Managing P & K for Corn and Soybeans – Short and Long-term Decisions

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AGVISE Seminar Series
Jan. 6, 7 & 8, 2015

Currently, how do you determine your fertilizer P and K rates for your farm?

- Based on soil test information
  - Grid / zone samples or whole fields
- Follow U of MN recommendations
  - for some or all nutrients
- Dealer or ag advisor (crop consultant)
  - if yes, what do they use?
- Crop removal
- Put on the same as last year (historically)
- Whatever I can afford

Soil Testing Concerns

- Best diagnostic tool we have for making P, K & Zn recommendations
- But it has uncertainties (temporal & spatial)
- Grid sampling and variable rate application
  - Newly acquired land,
  - Geo-referenced
  - Increases potential for higher and more profitable yields and lowers risk of yield loss due to insufficient P or K.

Phosphorus

P Fertilizer Management Philosophies

1) Sufficiency / Response – based
   - data base adequately predicts a crop response under good or normal conditions
2) Buildup / Maintenance – based
   - P removed in crop should be replaced
   - often used on soils testing Med. or High
   - Yield response to extra maintenance fertilizer is NOT expected, but the fertilizer is added to maintain STP over time.
   - STP is greater than for Sufficiency philosophy

Response-based P Management

- Emphasizes short-term returns
- Requires high accuracy of soil testing, calibrations, and optimum economic fertilizer rates each year.
- Requires frequent soil sampling and careful fertilizer application methods
- Reasonable for “fixing” soils where buildup and maintenance is not practical

Source: A. Mallarino

Buildup/Maintenance-based P Management

- Emphasizes long-term productivity and returns, and reduced risk of yield loss.
- Less sensitive to errors in soil testing and calibration.
- Does not require as frequent soil testing.
- Reasonable for soils with little to moderate “fixation”.
- Suitable when land tenure is secure for at least 2-3 years.
- Suitable for larger farming operations.
- Provides flexibility when fertilizer prices change!

Source: A. Mallarino

Other P Management Issues

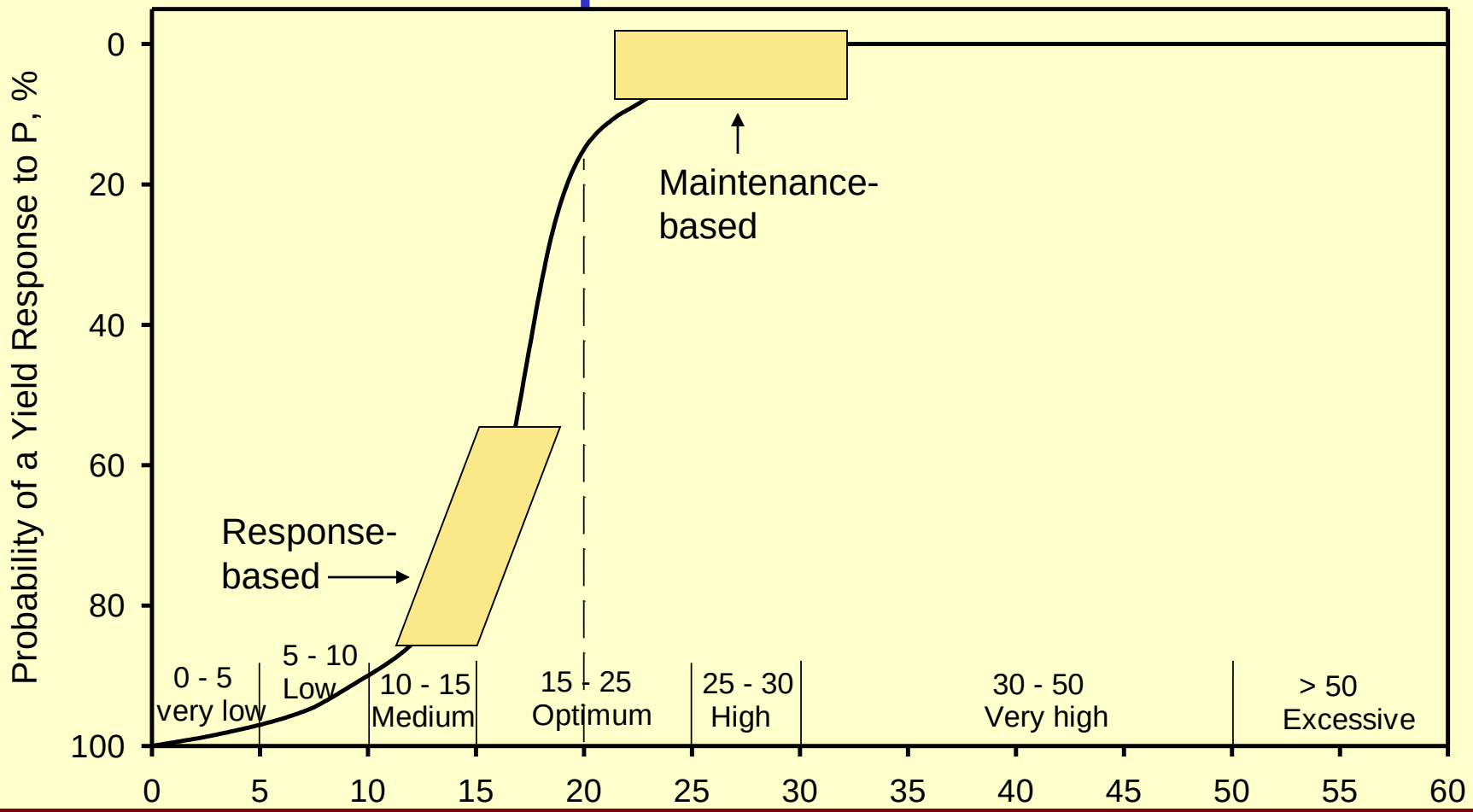
- To a large extent, P & K can be “banked”.
- Retention by soil is not necessarily “fixation”.
- Soil testing is not perfect ---uncertainties.
- Use long-term soil test trends to monitor P & K additions and removal.
- Land tenure, farmer’s management philosophy and cash position, and other practical issues should be considered in conversations among farmer, dealer, consultant, and lender.
- What probability of yield response & risk of yield loss is the farmer comfortable with?

P and K Recommendations

"A Model for the Future"

Proposed

Phosphorus soil test model for Minnesota corn production.



Long-term P Management Study

Waseca, 1999-2004

- Study was started at Waseca and Morris by George Rehm with the first broadcast applications made in the fall of 1998.
- Purpose: to determine the effect of various P management strategies on the long-term agronomic response and economic returns of corn and soybean.
- Fertilizer P was applied for both corn and soybeans over a 5-yr period (1999-2003). George terminated the study after harvest in 2003 due to plot charges of $400.
- Because of the P history and the large range in STP, we continued the study in 2004 to determine the yield response to residual P (STP).

Long-term P Management Study

Waseca, 1999-2004

TREATMENTS

	Strategy			P Rate	
No.	Freq.	Philos.	Method	Corn	Soybean
				-- lb P_2O_5/A --	
1	None, Control			0	0
2	Annual	CR	Bdct.	60	45
3	Biennial	CR	Bdct.	105	0
4	“	2xCR	Bdct.	210	0
5	Annual	UM	Bdct.	40	15
6	Biennial	UM	Bdct.	80	0
7	Annual	UM	2x2	30	15
8	“	2xUM	2x2	60	30

Experimental Details

Soil: Nicollet cl

Crops: Corn-soybean rotation, both crops each year

Reps: 4 per crop.

Initial STP (Bray 1): 17 ppm (H)

CR: Crop removal

Corn = 0.35 lb P_2O_5/bu YG = 170 bu/A
Soybean = 0.90 lb P_2O_5/bu YG = 50 bu/A

P Applied: for 1999-2003 crops, residual = 2004

Experimental Details cont.

Prices:	Low	High
Bdct. P_2O_5[1/] ($/lb)	0.30	0.60
Row P_2O_5[1/] ($/lb)	0.45	0.80
Corn ($/bu)	2.40	5.00
Soybean ($/bu)	5.50	12.00

[1/] P sources: Bdct = 0-46-0, Row = 10-34-0

Annual Fertilizer Cost across Five Years of a 50:50 Corn-Soybean Rotation as Affected by P Strategy

Trt. No.	Strategy	P_2O_5 Rate		Fert. Price	
		Corn	Soybean	Low	High
				-- $ A/yr --	
1	None	0	0	0	0
2	Annual Bdct.	60	45	15.80	31.50
3	Biennial “	105	0	15.80	31.50
4	“	210	0	31.50	63.00
5	Annual Bdct.	40	15	8.20	16.50
6	Biennial Bdct.	80	0	12.00	24.00
7	Annual Row	30	15	10.10	17.80
8	“	60	30	20.20	35.60

Long-term P Mgmt. – Yields

	Strategy			5-Yr Avg. Yield	
No.	Freq.	Philos.	Method	Corn	Soybean
				-- bu/A --	
1	None, Control			165.3	52.2
2	Annual	CR	Bdct.	170.7	53.9
3	Biennial	CR	Bdct.	167.4	53.7
4	“	2xCR	Bdct.	175.5	54.5
5	Annual	UM	Bdct.	165.7	53.8
6	Biennial	UM	Bdct.	171.4	53.6
7	Annual	UM	2x2	164.7	53.3
8	“	2xUM	2x2	168.7	53.8
		LSD (0.10) =		5.8	NS
		Yr x Trt IA (P>F):		0.650	0.192

5-Yr Avg. Yields - Conclusions

- Corn yields averaged across the 5-yr study were significantly affected by the P management studies, but soybean yields were not.
- Using a LSD of 5.8 bu/A, corn yields from two treatments (biennial broadcast rates for corn of 80 lb P_2O_5/A and 210 lb P_2O_5/A) were significantly greater than for the no-P control.
- The Year x P treatment interaction was not significant for either crop.

LTPM – Economic Return to P

No.	Strategy Freq.	Philos.	5-Yr. Avg. Yield Response Corn	SB	5-Yr Avg. [1/] Econ. Return Low[2/]	High[3/]	2003 STP
			- - - bu/A/yr - - -		- - - $/A/yr - - -		ppm
1	Control		0	0	--	--	11
2	Annual	CR	5.4	1.7	-4.60	-7.80	32
3	Biennial	CR	2.1	1.5	-9.20	-17.20	30
4	“	2xCR	10.2	2.3	-12.90	-23.70	54
5	Annual	UM	0.4	1.6	-3.30	-5.90	20
6	Biennial	UM	6.1	1.4	-0.80	-0.40	26
7	Annual	UM	-0.6	1.1	-7.80	-12.70	14
8	“	2xUM	3.4	1.6	-11.70	-17.50	20

[1/] Compared to control across corn & soybean

[2/] Low: crop & fertilizer prices.

[3/] High: crop & fertilizer prices.

5-Yr Economic Return - Conclusions

- When using the prices of the early 2000's (Low) and the current prices (High) for fertilizer P, corn, and soybeans shown in an earlier slide, none of the P management strategies resulted in an economic return to P fertilizer over the 5-year application period.

- However, Bray P_1 STP was considerably affected by the P management strategies, ranging from 11 ppm (M) for the No-P control to 54 ppm (VH) for the 210-lb P_2O_5 rate broadcast biennially.

- Soil test P was lowest (14 to 20 ppm) for the annual broadcast and row-applied rates using University of Minnesota P recommendations.

Long-term P Mgmt. – Residual Effect

	1999-2003 Strategy			2004 Yields	
No.	Freq.	Philos.	Method	Corn	Soybean
				-- bu/A --	
1	None, Control			172.7	51.5
2	Annual	CR	Bdct.	176.7	53.2
3	Biennial	CR	Bdct.	178.6	53.6
4	“	2xCR	Bdct.	194.2	54.1
5	Annual	UM	Bdct.	176.8	52.6
6	Biennial	UM	Bdct.	186.3	53.3
7	Annual	UM	2x2	174.8	50.5
8	“	2xUM	2x2	177.0	53.0
			LSD (0.10) =	9.6	NS

Residual P (STP) Effect - Conclusions

- Corn yields in 2004 from two treatments [biennial broadcast rate of 80 lb P_2O_5/A (186.3 bu/A) and the biennial broadcast rate of 210 lb P_2O_5 /A (194.2 bu/A)] were significantly greater than for the no-P control (172.7 bu/A).
- Soybean yields in 2004 were not significantly affected by the P management strategies.

Yield and Economic Response to Residual P

Trt.	Corn Response			Soybean Response		
		Corn Prices			Sb Prices	
No.	Yield	Low	High	Yield	Low	High
	bu/A	- - - $/A - - -		bu/A	- - - $/A - - -	
1	--	--	--	--	--	--
2	4.0	9.60	20.00	1.7	9.40	20.40
3	5.9	14.20	29.50	2.1	11.60	25.20
4	21.5	51.60	107.50	2.6	14.30	31.20
5	4.1	9.80	20.50	1.1	6.00	13.20
6	13.6	32.60	68.00	1.8	9.90	21.60
7	2.1	5.00	10.50	-1.0	-5.50	-12.00
8	4.3	10.30	21.50	1.5	8.20	18.00

Yield and Economic Response to Residual P - Conclusions

- In economic terms, corn yields were improved over the no-P control by 2.1 to 21.5 bu/A. Economic response to STP ranged from $5.00 to $51.60/A using the LOW prices and from $10.50 to $107.40/A when using the HIGH prices. Economic response tended to be least for the annual row and broadcast P_2O_5 treatments.
- Soybean response to residual P (STP) was minimal, ranging from –1.0 to 2.6 bu/A. Consequently, economic responses were consistently less for soybeans than for corn regardless of price level. Economic responses were lowest for the annual broadcast and row-applied rates using University of Minnesota P recommendations.

Improved P Management for Corn-Soybean Rotations in Very Reduced Tillage Systems

•*Opt. Tillage Systems for Corn and Soybean Production in South-Central Minn. Minn. Ext. Bul 08315. (2005)*

Years: 1997-2005
Location: Waseca Co., SROC (Both crops each year)
Soil: Webster-Nicollet cl complex
Tillage: NT, ST, Field cult./spr. Disk, CP+
Bray STP (ppm): 4-5 (V. low) and 19 (High)
P_2O_5 rates (lb/A): 0, 50 & 100 for corn on VL site
0, 40 & 80 " " " H site
0 for soybean on both sites

P placement: In-furrow w/seed, broadcast, 6" deep band

Six-year average C-S rotation yields as affected by P rate and placement on LOW and HIGH P-testing soils.[1/]

Year 1, 3 & 5 total P_2O_5 on		Avg. Corn Yield		Avg. Soybean Yield	
LOW-P	HIGH-P	LOW-P	HIGH-P	LOW-P	HIGH-P
- - - - lb/A - - - -		- - - - - - - - - - - - - - - - bu/A - - - - - - - - - - - - - - - -			
0	0	103	165	30	51
150	120	154	170	50	54
300	240	166	176	52	55

[1/] CP^+ tillage each year.

Two-year average C-S rotation yields in years 7 & 8 as affected by residual P (STP) on LOW and HIGH P-testing soils.[1/]

Year 1, 3 & 5 total P_2O_5 on		Yield			
		Corn (Yr 7)		Soybean (Yr 8)	
LOW-P	HIGH-P	LOW-P	HIGH-P	LOW-P	HIGH-P
- - - - lb/A - - - -		- - - - - - - - - - - - - - - - bu/A - - - - - - - - - - - - - - - -			
0	0	100	169	26	44
150	120	158	182	46	49
300	240	171	188	50	55

[1/] CP^+ tillage each year.

Economic return to residual fertilizer P (STP) in years 7 and 8 (2 site-years for each crop) of a C-S rotation as affected by P management on a HIGH P-testing soil.

Year 1, 3 & 5			Economic Return for [1/]		
Tillage	P_2O_5 Total	Place.	Corn	Soybean	C-S Avg.[2/]
	lb/A		- - - - - - - - - - $/A/yr - - - - - - - - - -		
FC/SD	120	Seed	32	12	22
"	120	Deep	25	32	28
"	240	Bdct.	25	26	26
CP^+	120	Seed	30	25	28
"	240	Bdct.	44	56	50

[1/] 10-34-0 = $1.32/gal., DAP = $0.26/lb P_2O_5, Corn = $2.30/bu, Soybean = $5.25/bu

[2/] Assuming a 50:50 C:S rotation

Economic return to residual fertilizer P (STP) in years 7 and 8 (2 site-years for each crop) of a C-S rotation as affected by P management on a HIGH P-testing soil.

Year 1, 3 & 5			Economic Return for [1/]		
Tillage	P_2O_5 Total	Place.	Corn	Soybean	C-S Avg.[2/]
	lb/A		- - - - - - - - - - $/A/yr - - - - - - - - - -		
FC/SD	120	Seed	70	26	48
"	120	Deep	55	72	64
"	240	Bdct.	55	60	58
CP^+	120	Seed	65	58	62
"	240	Bdct.	95	127	111

[1/] 10-34-0 = $3.15/gal., DAP = $0.60/lb P_2O_5, Corn = $5.00/bu, Soybean = $12.00/bu

[2/] Assuming a 50:50 C:S rotation

- Across the 2-yr period (years 7 and 8) for the C-S rotation, economic return to residual P from the fertilizer P applications in yrs 1, 3 & 5 ranged from $22 to $50/A/yr when using the 2003 prices and from $58 to $111/A/yr when using the 2008 prices.

Long-term P studies in Minnesota

Morris, MN: Aastad cl, pH = 7.6 and
Bray P = 10 ppm (L)

Waseca, MN: Webster cl, pH = 6.0 and
Bray P = 22 ppm (VH)

Time: 8 yrs cont. corn (1974-81) followed by
12 yrs Sb-C rotation.

P Treatments: 0, 50 & 100 lb P_2O_5/A broadcast annually and 150 lb P_2O_5/A broadcast triennially from 1973-84.

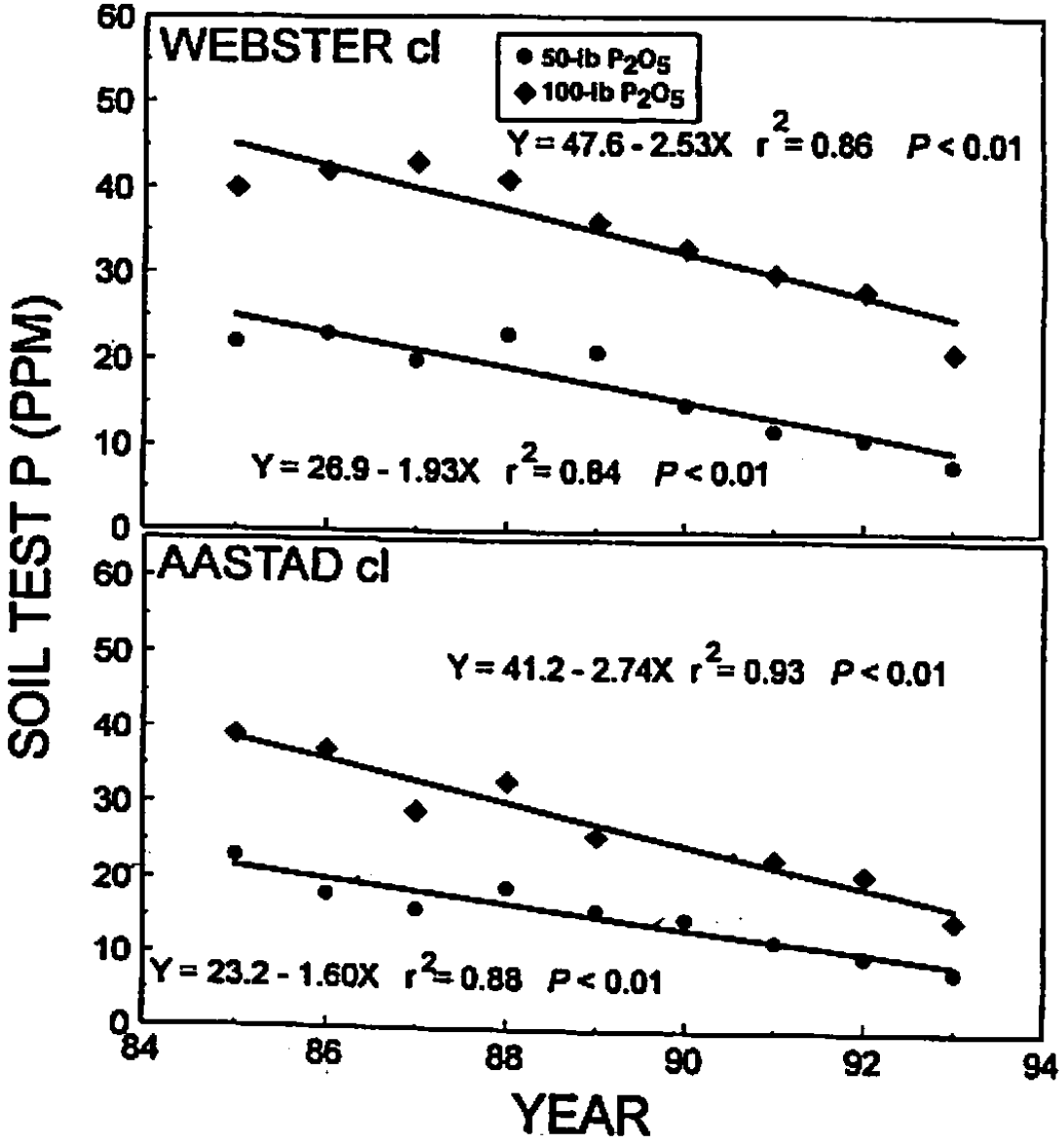


Fig. 3. Decline rates of STP in an 8-yr period when no fertilizer P was added to very high testing soils built up by 50- and 100-lb P_2O_5 rates.

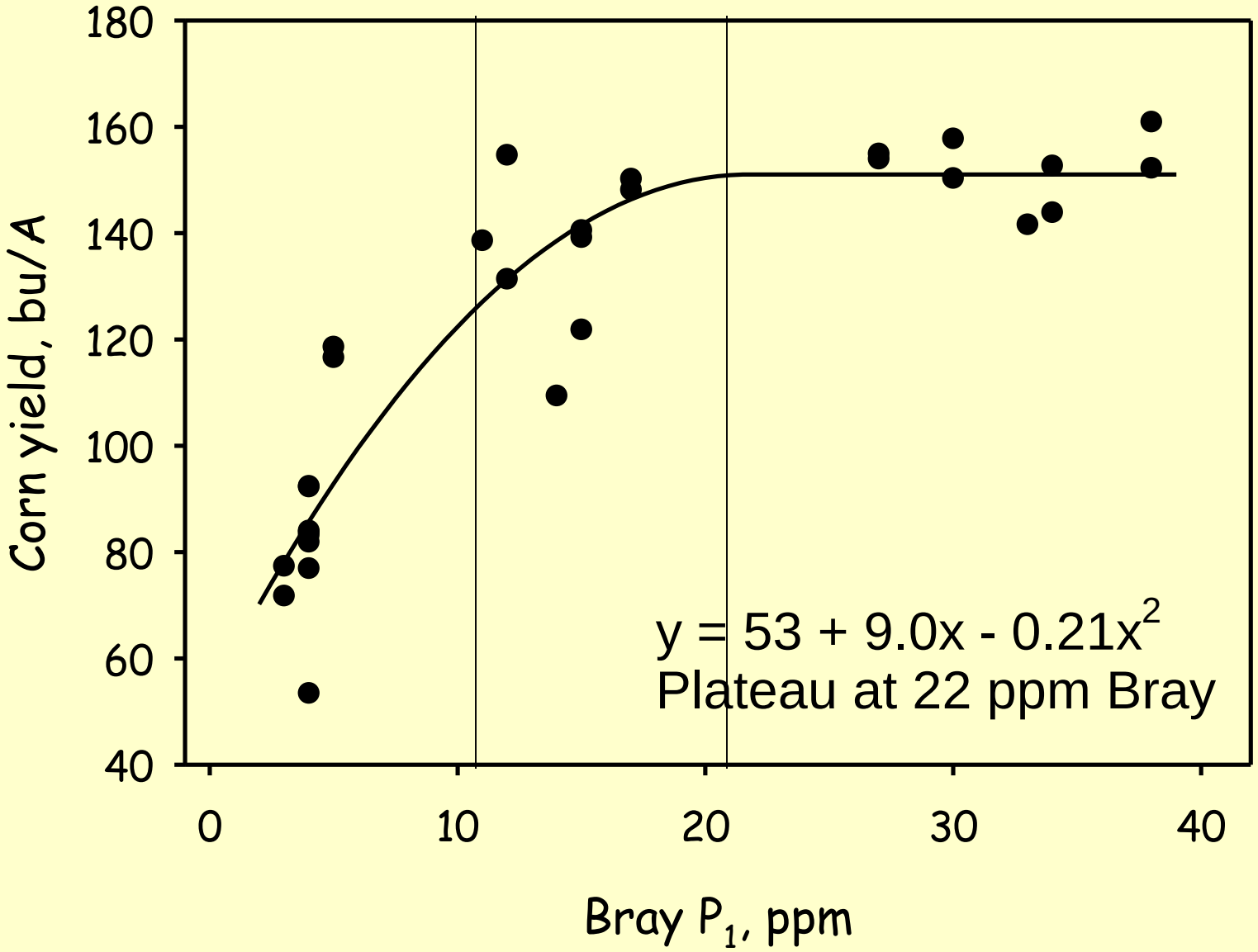
Decline rates for STP during a 8-yr period at Waseca and Morris **(1973-1993).**

Waseca site:

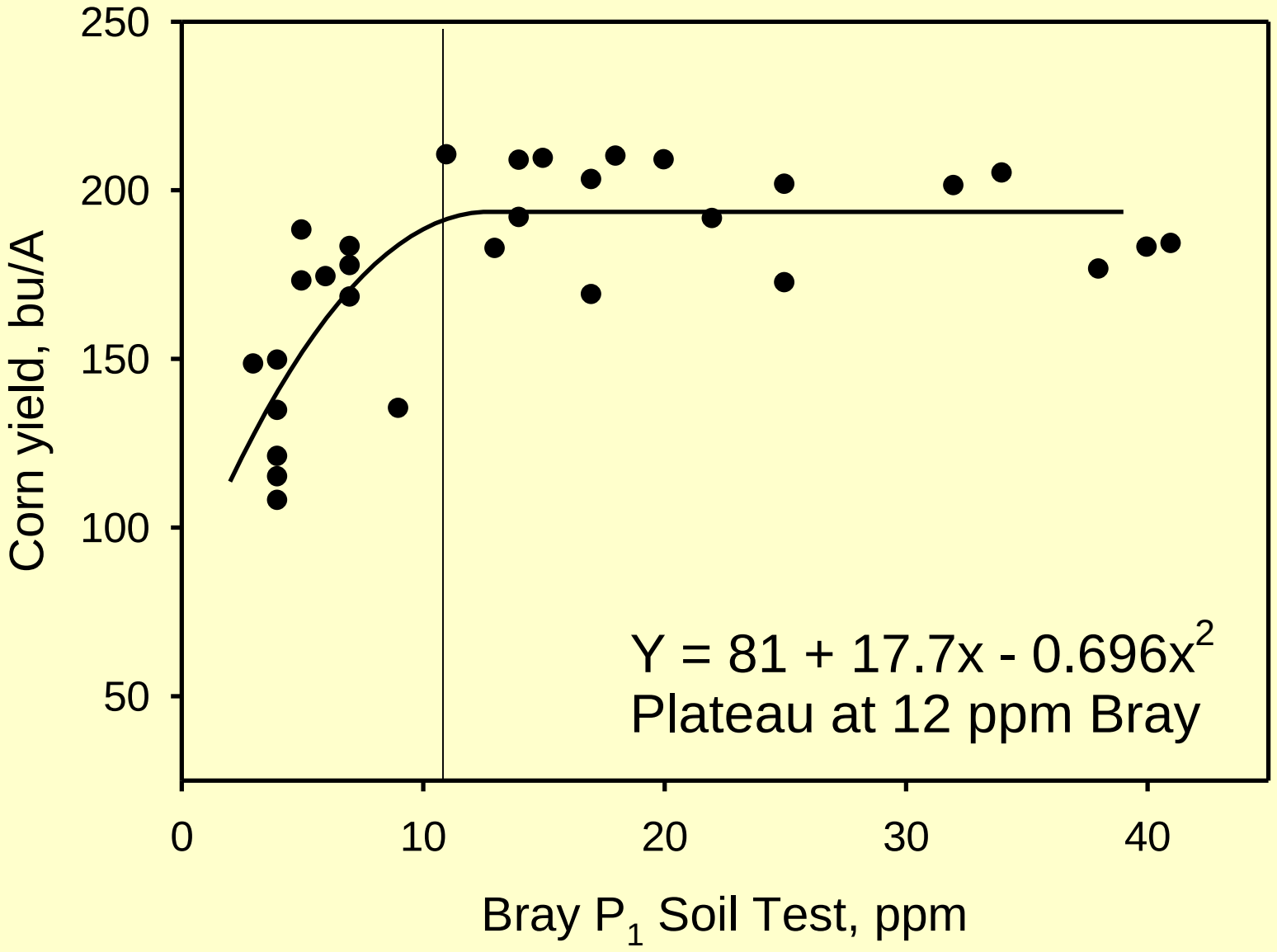
8-yr period ('85–'93)
Starting at 40 ppm
declined about 2.5 ppm/yr
no decline for 4-yrs after long-term annual application

8-yr period ('85–'93)
Starting at 22 ppm
declined about 1.9 ppm/yr

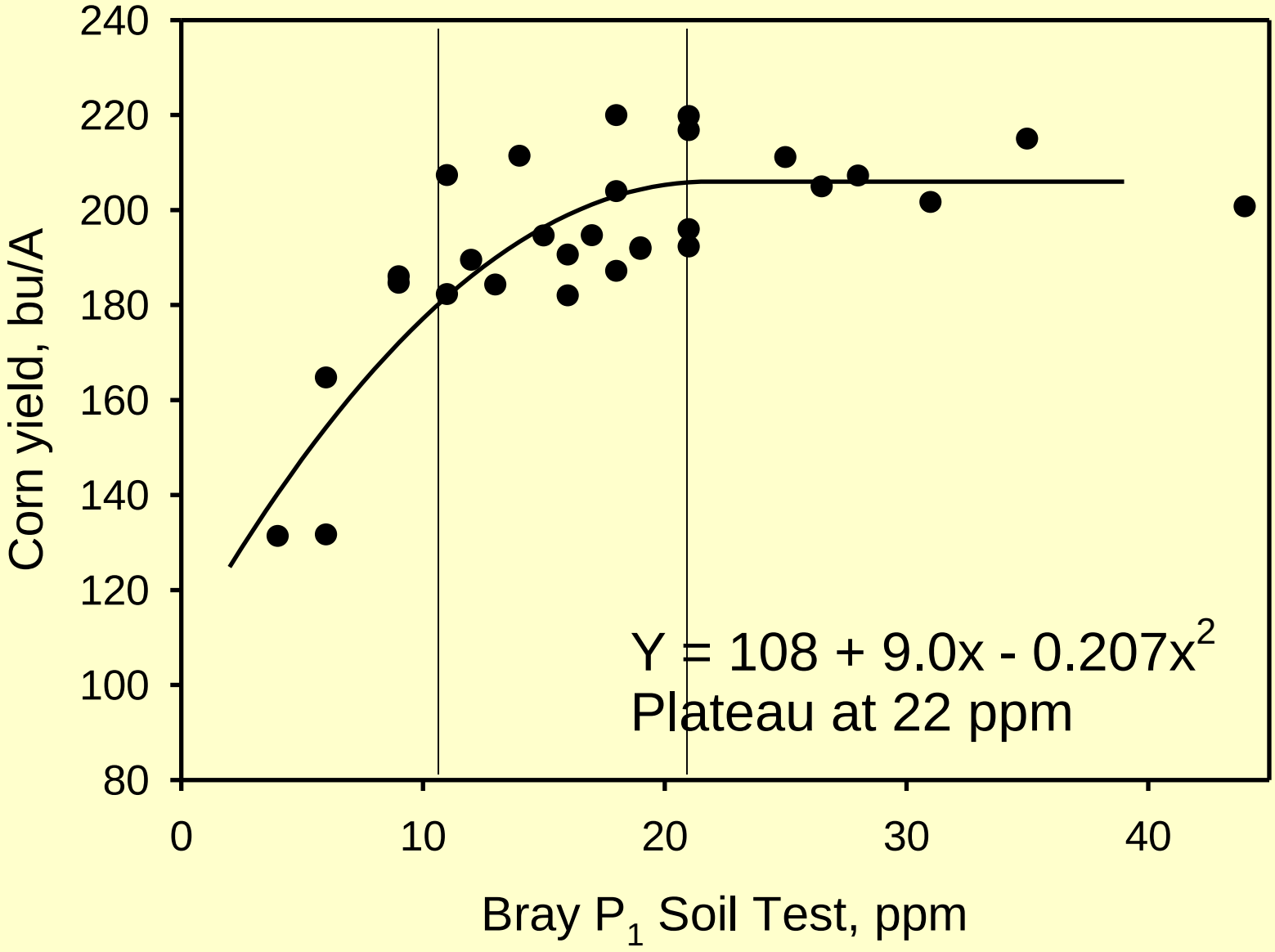
Corn yield response as affected by soil test P (Bray) at Waseca in 2004.



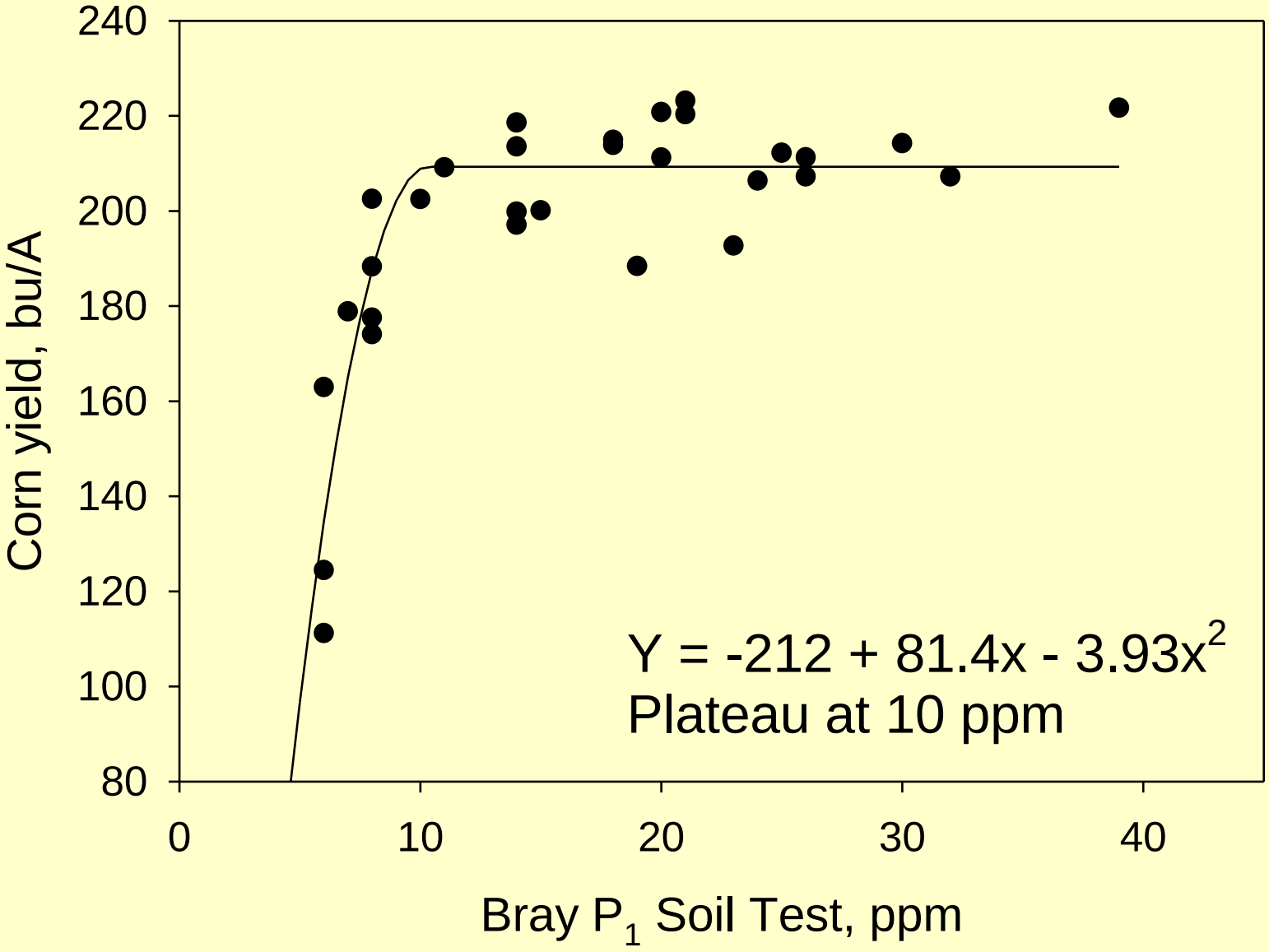
Corn yield response as affected by soil test P (Bray) at Waseca in 2006 (warm spring).



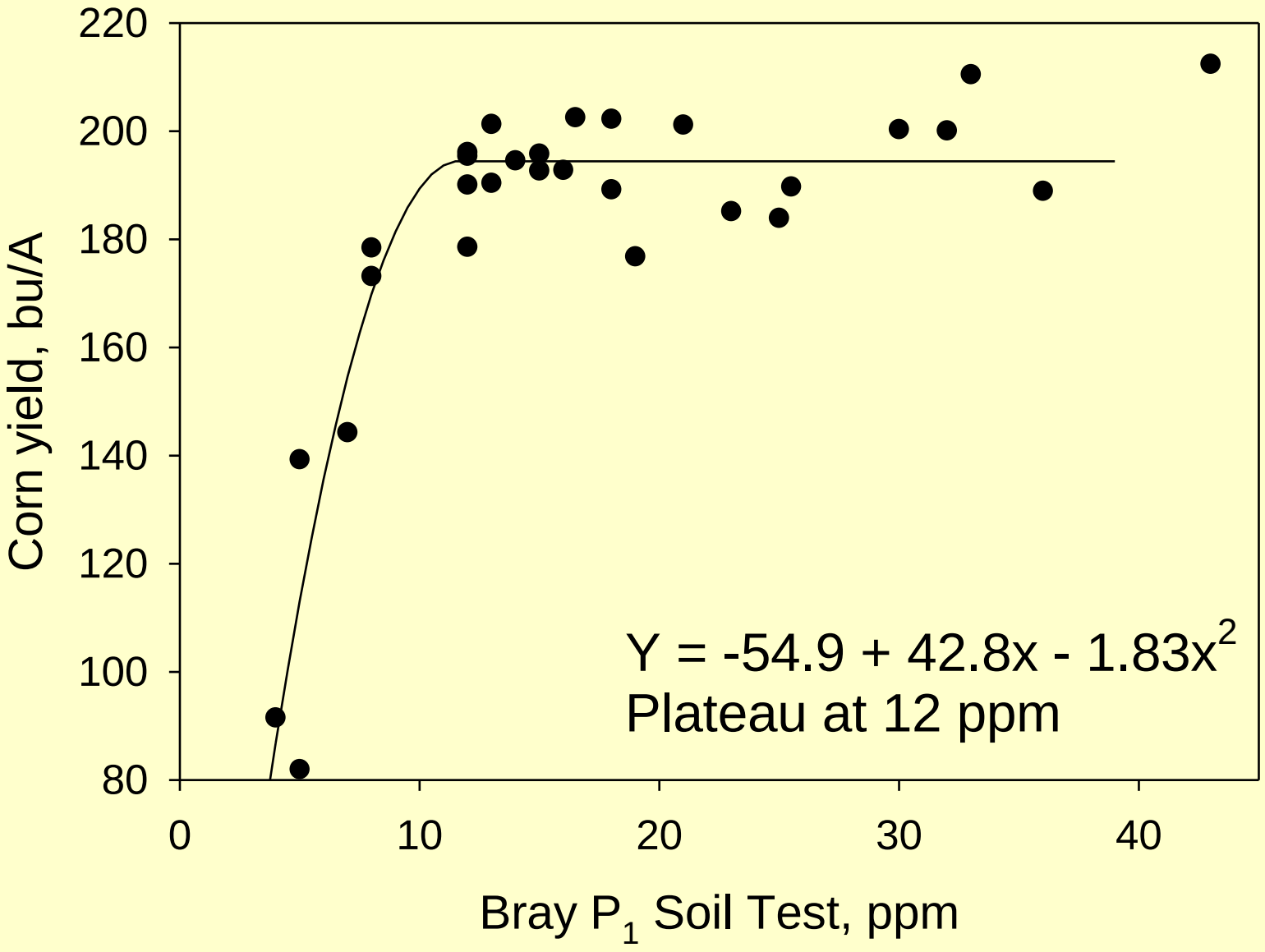
Corn yield response as affected by soil test P (Bray) at Waseca in 2008 (cool spring).



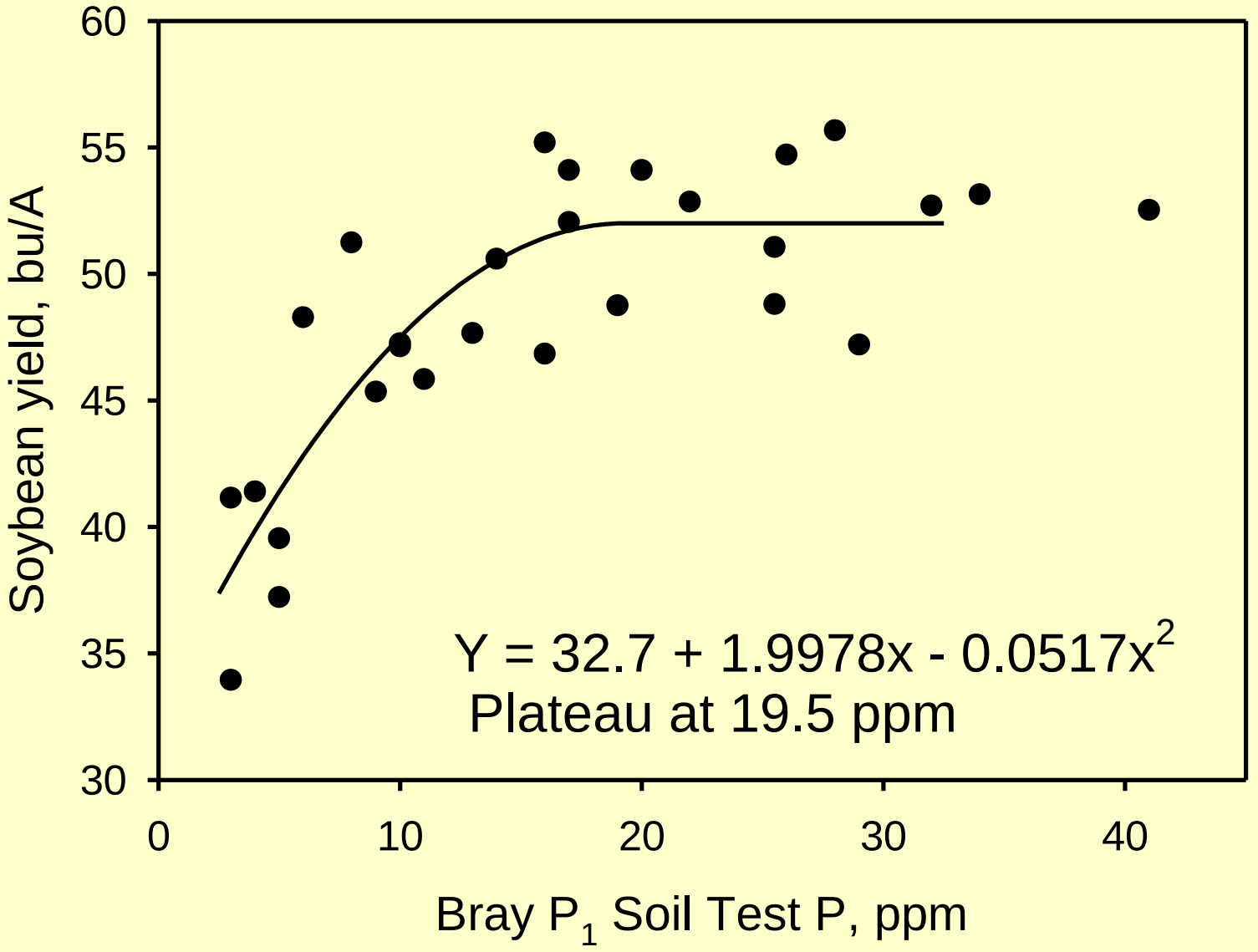
Corn yield response as affected by soil test P (Bray) at Waseca in 2010.



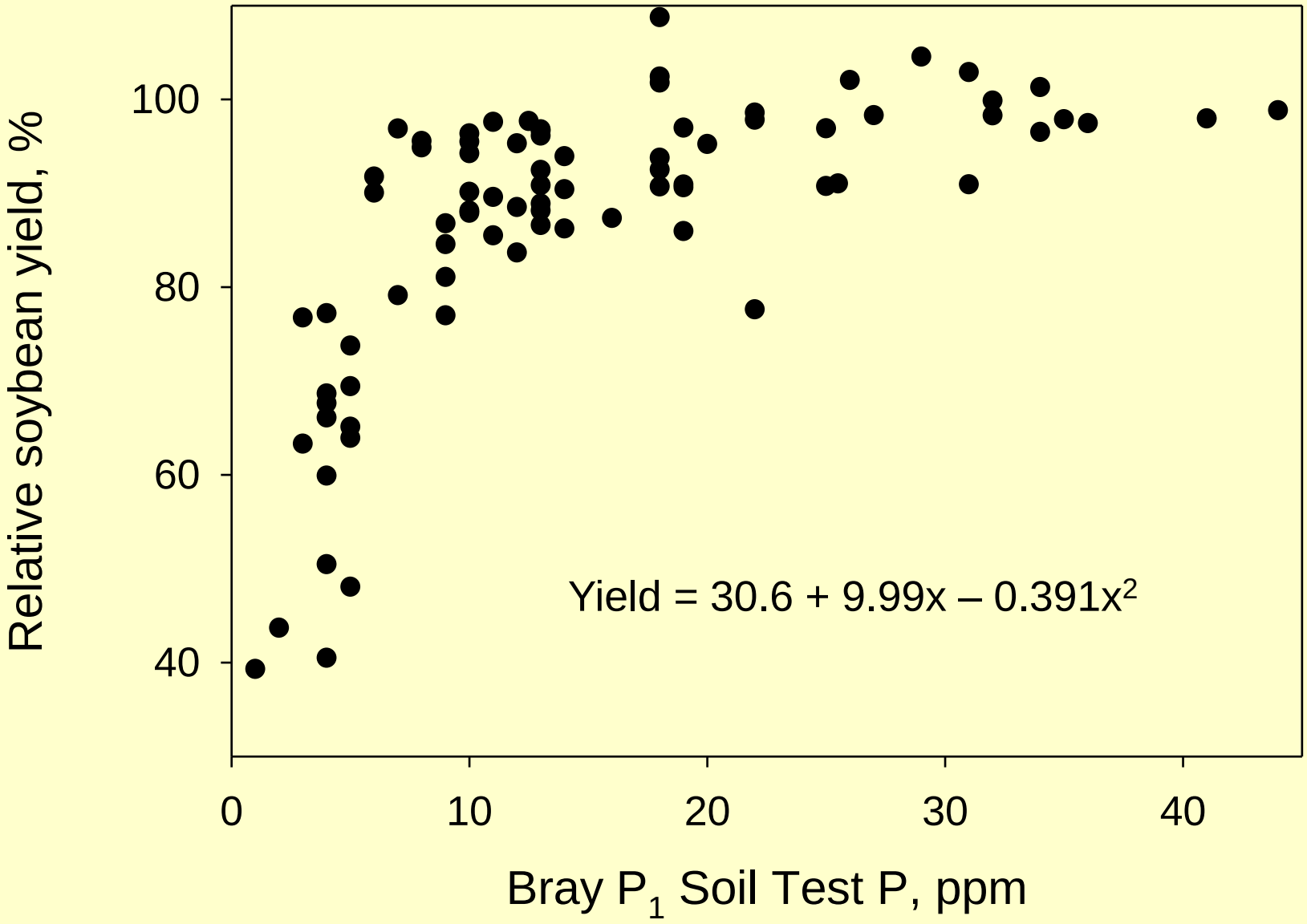
Corn yield response as affected by soil test P (Bray) at Waseca in 2012.



Soybean yield response as affected by soil test P (Bray) at Waseca in 2009 (cool growing season).



Relative soybean yields as affected by soil test P (Bray) at Waseca (3-yr average).



Yield response to soil test P (Bray)

- Corn: yield response to P varies
  - In cool years (2004 and 2008) critical value around 22 ppm Bray P
    - 30 bu./A penalty at 10 ppm Bray
  - In warm springs critical value was 10-12 ppm
    - only a 10 bu./A penalty at 10 ppm

- Soybean: response can vary, not as much as corn
  - Critical value usually around 10-12 ppm
  - 40% yield reduction at 5 ppm
  - Later planting & slower early growth = warmer soils

Annual vs. Triennial Conclusion

Economic return during the application phase (10 years of corn and 2 yrs of soybean) was greatest for the 150-lb P_2O_5 rate applied every third year at both sites.

Can VERY HIGH Corn and Soybean Yields be Produced on Low P-Testing Soils?

Corn production research on low vs. high to very high P-testing soils

- Location: SROC, Waseca
- Soils: Webster clay loam, tiled 75’
- Soil Test Bray P: 7 ppm (L) vs. 25 ppm (VH)
- Low P site mined with no P or K applied for previous 8 years
- Corn: 2005, 2006, 2007
- Soybean: 2006, 2007, 2008
- Potassium applied at 120-200 lb K_2O/A/yr
- Hybrids, varieties, planting dates, etc same for both L & VH sites each year
- Strip-till corn, No-till soybean

Corn yield as affected by soil P test and P placement

P Treatment		P Test	
Rate	Placement	Low	VH
lb P_2O_5/A		- - - - bu/A - - - -	
0	--	148	193
50/40	Deep-band[1/]	166	186
50/40	Pop-up	166	194
50/40	Broadcast	167	190
50/40	DB + Pop-up	172	189

[1/] 6-7” below soil surface under row.

Soybean yield as affected by soil P test and P placement for previous corn crop

Residual P Treatment		P Test	
Rate	Placement	Low	VH
lb P_2O_5/A		- - - - bu/A/yr - - - -	
0	--	34.5	49.1
50/40	Deep-band	38.5	49.1
50/40	Pop-up	38.2	48.9
50/40	Broadcast	37.1	48.4
50/40	BD + Pop-up	40.8	49.3

Yield and profitability advantage for a VH P-testing soil

Crop	Advantage	
	Yield	Econ Return[1/]
	bu/A/yr	$/A/yr
Corn	25	112
Soybean	10	110
Avg.		111

[1/] Corn @ $4.50/bu and soybean @ $11.00/bu, not counting fertilizer cost.

What did we learn?

- High and profitable corn and soybean yields could not be produced on L P-testing soils even though the P rate used for corn was greater than the UM recommendation.
- There was no advantage to deep-band placement over broadcasting.
- Important to know soil test P when acquiring or renting new land.

Optimum P Placement for C-S Rotations in a Strip-Till System

Location: Waseca, 2005-2007

Soil: Webster cl

Sites: (2) Low P-testing, Avg. = 7 ppm Bray P
High P-testing, Avg. = 25 ppm Bray P

P placements: (3)in-furrow, pop-up; deep-band (7" below soil surface); broadcast

P rates: (2) 20/25 and 40/50 lb P_2O_5/A on H/L sites respectively + a no P control

N rate: 140 lb N/A

Corn yield (3-yr avg.) as affected by P placement on a VH and L P-testing soil

Placement	P_2O_5 Rate	P Test Site	
		VH	L
	lb/A (VH/L site)	- - - bu/A - - -	
Pop-up	40/50	194	166
Deep band	40/50	186	166
Broadcast	40/50	190	167
Pop + D. Band	20/25+20/25	189	172
No P, control	0	193	148
P>F:		0.392	<0.001
LSD (0.10):		NS	9

Opt. P Placement – Yield -- Conclusions

- On the VH testing site (25 ppm P), P placement and P rate did not affect corn grain yield across the 3-yr period.
- On the L testing site (7 ppm P), 3-yr grain yields were significantly increased by P (18 to 24 bu/A for the 50-lb rate) but were not affected significantly by the different placement positions. The P rate was significant (161 bu/A for the 25-lb rate vs. 166 for the 50-lb rate), but there was not a significant P rate x P placement interaction.

Yield and economic loss (3-yr avg.) on a LOW P-testing site compared to a VH testing site as affected by P placement.

Placement	P_2O_5 Rate	Loss compared to VH site[1/]	
		Yield	Economic
	lb/A (VL site)	bu/A/yr	$/A/yr
Pop-up	50	27	175
Deep band	50	27	165
Broadcast	50	26	160
Pop + D. Band	25 + 25	21	140
No P, control	0	45	225

1/ VH site with no P added = 193 bu/A.

2/ Corn = $5.00/bu, 10-34-0 = $3.15/gal, DAP = $0.60/lb P_2O_5

Opt. P Placement – Loss -- Conclusions

- Compared to three sites averaging 25 ppm Bray P (VH), yields on nearby Low P-testing (7 ppm) sites averaged 21 to 27 bu/A lower even though 50 lb P_2O_5/A was applied. Furthermore, when considering corn at $5.00/bu and the cost of dry and fluid fertilizers, the economic penalty/loss associated with a LOW P-testing field supplemental with P (50 lb P_2O_5/A) compared to a VH testing field without supplemental P ranged from $140 to $175/A/yr.
- The STK for the VH and LOW P-testing sites was 212 ppm (VH) and 138 ppm (H), respectively.
- These data clearly indicate the productive and economic value of keeping soils at the H or VH P-testing level for a C-S rotation with strip tillage.

Fertilizer Placement

35,000 plants/A in 30” rows = 1 plant/6”
Root zone = 6” x 30” x 48” = 8640 in.^{2}

- Band vs. Broadcast ??
  - 2” diam. Band = 0.2% of root zone
  - 3” diam. Band = 0.5% of root zone

- Soil moisture often limited in top 24” for 1 to 6-week periods in mid-to late season under rainfed conditions.

Potassium

Initial Soil Test K in Studies Conducted at Waseca and Morris, MN (1974-1993)

Location	pH	Exch. K
		- - - ppm - - -
Waseca	6.0	150 (H)
Morris	7.6	228 (VH)

Corn and Soybean Yield Response to K

	Years with Yield Response	
Location	Corn	Soybean
Waseca	4 of 14*	0 of 6
Morris	0 of 10**	0 of 2**

* 150 lb K_2O/A every third year gave the greatest economic return.

** STK for the Zero-lb control treatment dropped below 150 ppm STK only twice in 12 years, averaging 163 ppm for the 12-yr period.

Economics: Annual vs. Triennial Application of K

Waseca: Economic return was greater for the triennial application of 150 lb K_2O/A than for annual application of 50 lb K_2O/A.

Morris: Corn and soybean did not respond to fertilizer K.

- very high STK

Potassium Fertilization

- Exchangeable soil test K should be >120 ppm to optimize soybean yields in MN.
- Most soybeans in MN follow corn where > 150 ppm K is suggested for optimum corn yield.
- Broadcast placement is preferred.
- Research to verify STK critical levels and dry vs. moist is being conducted.

Future P & K Recommendations
CONSIDERATIONS

- Land tenure
  - owned vs. rented, length of rental contract
  - long-term vs. short-term
- Financial position
  -strong position vs. cash short
- Risk
  - losing yield due to inadequate fertility
  - economic vs. environmental*

Risks & Uncertainties

- Within field soil test variability
- Year-to-year soil test and yield response variability

Bermudez & Mallarino, Iowa State Agron. J. 99:822-832 (2007)

Characteristics of study

- Six experimental fields, 4 C-N-W assn.
- Corn-soybean rotation
- Replicated strip trials comparing fixed vs. variable rates of P (2 acre/strip)
- Intensive grid sampling, 0.15-0.20 A/Cell
- Median Mehlich – 3 test was ≤ 20 ppm for each field, while mean Mehlich-3 was < 23 ppm.

Procedures

- Identified the soil-test P classes for each field for corn

  VL = ≤ 8 ppm
  L = 9-15 ppm
  Opt. = 16-20 ppm
  H = 21-30 ppm
  VH = ≥ 31 ppm

- Applied 70, 110, and 140 lb P_2O_5/A for the Opt., L, and VL soil test categories before year 1 and again before year 3 of the rotation.

- Measured yield responses to P by corn for two years & soybean for two years.

Results cont.

- Fields exhibited high STP variability

	STP		STP Class			
Field*	Mean	Median	VL	L	Opt.	H
	- - - - - ppm - - - - -		- - - - - % - - - - -			
3	18	17	5	34	29	25
4	23	20	0	25	21	43
5	22	20	0	8	22	55

* All three fields were considered to be “Optimum” based on median STP.

MDA Tile Demo

- 31 acre site grid sampled at 1 acre/cell
- UNIFORM crop and fertilizer history
- Olsen STP results
  - Mean = 13 ppm (H), Range = 4-28 ppm

    U of M recommends 15 lb P_2O_5/A (bdct) for corn
- Soil pH
  - Mean = 6.4, Range = 5.7-7.5

    4 cells were > 7.0

MDA Tile Demo (cont.)

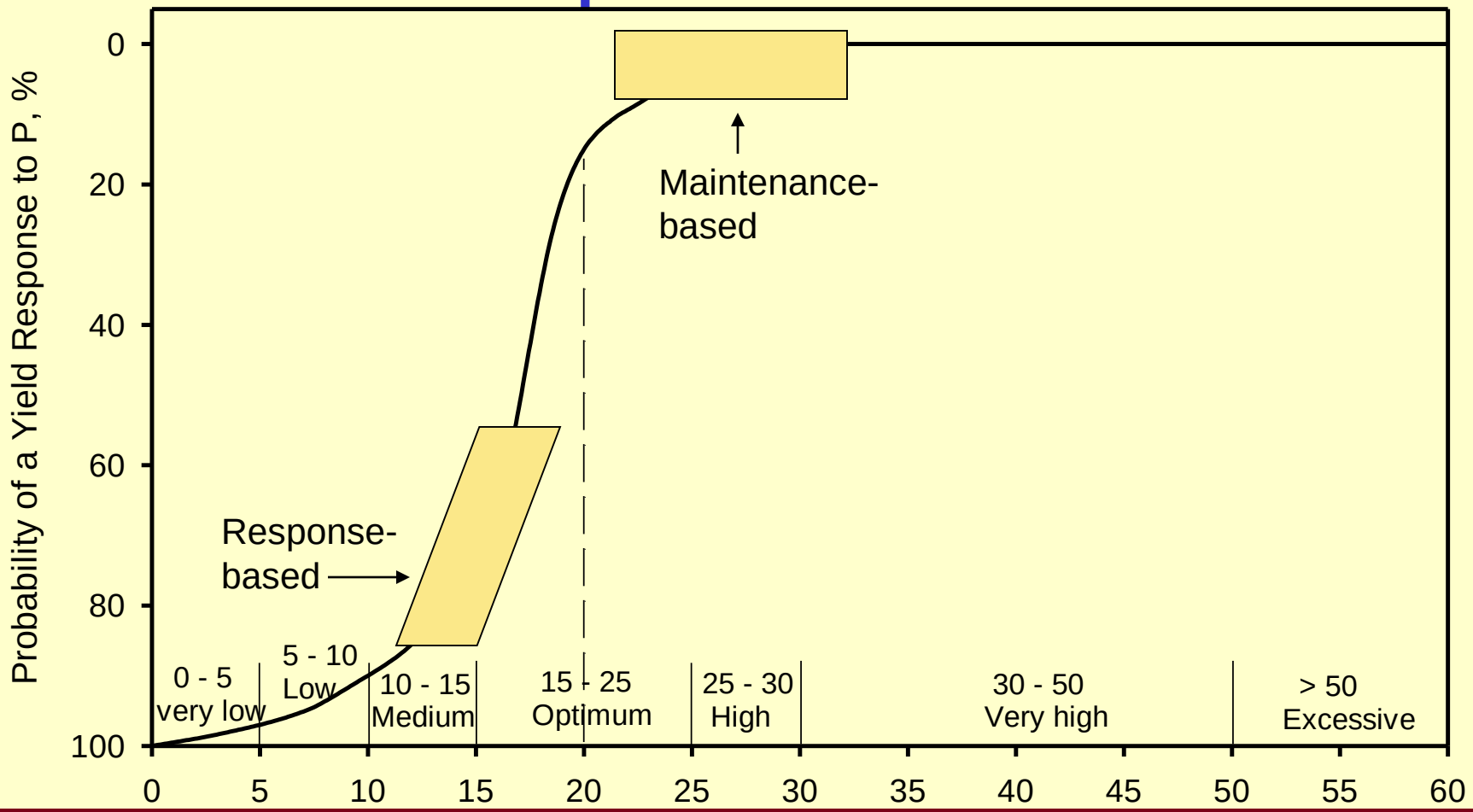
- STP Distribution (Olsen P)

Class	STP range	No. of Cells	Bdct. P recommended
	ppm		lb P_2O_5/A
VL	0-3	0	120
L	4-7	8	85
M	8-11	5	50
H	12-15	4	15
VH	16^+	14	0

Mean = 13 ppm

Proposed

Phosphorus soil test model for Minnesota corn production.



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Questions

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