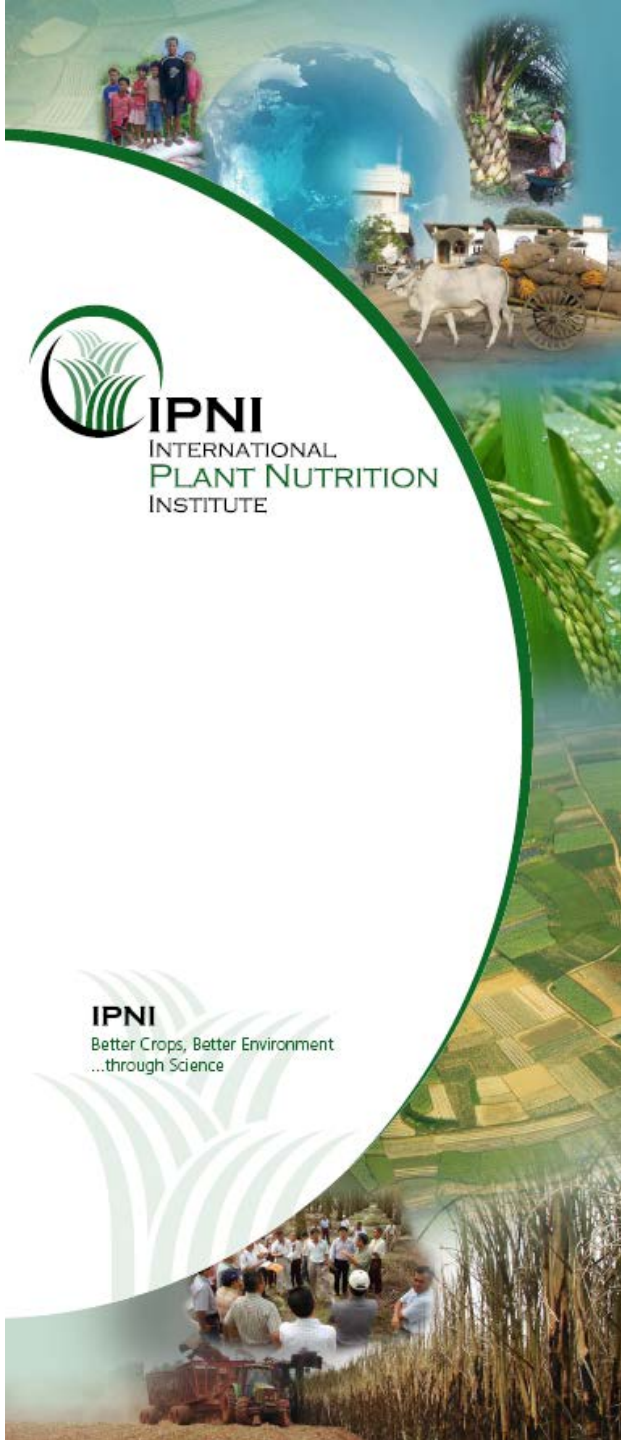
Phosphorus Placement for Corn, Soybeans, and Wheat

T.W. Bruulsema
T.S. Murrell

Heartland Nutrient Management Workshop
20 February 2013
Lied Lodge and Conference Center, Nebraska City, NE



Outline

- Theory of nutrient placement
  (*Scott Murrrell*)
  - Transport pathways
  - Nutrient influx
  - Root architecture
  - Fertilized soil volume
- Practical aspects of placement methods
  (*Tom Bruulsema*)
  - Broadcast, band, with seed
  - Nutrient stratification
  - Sampling soils where bands have been applied
  - Impacts on environmental protection

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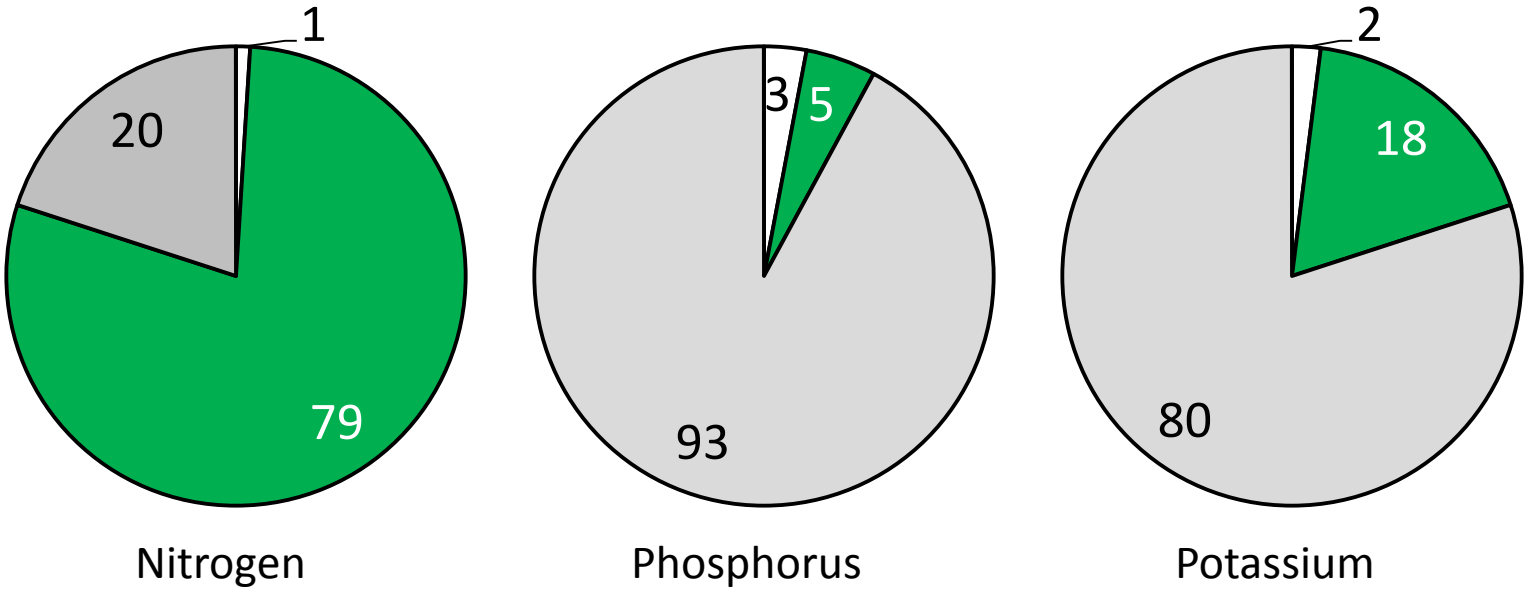
Root interception
(root grows into a nutrient location)

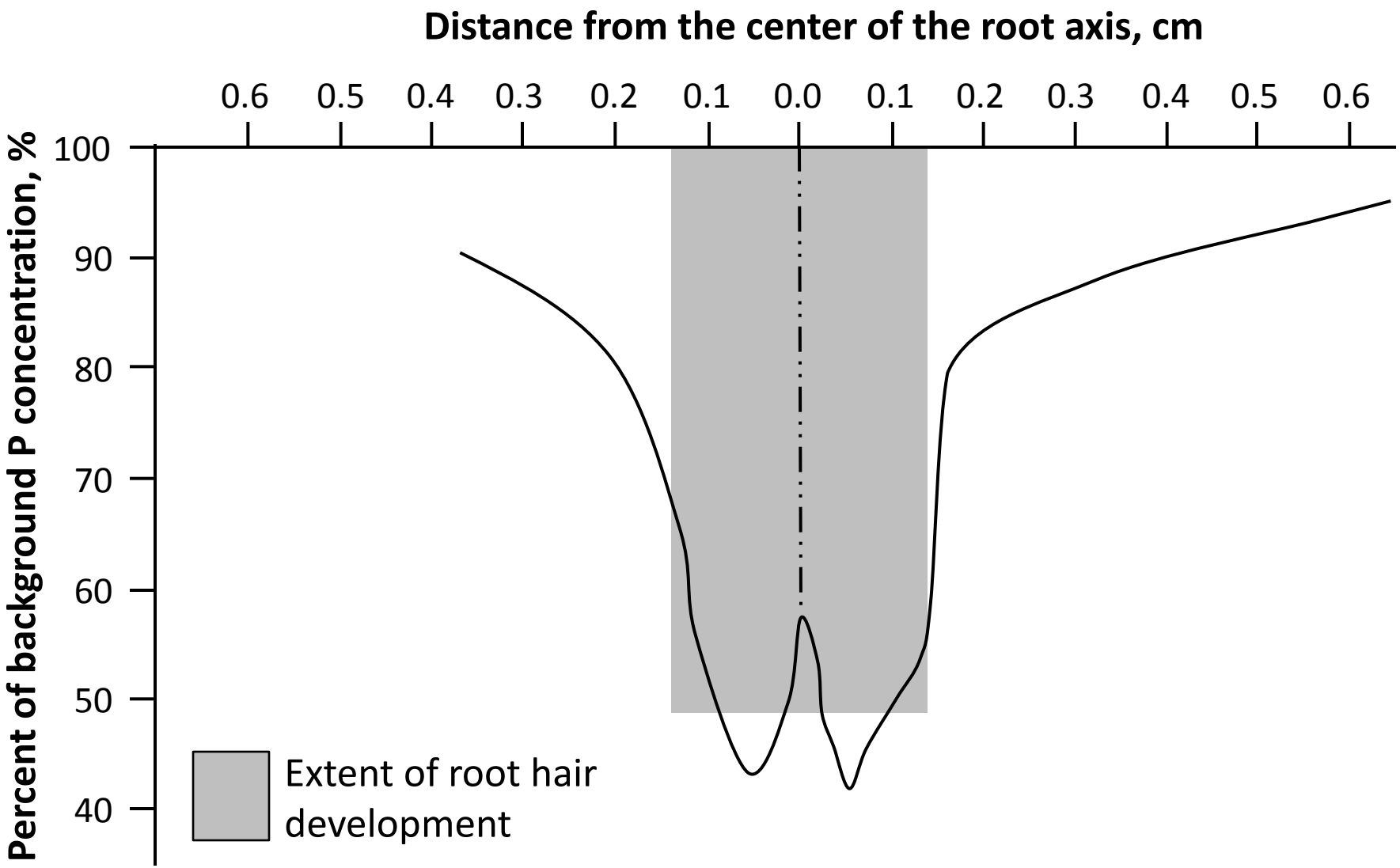
Mass flow
(nutrient moves with the water absorbed by a plant)

Diffusion
(nutrient moves from higher to lower concentration)

Relative contribution of each pathway for corn (%)



Barber, S.A. 1995. Soil nutrient bioavailability: A mechanistic approach. 2nd ed. John Wiley and Sons, New York, NY.



Bhat, K.K.S. and P.H. Nye. 1973. Plant Soil 38:161-175.

Comparative rates of diffusion for P and K

Soil	Time to travel one inch†		K diffusion rate, expressed as a multiple of the P diffusion rate
	P	K	
	-------- (yr) -------		(times as fast as P)
Raub silt loam	22	2.7	8
Chalmers silt loam	12	2.6	5

† Time was calculated from the following equation, using the effective diffusion coefficients (D_e) reported for various soil moisture contents: $t = d^2/(D_e)$, where t is time (s) and d is the distance travelled (cm).

Raub silt loam: 46 ppm P, 175 ppm K
Chalmers silt loam: 95 ppm P, 148 ppm K

Silberbush, M. and S.A. Barber. 1983. Soil Sci. Soc. Am. J. 43:262-265.

The effect of P application rate on P diffusion rates

Banded rate of P_2O_5	Time for P to travel one inch by diffusion†		
	Coly silt loam	Nora silt loam	Sharpsburg silty clay loam
(lb P_2O_5 / acre)	---------- (years) ----------		
30	1.6	1.7	1.9
46	1.3	0.7	1.4
62	1.2	0.7	1.1
77	1.4	0.7	0.7
92	1.0	0.6	0.8
122	0.8	0.4	1.0

† Time was calculated from the following equation, using the apparent diffusion coefficients (D_a) reported for various soil moisture contents: $t = d^2/(D_a)$, where t is time (s) and d is the distance travelled (2.54 cm).

Eghball et al., 1990. Soil Sci. Soc. Am. J. 54:1161-1165

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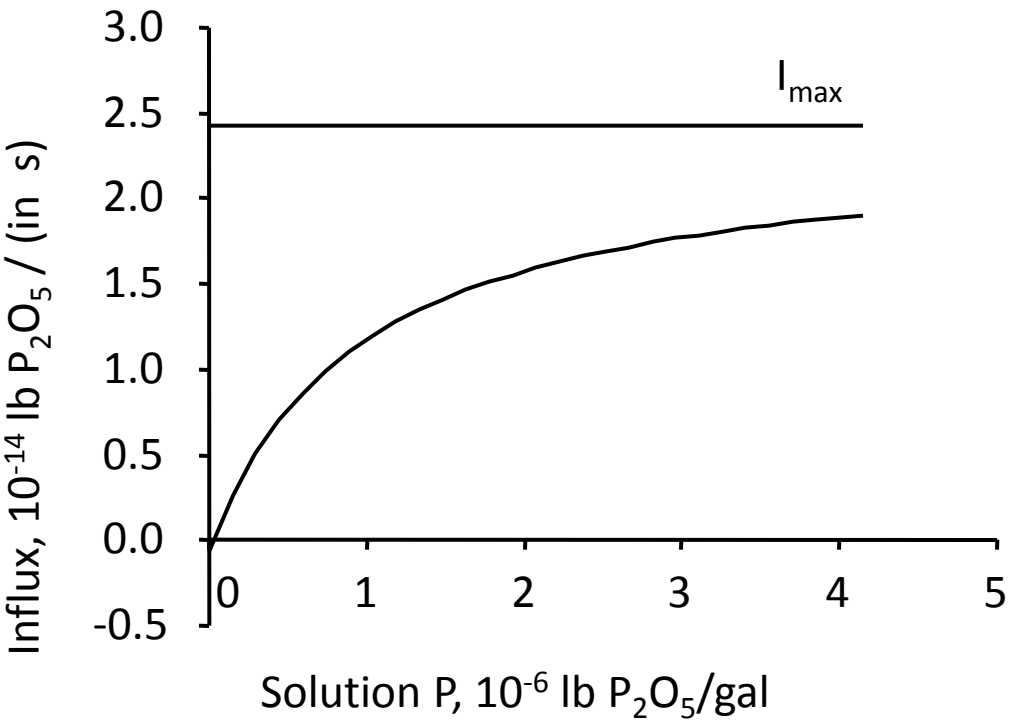
Nutrient influx by roots

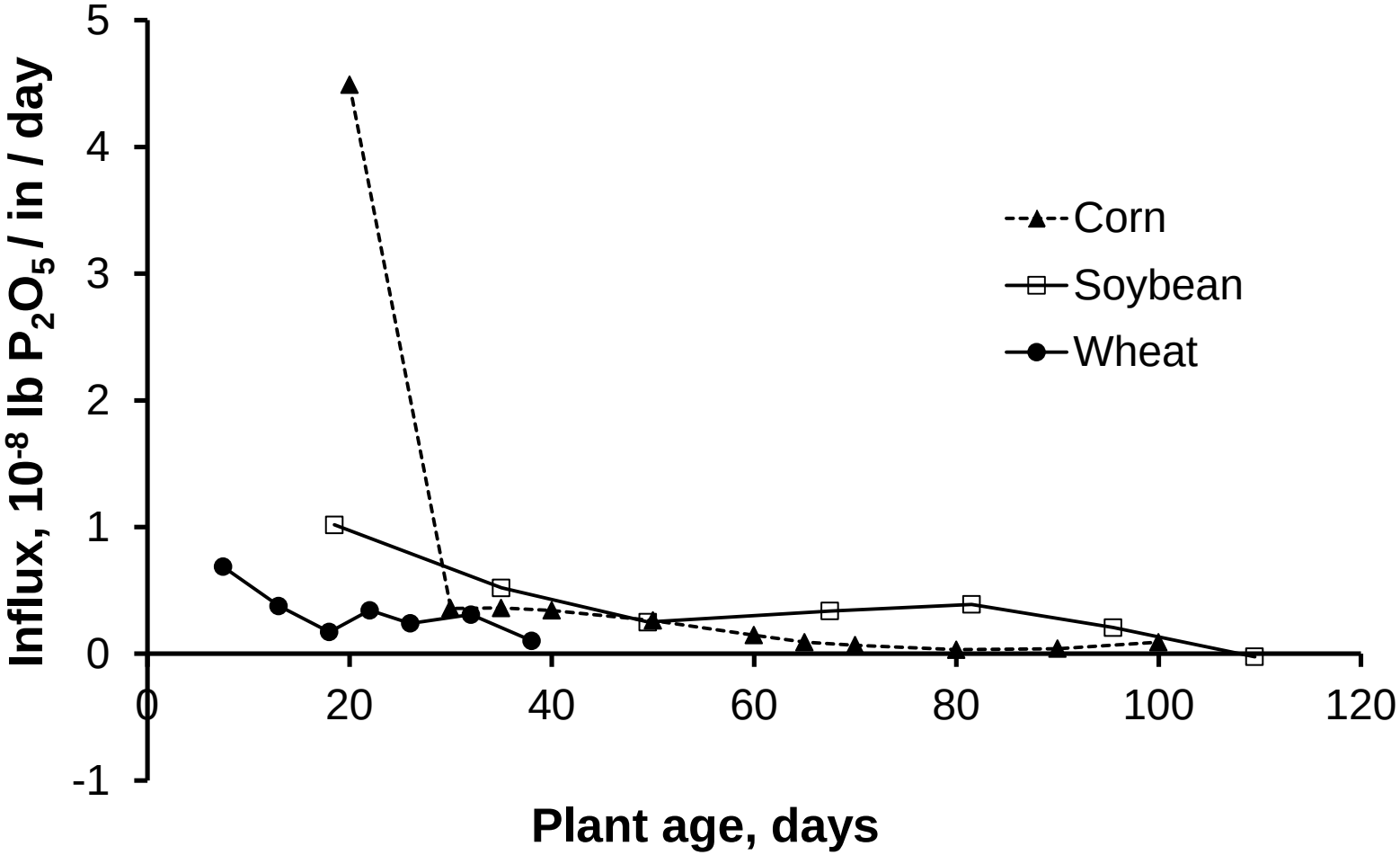
- Nutrient ions require energy to be absorbed
  - $H_2PO_4^-$, HPO_4^{2-}
  - K^+
- Maximum influx is reached at higher solution concentrations (I_{max})

22-23 day old soybean roots



Barber, S.A. 1984. Soil nutrient bioavailability: A mechanistic approach. Wiley Interscience, New York, NY;
Edwards, J.H. and S.A. Barber. 1976. Agron. J. 68:973-975.

Influx changes with plant age



Anghinoni, I., et al. 1981. J. Plant Nutr. 3:923-933
Barber, S.A. 1978. Agron. J. 70:457-461
Mengel, D.B. and S.A. Barber. 1974. Agron. J. 66:399-402

Root Architecture

corn:
36 days old

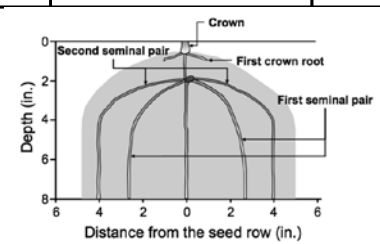
sugarbeet:
60 days old

soybean:
30 days
old

Weaver,
1926

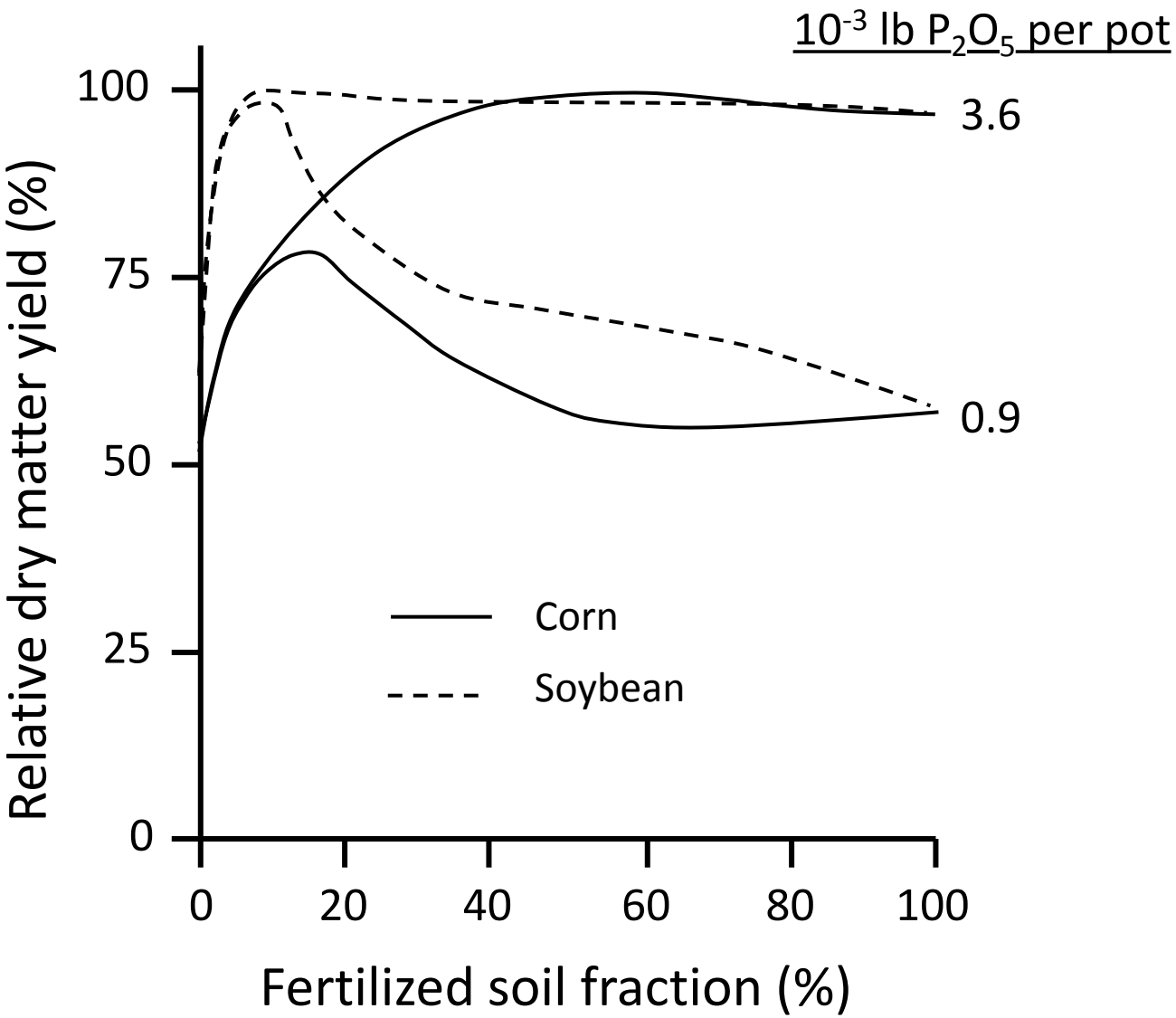
wheat:
Z3.1

Mitchell and
Russel, 1971



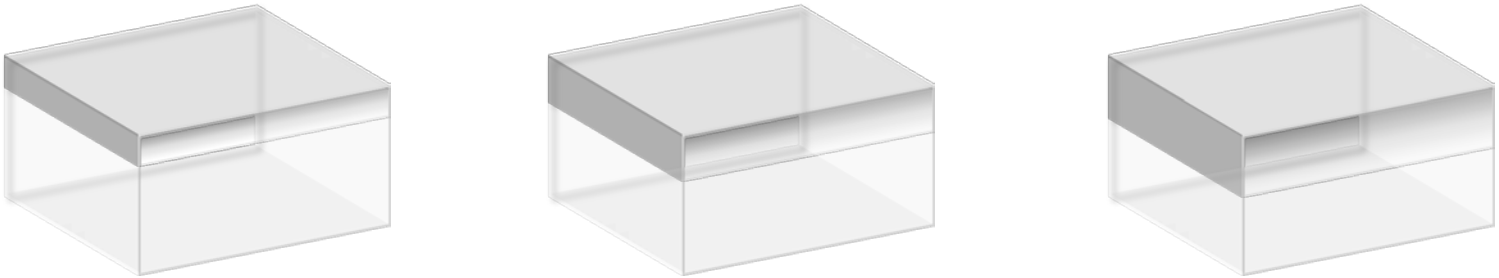
12 in.

Veseth et al.,
1986

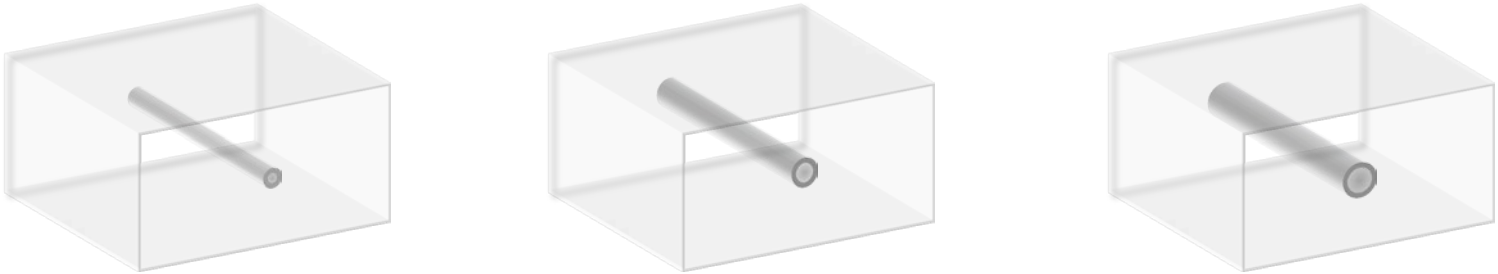


Anghinoni, I. and S.A. Barber. 1980. Soil Sci. Soc. Am. J. 44:1016-1020;
Borkert, C.M. and S.A. Barber. 1985. Soil Sci. Soc. Am. J. 49:901-904

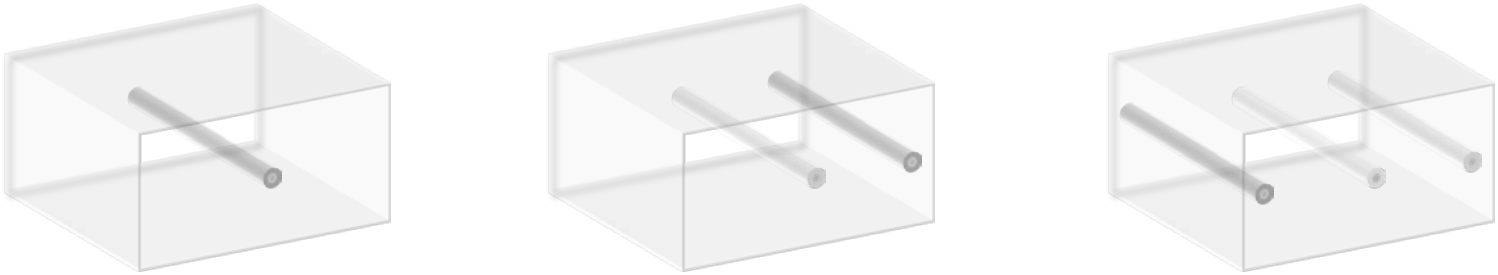
Broadcasting nutrients over time (conservation tillage)



Banding nutrients in the same location over time



Banding nutrients in different locations over time



Increasing time

Outline – Practical Aspects of P Placement

1. 4Rs and Right Place – what's the goal?
2. Broadcast versus band comparison
3. Soil P stratification
4. Reducing loss of dissolved P

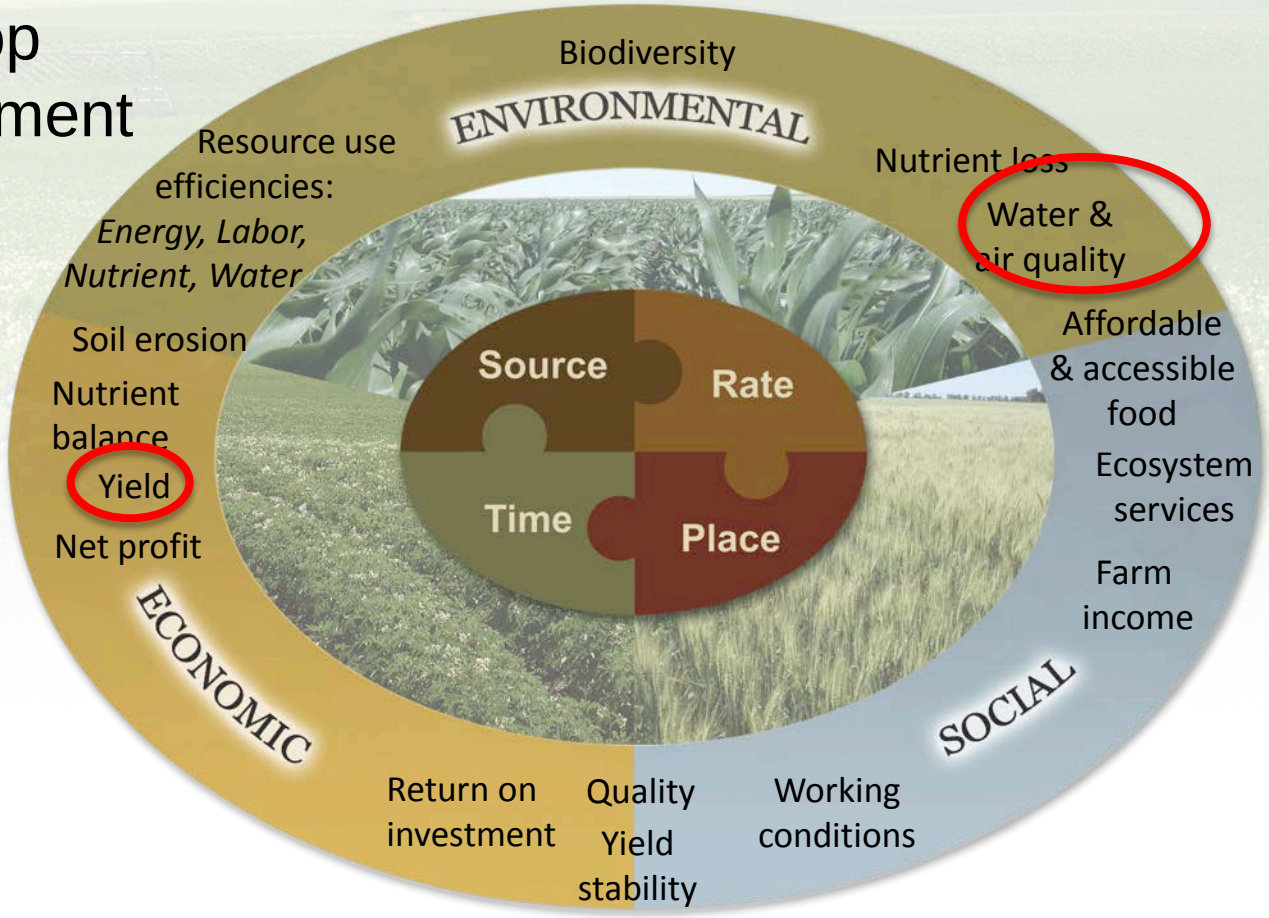
Tom Bruulsema, PhD, CCA
Director, Northeast Region
IPNI North America

4R nutrient stewardship

IPNI

The 4Rs influence many performance indicators

- social, economic and environmental performance
- influenced by crop and soil management as well
- whole system outcomes



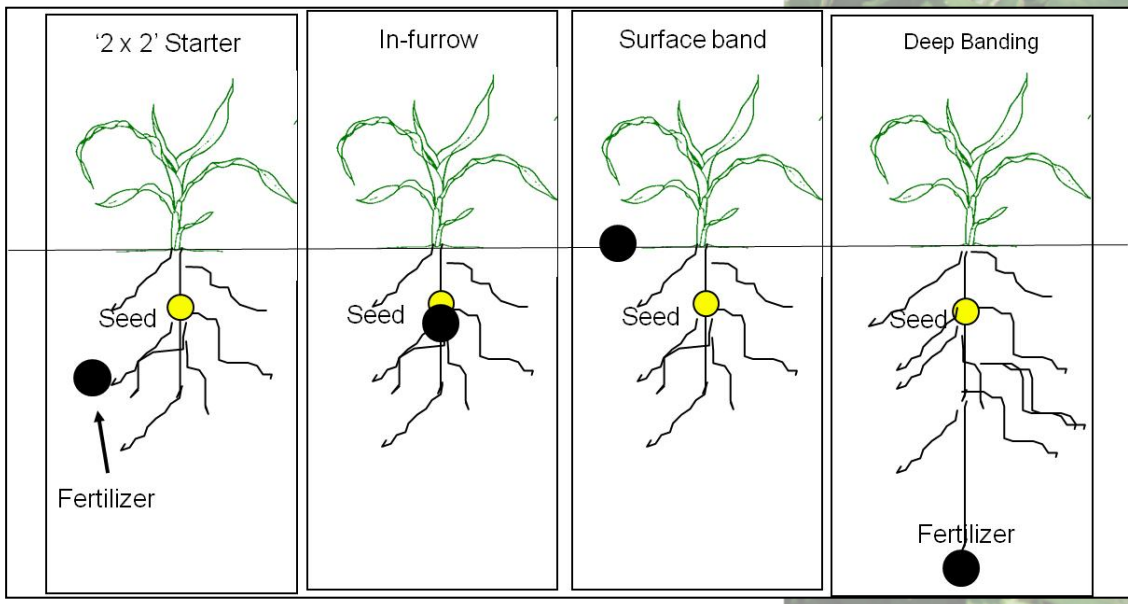
Right Place

Scientific Principle:

- Place nutrients where they are accessible to the crop.

Practices:

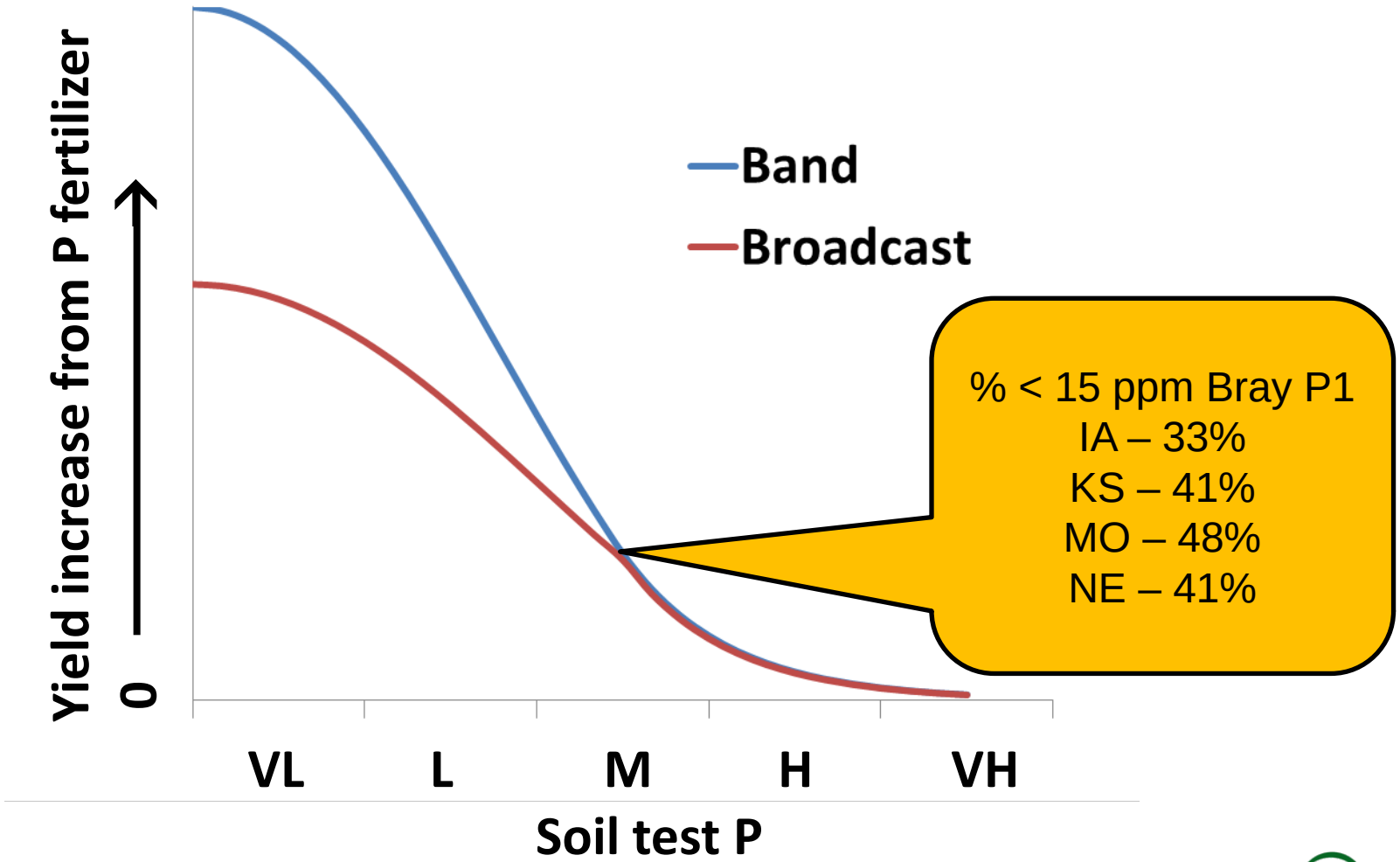
- **Placement** near seedlings
- **Broadcast, band, inject, or incorporate**
- Precision RTK-GPS
- Within-field management zones



4R PLANT NUTRITION

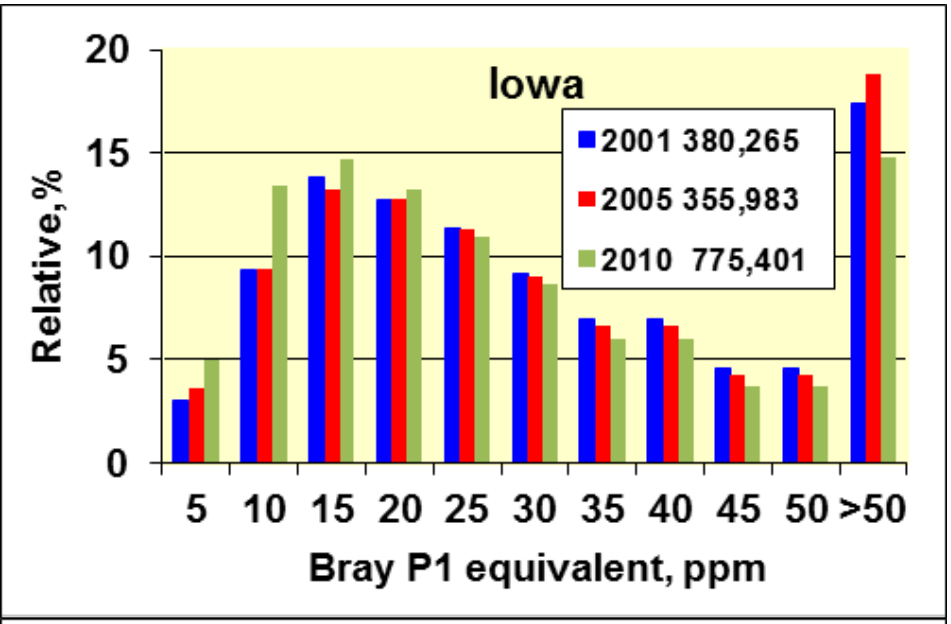
nutrient stewardship

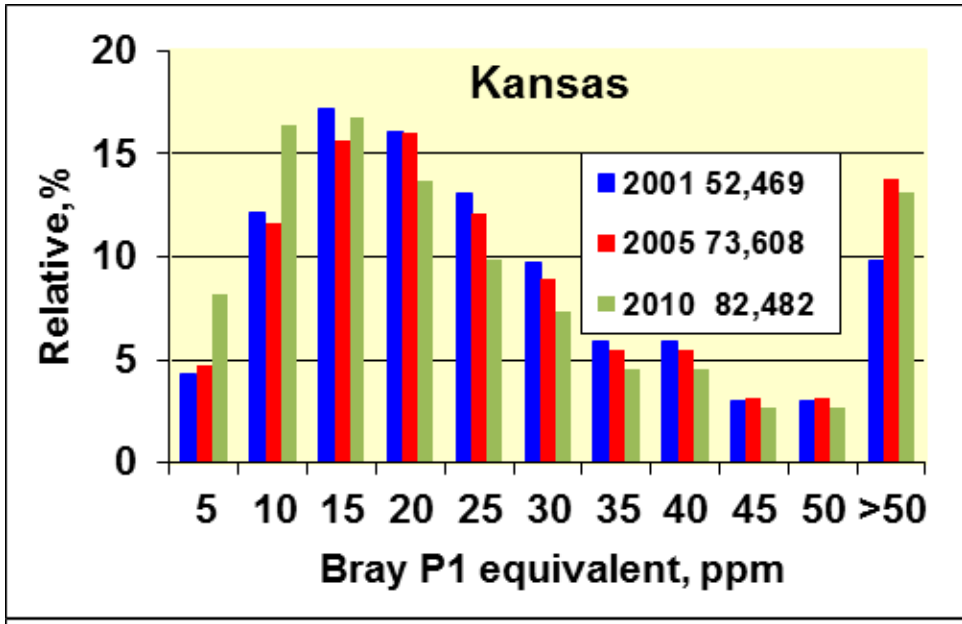
Idealized effect of placement on crop response

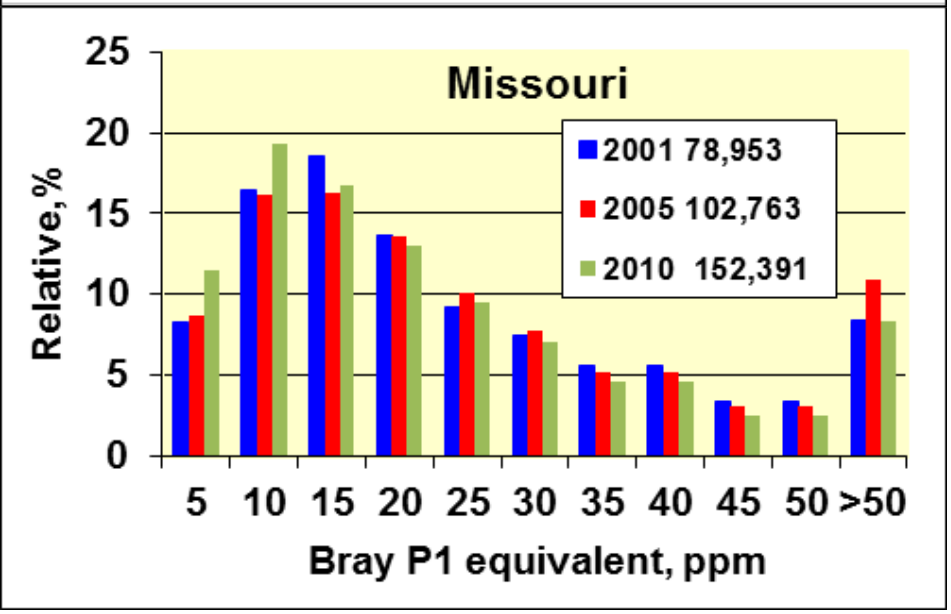


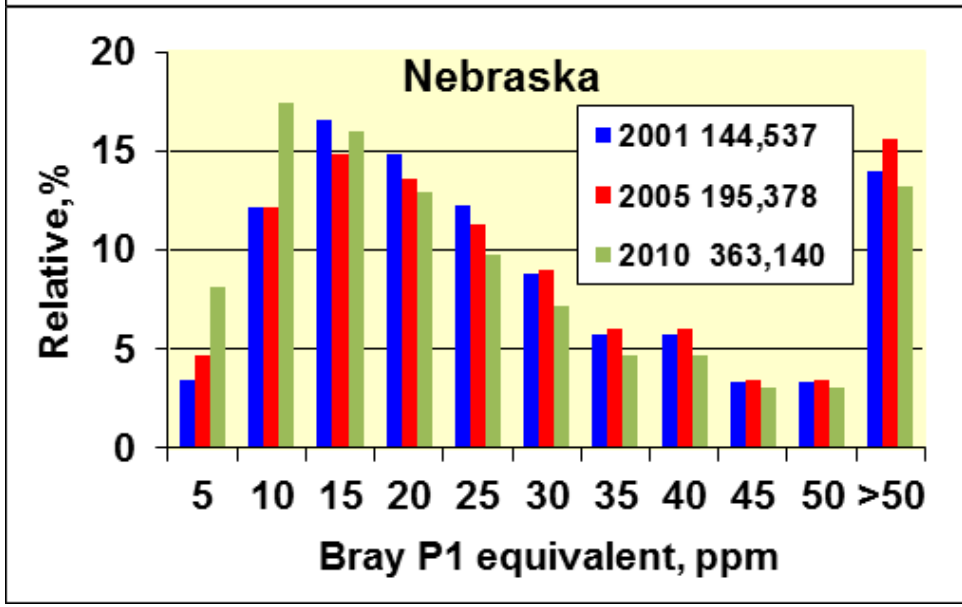
Randall and Hoeft, 1988

Bray P1 equivalent soil test levels





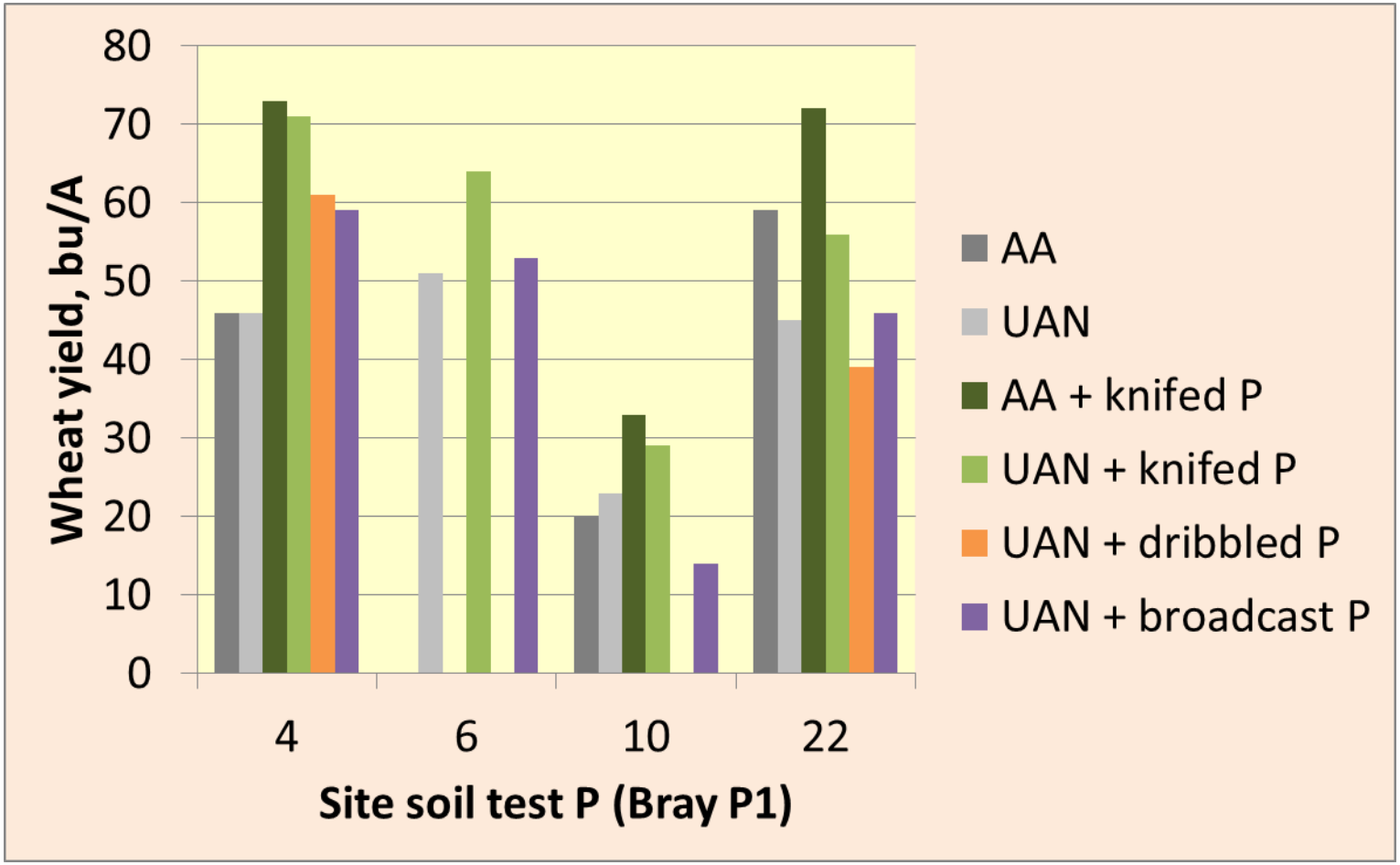




Soil Test Levels in North America, IPNI, 2010

IPNI

Wheat response to dual knife N-P application

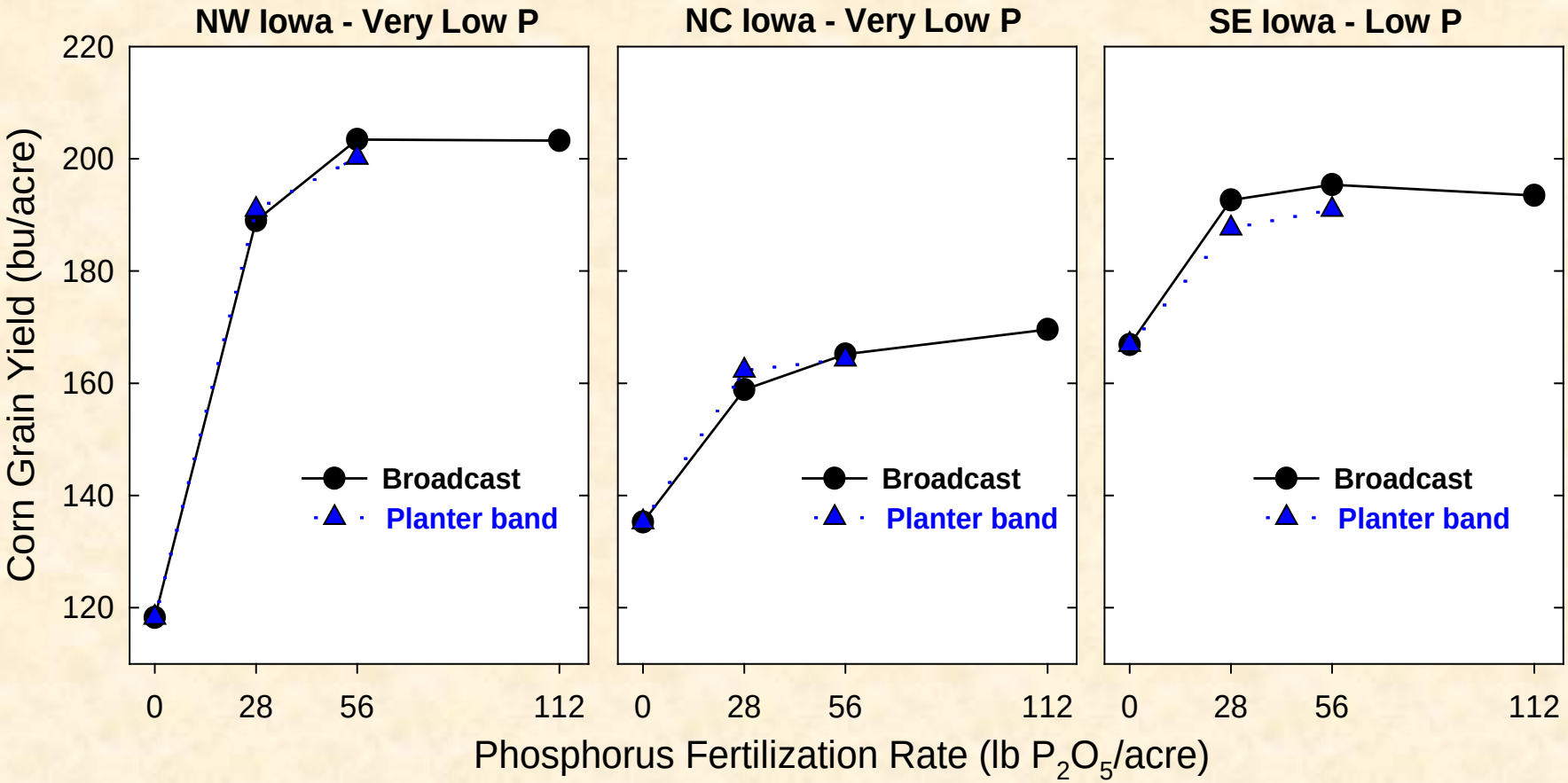


Leikam, et al., 1983

Broadcasting – practical advantages

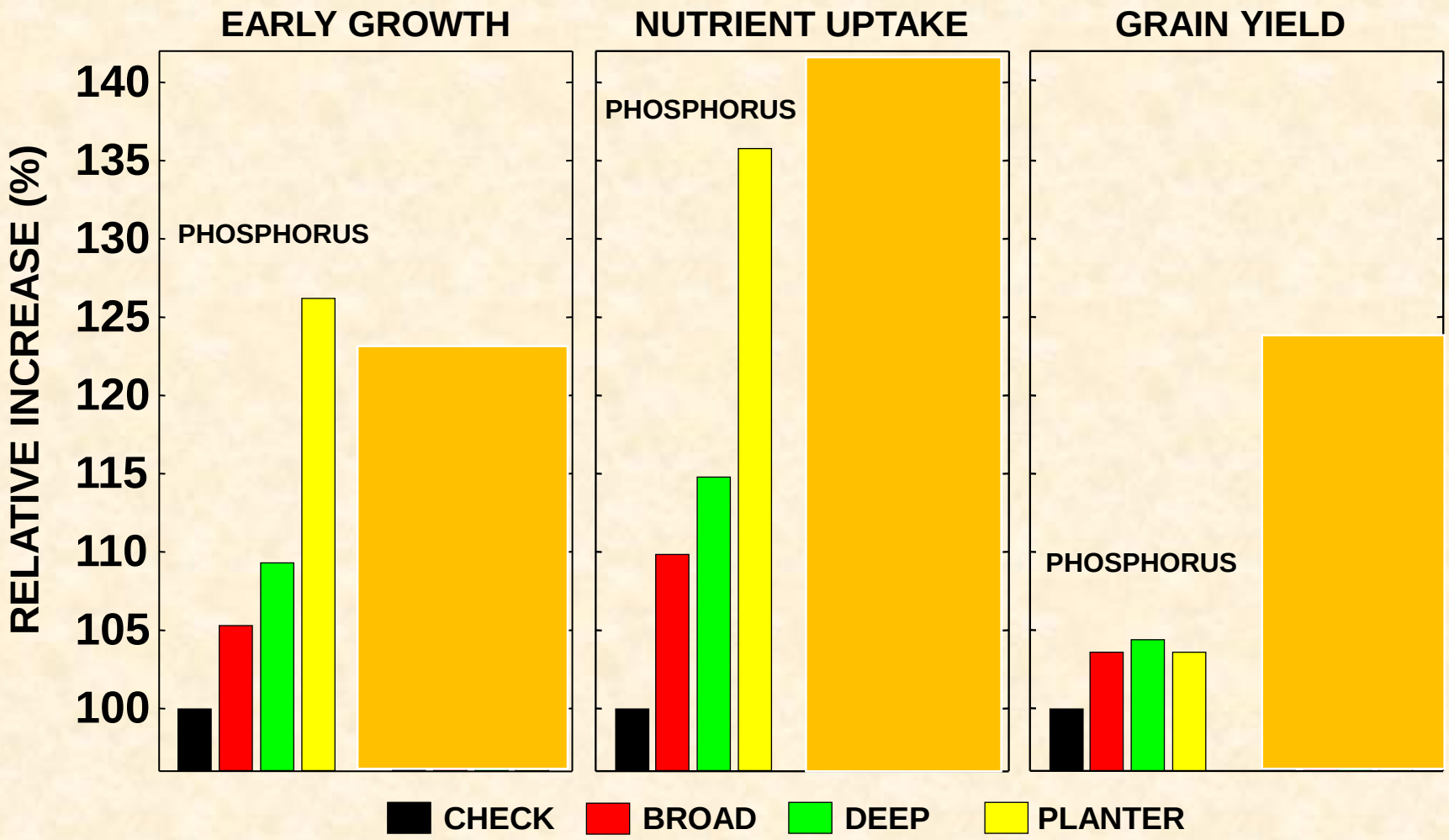
- Lowest application cost
- Granular or fluid forms
- Can combine with herbicide application
- Can avoid soil compaction
- Flexible timing – 20 field trials over 3 years on no-till corn and soybeans in Iowa found no difference in yields between fall and spring application (Mallarino et al., 2009; Bray-P1 6-29 ppm; 12 yield responses out of 20 sites)

Phosphorus Placement for No-Till Corn



Mallarino, ISU. 2010

P Placement for Growth, Uptake, Yield for No-Till Corn



Mallarino, Borges, Bordoli. ISU

Band placement – new approaches

- Large planters require tanks for fluids, or air carts for granular forms of P
- RTK-GPS allows banding before planting – spring or fall
- For cereals in semi-arid plains, either seed-placed or deep-banded P produces better responses than broadcast
- In-furrow or seed-placed P with corn produces yield responses more in the northern than southern Corn Belt, and the response can be independent of soil test P or other applied P

IPNI

Sampling soils with history of bands

If band locations are known:

- For narrow bands at 30-inch row spacing, a ratio of 1:20 in-band to between-band cores.
- For wider zones, as in strip-tillage, ratio of in:between same as strip:non-strip width; e.g. 1:3 (Fernandez and Schaefer, 2012)

If band locations are unknown:

- Paired sampling approach (Kitchen et al., 1990):
  - first of each pair at random;
  - second at half the band spacing away, perpendicular to the band
  - Sample with the lower soil test P level most likely to be representative.

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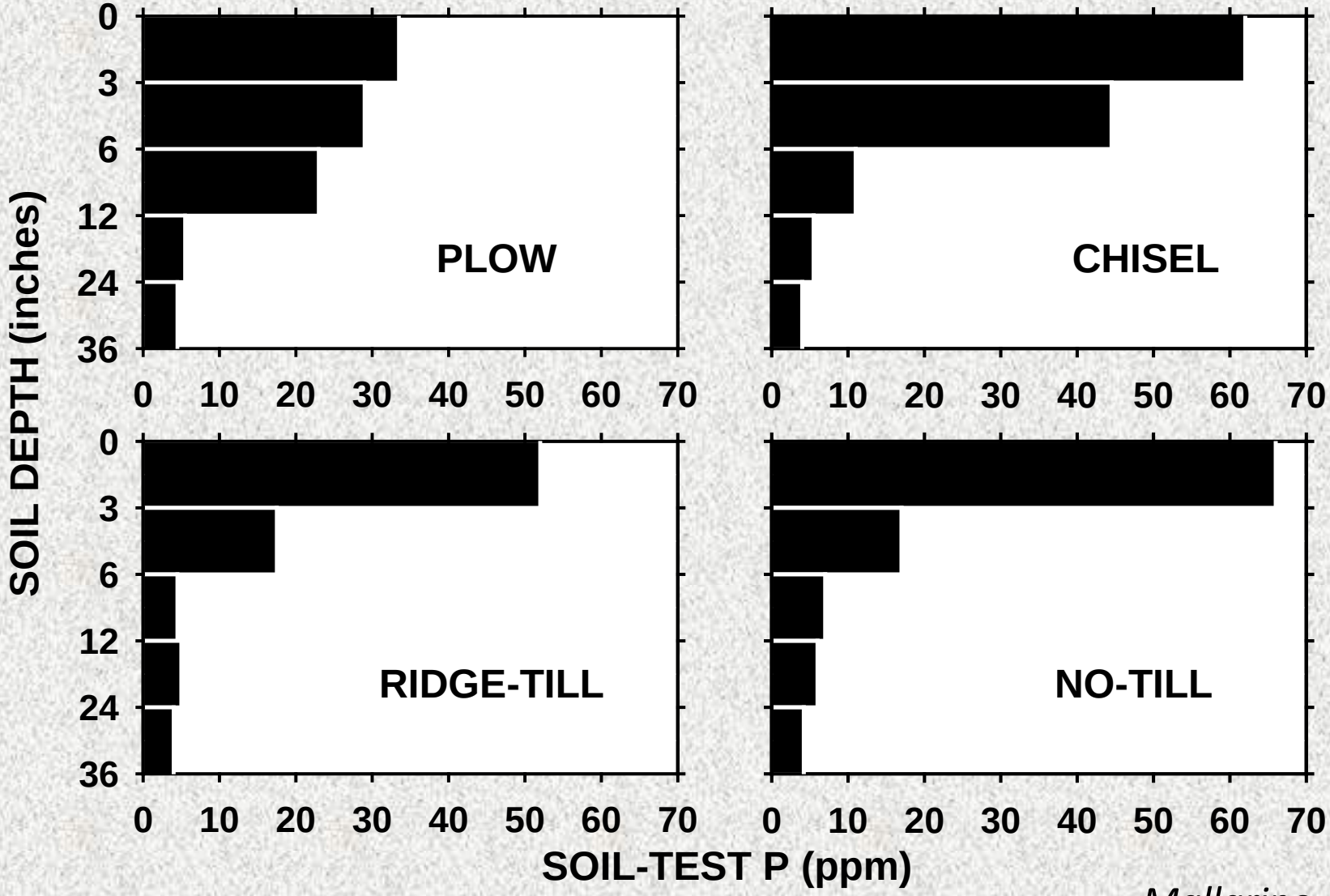
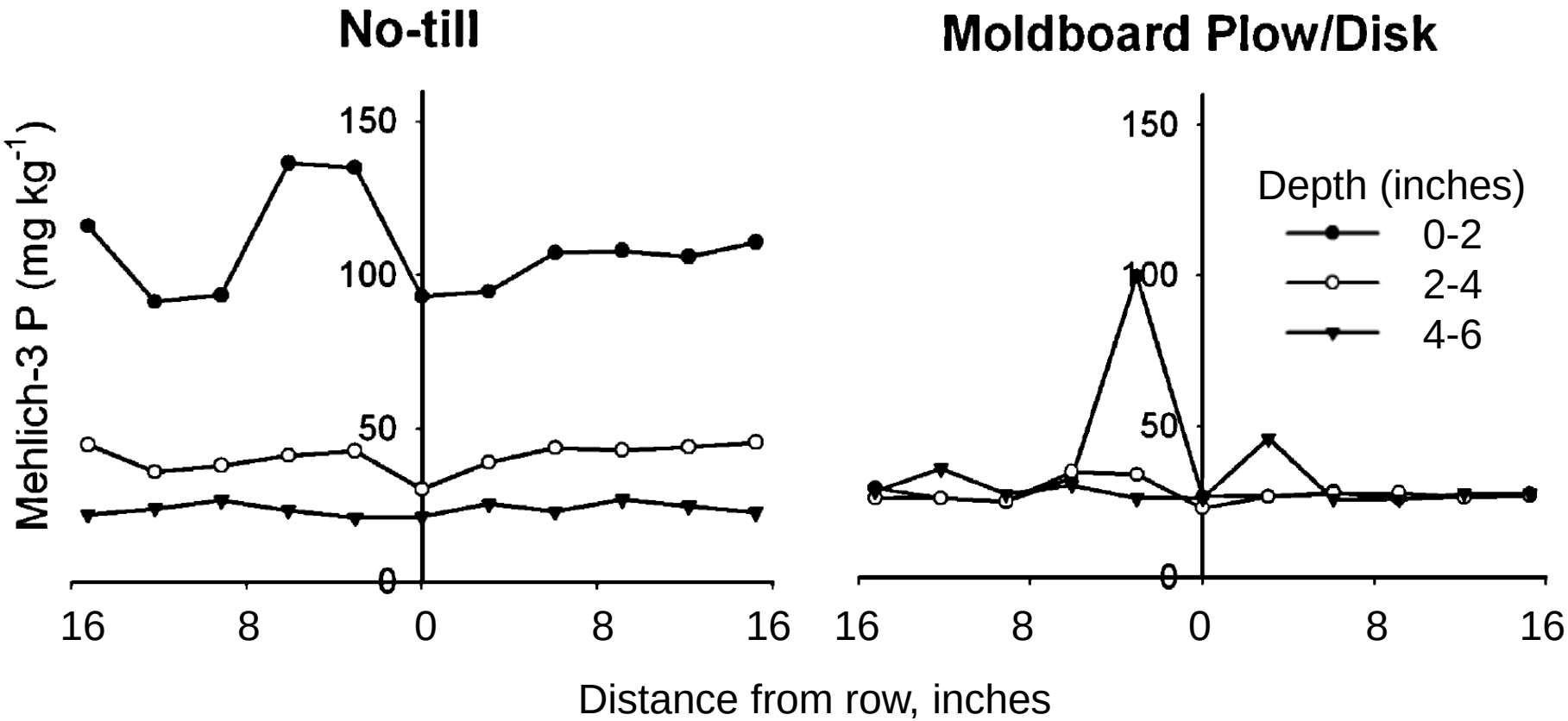
Tillage and Soil P Stratification



Mallarino, ISU.

Soil P stratification after 25 years in PA



Continuous corn 1978-2003 except oats in 1986 and soybean in 1995/1996.
Average yield 100 bu/A. Starter fertilizer contained 22-33 lb P_2O_5/A each year.
One broadcast application in spring 2001 contained 61 lb P_2O_5/A.
Soil sampled November 2003.

Duiker and Beegle, 2006

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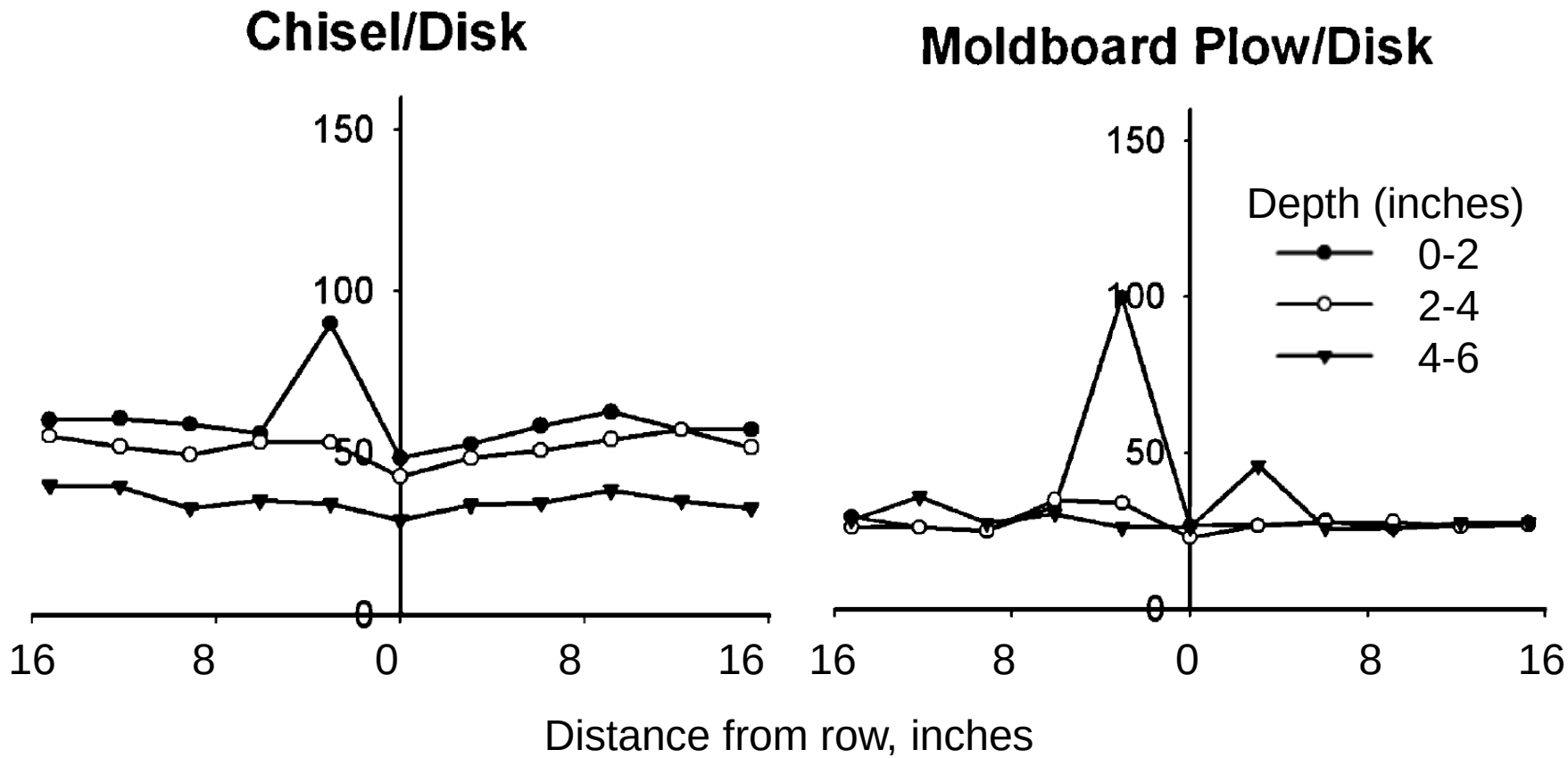

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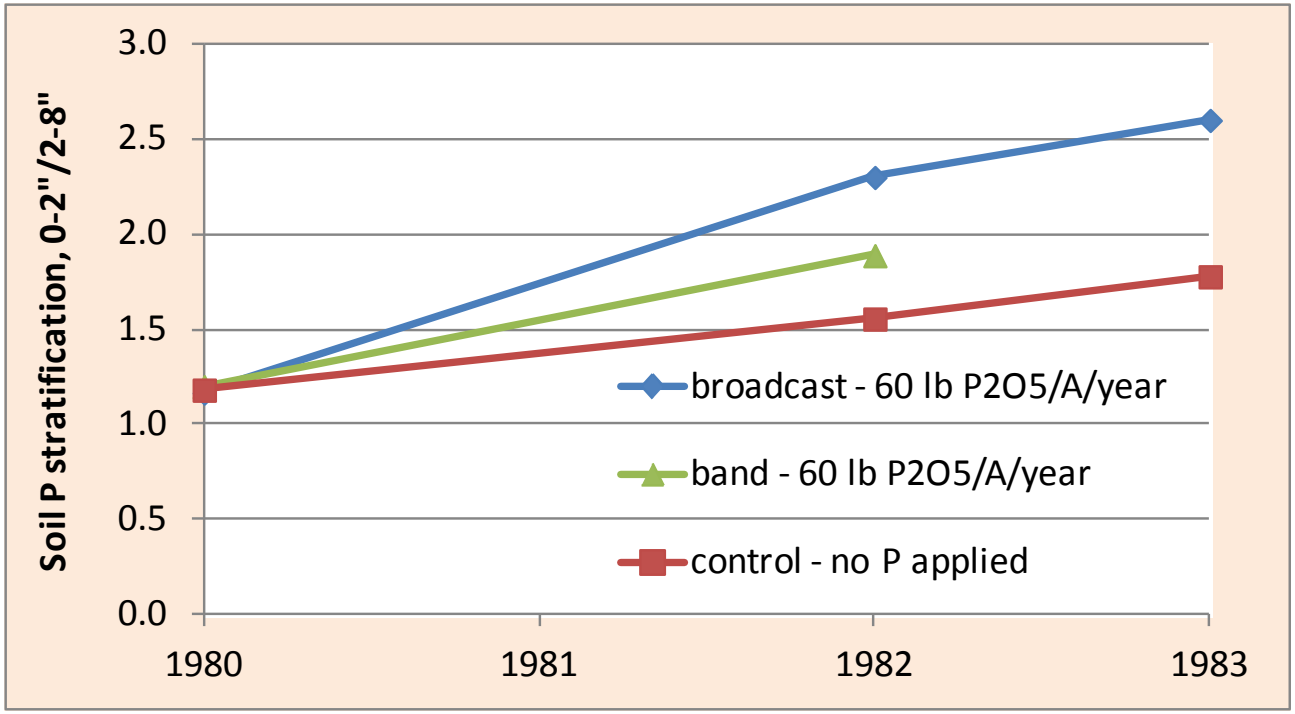
Duiker and Beegle, 2006

Soil test P stratifies more with broadcast than with banding



Soil P stratification—the ratio of soil test P in the top 2” compared to that in the 2-8” depth—increased more with broadcast than with band application. Silt loam soil near Wooster, Ohio; continuous corn, no-till from spring 1980. Data from Eckert and Johnson (1985).

Algae in Lake Erie

Setting and achieving phosphorous targets will prevent excessive algal blooms such as this one near Maumee Bay, Ohio in September 2008. Photo credit: Joe Barber, Ohio Department of Natural Resources Division of Wildlife

Conservation tillage and dissolved P in runoff

"Conservation tillage practices are ineffective in reducing the loss of water soluble nutrients; however, they did reduce total nutrient loss by controlling erosion" (Barisas et al., **1978**)

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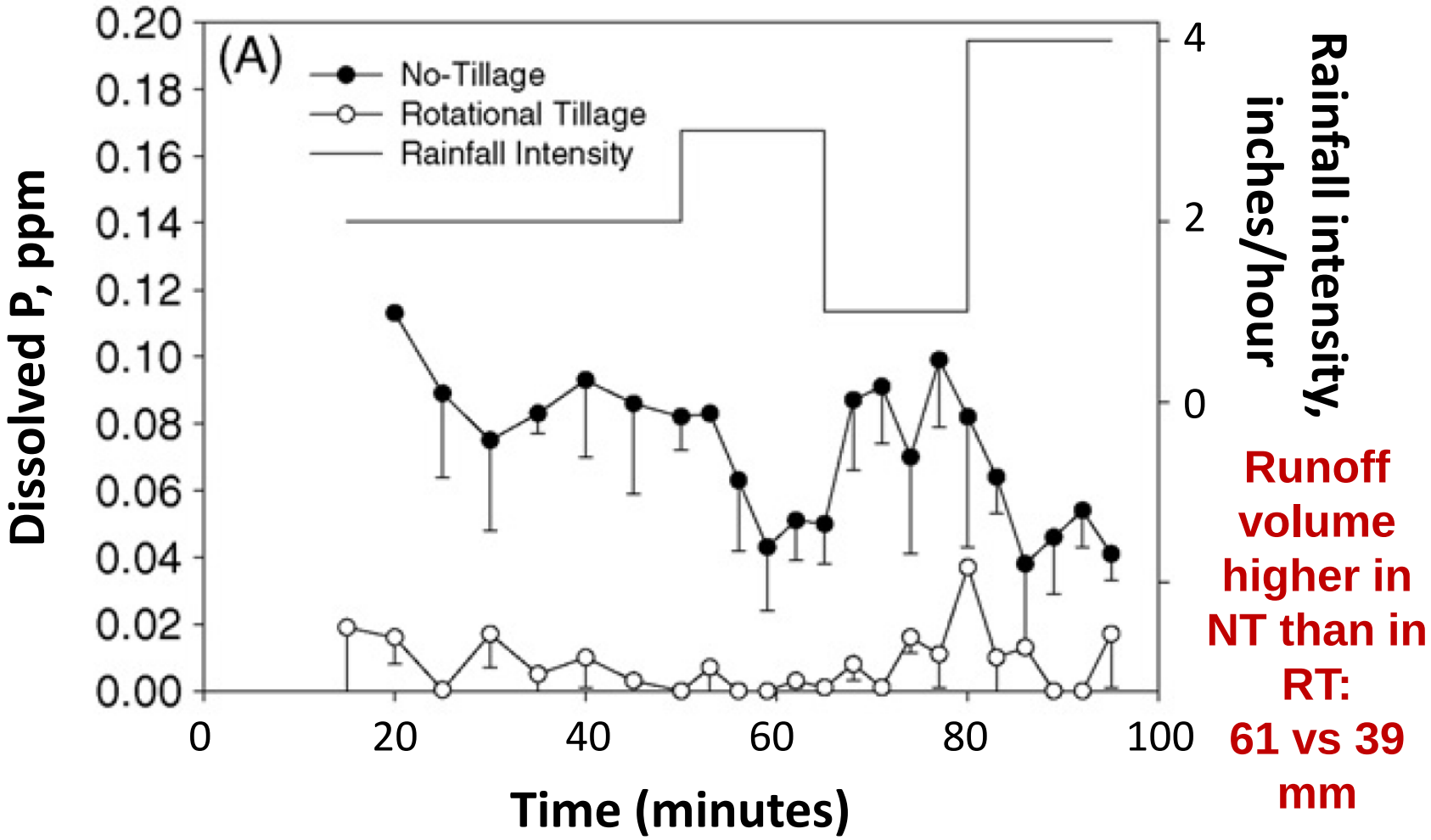
Rotational tillage & dissolved P – Waterloo, IN

before fertilizer application

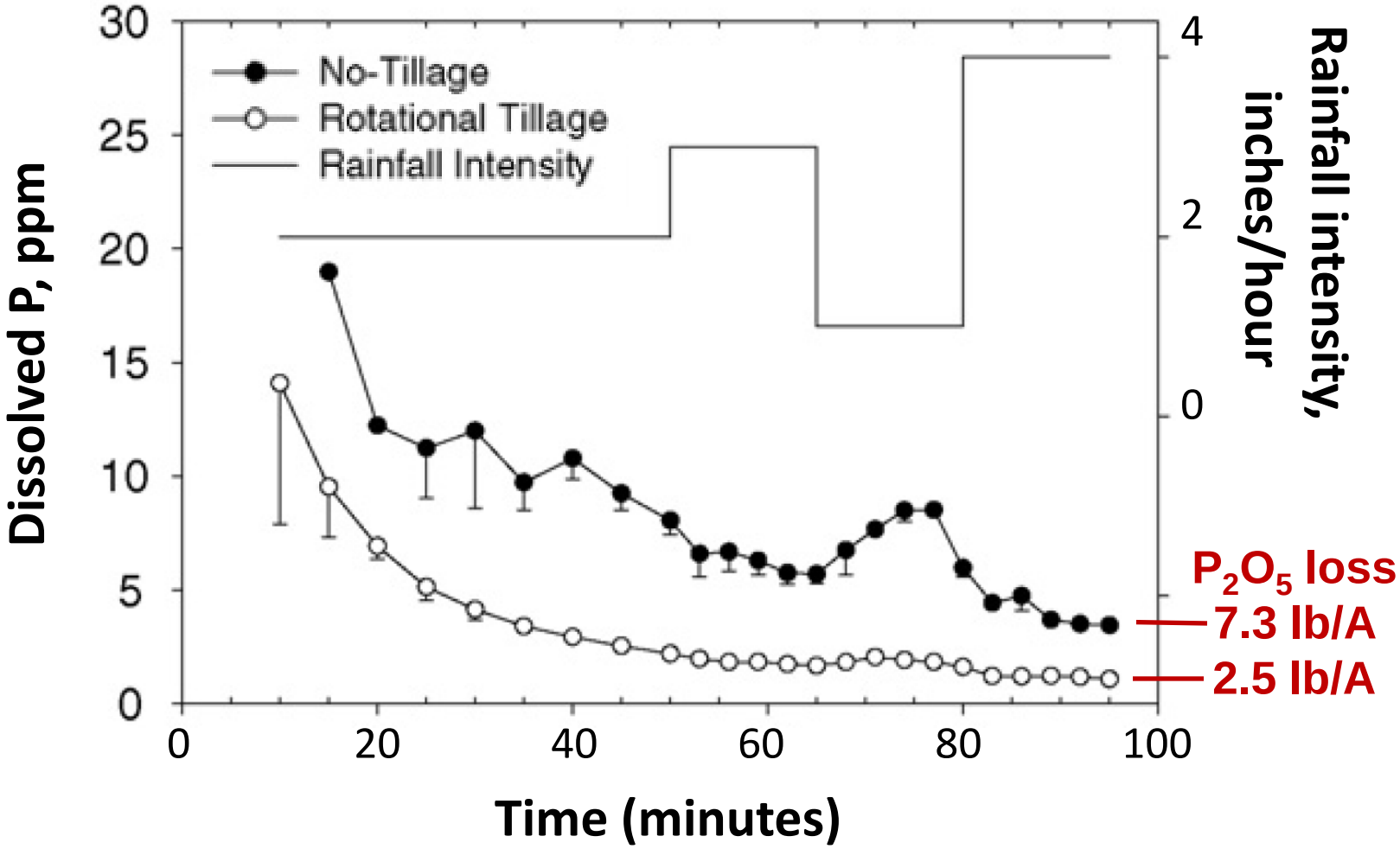


Runoff volume higher in NT than in RT: 61 vs 39 mm

15-year no-till sites, corn-soybean rotation. Tillage 12 April with "finisher" chisel plow to 6" depth. Residue cover 57% for NT and 20% for RT. Rainfall applied 22 June to 2 July. *Smith et al. 2007. Soil & Tillage Research 95:11–18*

Rotational tillage & dissolved P – Waterloo, IN

one day after 0-46-0 fertilizer surface applied @ 100 lb/A P_2O_5



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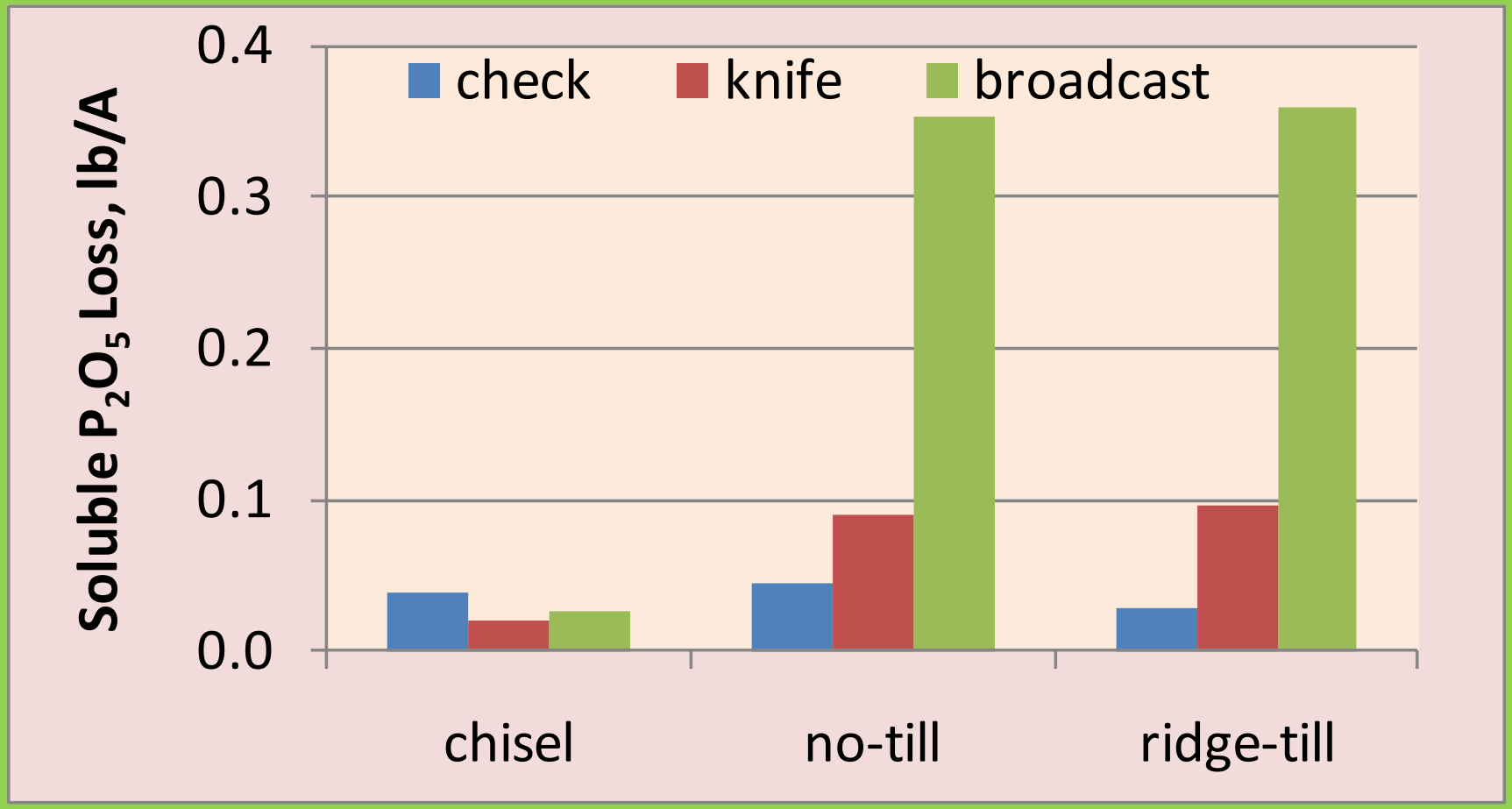
Fluid P – knifed-in versus broadcast



Annual runoff P losses as affected by tillage x placement in sorghum – soybean rotation. East-central Kansas.
Fluid applied @ 50 lb P_2O_5/A.

Kimmel et al. 2001. J. Environ. Qual. 30:1324-1330

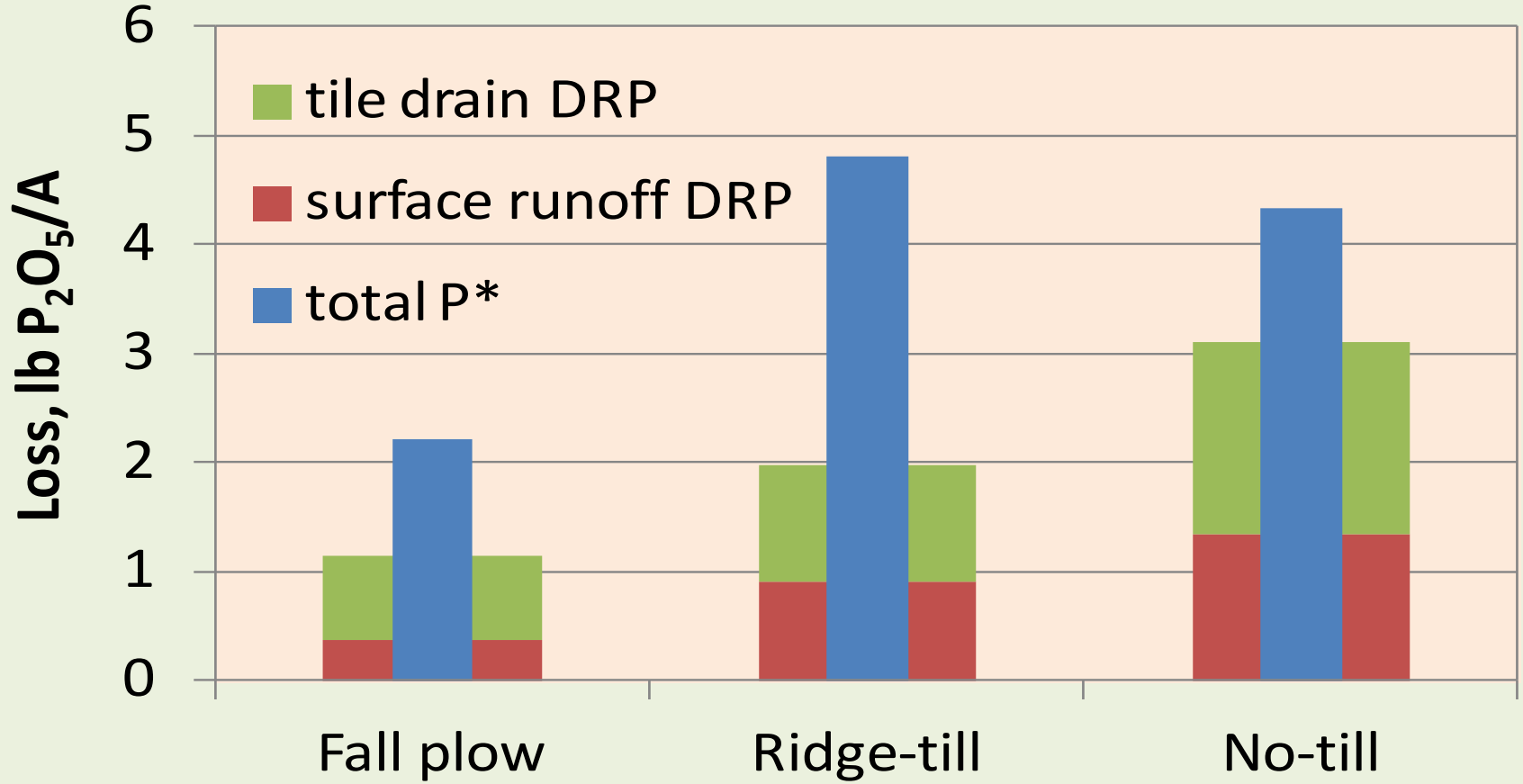
No-till may reduce P loss when runoff volume is reduced

Tillage system	Runoff volume, mm	Runoff dissolved P, mg/L	Dissolved P loss, lb P_2O_5/A
No-till	8	5.1a	0.6 b
Chisel plow	29	2.2b	0.8 ab
Moldboard plow	45	2.3b	1.4 a

The total dissolved P lost represented about 2.6% of the fertilizer P applied.

Seta, et al., 1993 – Maury silt loam in Kentucky

P loss from three corn tillage systems, Woodslee, ON 1988-1990

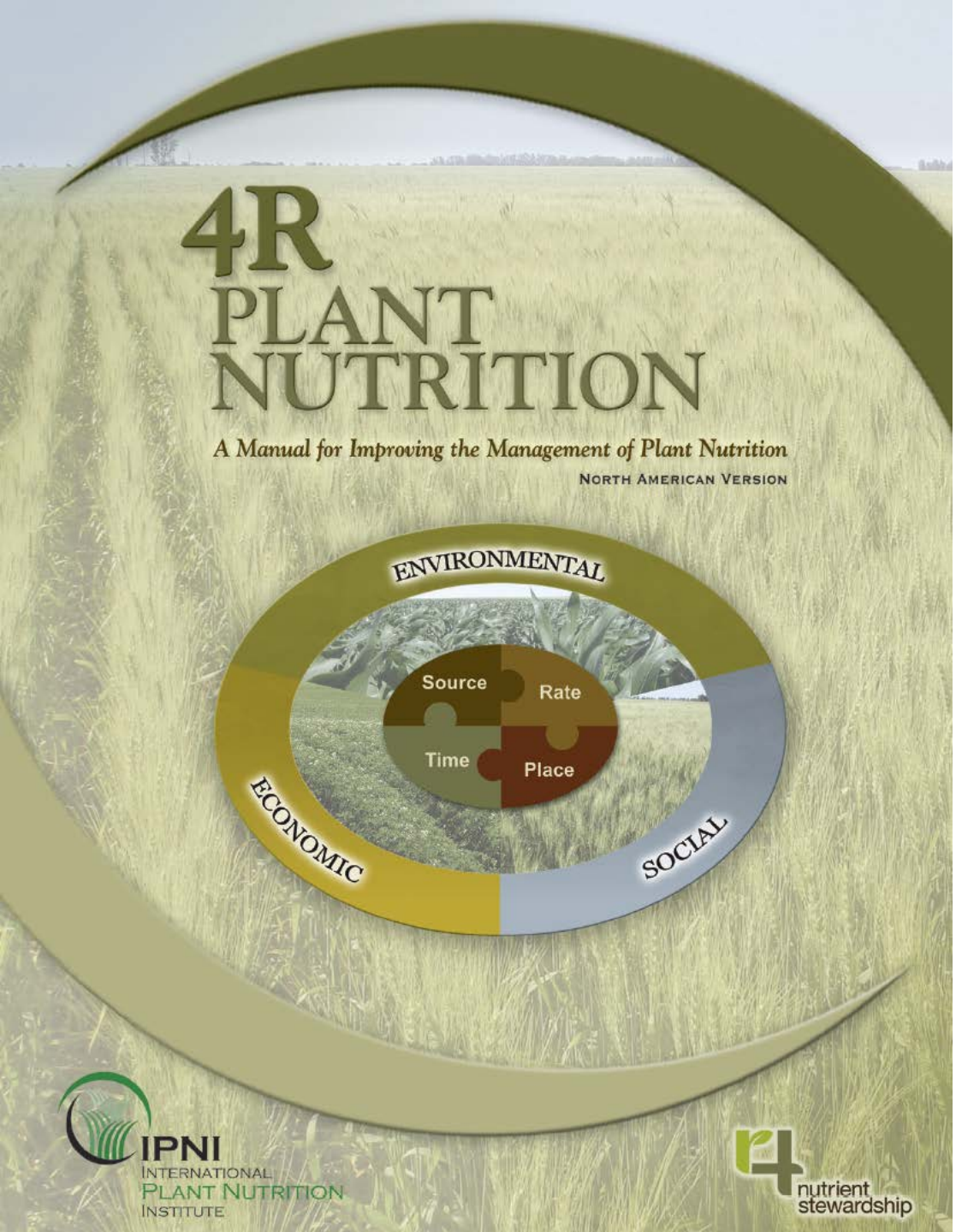


Continuous corn; Brookston clay loam; 3-year average
No-till had 40% more surface runoff water, 20% less tile drain water than plow
*estimated from 1990 data only
Gaynor and Findlay, 1995

Summary

1. The right place for P is where it's accessible to plants.
2. When soil test P is in the optimum range, broadcast is as good as band for agronomic response.
3. Soil P stratification under conservation tillage can be partly limited by band application.
4. Band application can reduce loss of dissolved P in runoff by keeping P fertilizer off the soil surface.

nutrient stewardship



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