

Making Effective, Flexible and Environmentally Responsible Fertilizer Recommendations

Dave Mengel

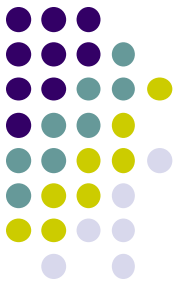
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Common Recommendation Systems Used for P and K in the US



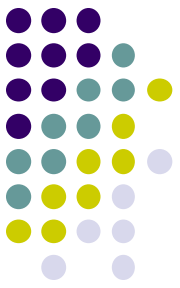
- “Feed the Crop”, the Nutrient Sufficiency Approach
- “Feed the Soil”, the Build and Maintain Approach
 - The “Cation Ratio System” is a variation on the build and maintain system and is used for managing the cations, Ca, Mg and K

Both Systems Requires Good Soil Test Correlation and Calibration



- Soil Test Correlation: Understanding the basic relationship between Soil Test Level and Crop Growth
 - Do you need fertilizer?
- Soil Test Calibration: Understanding the response to fertilizer one can expect at a given soil test level
 - If I need fertilizer, how much?

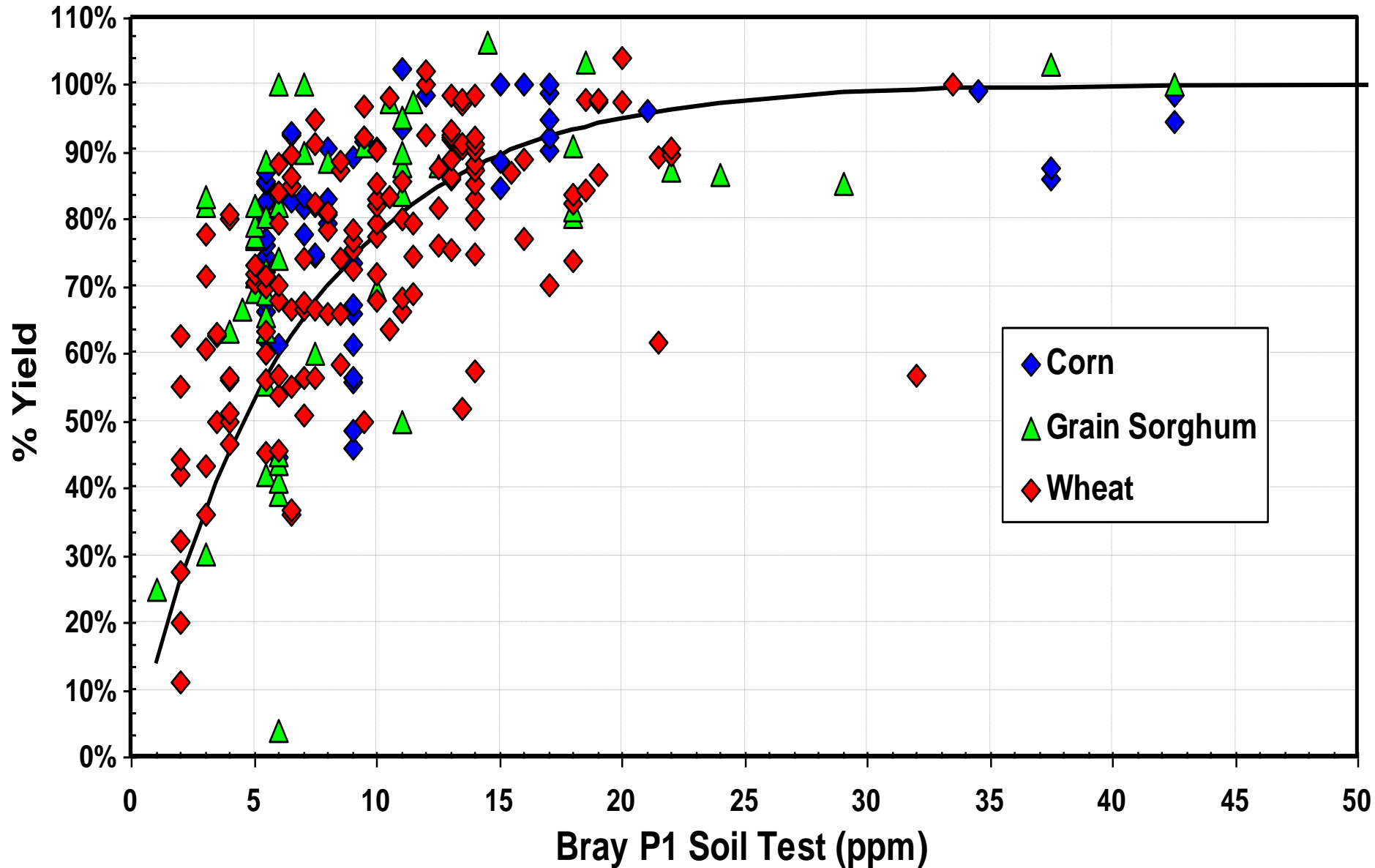
Collecting soil test correlation and calibration data

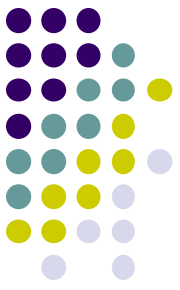


- In basic form, simple rate response studies with 5-8 rates, (0, 20, 40, 60, 80, 100 lbs P_2O_5/ac)
 - A true check
 - Rates which will exceed likely response
- Multiple sites, multiple years, multiple crops
 - May need individual correlations for each crop
- The correlation graph is a plot of normalized check plot yield vs soil test level

Corn, Grain Sorghum and Wheat P Sufficiency

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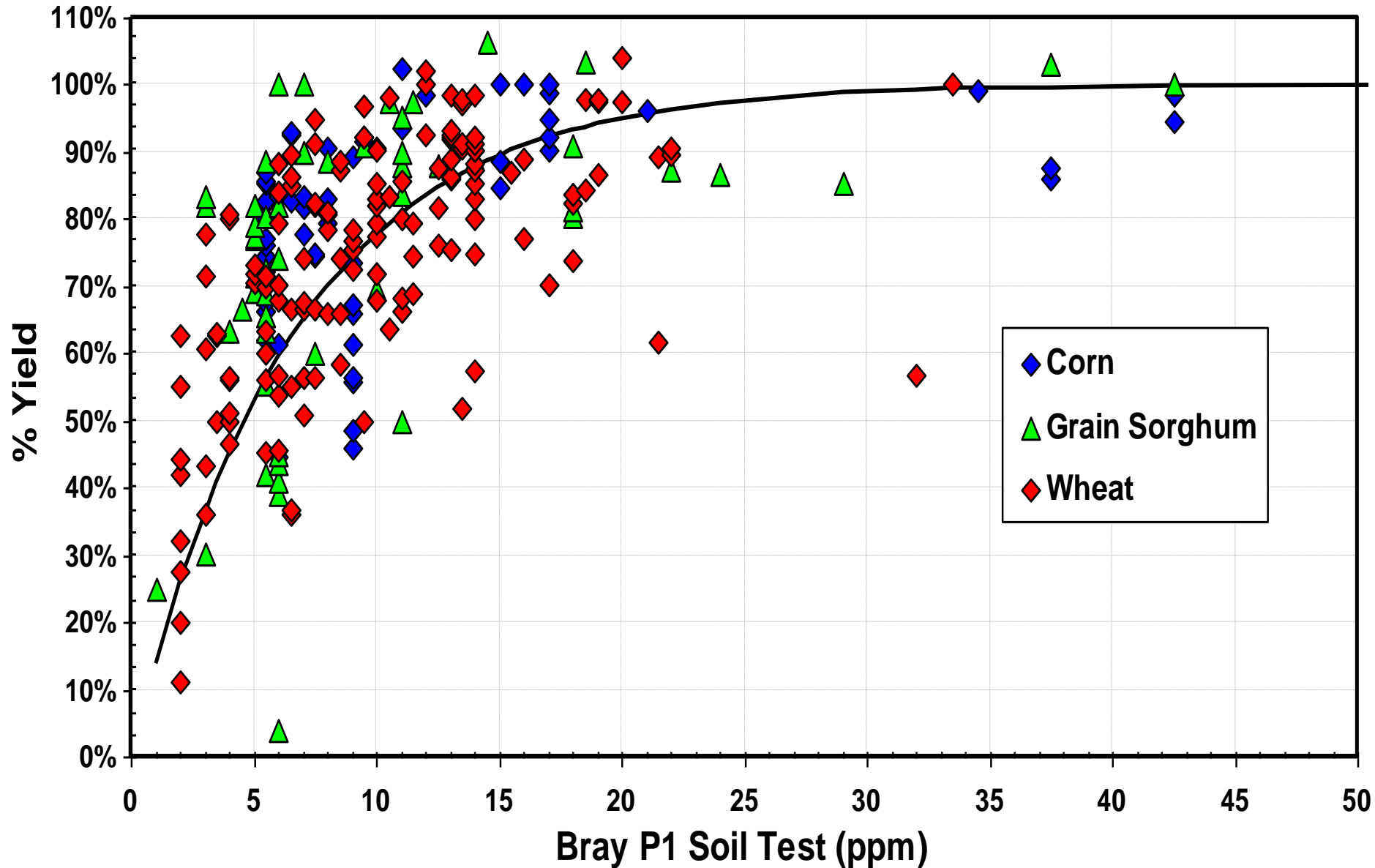


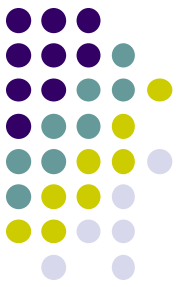
Building a correlation graph

- Use two treatments in developing the relationship of yield to ST level:
 - Unfertilized check plot
 - Highest yielding fertilizer treatment (100%)
- Calculate relative or normalized yield at each experiment
 - $\text{Relative Yld} = \text{Check Yld} / \text{Highest Yld} \times 100$
- Plot the relative yield without P (check plot yield) vs. Soil Test
- Takes many, many experiments to build a ST correlation

Corn, Grain Sorghum and Wheat P Sufficiency

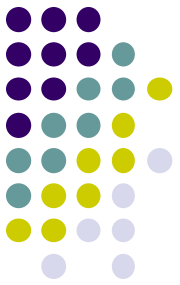
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Elements of the curve

- Critical level: The soil test level above which no economic response to fertilizer would be expected
- Economic Optimum Yield: Since price of commodity and price of fertilizer fluctuate from year to year, recommendations to achieve economic optimum yield are estimated as 95 to 97% of maximum yield.

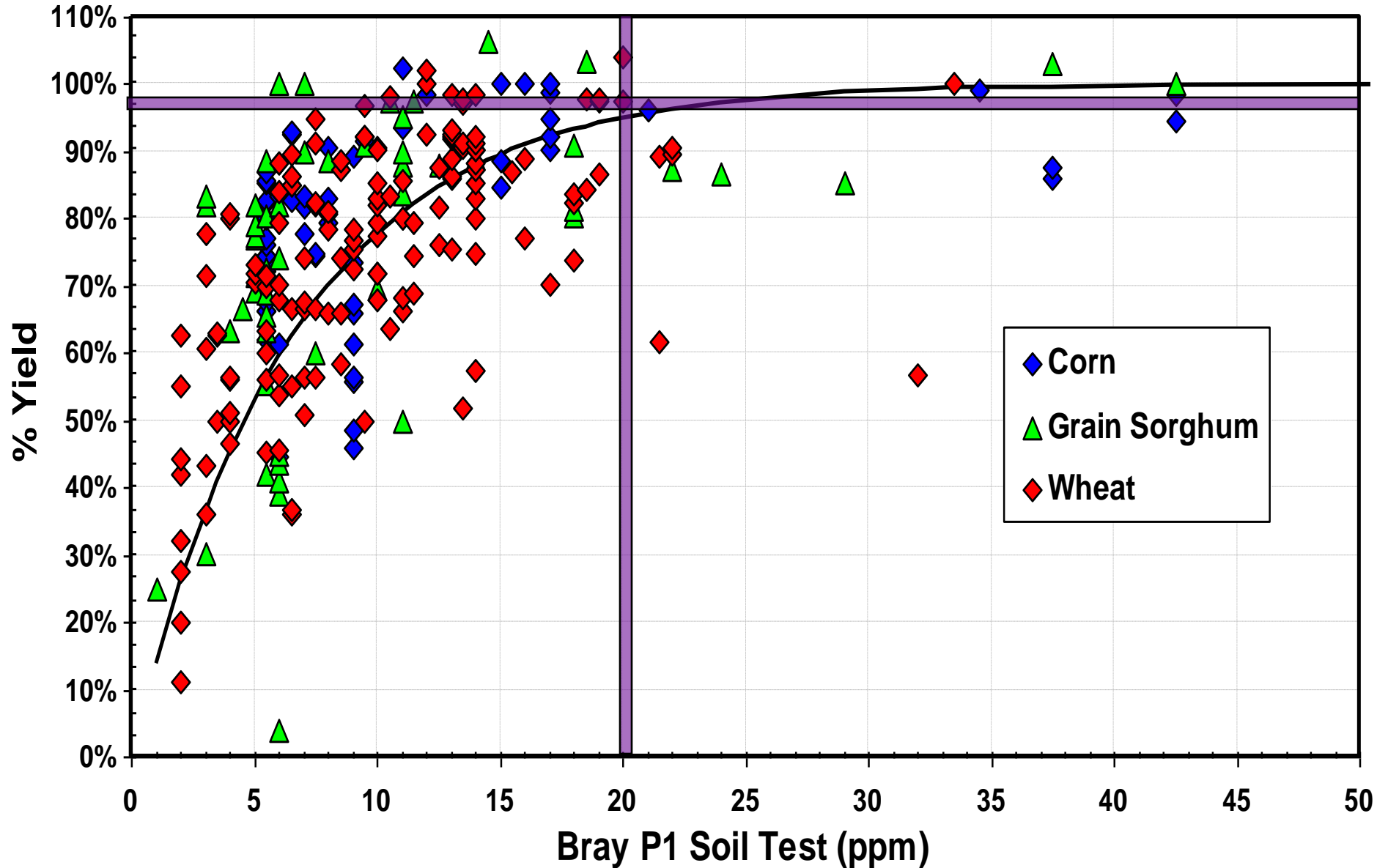


Determining critical level

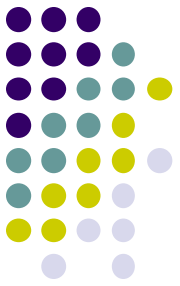
- Fit an appropriate math function to the data:
 - Linear
 - Quadratic
 - Plateau
- Use the Cate-Nelson graphical approach

Corn, Grain Sorghum and Wheat P Sufficiency

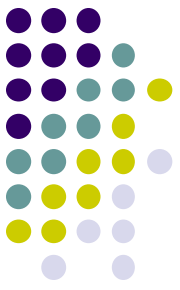
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Probability and Magnitude of Fertilizer Response at Different P Soil Tests



P Test Level	Probability of Response	Magnitude of Response
<6, VL	85-100%	70-100%
6-12, L	60-85%	30-50%
13-20, M	30-60%	10-25%
21-30, H	10-30%	5-10%
>30, VH	0-10%	0-5%



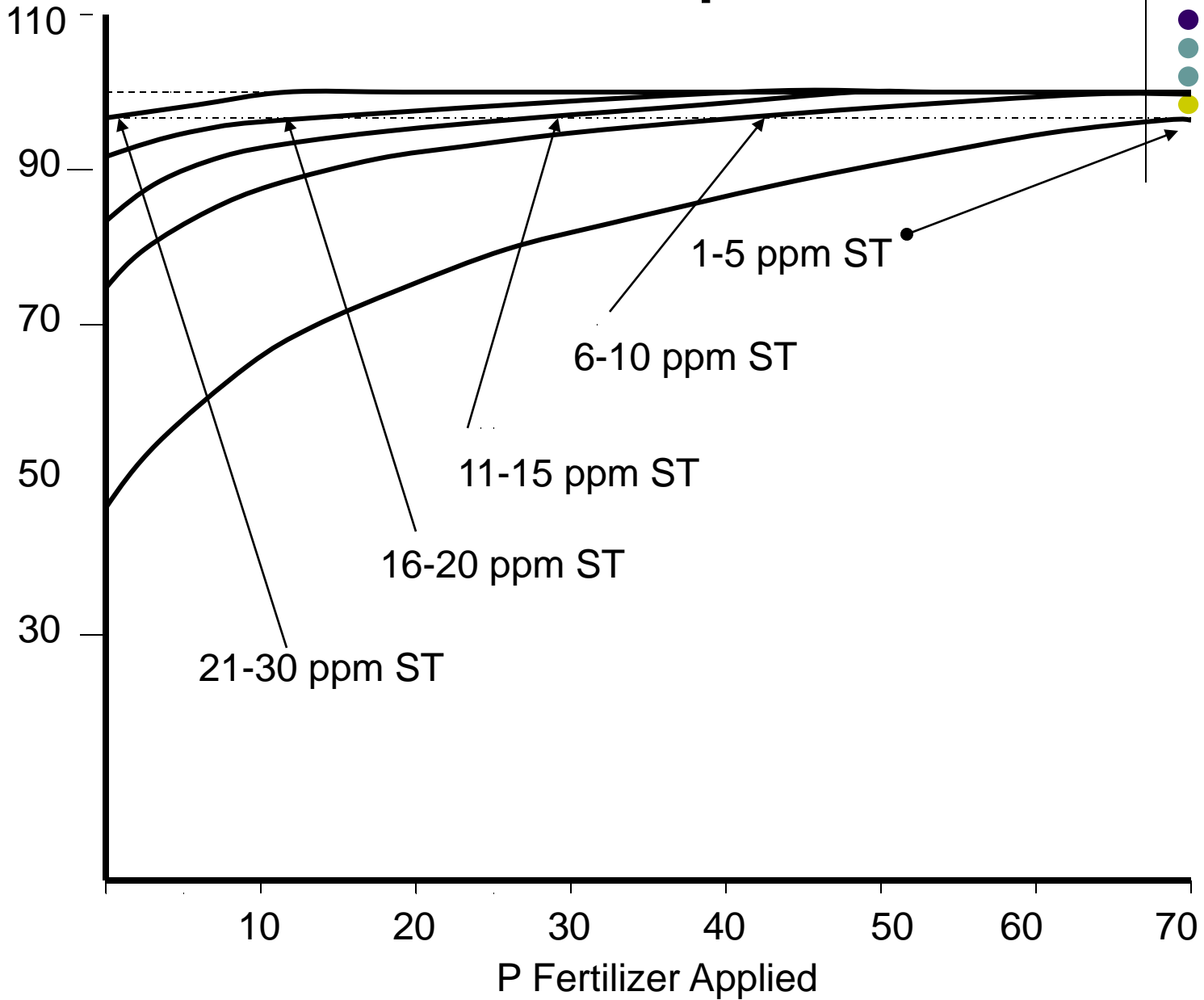
The calibration component

- Group the experiments into groups with similar ST.
 - Three groups VL, L and medium below the critical level,
 - Two groups above the critical level H and VH?

Plot a response curve for each of the groups:

- Relative Yield vs. Fertilizer added
- Recommended P or K rate is where the curve crosses the 95 or 97% Yield line,

Soil Test Calibration Response Curves

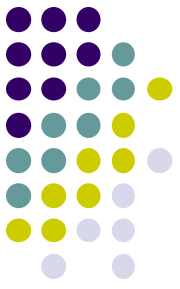


Other useful information that can be collected from correlation and calibration experiments



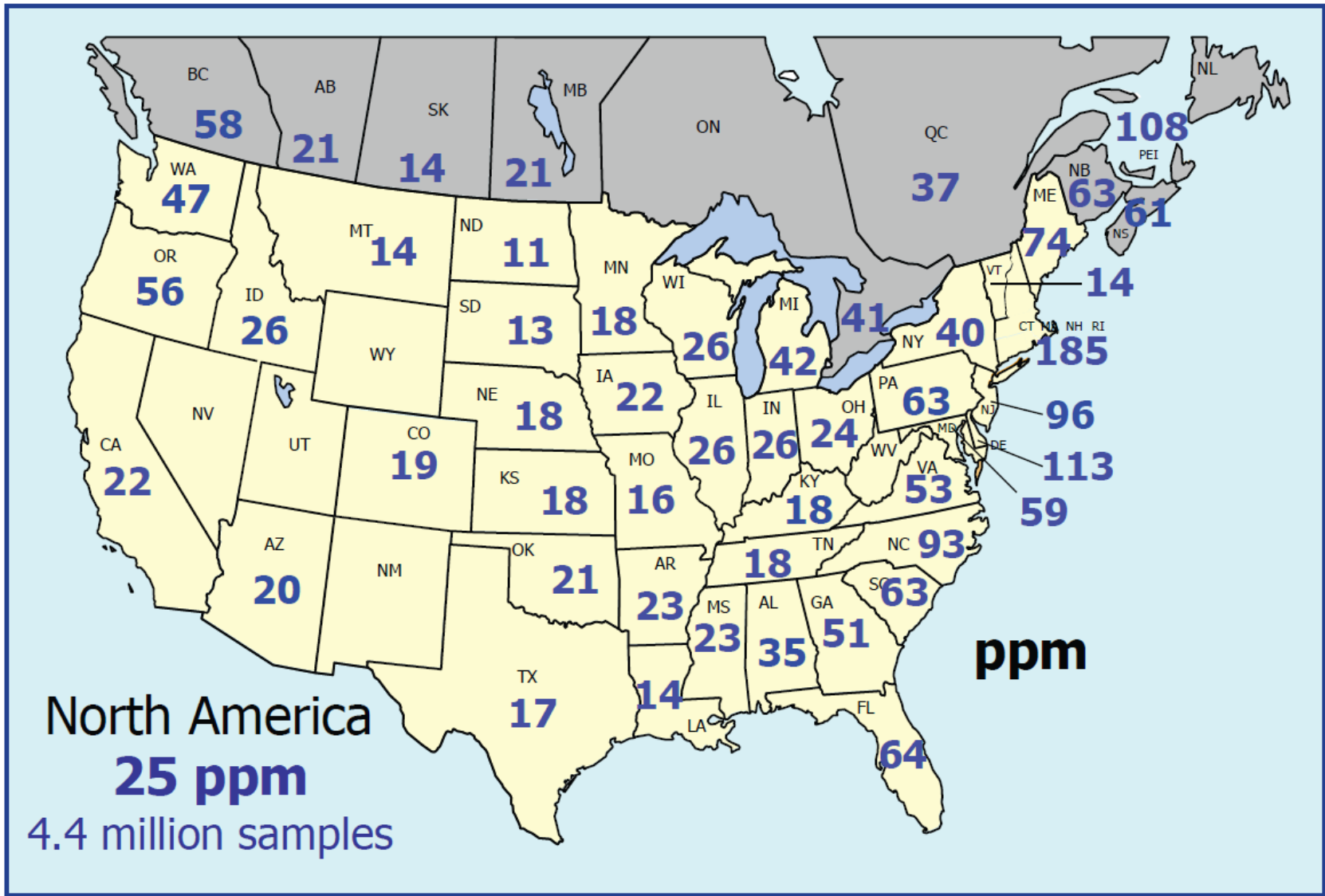
- Plant analysis data
 - Plant parts for monitoring: earleaf in corn
 - Total plant uptake
- Crop removal
 - Grain
 - Biomass
- Soil buffer capacity, lbs or kg P_2O_5 to change ST 1 ppm
 - Build-up
 - Draw-down

Where these Recommendation Systems are Used in the US

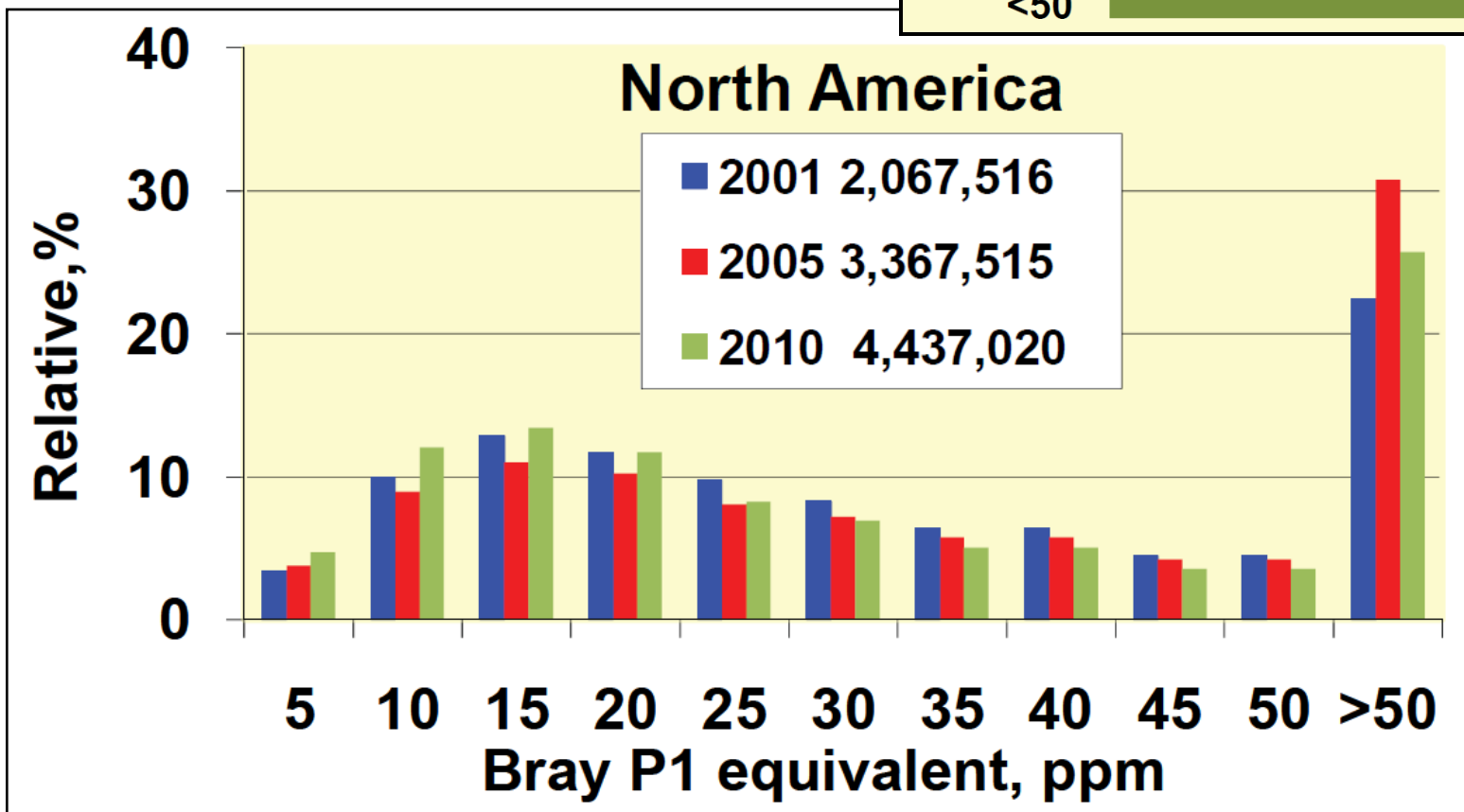
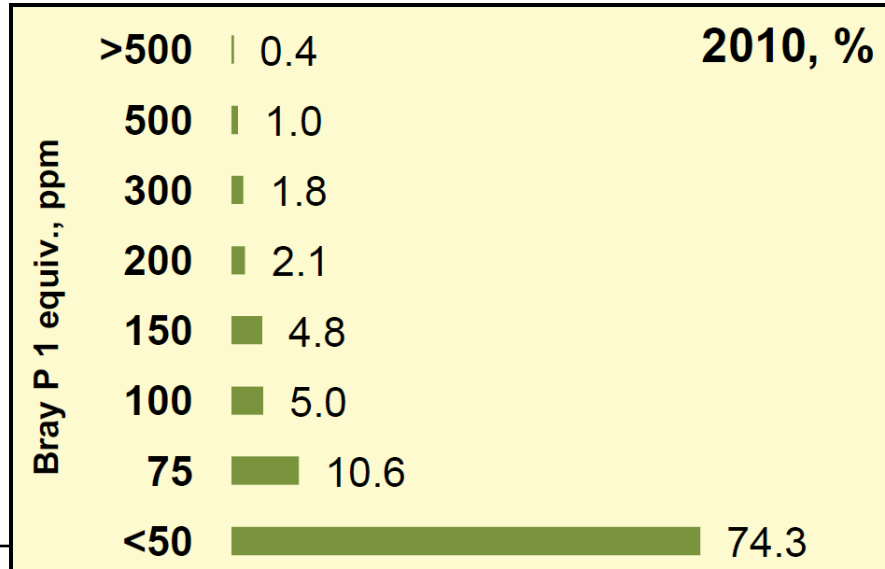


- “Feed the Crop”, the Nutrient Sufficiency Approach
 - Traditional system used in the Great Plains and Northern and Western Cornbelt (Higher Agronomic Risk)
- “Feed the Soil”, the Build and Maintain Approach
 - Traditional system used in the Eastern and central Cornbelt (Lower Agronomic Risk)

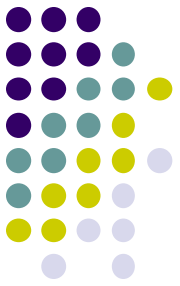
Median Bray P-1 equivalent soil test levels, 2010.



Soil test P frequency distribution in 2001, 2005, and 2010.

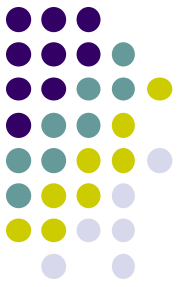


KSU Approach to Making Recommendations for P and K



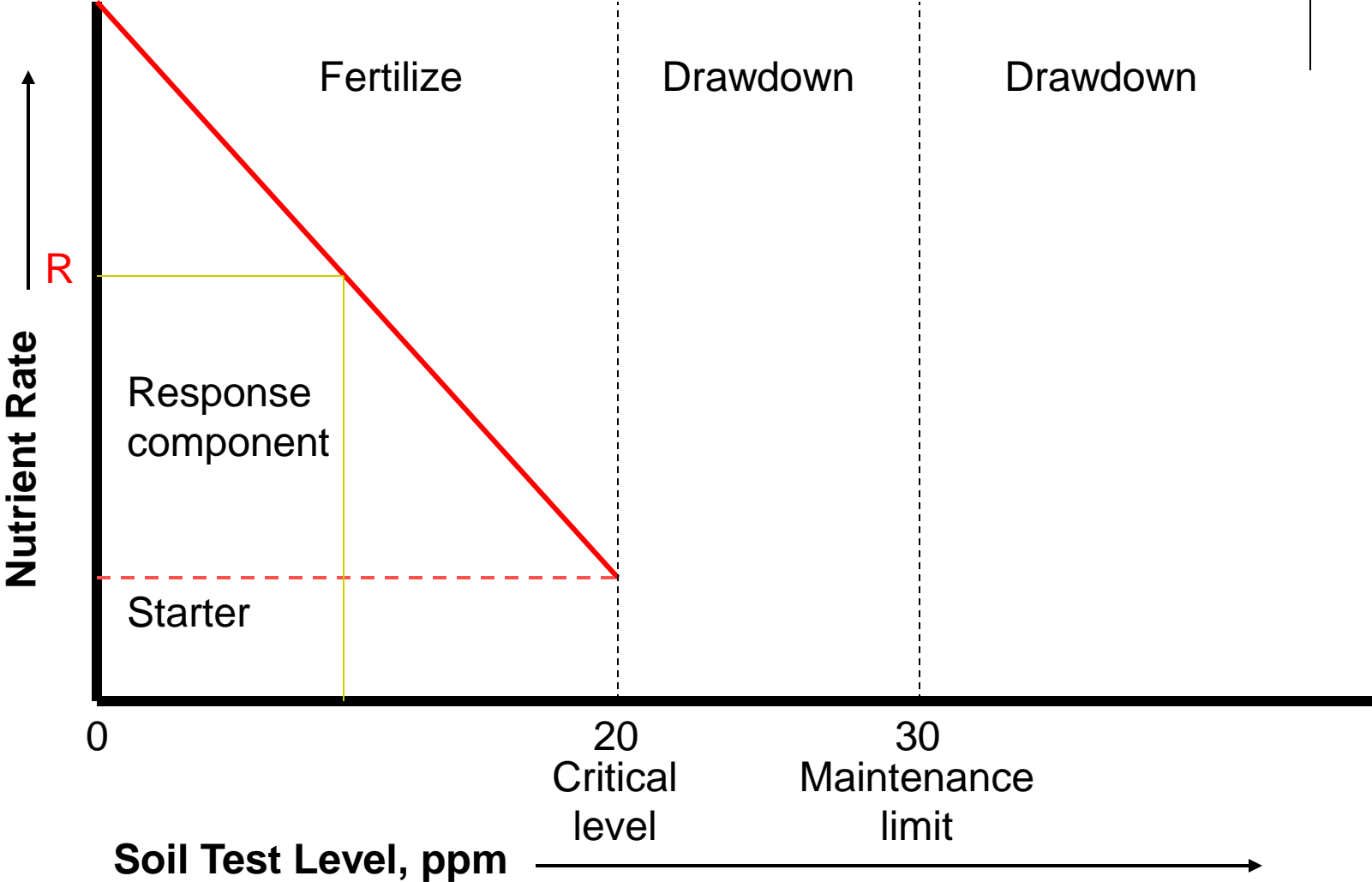
- KState offers both a traditional “Nutrient Sufficiency” and a “Build and Maintain” recommendation
- The Nutrient Sufficiency recommendations are most widely used.
- Both are appropriate in Kansas
- Which to use is a personal choice driven by:
 - Economics
 - Farm Size
 - Risk and Risk Aversion
 - Land Tenure

Sufficiency Recommendations

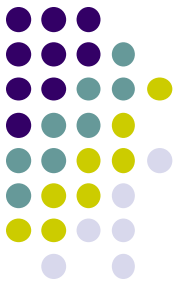


- Traditional recommendation system used in the Great Plains/Northern and Western Corn Belt.
- Estimates the amount of P and/or K that provides optimum economic returns in the year of application.
- No consideration of future soil test values.
- Requires a strong set of soil test correlation and calibration data.
- Over long term, will result in about 95% of maximum yield.

Nutrient Sufficiency Application Model: P

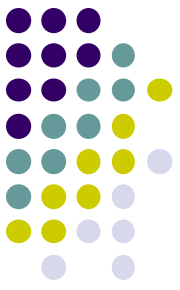


Sufficiency Recommendations



- No P or K is recommended at soil test values above the “critical” level.
- Soil tests levels equilibrate around 10-12 ppm.
- **Unless initial soil test levels are high, little year to year flexibility in nutrient application.**
- **Nutrient application required for every crop, every year.**

Soybean Response to Direct Application of P in Corn/Bean Rotation: 2006-2008. ST = 10 ppm



Treatment	Early Biomass	Early P Uptake	Leaf P Pod set	Yield Bu/a
No P	680	1.9	0.27 ef	51 d
20 ST on corn	720	2.1	0.29 bcde	54c
20 St + 20 Broadcast	690	2.1	0.28 def	55 bc
20 ST + 60 Broadcast	710	2.1	0.28 def	57 bc
20 St + 60 + 40 bdcst on beans	640	2.0	0.31 a	61 a

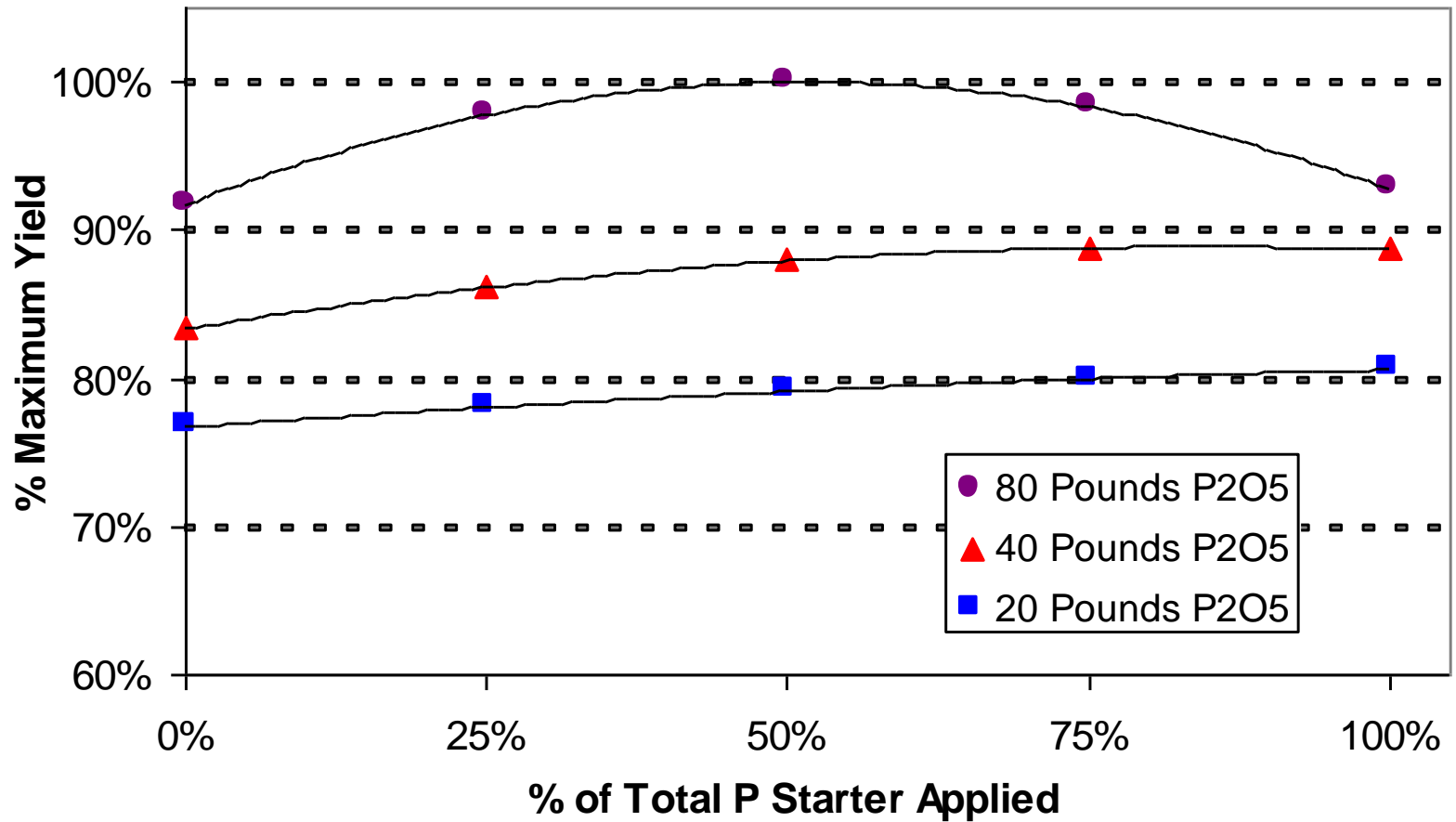
Scandia, KS

Sufficiency Recommendations



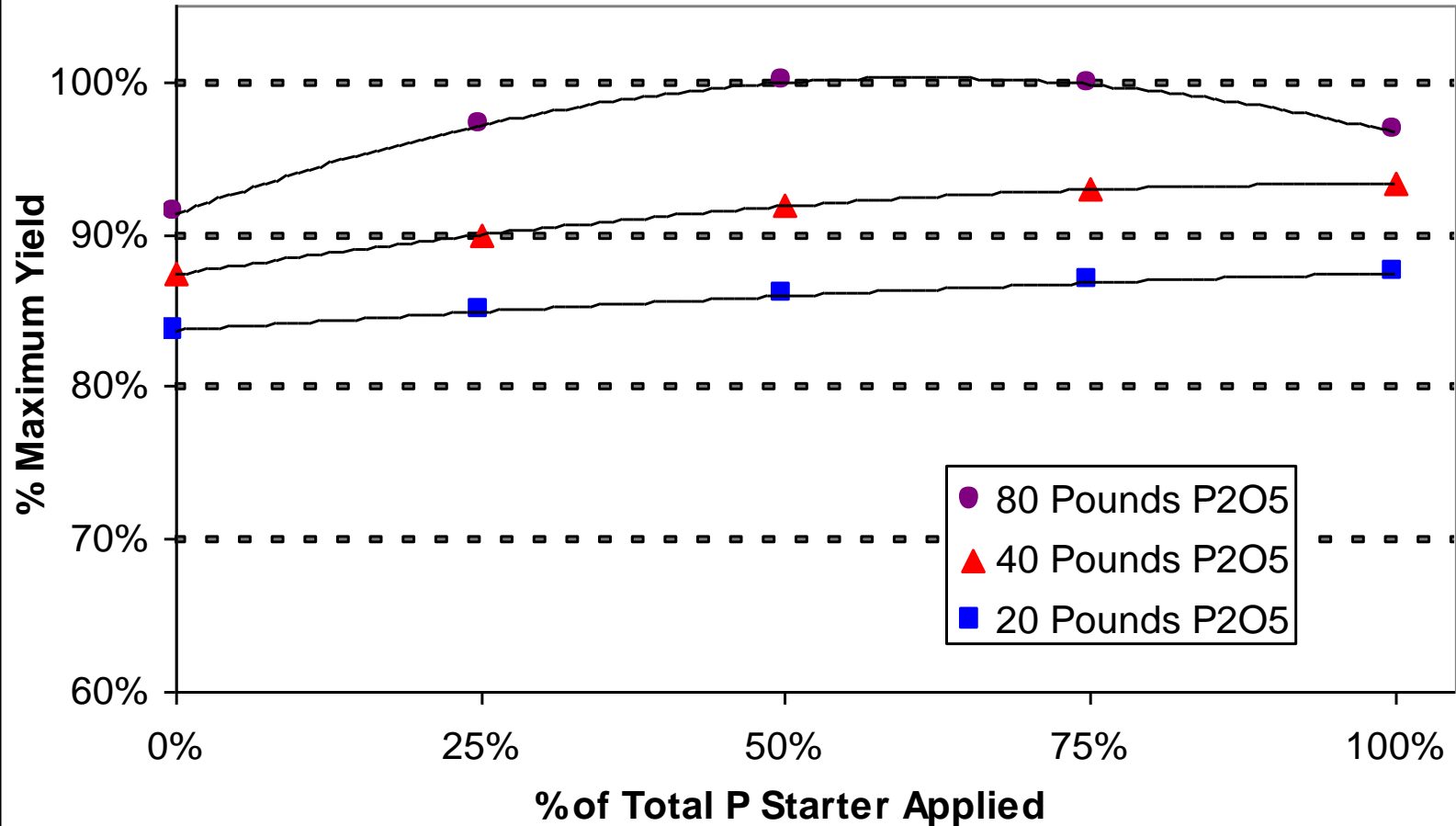
- No P or K is recommended at soil test values above the “critical” level.
- Soil tests levels equilibrate around 10-12 ppm.
- Unless initial soil test levels are high, little year to year flexibility in nutrient application.
- Nutrient application required for every crop, every year.
- **Starter fertilizer should be considered at low to very low ST.**

Corn Yield At Various Percentages Of Broadcast and Starter Applied P - Welch et al.



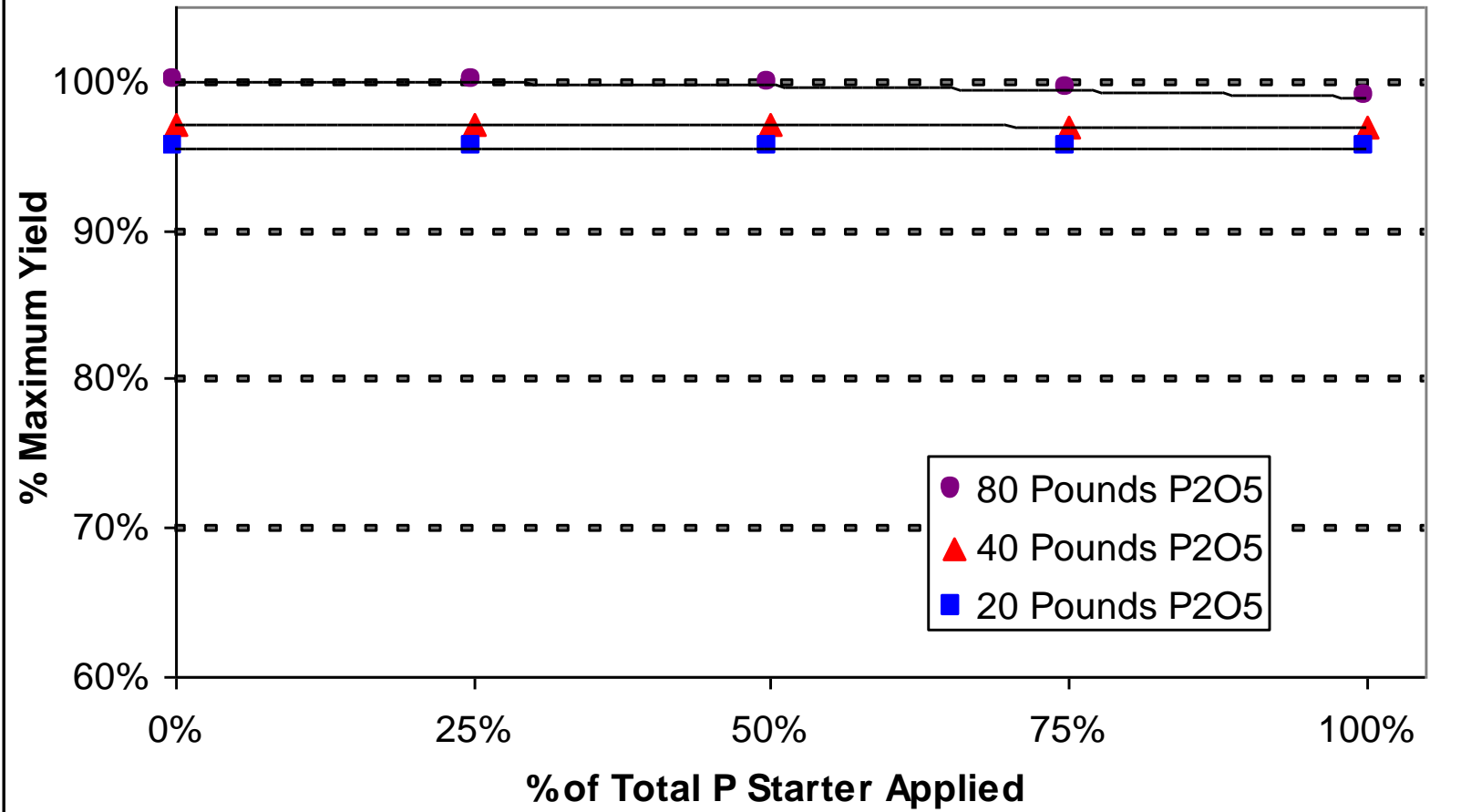
Zanesville Soil – Low Yield, Low Fertility

Corn Yield At Various Percentages Of Broadcast and Starter Applied P - Welch et al.



Elliott Soil – High Productivity, low fertility

Corn Yield At Various Percentages Of Broadcast and Starter Applied P - Welch et al.



Muscatine Soil – Very High Productivity, High fertility

Sufficiency Recommendations



- No P or K is recommended at soil test values above the “critical” level.
- Unless initial soil test levels are high, little year to year flexibility in nutrient application. Nutrient application required for every crop, every year.
- Eventually, recommended rates stabilize at levels that replace what is being removed.
- **Minimizes input costs in early years, but annual costs stabilize at levels equal to those of Build and Maintain.**

Corn P and K Sufficiency Recommendations



Sufficiency P Recommendations For Corn ¹

Bray P-1 (ppm)	Expected Yield (Bu/A)				
	80	120	160	200	240
	----- Lb P ₂ O ₅ /A -----				
0-5	60	65	70	80	85
6-10	40	45	50	55	60
11-15	25	30	30	35	35
16-20	15	15	15	15	15
21+	0 ²	0 ²	0 ²	0 ²	0 ²

Sufficiency K Recommendations For Corn ¹

Exch. K (ppm)	Expected Yield (Bu/A)				
	80	120	160	200	240
	----- Lb K ₂ O/A -----				
0-40	75	85	90	95	105
41-80	50	55	55	60	65
81-120	20	25	25	25	30
121-130	15	15	15	15	15
131+	0 ²	0 ²	0 ²	0 ²	0 ²

Crop Removal ³	26	40	53	66	79	Crop Removal ³	21	31	42	52	62
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¹ Crop P & K recommendations are for the total amount of broadcast and banded nutrients to be applied. At low to very low soil test levels applying at least 25 to 50% of total as a band is recommended.

² Starter application of small amounts of nutrients found in 100 pounds of a complete NPK or NPKS fertilizer may be beneficial regardless of P soil test level, especially when for cold/wet soil conditions and/or high surface crop residues.

³ Crop removal numbers provided for comparative purpose only. If crop removal exceeds nutrient applications, soil test levels would be expected to decline over time.

$$\text{Corn Sufficiency P Rec} = [50 + (\text{Exp Yield} \times 0.2) - (\text{Bray P} \times 2.5) - (\text{Exp Yield} \times \text{Bray P} \times 0.01)]$$

If Bray P > 20 ppm then basic P Recommendation = 0

If Bray P < 20 ppm then the minimum P Recommendation = 15 Lbs P₂O₅/A

If Bray P > 20 ppm then starter P suggested

$$\text{Corn Sufficiency K Rec} = [73 + (\text{Exp. Yield} \times 0.21) - (\text{Exch K} \times 0.565) - (\text{Exp Yield} \times \text{Exch K} \times 0.0016)]$$

If Exch K > 130 ppm then basic K Recommendation = 0

If Exch K < 130 ppm then the minimum K Recommendation = 15 Lbs K₂O/A

If Exch K > 20 ppm then starter K suggested

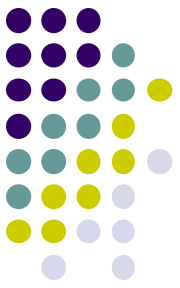
Sufficiency Recommendations



- No P or K is recommended at soil test values above the “critical” level.
- Unless initial soil test levels are high, little year to year flexibility in nutrient application. Nutrient application required for every crop, every year.
- Eventually, recommended rates stabilize at levels that replace what is being removed.
- Minimizes input costs in early years, annual costs stabilize at levels equal to those of Build and Maintain.
- **Well suited to competitive cash rent situations.**

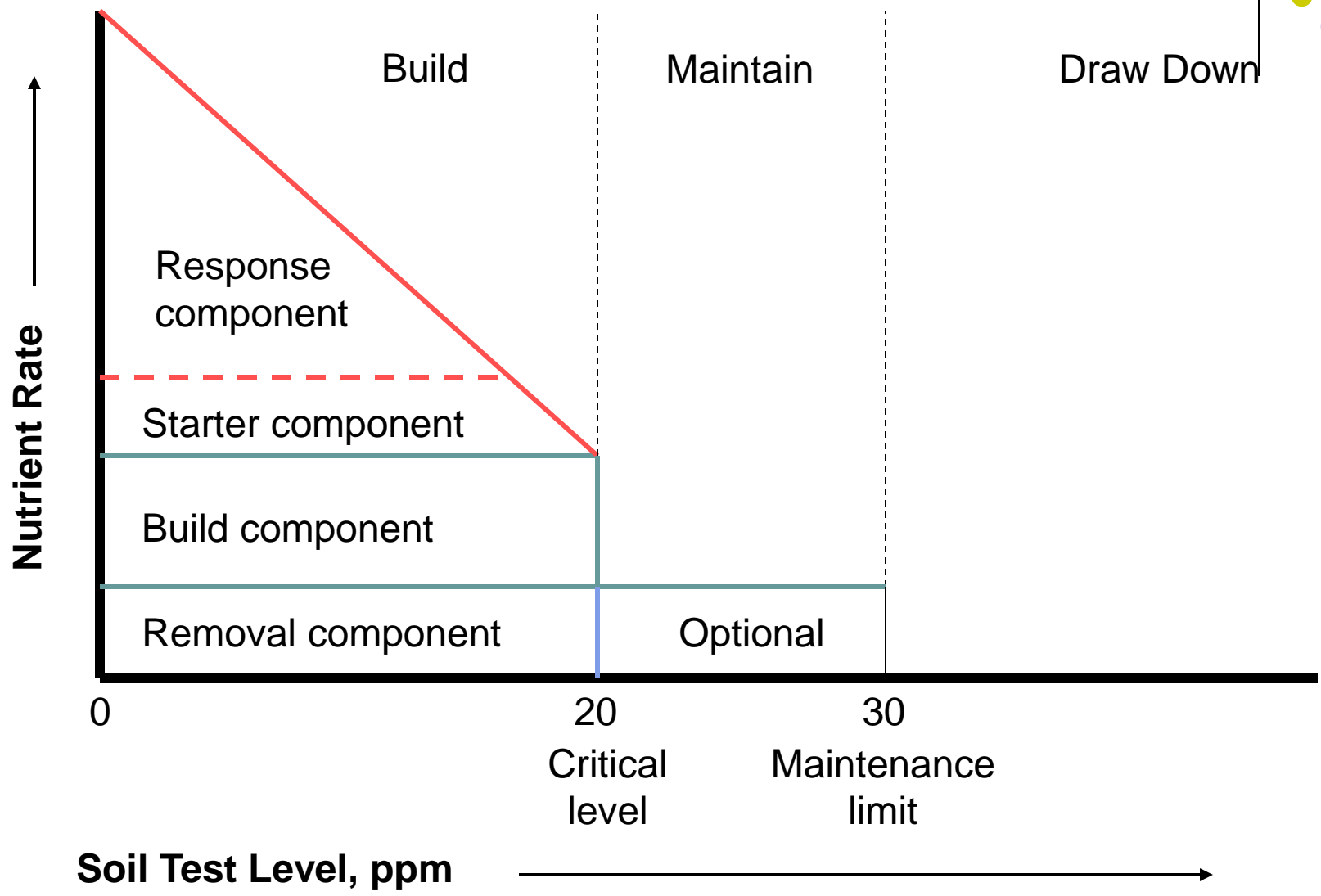
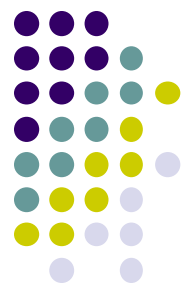


Build and Maintain Recommendations

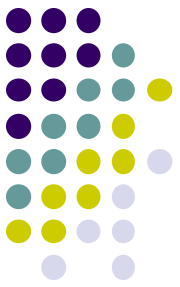


- Traditional system used in high yielding environments of Eastern and Central Cornbelt.
- Results in close to 100% of maximum yield.
- Manages a controllable factor by building soil test levels to a non-responding value then maintaining them there.
- Requires good correlation data to identify CL
- Does not require as much calibration data as nutrient sufficiency, because rates at low ST are above required for optimum yield due to combination of response + build + removal components. Excess fertilizer used to build rates covers any errors or mistakes.

Build and Maintain Application Model



Build and Maintain Recommendations



- Focus on maintaining soil test values in non-responsive range, slightly above “critical level”, to ensure maximum yield.
- Nutrient application is not required every year.
- Provides great flexibility in nutrient application, time management and cash flow.
- Higher fertilizer costs than sufficiency programs in early years. Requires an investment equivalent to the cost of fertilizer needed for the “Build” component.
- Once soil test level is above critical, annual costs are similar to long-term “nutrient sufficiency”.
- Best suited for longer land tenure situations.

Corn P and K Build-Maintenance Recommendations

Phosphorus Build-Maintenance Corn Recommendations ¹

Bray P1 Soil Test (ppm)	4 Year Build Timeframe			6 Year Build Timeframe			8 Year Build Timeframe		
	80	160	240	80	160	240	80	160	240
	Lbs P ₂ O ₅ /A			Lbs P ₂ O ₅ /A			Lbs P ₂ O ₅ /A		
0-5	105	132	158	79	105	132	66	92	119
6-10	83	109	135	64	90	117	55	81	107
11-15	60	87	113	49	75	102	43	70	96
16-20	38	64	90	34	60	87	32	58	85
21-30 ²	26	53	79	26	53	79	26	53	79
31+	0 ³	0 ³	0 ³	0 ³	0 ³	0 ³	0 ³	0 ³	0 ³

Potassium Build-Maintenance Corn Recommendations ¹

Exch. K Soil Test (ppm)	4 Year Build Timeframe			6 Year Build Timeframe			8 Year Build Timeframe		
	80	160	240	80	160	240	80	160	240
	Lbs K ₂ O/A			Lbs K ₂ O/A			Lbs K ₂ O/A		
0-40	268	289	310	186	207	227	145	165	186
41-80	178	199	220	126	147	167	100	120	141
81-130	77	98	119	58	79	100	49	70	91
131-160 ²	21	42	62	21	42	62	21	42	62
161+	0 ³	0 ³	0 ³	0 ³	0 ³	0 ³	0 ³	0 ³	0 ³

¹ Four, six and eight year timeframes below are examples only. Build programs can be over longer timeframe, however, build-maintenance recommendations should not be less than crop sufficiency based fertility programs.

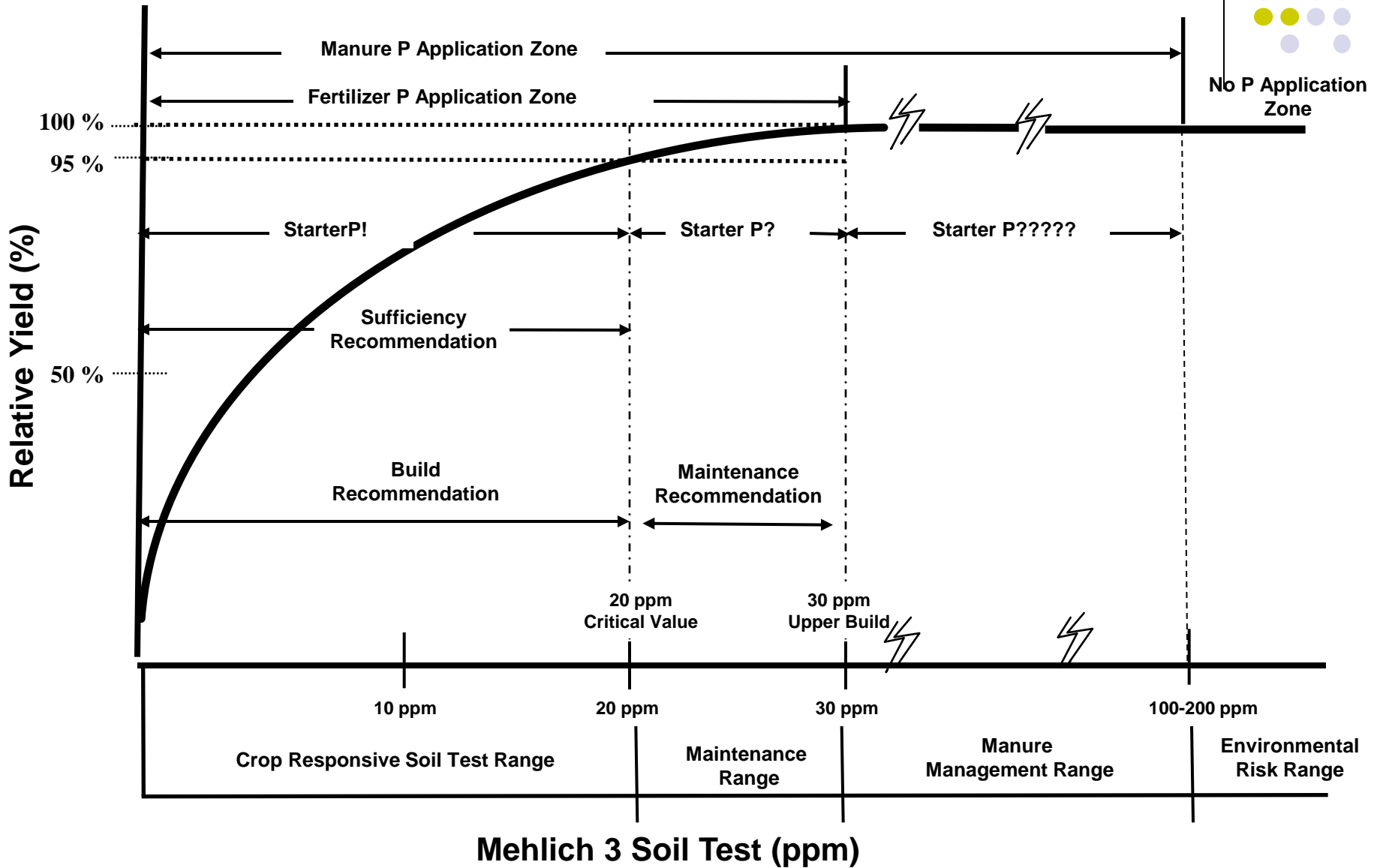
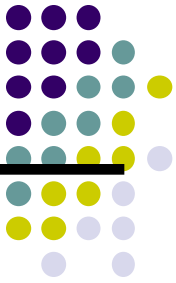
² Recommended amounts of P₂O₅ and K₂O are based on crop nutrient removal at the indicated yields (0.33 lb P₂O₅/bu and 0.26 lb K₂O / bu).

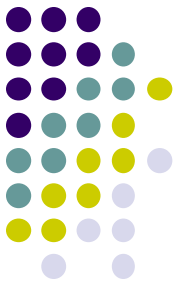
³ Starter application of small amounts of nutrients found in 100 pounds of a complete NPK or NPKS fertilizer may be beneficial regardless of K soil test level, especially when for cold/wet soil conditions and/or high surface crop residues.

$$\text{Corn P Build-Maintenance Rec} = \frac{\{(20 - \text{Current P Soil Test}) \times 18\}}{\text{Years To Build}} + \text{P2O5 Removal In Grain}$$

$$\text{Corn K Build-Maintenance Rec} = \frac{\{(130 - \text{Current K Soil Test}) \times 9\}}{\text{Years To Build}} + \text{K2O Removal In Grain}$$

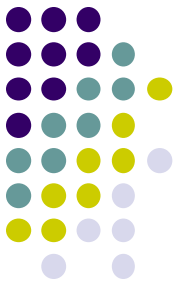
Kansas Phosphorus Management Model





What about water quality?

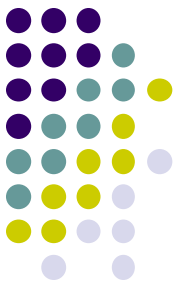
- Will using a Build and Maintain fertilizer program threaten Canadian Lakes?
 - NO!!
- Some of the key issues:
 - Sediment bound P vs. reactive, water soluble P
 - Desorption from previously lost sediment residing in stream and lake beds
 - ST level
 - Tillage
 - Method of application



Controlling Total P loss

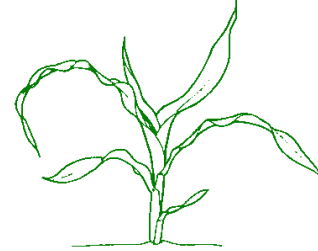
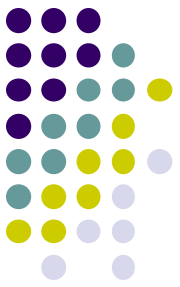
- Technology to control erosion and sediment loss is available
 - No-tillage
 - Structures
 - Buffer strips
 - Cover crops

Controlling water soluble P loss in sensitive environments



- Limit runoff water contact with reactive P
 - St P levels $> 30-50$ ppm seem to be threshold for elevated P in runoff.
 - High nutrient content on the soil surface due to nutrient stratification.
 - Bulk soil test level (0-6 or 8 in) has limited relevance.
 - Fertilizer placement can slow stratification.
 - Biocycling through residue increases stratification.

Surface ST levels in no-till systems after 6 years



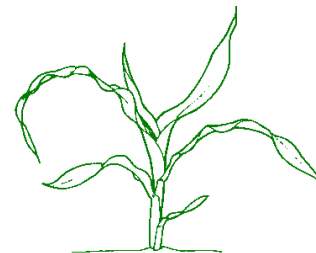
No P

23.8	27.3	31.8	22.5	13.1	29.4	28.1	24.8
16.5	11.6	8.7	14.5	11.3	10.0	6.7	6.6
10.5	26.2	13.8	15.1	4.2	4.7	7.4	9.8
3.0	4.8	3.5	4.2	2.0	2.0	3.6	3.1

Starter
Only

41.8	38.1	21.4	107.0	23.0	47.1	22.6	25.1
20.9	12.0	4.2	13.0	10.1	14.0	10.4	12.3
13.5	11.5	9.3	9.6	11.1	8.3	9.0	16.2
13.2	5.1	4.4	3.1	3.6	3.2	3.7	3.9

Surface ST levels in no-till systems after 6 years



	160.0	67.8	77.9	93.7	59.2	106.0	53.8	69.1
80 Bdcst Every 2 years	10.0	13.7	14.5	21.8	13.1	6.3	10.6	6.6
	12.1	9.8	7.9	10.8	5.6	7.5	11.9	7.9
	7.0	4.7	3.2	2.6	6.4	2.8	9.0	4.5
80 Deep Banded Every 2 years	31.5	48.7	34.3	15.8	32.4	28.5	53.4	38.1
	9.6	14.9	23.3	37.0	7.8	7.9	12.3	16.0
	8.8	8.6	51.7	92.9	8.4	12.0	10.8	14.0
	2.8	5.6	4.9	67.4	3.4	2.8	2.6	7.4

Questions?

Contact me at dmengel@ksu.edu

