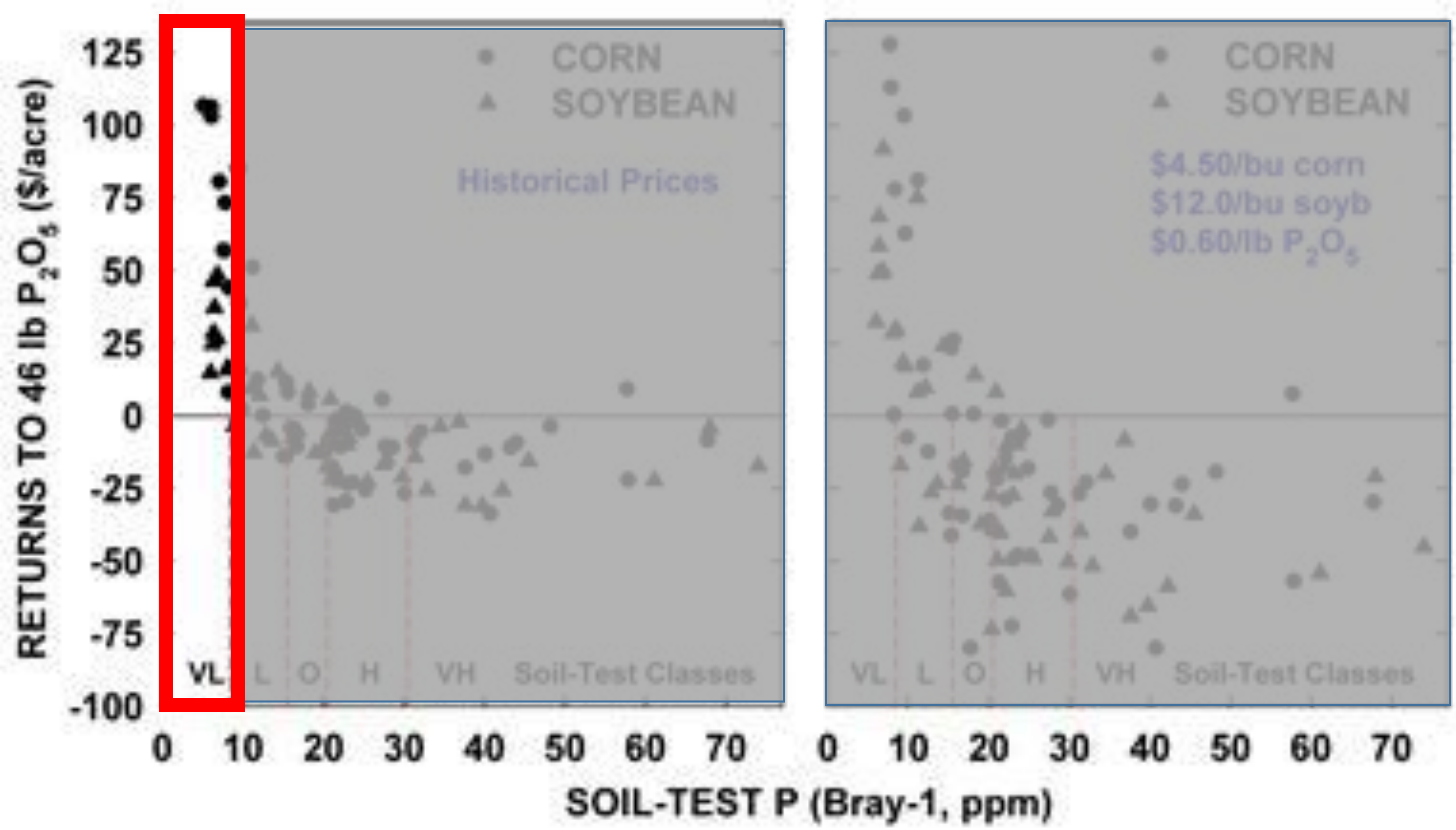
- Proper Interpretation (Tables from Scientific Studies)

- Soil testing is proven, although not perfect

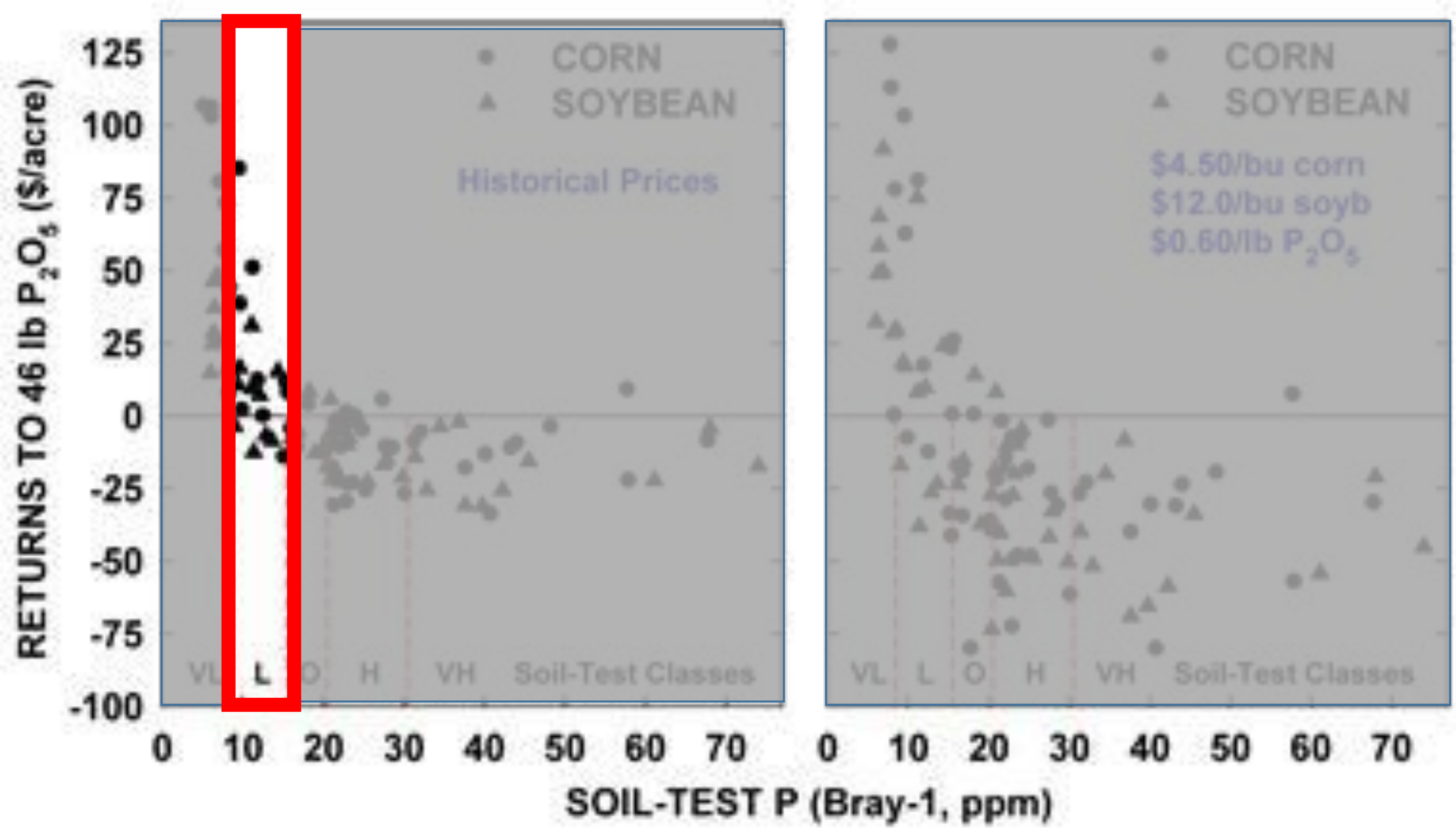


https://crops.extension.iastate.edu/cropnews/2008/09/making-fertilization-decisions-fertilizer-prices-escalate-and-production-costs-are

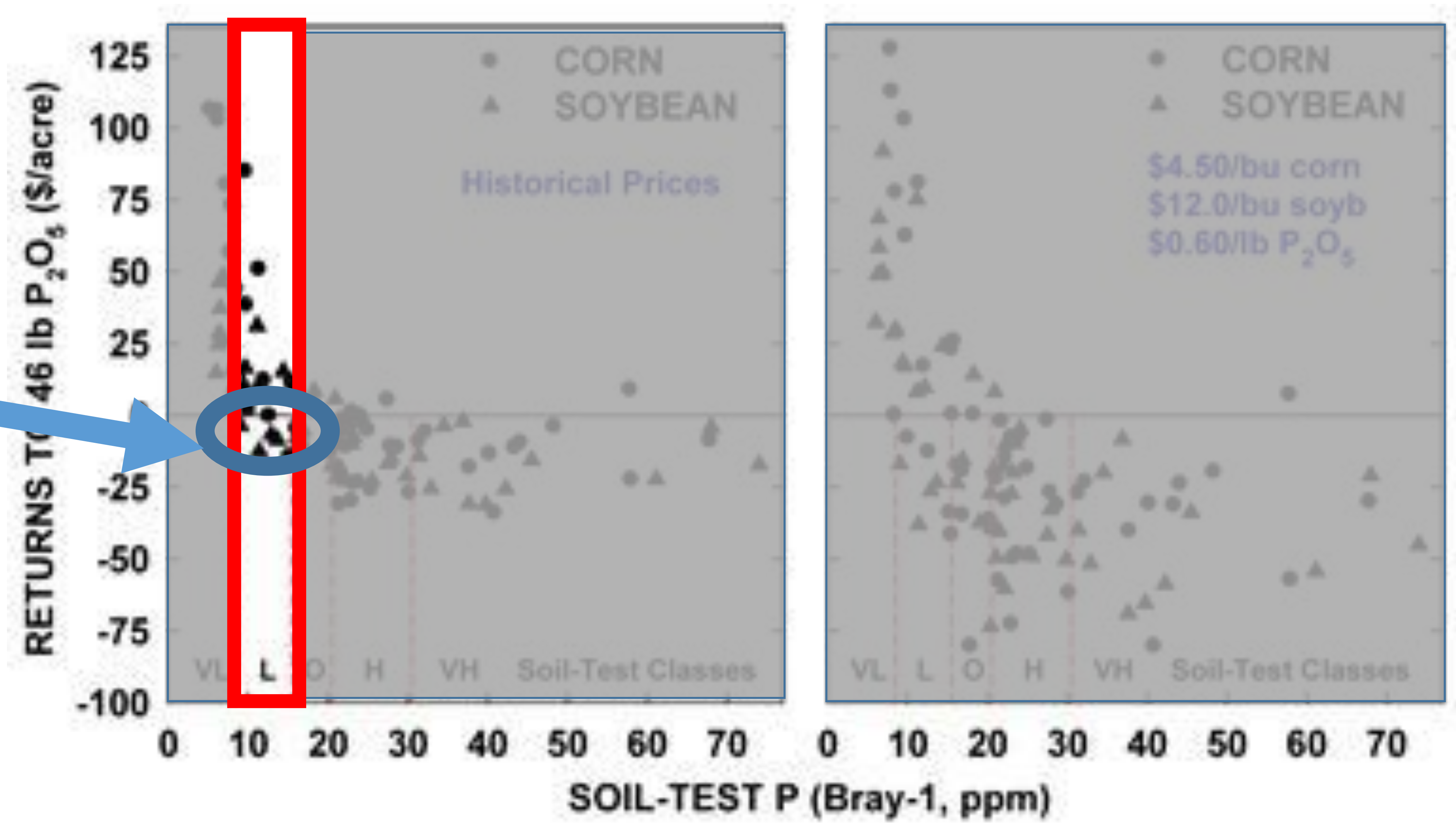
- P fertilizer was always profitable when soil test was "*very low*".



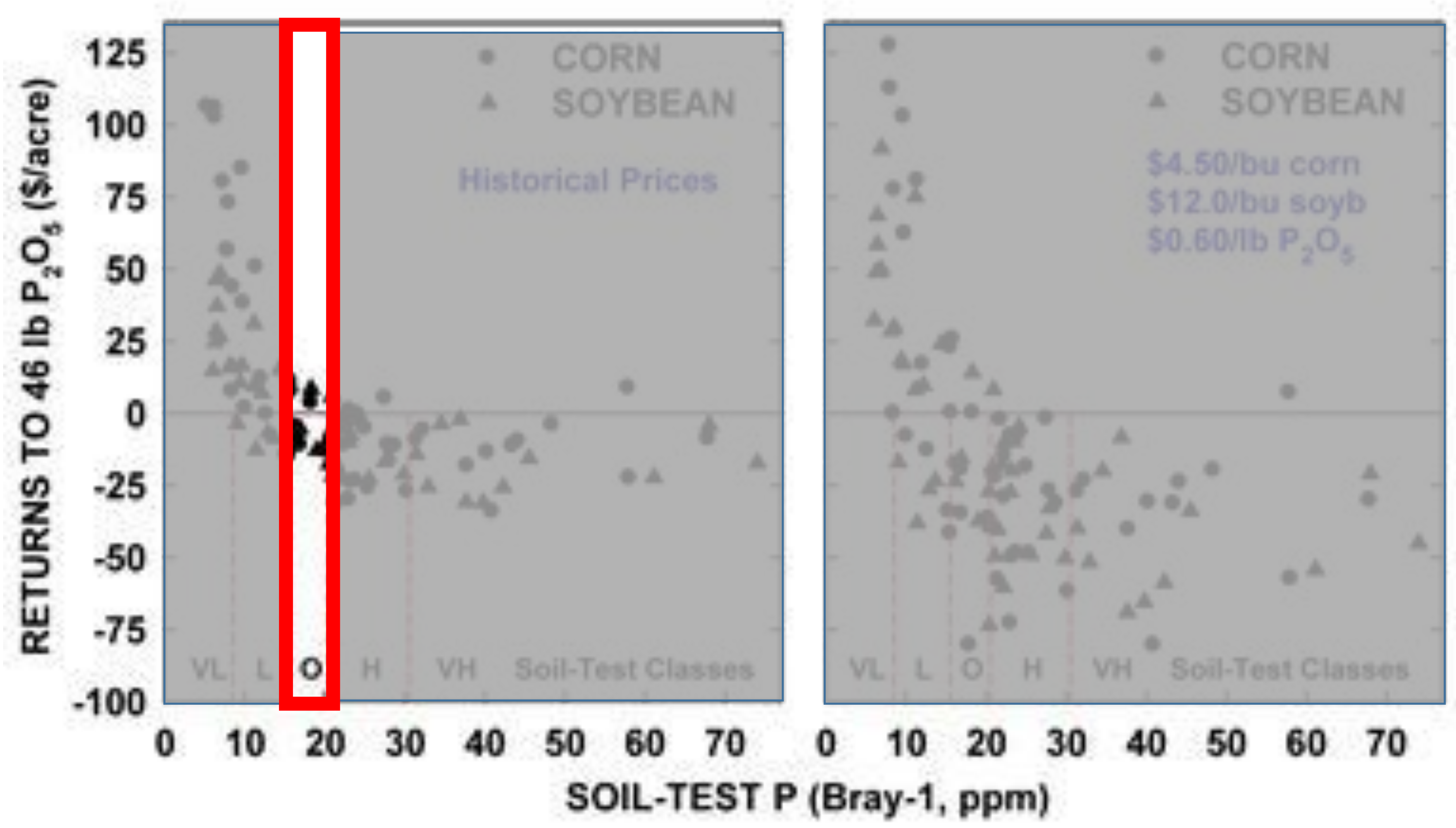
- P fertilizer was generally profitable when soil test was "*low*".



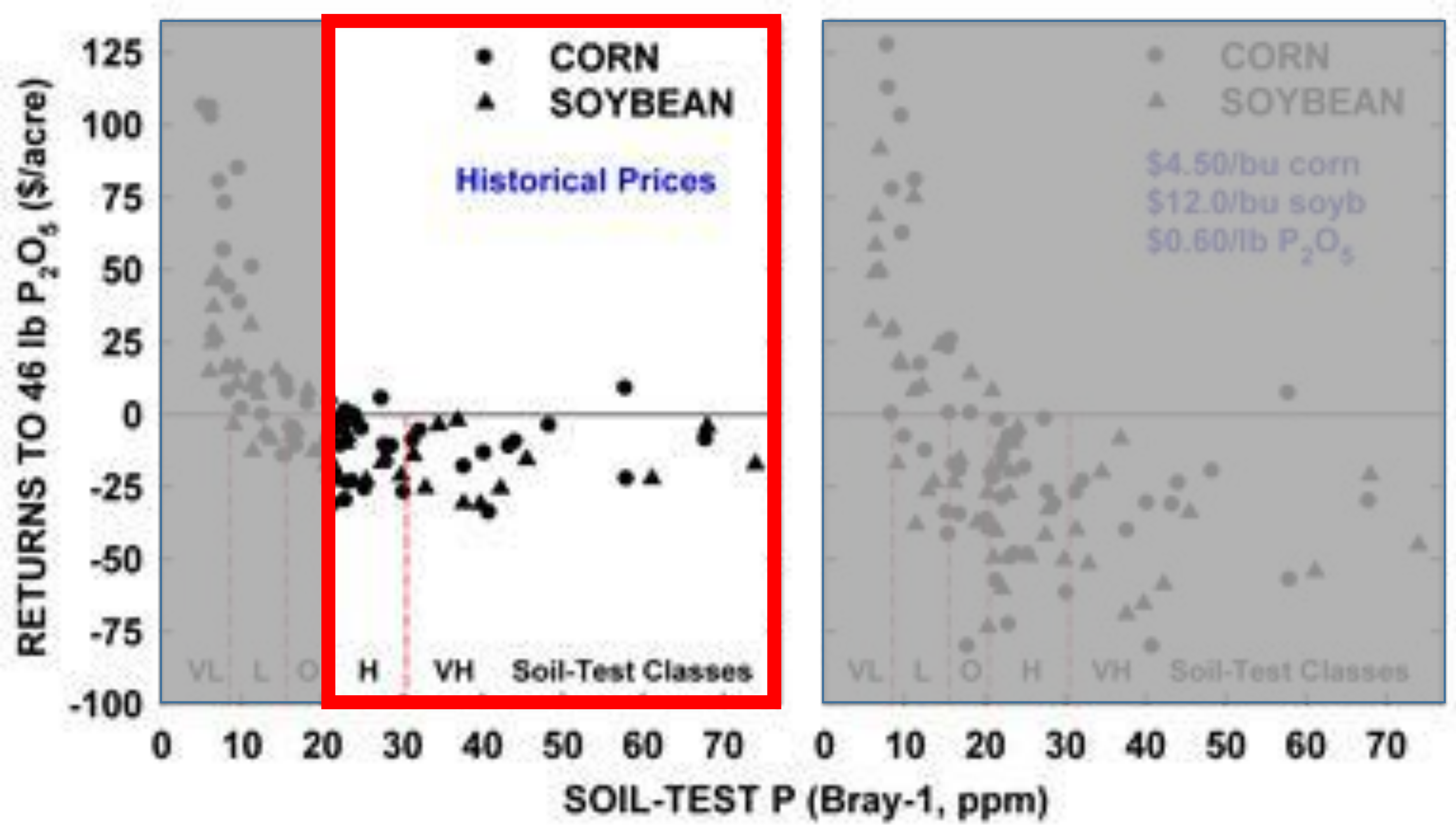
- However, the prediction was not perfect in every case.



- P fertilizer was not needed when soil test was at the "*optimum*" level.

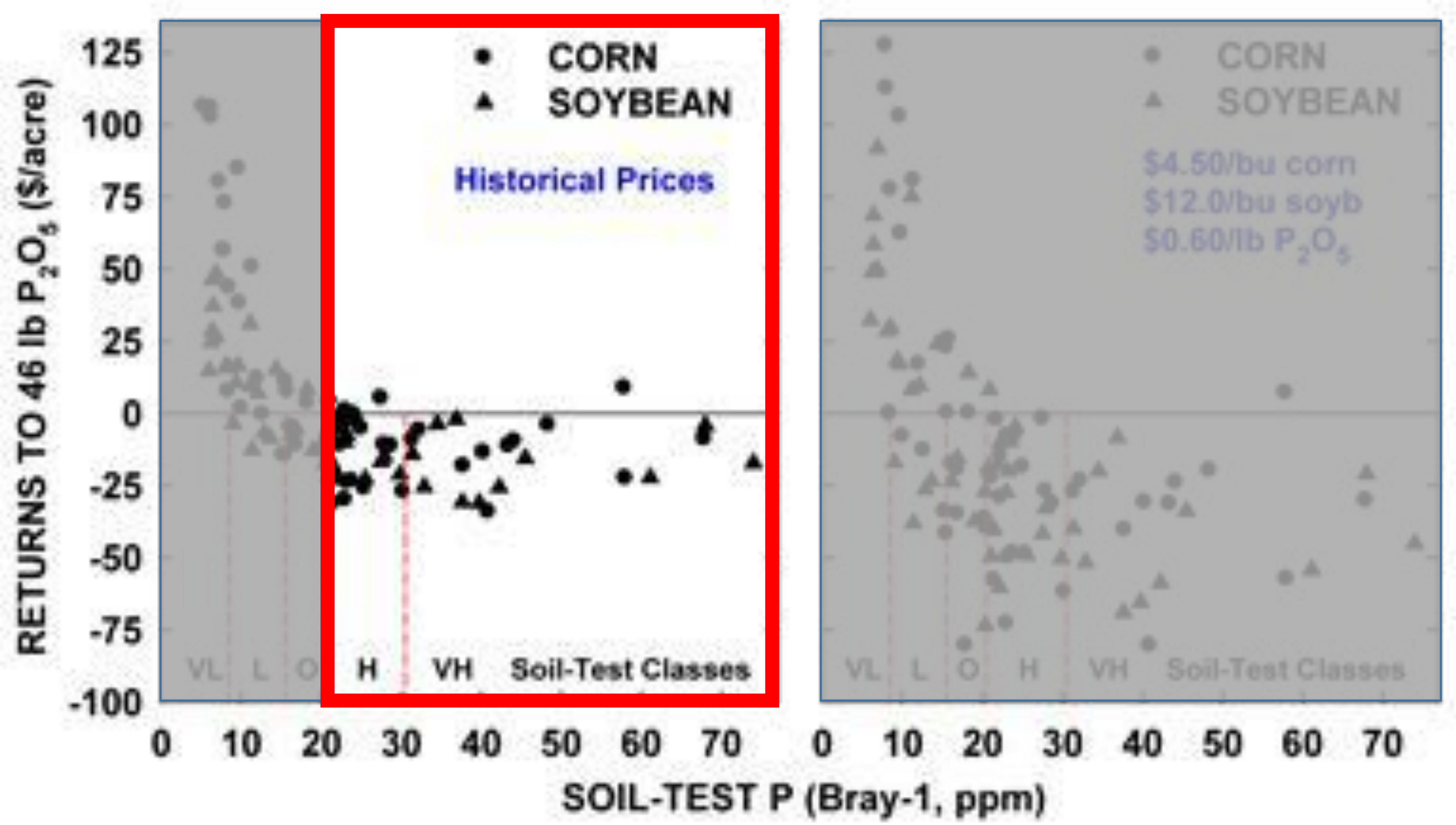


- P fertilizer had a negative return when the soil test was "*high*" or "very *high*".

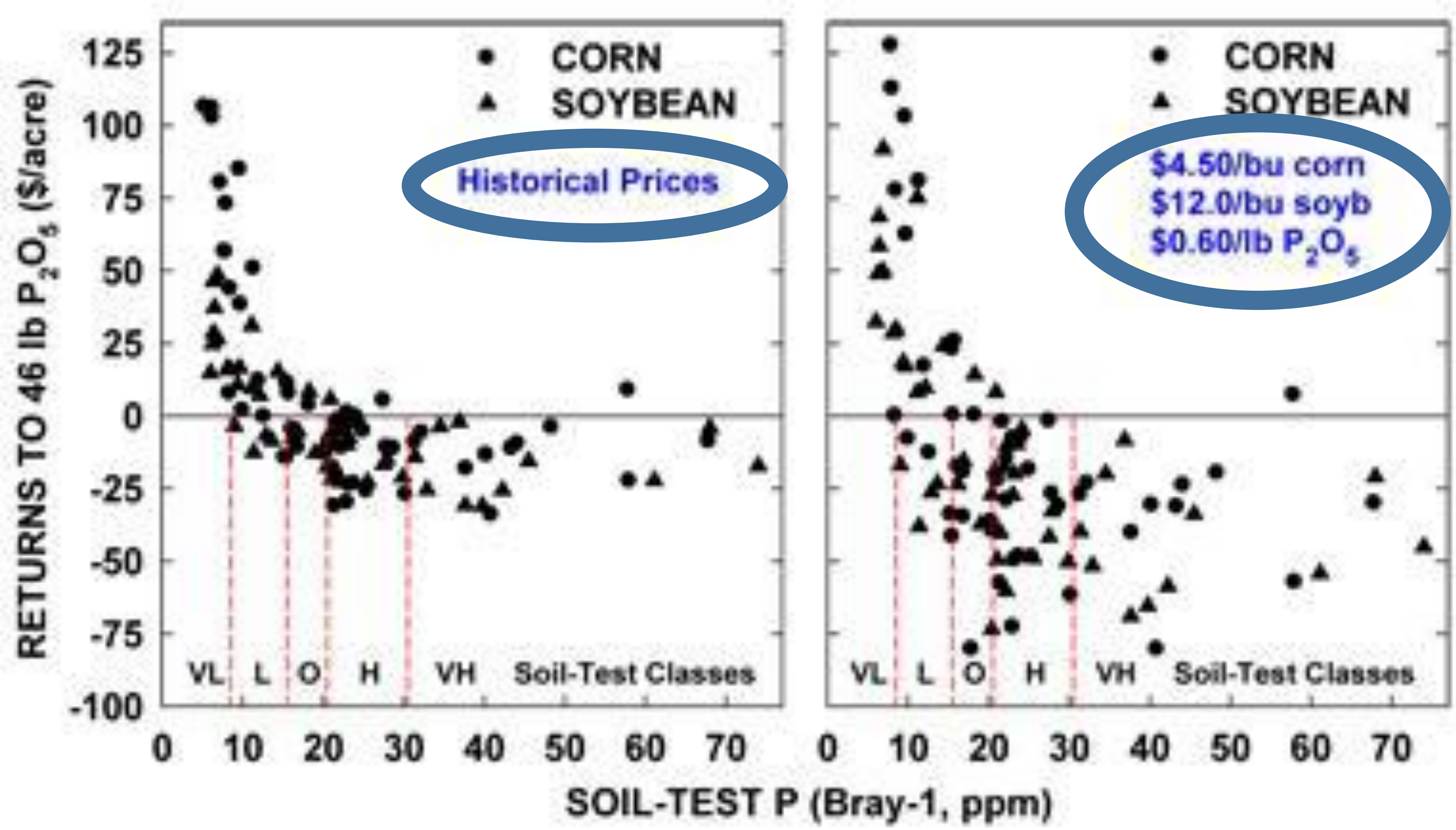


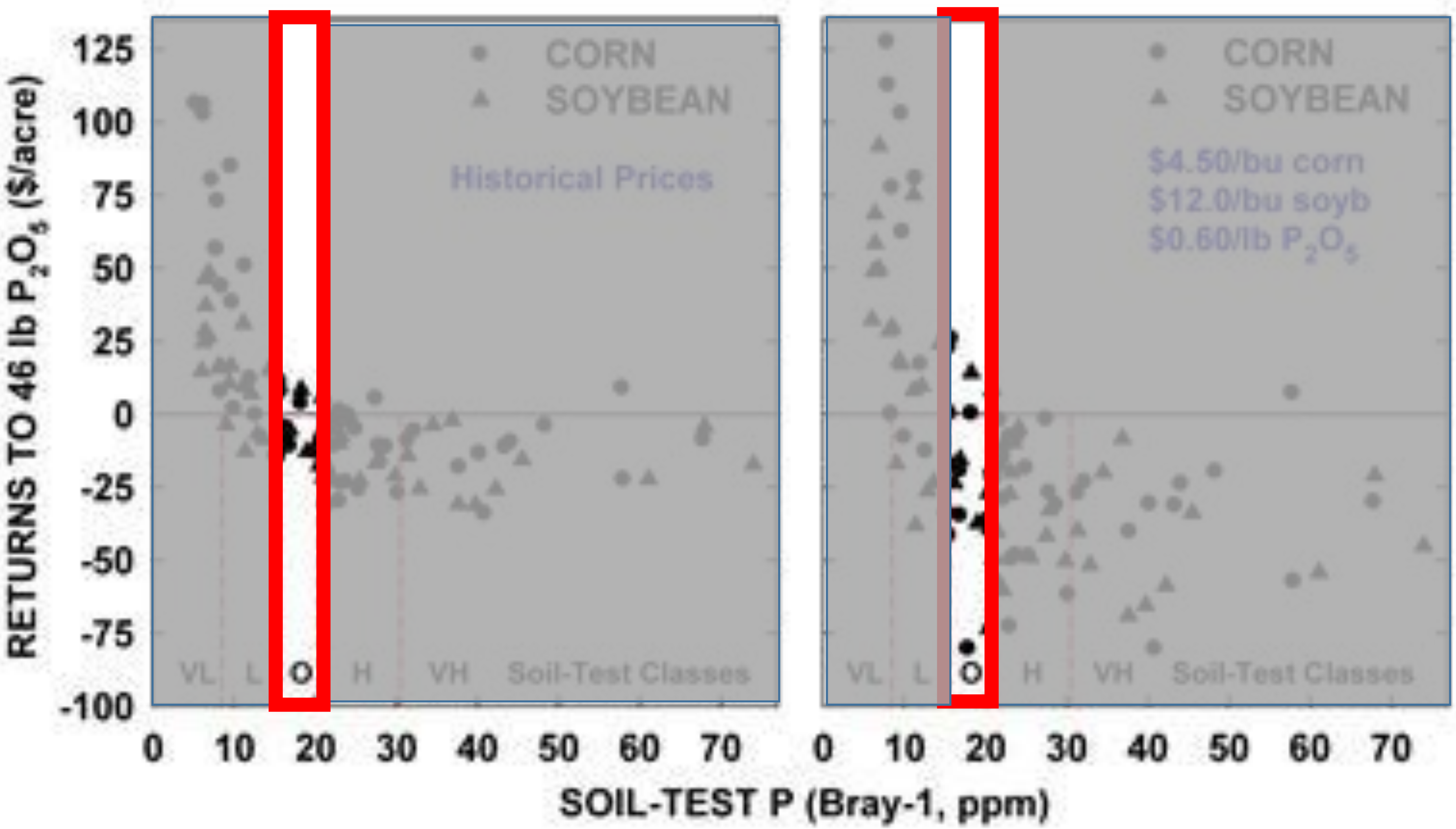
Rate / Velocidad

- But, overall, this is a good tool that would be foolish to dismiss.



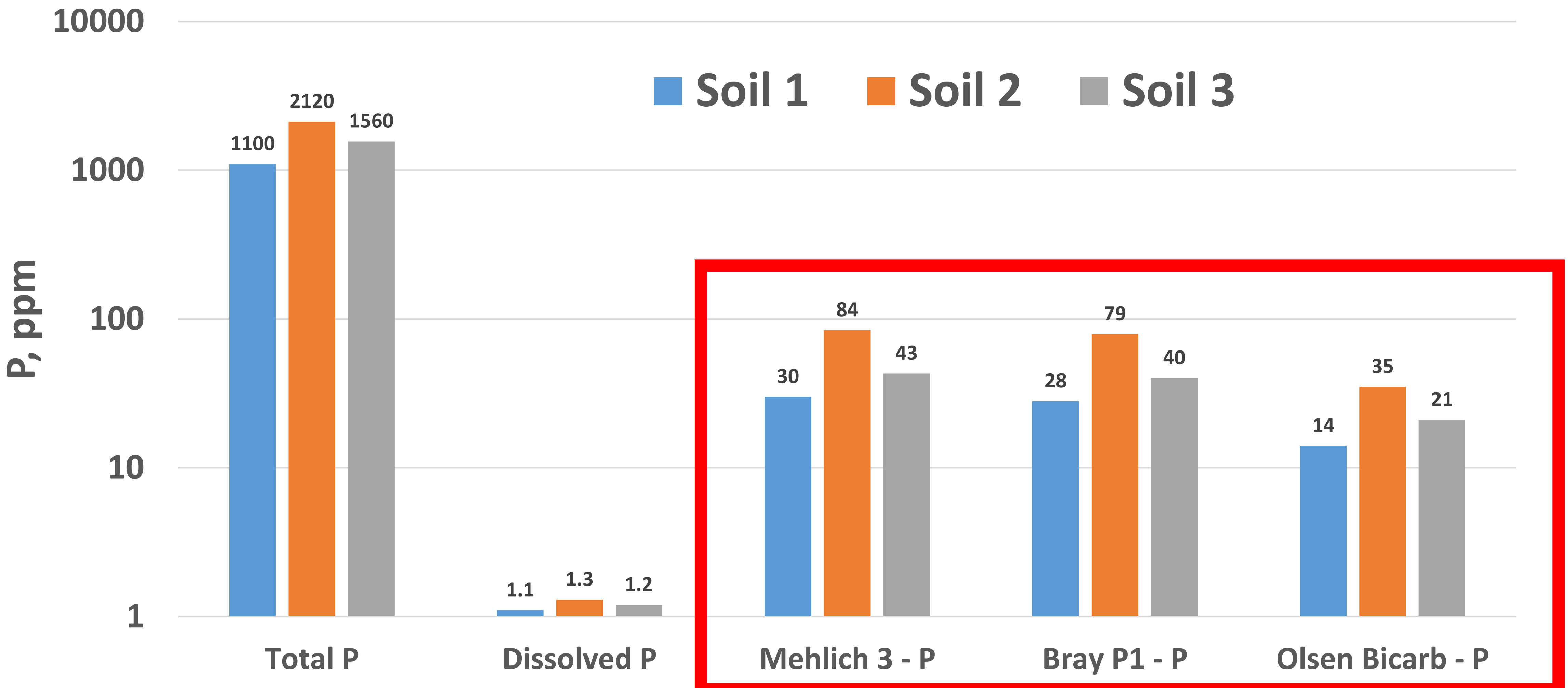
- The interpretation shifts based on the value of the crop and price of fertilizer P.





RETURNS TO 46 lb P_2O_5 ($/acre)
125
100
75
50
25
0
-25
-50
-75
-100
CORN
SOYBEAN
Historical Prices
VL
L
O
H
VH
Soil-Test Classes
$4.50/bu corn
$12.0/bu soyb
$0.60/lb P_2O_5
0
10
20
30
40
50
60
70
SOIL-TEST P (Bray-1, ppm)

Soil Test Methods vary in value, but common methods are generally effective if used on intended soils.



Hopkins, B.G. unpublished data—example of P concentrations in three non-calcareous soils from the Midwestern region of the USA.

Soil Testing is valuable if . . .

- Sampling done properly (account for differences in spatial and depth differences, avoid contamination, etc.)

Soil Testing is valuable if . . .

- Good analysis by a competent lab using a good method.

Soil Testing is valuable if . . .

- Proper interpretive scale needs to be used.

Ok, how do we manage?

- 4Rs
  - Right Rate
  - Right Timing

Right Timing

- Fall vs. Spring?
- Fertigation or Foliar?

In general, P timing is very different than N & K fertilizer due to chemistry.

- Apply pre-plant so it can be placed in the root zone.

P Use Efficiency (PUE) in decreasing order

- Pre-Plant or At-Planting
  - concentrated bands in root zone (~25-35% uptake in 1st year)
  - broadcast and incorporated (~5-10%)
- In-Season (~1-8%)
  - surface concentrated bands
    - (although drip fertigation can be higher)
  - injection into overhead irrigation (fertigation),
  - foliar sprays, and
  - surface broadcast not-incorporated

Ok, how do we manage?

- 4Rs
  - Right Rate
  - Right Timing
  - Right Placement

Right Placement

- Incorporate into the soil is better than applied to surface (or use a mobile form of P fertilizer)

Right Placement

- Place in a concentrated band near the roots increases 1^{st} year P uptake by more than double.

Majority of P taken up from soil
(even when foliarly applied)

Broadcast P needs to be incorporated into the soil

In-Season

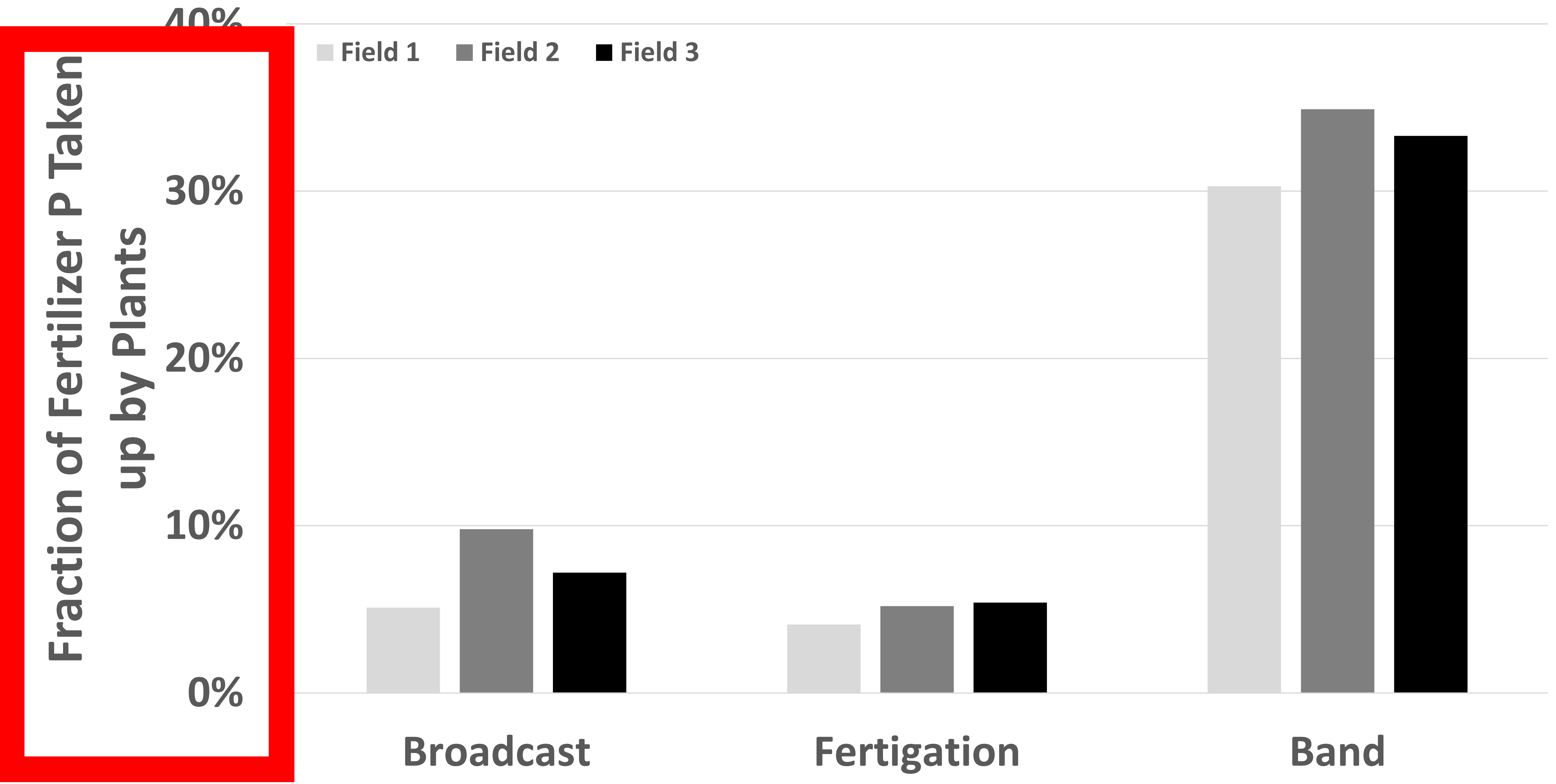
- Not as effective, but may be needed as a “rescue”.

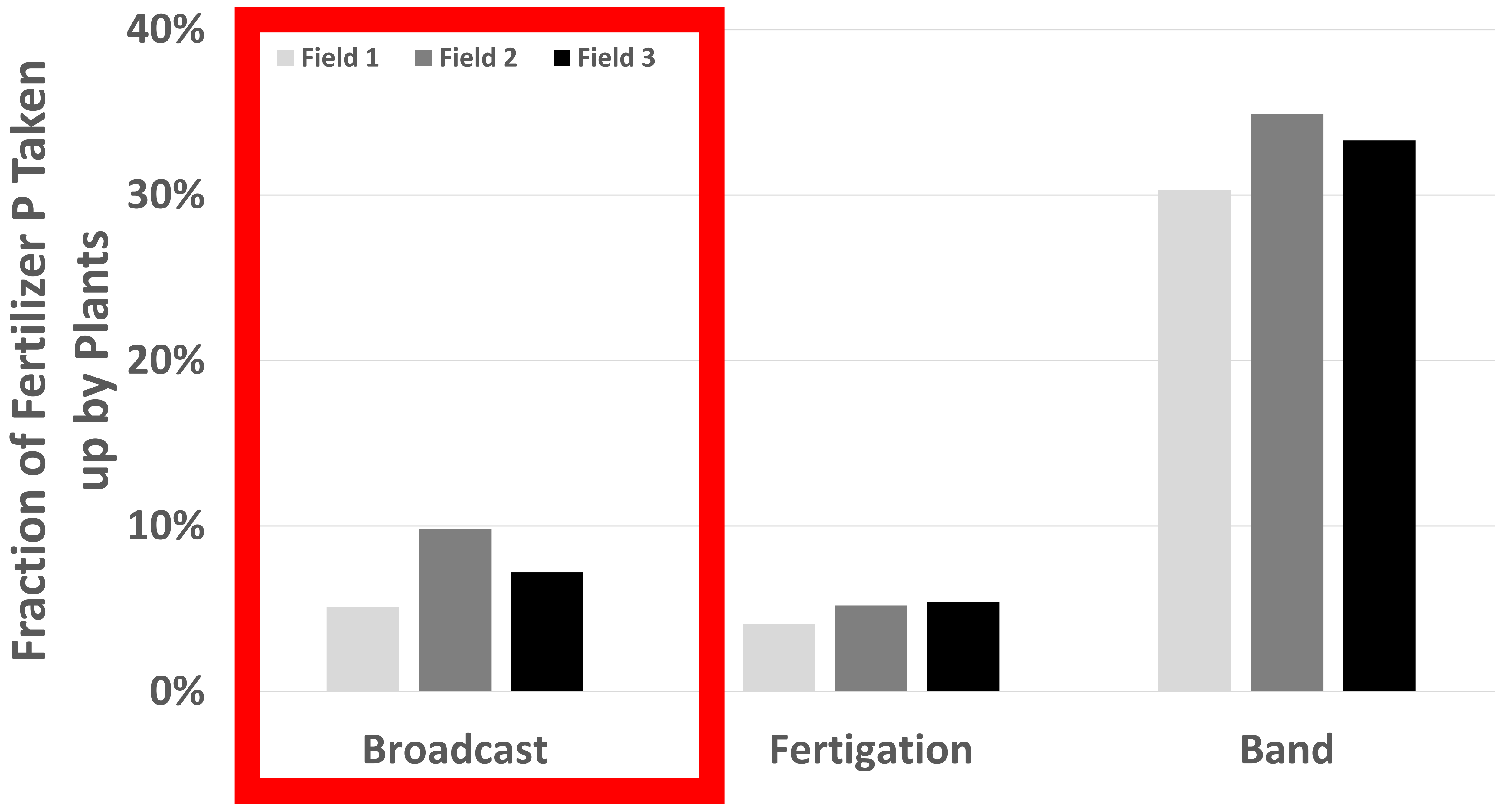
In-Season

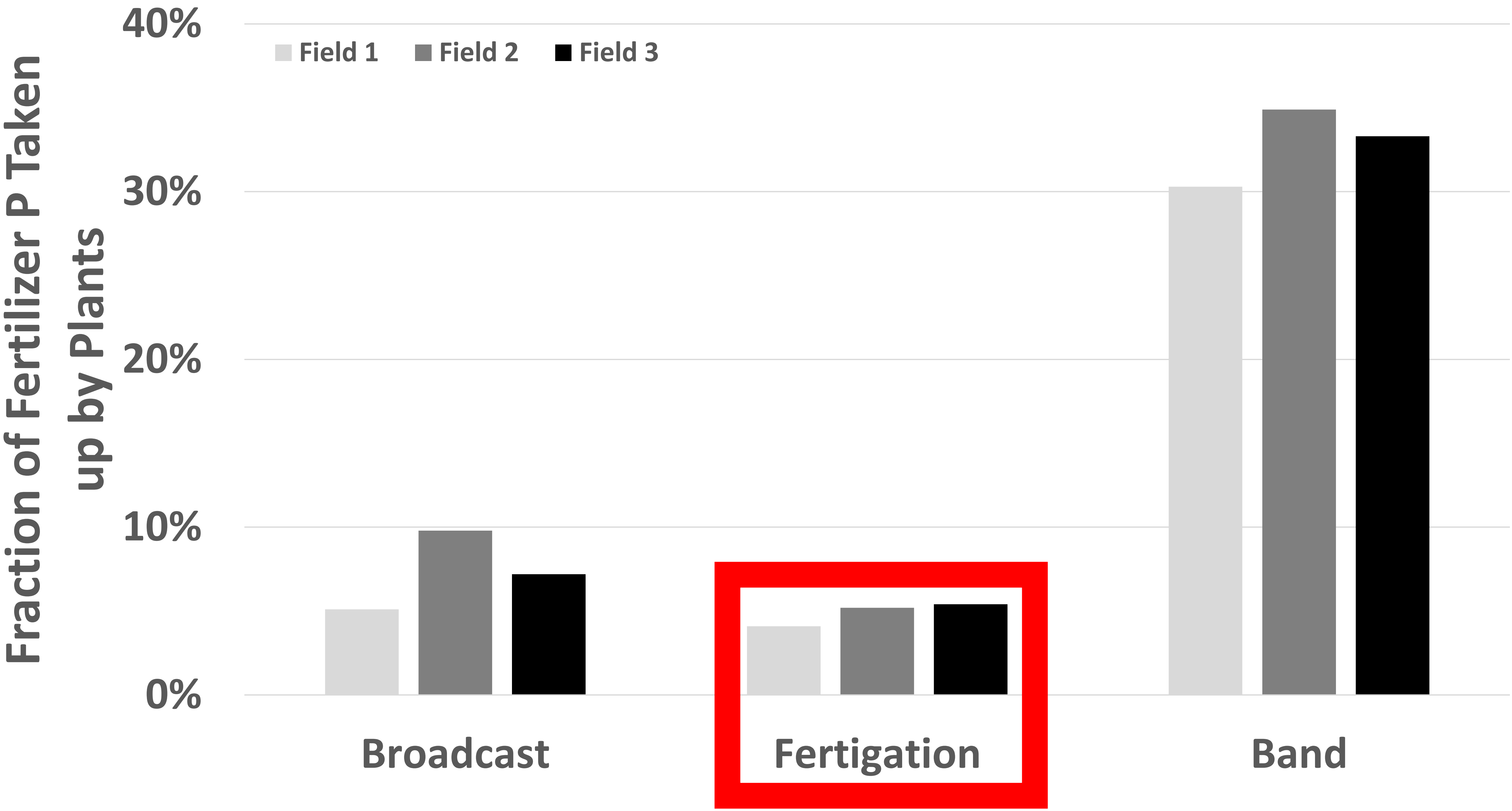
- More likely to be efficient if surface soil is moist and there are surface roots present.

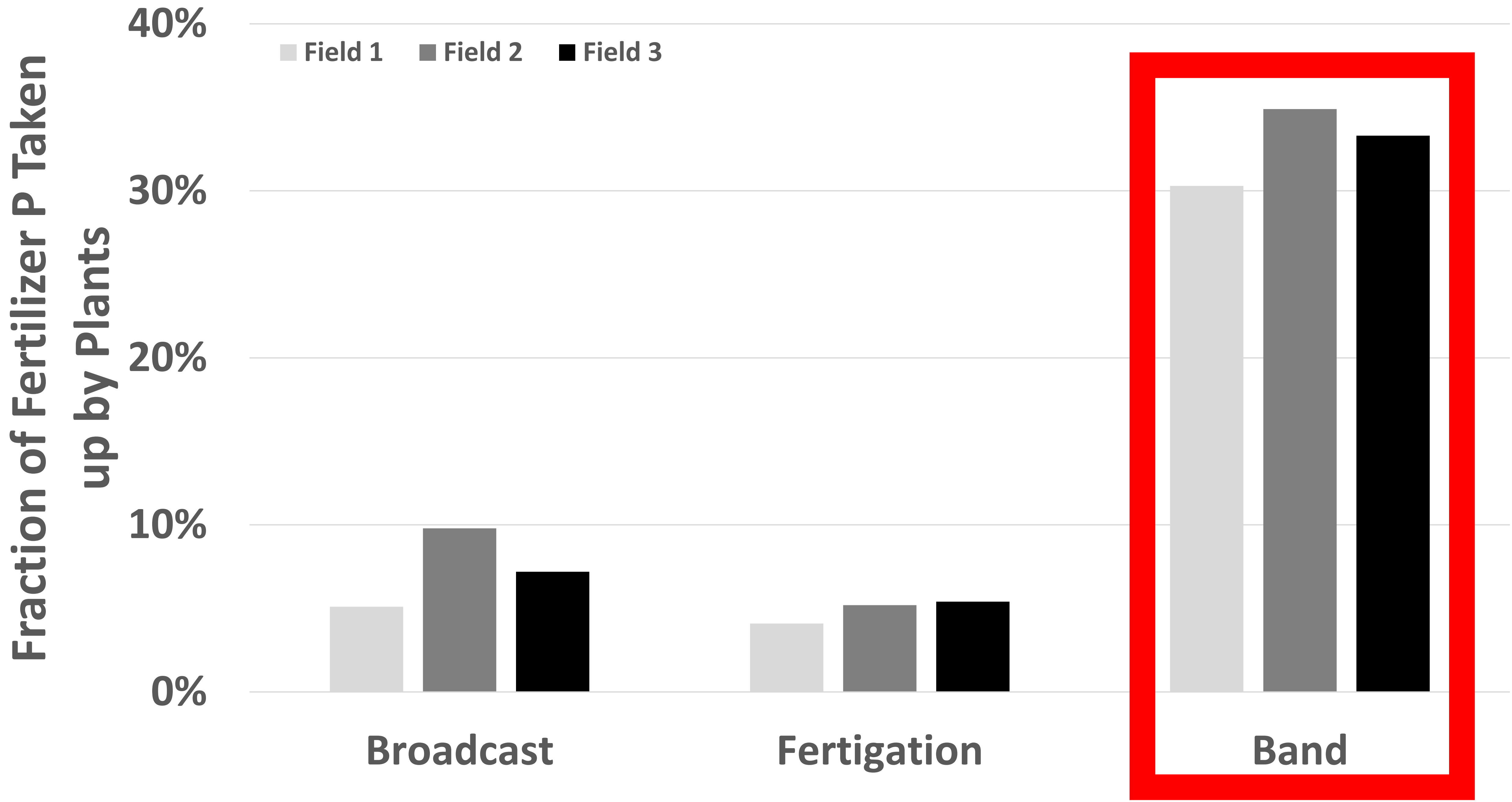
In-Season

- Need to understand uptake patterns


Fraction of Fertilizer P Taken up by Plants
40%
30%
20%
10%
0%
Field 1
Field 2
Field 3
Broadcast
Fertigation
Band


Fraction of Fertilizer P Taken up by Plants
40%
30%
20%
10%
0%
Field 1
Field 2
Field 3
Broadcast
Fertigation
Band


Field 1
Field 2
Field 3
40%
30%
20%
10%
0%
Fraction of Fertilizer P Taken up by Plants
Broadcast
Fertigation
Band


Fraction of Fertilizer P Taken up by Plants
40%
30%
20%
10%
0%
Field 1
Field 2
Field 3
Broadcast
Fertigation
Band

However, ~90% of the fertilizer P is taken up by plants after 10 years.

Johnston, A.E., P.R. Poulton, P.E. Fixen, and D. Curtin. 2014. Phosphorus: its efficient use in agriculture. Adv. Agron. 123:177-228. doi.org/10.1016/B978-0-12-420225-2.00005-4

Syers J.K., A.E. Johnston, and D. Curtin. 2008. FAO fertilizer and plant nutrition bulletin 18. Efficiency of soil and fertilizer phosphorus use. Food and Agriculture Organization of the United Nations, Rome. http://www.fao.org/3/a1595e/a1595e00.htm (Accessed February 16, 2019).

Ok, how do we manage?

- 4Rs
  - Right Rate
  - Right Timing
  - Right Placement
  - Right Source

Right Source

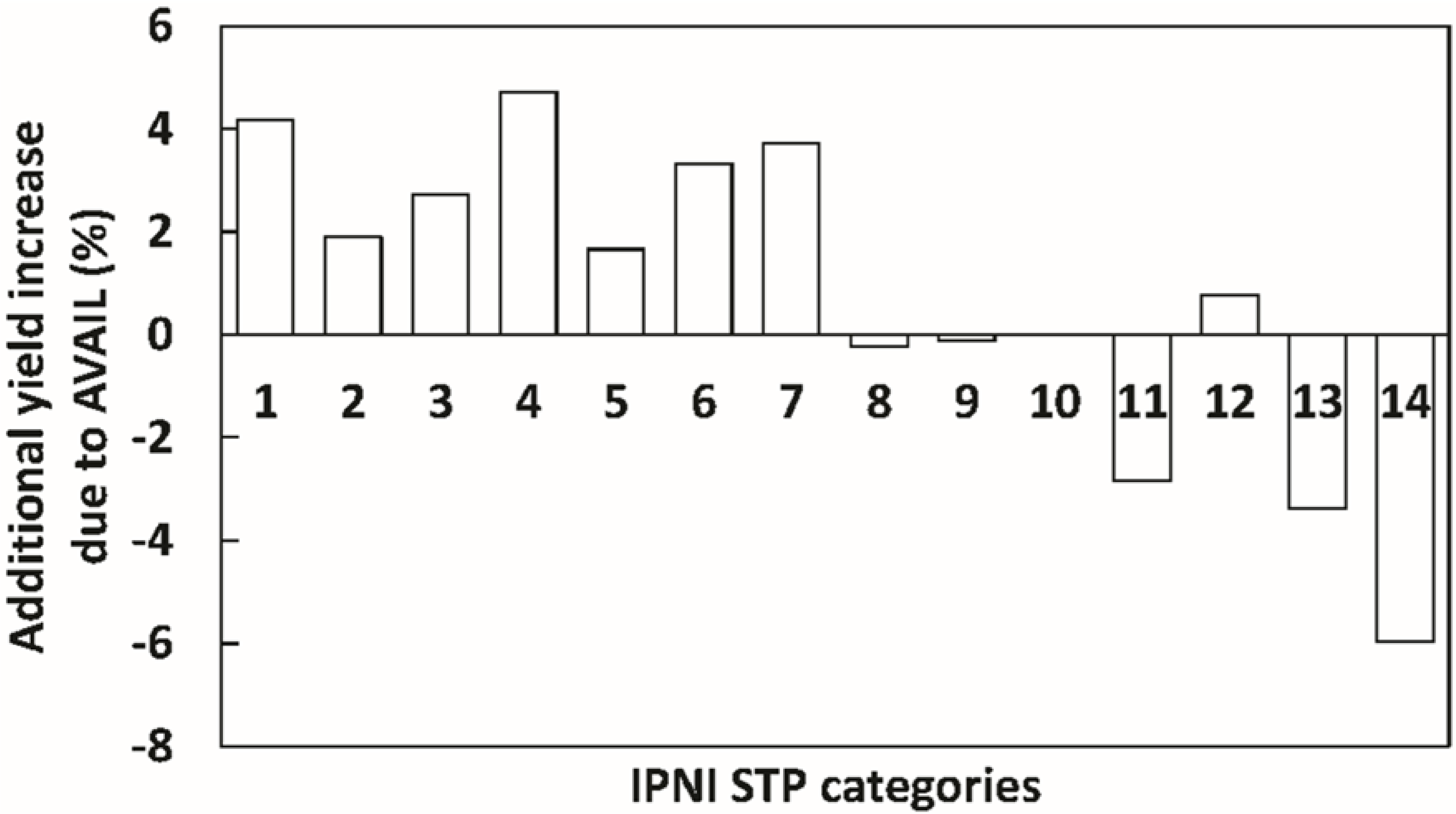
Traditional P Sources

- Generally effective
  - Especially the ammonium phosphates (dry vs. liquid)
    - Dry
      - 11-52-0
      - 18-46-0
    - Liquid
      - 10-34-0
      - 11-37-0

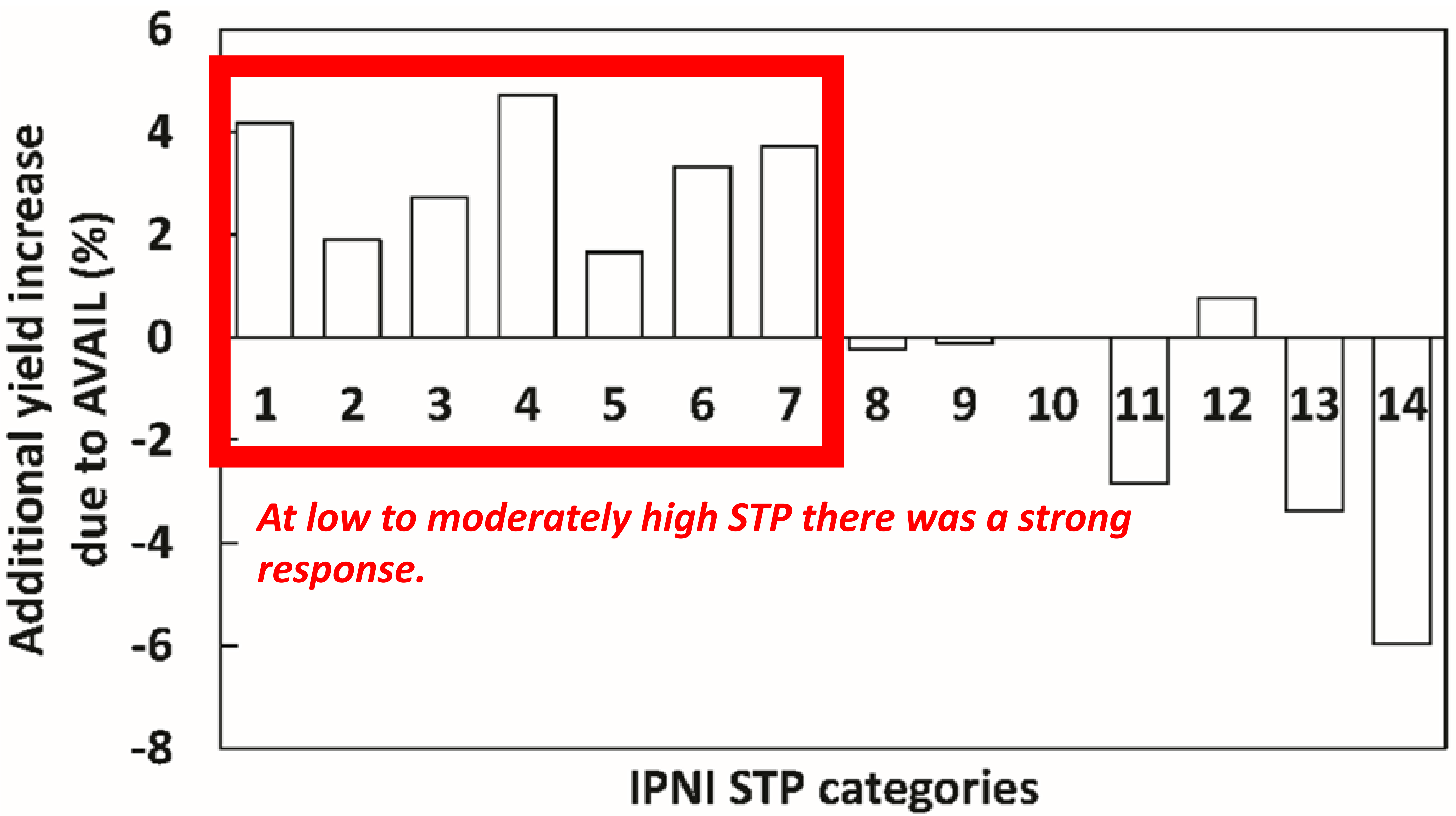
Forms

- Waste products (manure, biosolids, etc.)?
- Coated, slow release products
- Polymer (AVAIL)
- Struvite
- Organic acid based
- Acids
- Nano-particles
- Steric P
- Other

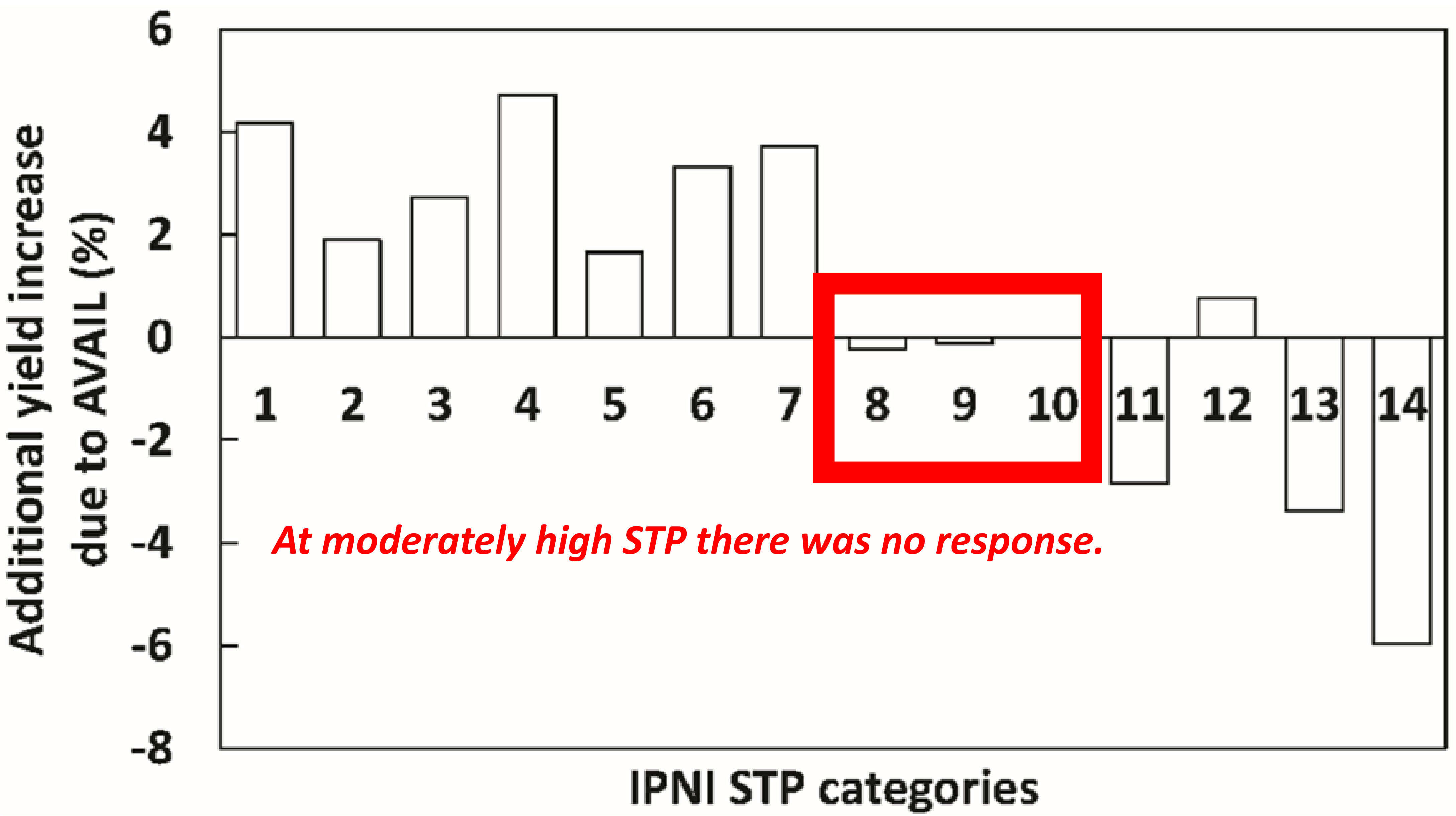
~500 field sites

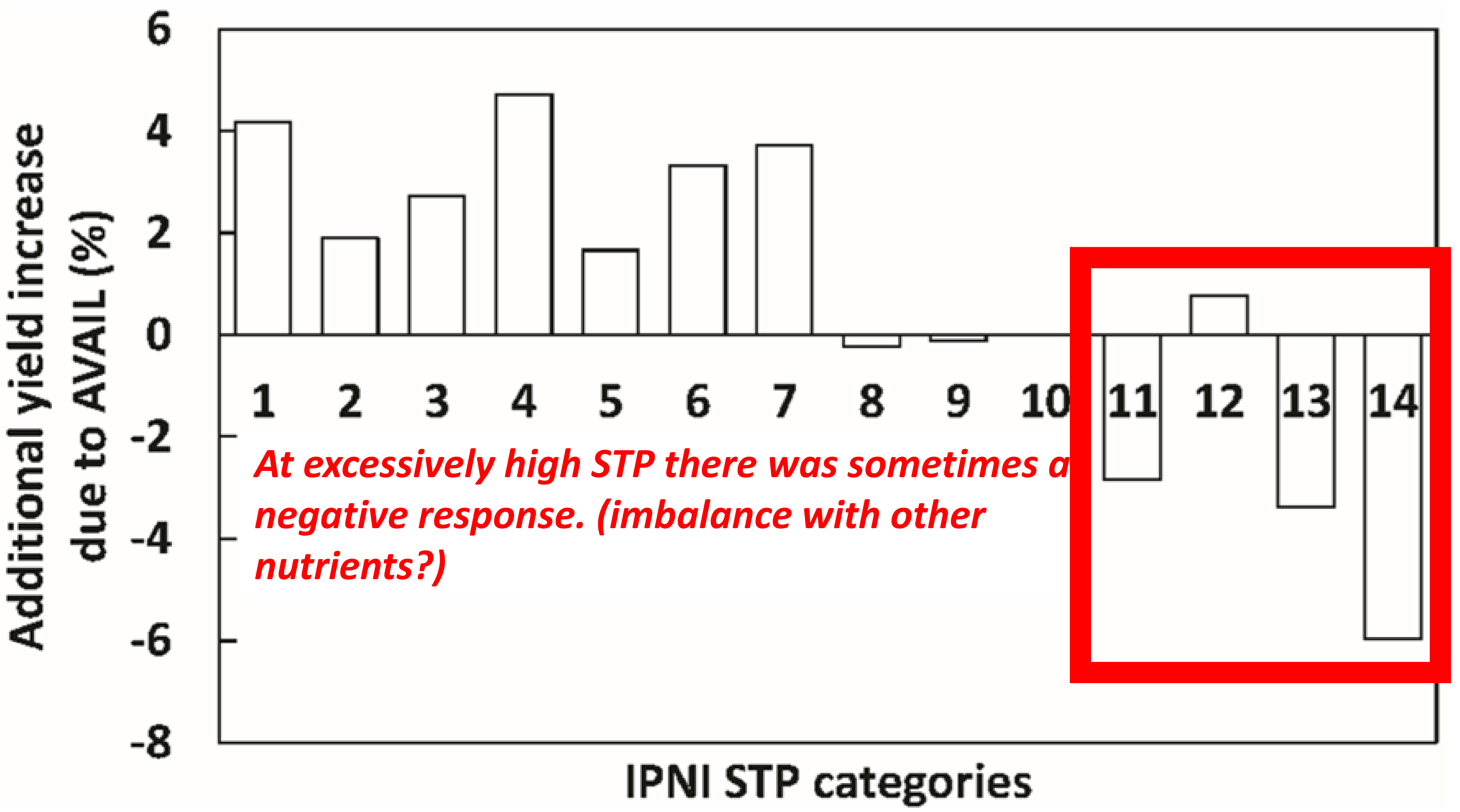


Hopkins, B.G., K.J. Fernelius, N.C. Hansen, and D.L. Eggett. 2018. AVAIL phosphorus fertilizer enhancer: Meta-analysis of 503 field evaluations. Agron. J. 110: 389-398. DOI:10.2134/agronj2017.07.0385

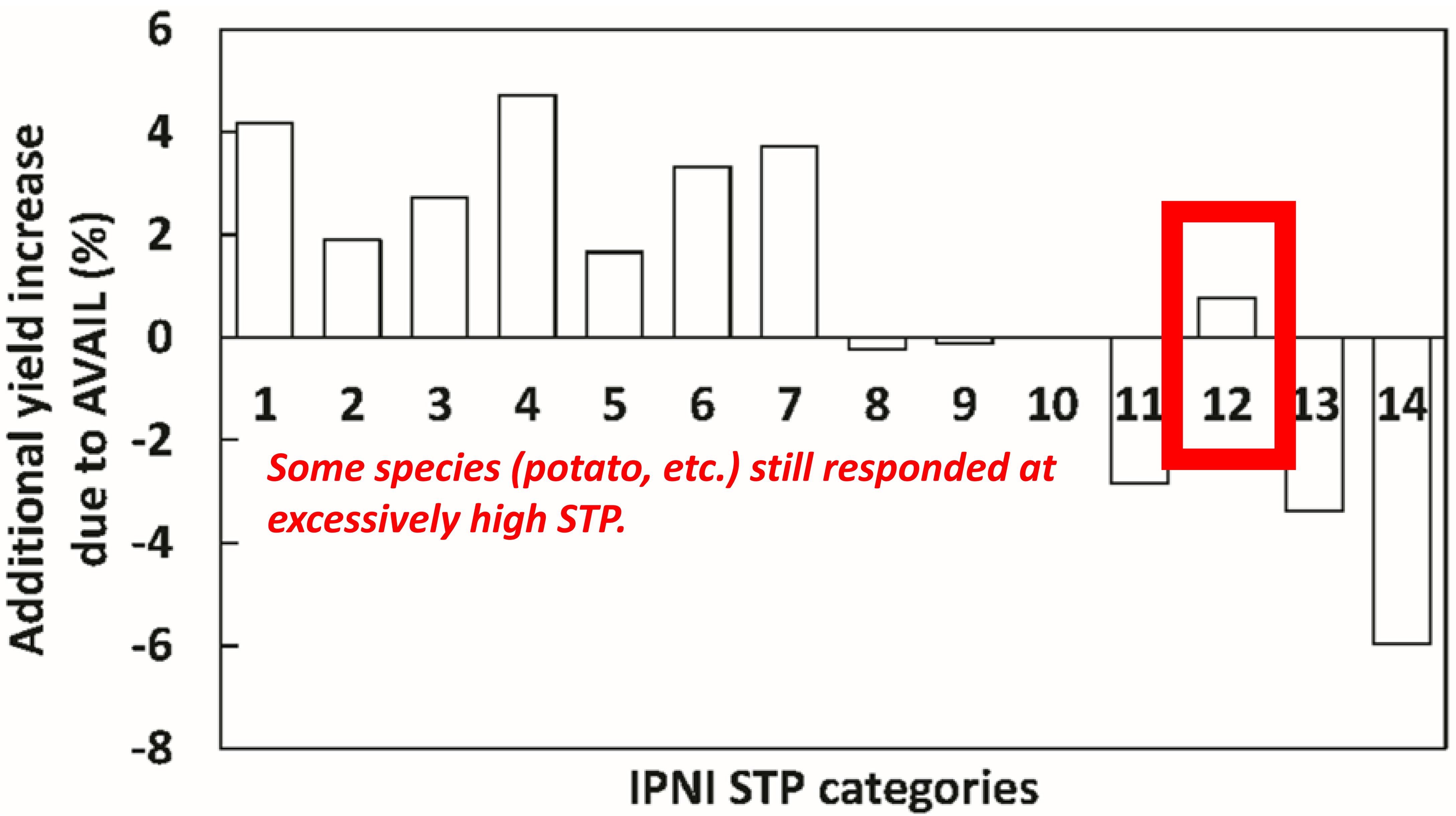


Additional yield increase due to AVAIL (%)
6
4
2
0
-2
-4
-6
-8
1 2 3 4 5 6 7 8 9 10 11 12 13 14
IPNI STP categories
At low to moderately high STP there was a strong response.


Additional yield increase due to AVAIL (%)
6
4
2
0
-2
-4
-6
-8
1
2
3
4
5
6
7
8
9
10
11
12
13
14
At moderately high STP there was no response.
IPNI STP categories

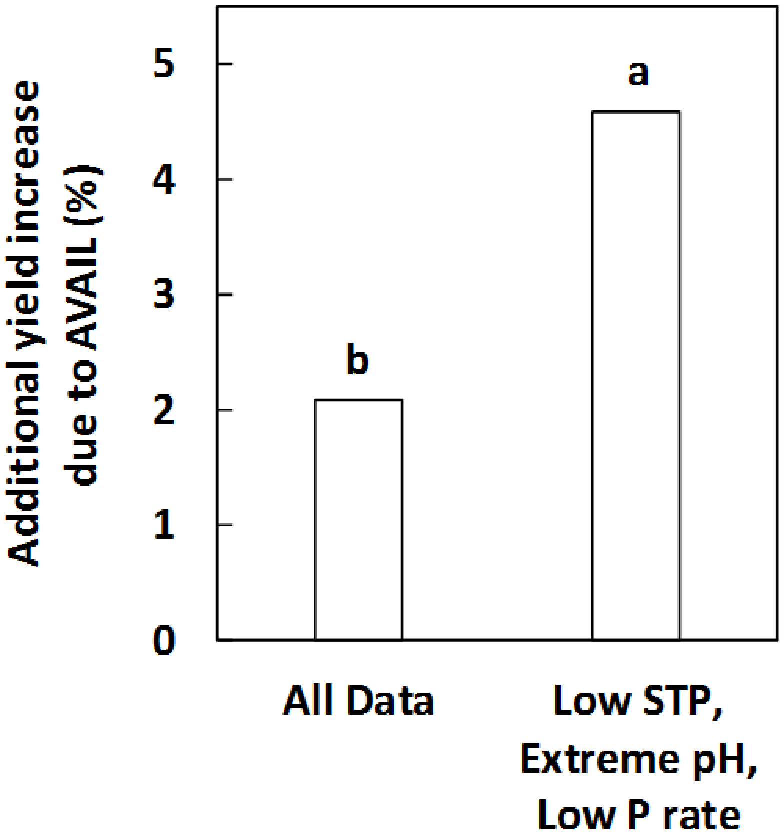


6
4
2
0
-2
-4
-6
-8
Additional yield increase due to AVAIL (%)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
At excessively high STP there was sometimes a negative response. (imbalance with other nutrients?)
IPNI STP categories

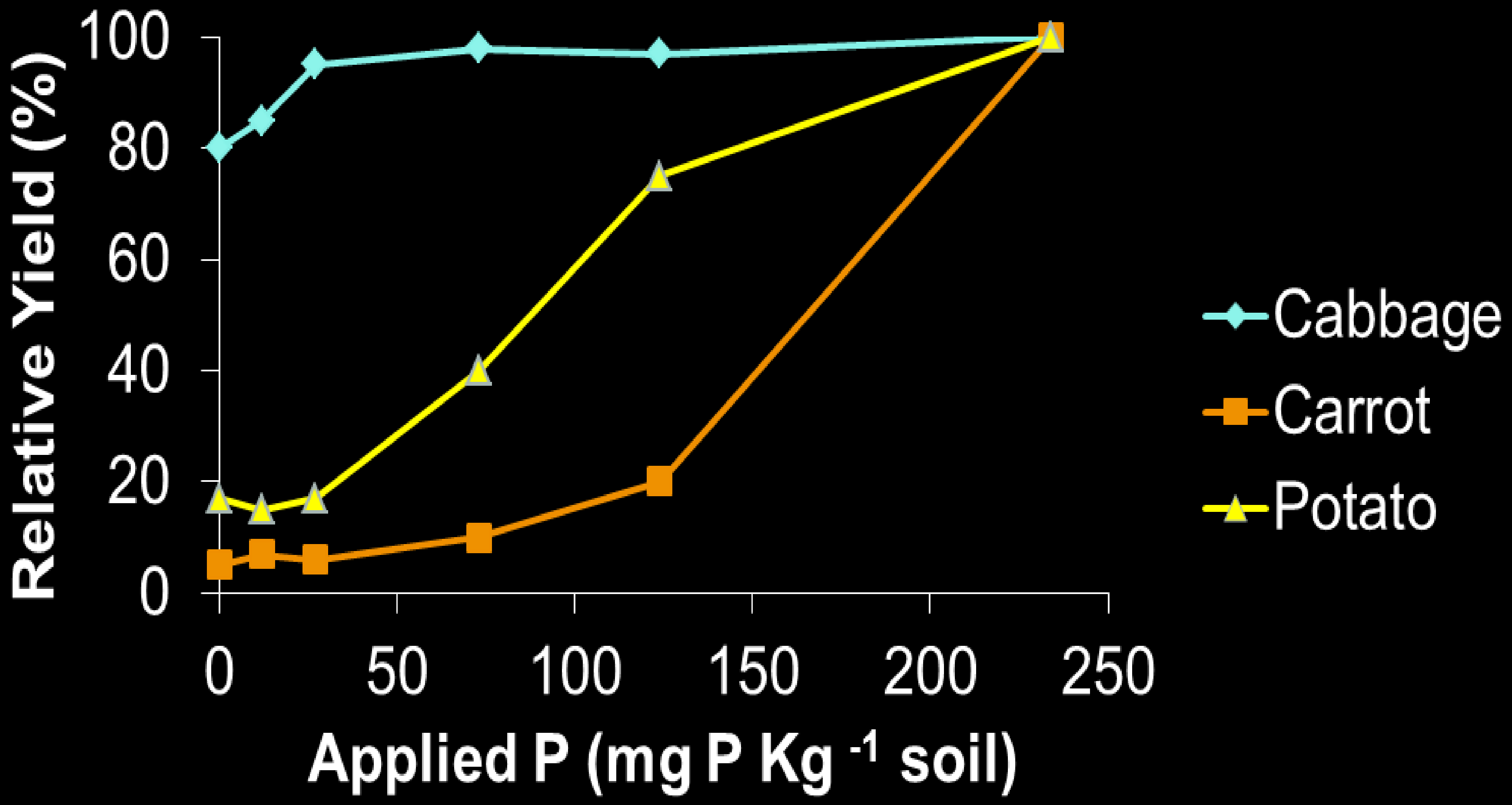


Additional yield increase due to AVAIL (%)
6
4
2
0
-2
-4
-6
-8
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Some species (potato, etc.) still responded at excessively high STP.
IPNI STP categories

AVAIL significantly increased crop yields when used under conditions where a P response would be expected. The average yield increase under such conditions was 4.5%

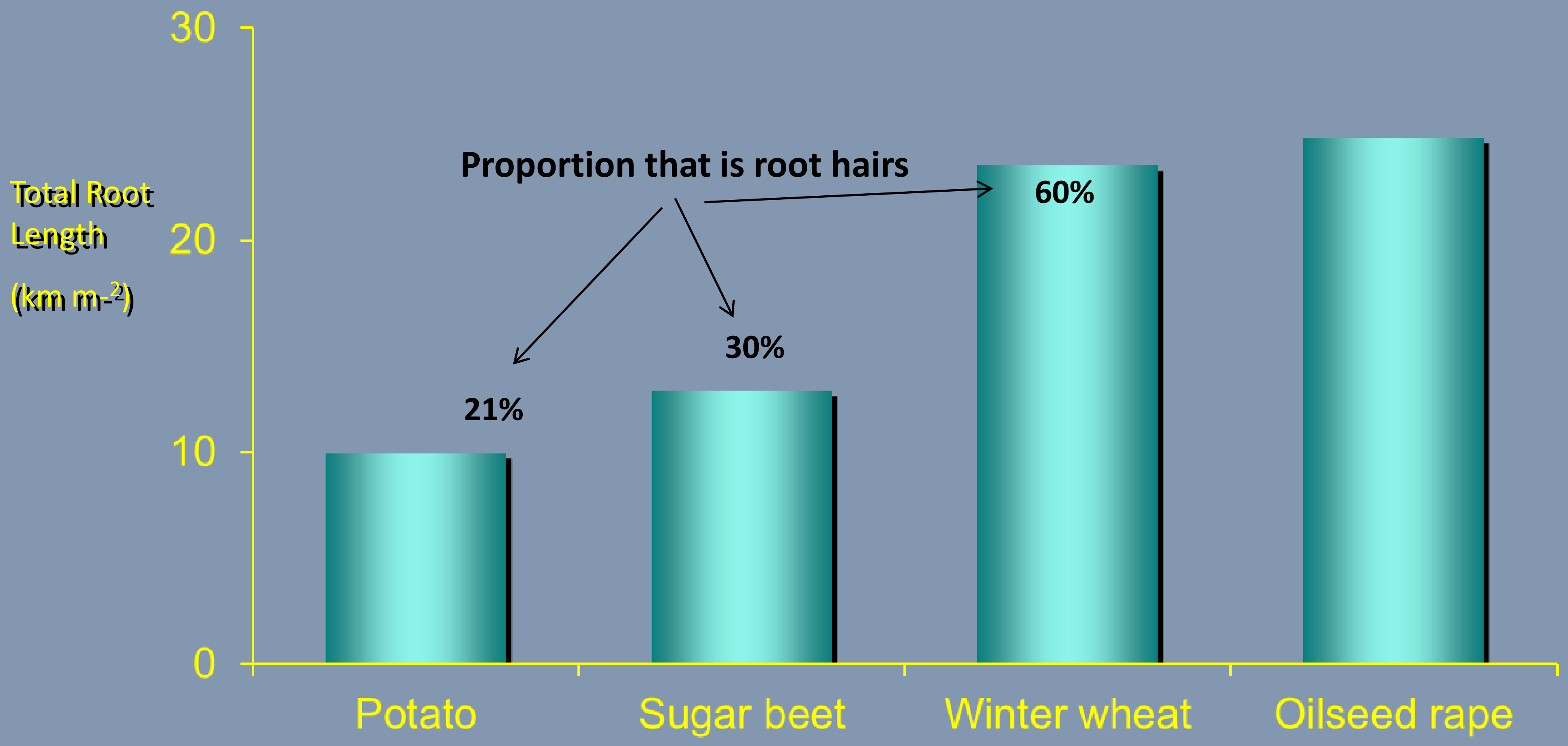


- Relatively poor use efficiency compared with other crops



Source: Dechassa et al., 2003

Potato roots pose some challenges

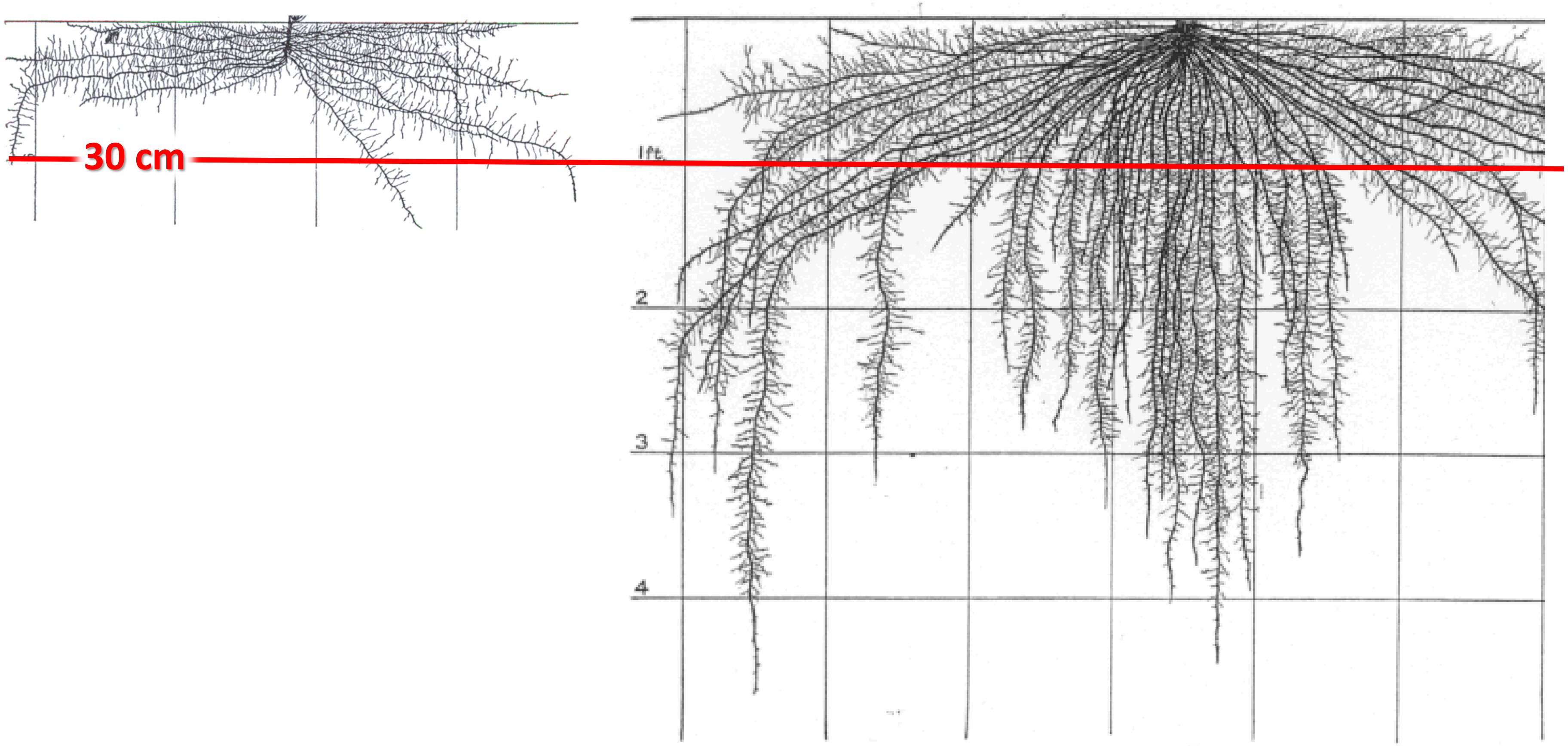


Adapted from: Stalham and Allen, 2001 and Yamaguchi, 2003

Potato vs corn roots at 56 days after planting

Potato

Corn



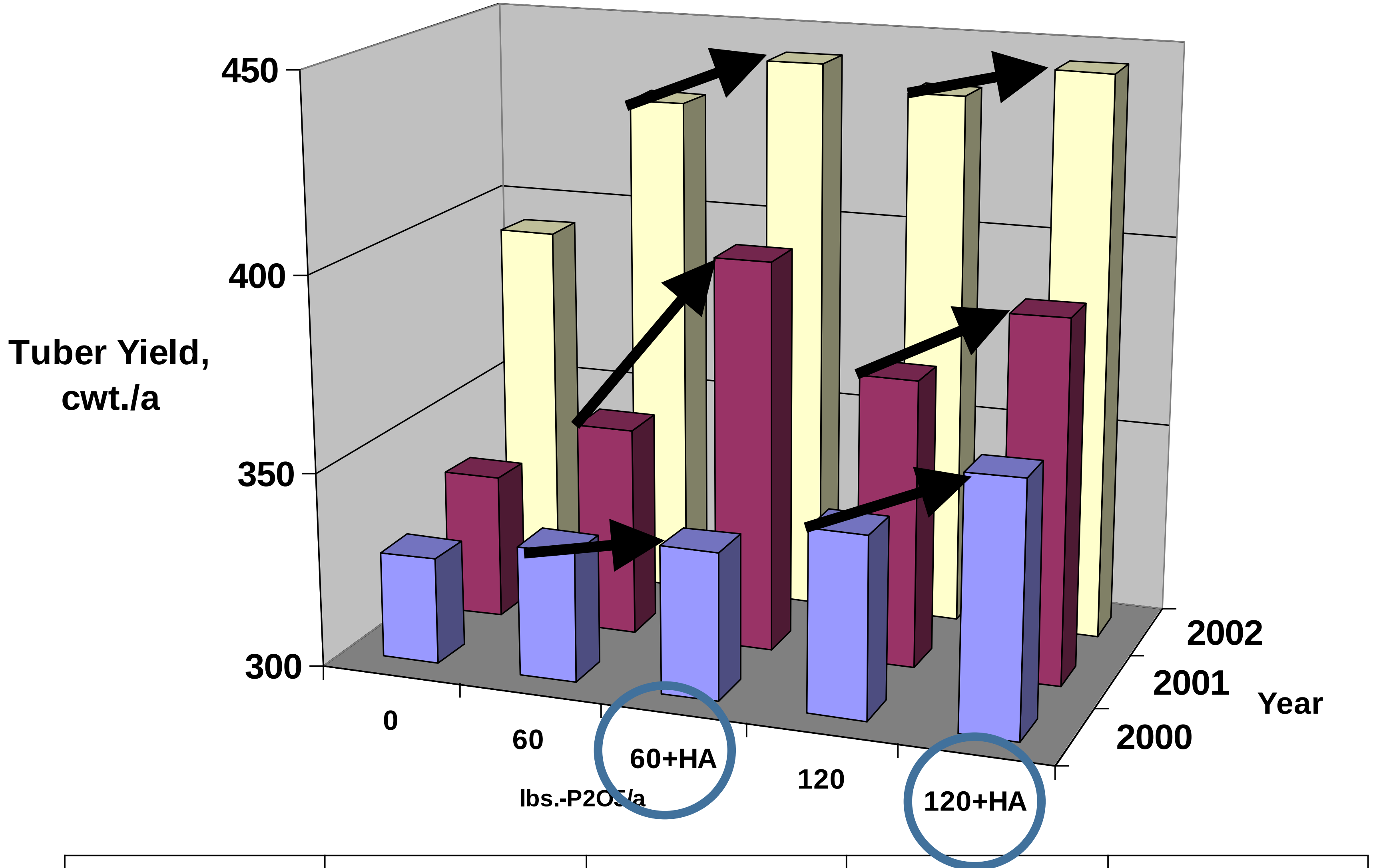
Weaver, 1926 (NE)

Organic Acids

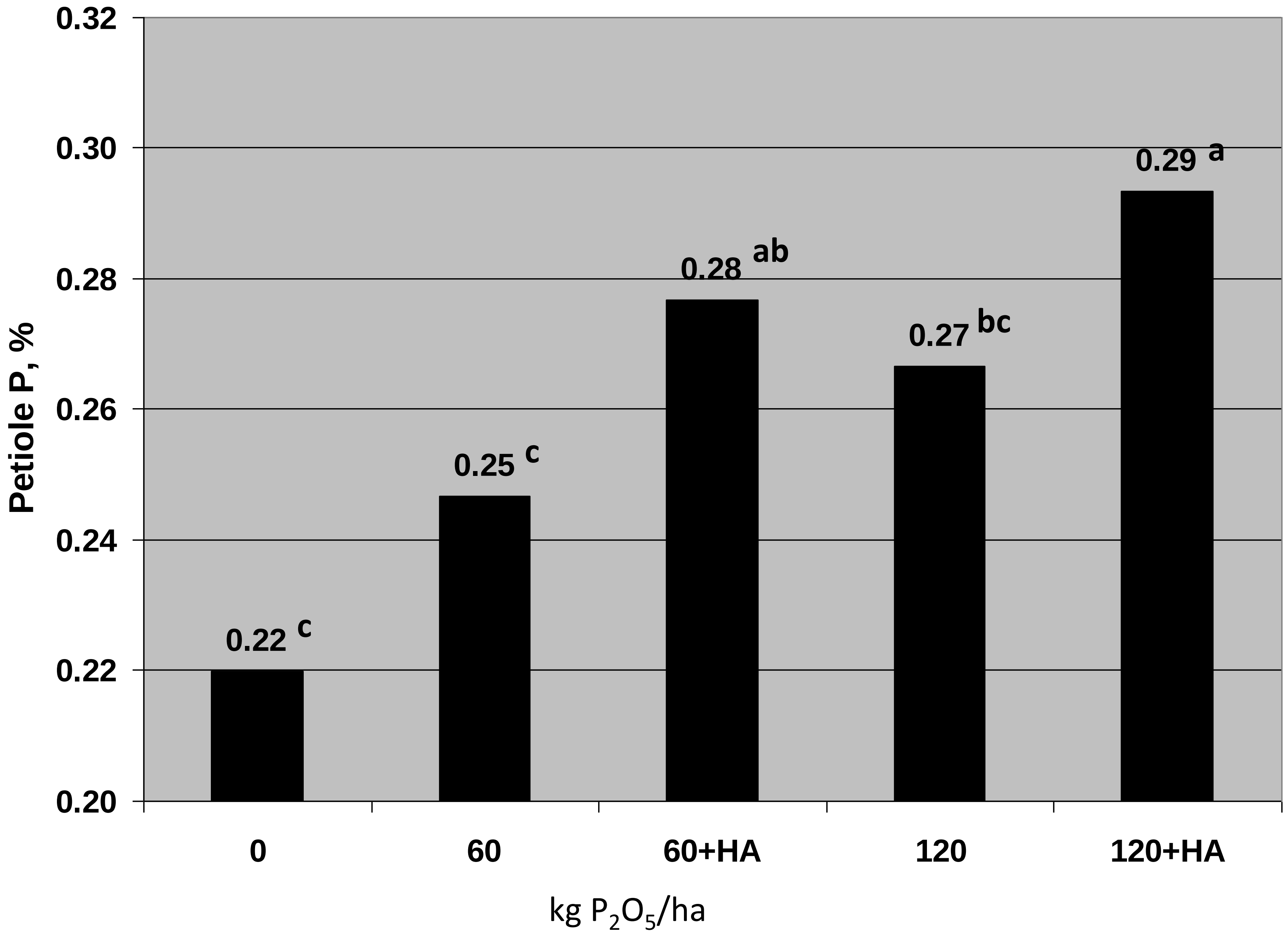
Humic Acid – Russet Burbank potato

- 3 years
- calcareous soil
- medium soil test P

- Ammonium polyphosphate (10-34-0)
- 3 inches to the side of seed
- with and without Humic Acid (HA)
  - 1:10 ratio of humic acid to 10-34-0
    - control
    - 15 gal 10-34-0 $\pm$ 1.5 gal HA
    - 30 gal 10-34-0 $\pm$ 3.0 gal HA

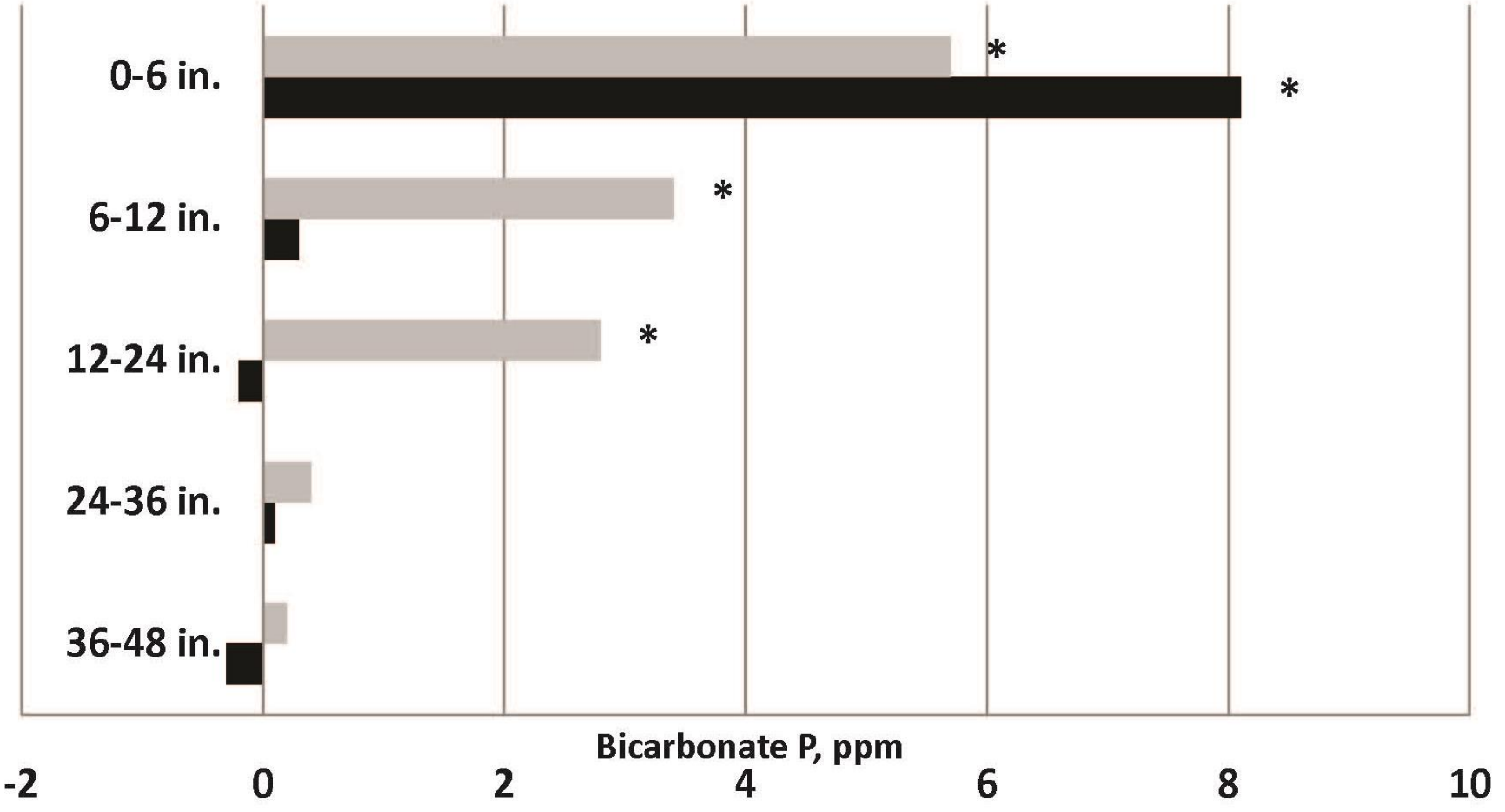


	0	60	60+HA	120	120+HA
2000	327 b	333	338	347	364
2001	337	354	401	374	393
2002	394	431	444	438	446

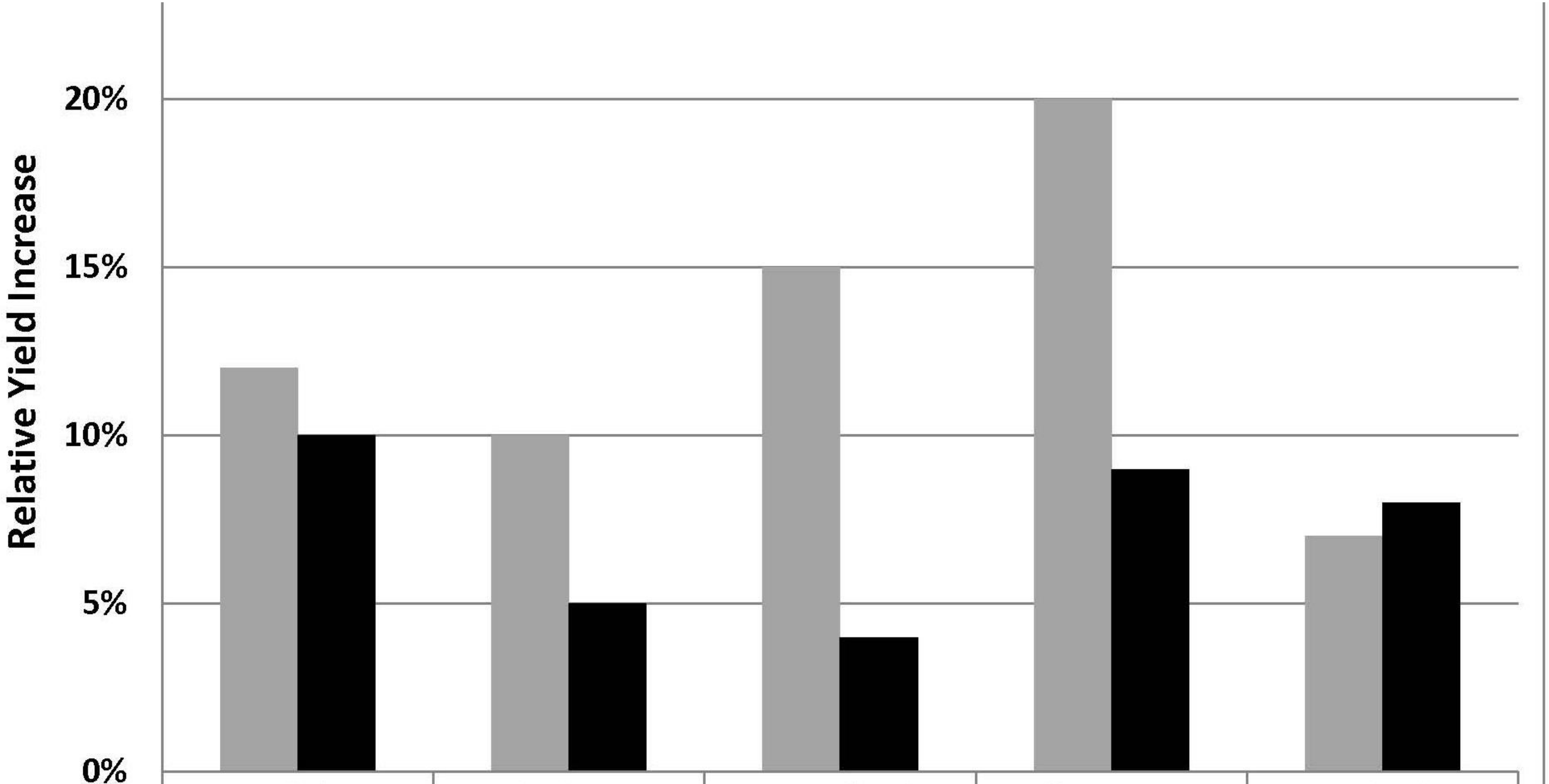


Petiole P, %
0.32
0.30
0.28
0.26
0.24
0.22
0.20
0.22 c
0.25 c
0.28 ab
0.27 bc
0.29 a
0
60
60+HA
120
120+HA
kg P2O5/ha

Bicarbonate Extractable Phosphorus Concentrations by Depth

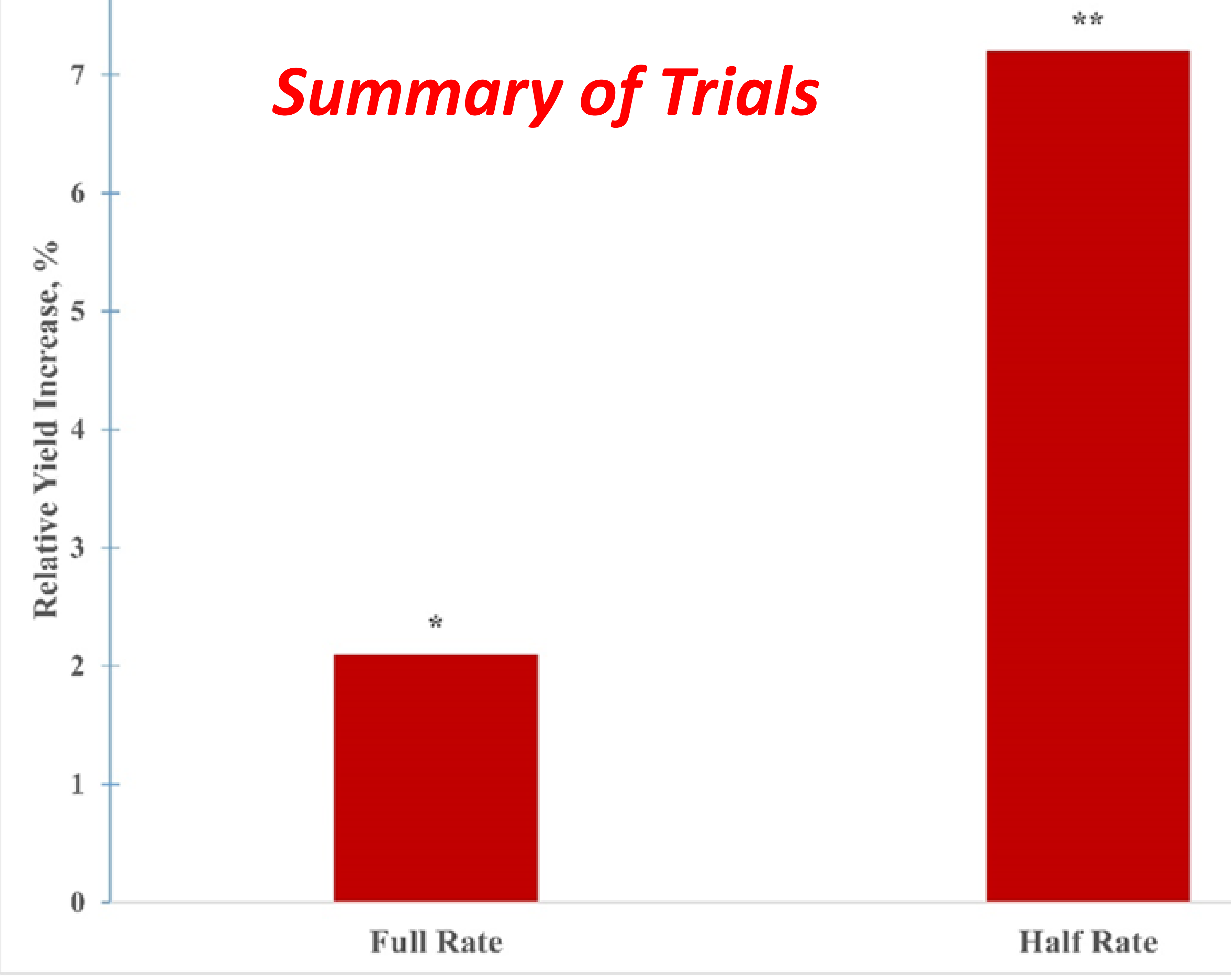


	36-48 in.	24-36 in.	12-24 in.	6-12 in.	0-6 in.
CB-P	0.2	0.4	2.8	3.4	5.7
APP	-0.3	0.1	-0.2	0.3	8.1



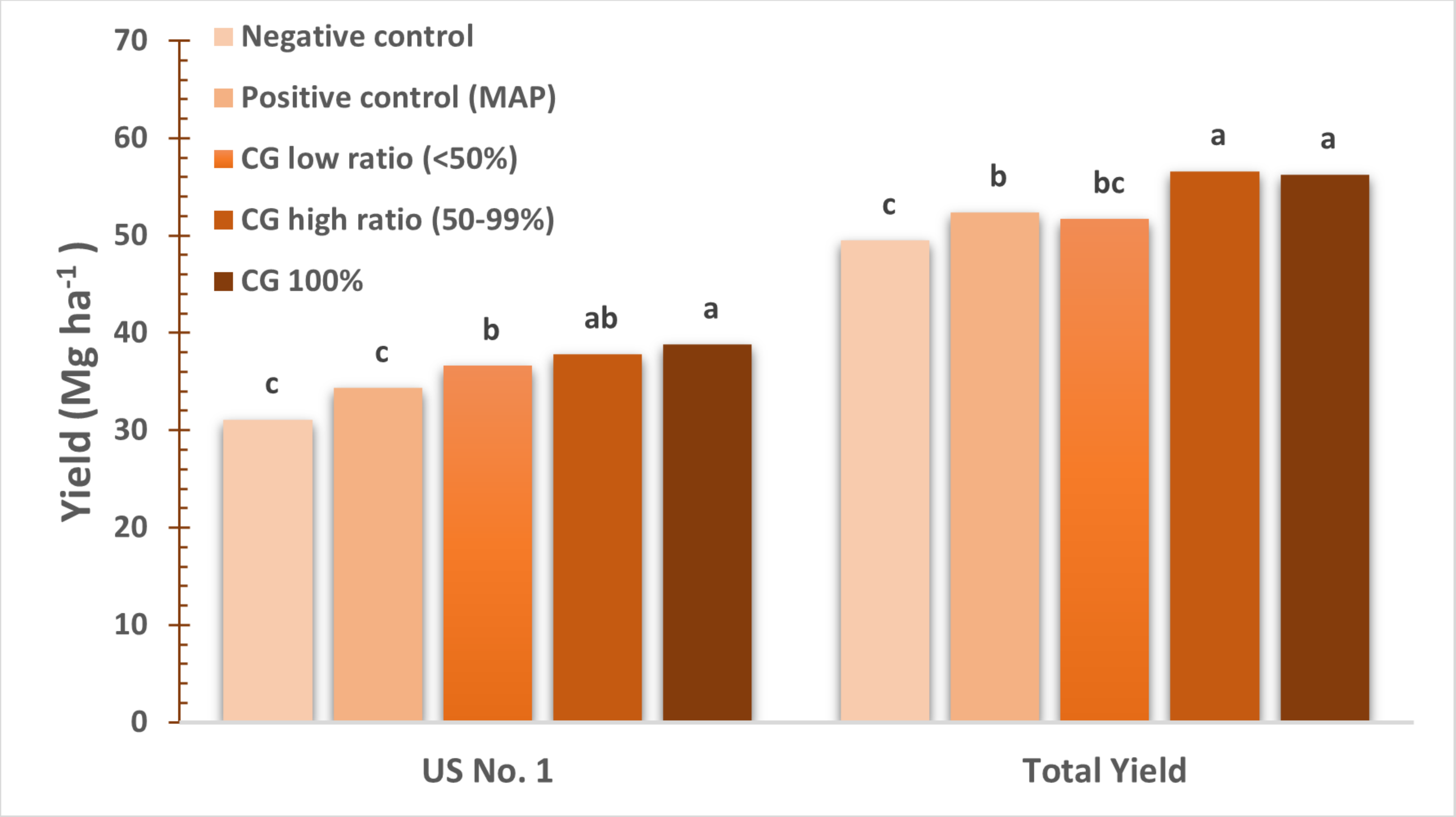
	potato	dry bean	sugarbeet	silage corn	wheat
P	12%	10%	15%	20%	7%
Yield	10%	5%	4%	9%	8%

Summary of Trials



Hopkins and Hansen, 2019

Struvite


Negative control
Positive control (MAP)
CG low ratio (<50%)
CG high ratio (50-99%)
CG 100%
Yield (Mg ha-1)
70
60
50
40
30
20
10
0
c
c
b
ab
a
c
b
bc
a
a
US No. 1
Total Yield

Our study was theoretically ideal for the opportunity for a potato yield increase with struvite application for the following reasons:

1) a high concentration of P in the planted seed pieces,

2) a variety with a relatively high probability of P response was used,

3) the soil test P concentrations were low-to-moderate for potato,

4) the soils had an alkaline pH,

5) the soils were calcareous with high limestone concentrations,

6) the form of struvite used was granular, not powdered, and scientifically proven to be effective,

7) struvite alone and a high ratio of struvite to traditional fertilizer were included as treatments,

8) P rates were based on research-based recommendations for the variety and conditions

We do have effective Enhanced Efficiency Phosphorus Fertilizers, but . . .

- Does it fit the soil type?
    - Organic matter?
    - pH?
    - Soil Test P?
- How responsive is the crop?
    - eg. potato vs. corn
- Reduce the rate
    - Enough is enough, adding more doesn’t add more yield

Conclusions

- We need fertilizer, although we can often cut back or not apply.

Conclusions

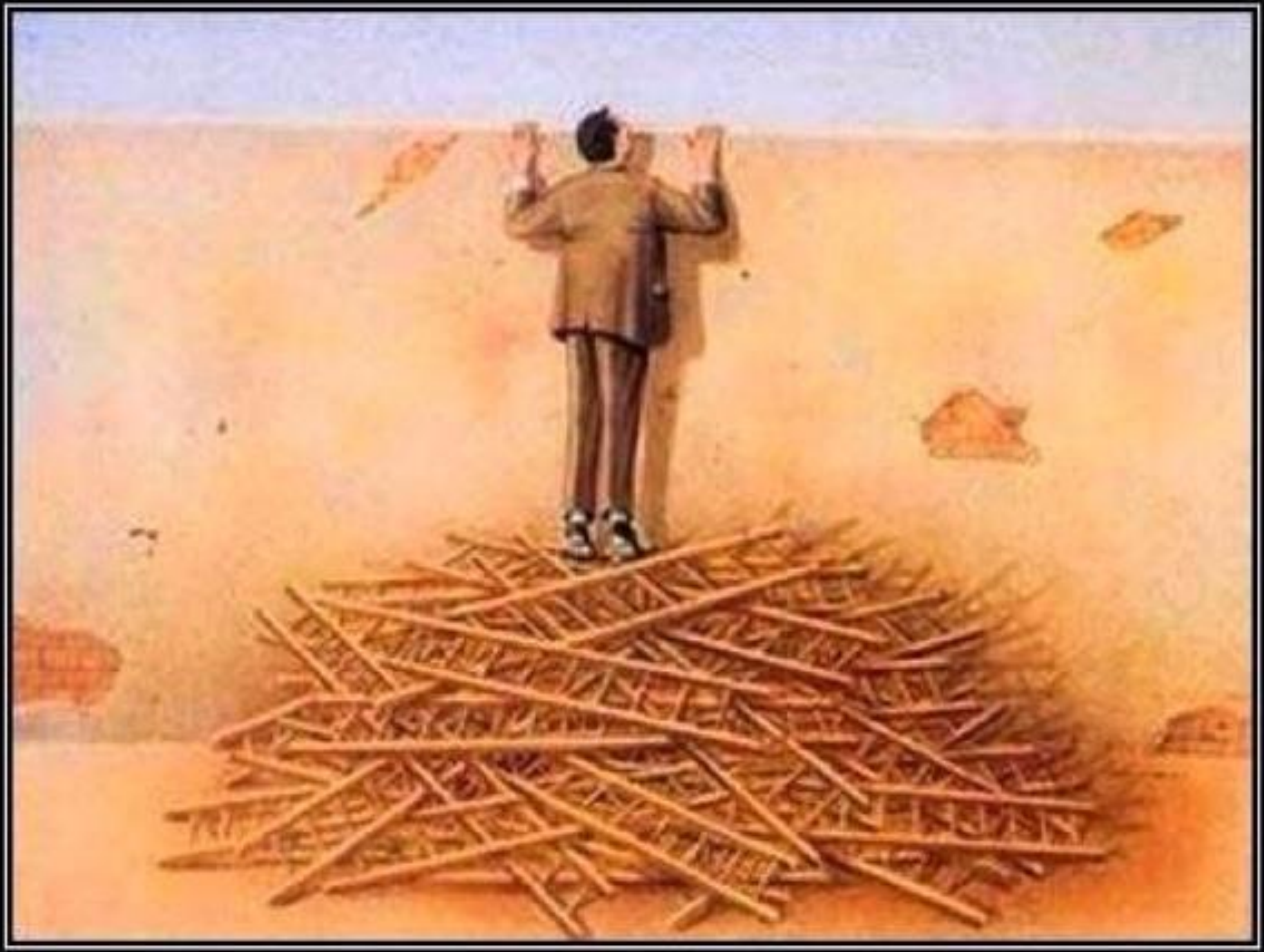
- Apply the correct rate (soil test) with optimized timing, placement, and source.

Conclusions

- Enhanced Efficiency P Fertilizers generally only work at low STP and reduced rates (and at a reasonable cost).

Conclusions

- We need fertilizer, although we can often cut back or not apply.
- We should not be complicit in the long-term destruction of soil fertility.
- Apply the correct rate (soil test) with optimized timing, placement, and source.
- **Enhanced Efficiency P Fertilizers generally only work at low STP and reduced rates (and at a reasonable cost).**



It doesn't matter how many resources you have

if you don't know how to use them, they will never be enough