Predictability of Yield Response to P and K Application Based on Soil Test Levels

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Steps in Soil Testing

1. Sampling

2. Analysis

3. Interpretation

Making Fertilizer Recommendations Using Soil Tests

- First, correlate soil test values with crop yield:
  - Determine values for a low, optimum, and high soil test
  - This establishes the potential responsiveness of the crop to added nutrients.
- Second, calibrate the amount of fertilizer needed to obtain yields which are profitable, sustainable, and are safe for the environment.

Correlation and Calibration Influenced by:

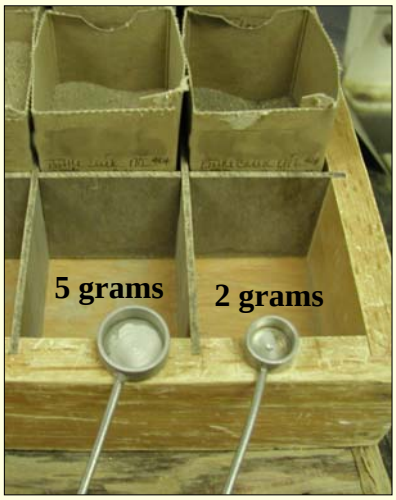
- Crop
- Cultivar
- Yield Potential
- Soil Fertility / Subsoil Nutrients
- Soil Type / Soil Texture
- Water Storage Capacity
- Tillage Practices
- Planting Date
- Climate

Correlation and Calibration Requires Extensive Field Studies

Purdue Research Centers

Variety of soil types, weather conditions, and cropping systems

Only a small amount of the sampled soil is used for analysis

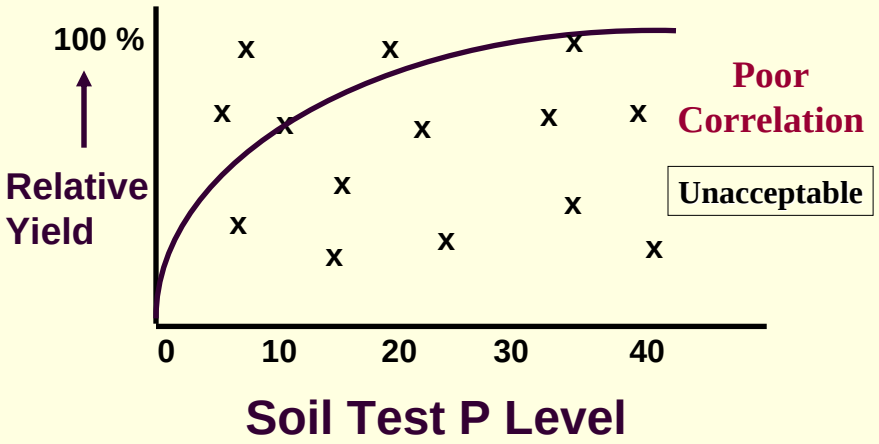


What chemical extractant should be used???

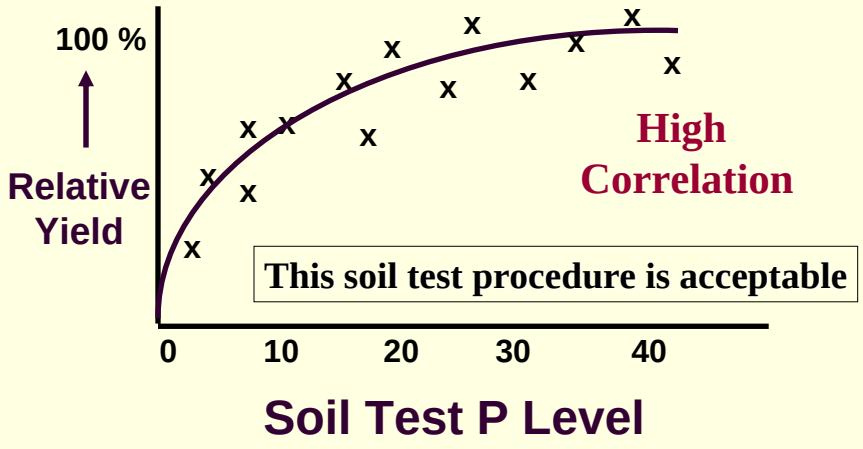
Soil Test Correlation

- Determining the correct laboratory procedure and extractant to predict available P and K for crop growth

Soil Test Correlation



Soil Test Correlation



Soil Extractants are Regionally Based

- **Phosphorus chemistry in soil is very complex and the extractant used must match the soil conditions to obtain useful results.**
  - **Northeast and Northwest (Acid Soils) – Morgan Extractant, a weak acid extractant.**
  - **Midwest (Soils with pH < 6.8) – Bray P1, Mehlich 3**
  - **Southeast (Acid Soils) – Mehlich I and 3**
  - **Western States (Calcareous Soils) – Bicarbonate-based Olsen Extractant**

Soil Extractants are Regionally Based

- **Potassium availability is difficult to predict especially as one changes from sandy soils and other low CEC soils to soils with 2:1 clays that "fix" potassium.**
  - **Ammonium Acetate, NH_4OAc, at pH 7.0 has traditionally been the most widely used extractant for exchangeable K**
  - **In the Northeastern U.S., NH_4OAc at pH 4.8 is the common K extractant**
  - **Mehlich 3 has become a common extractant for K in recent years and is highly correlated to ammonium acetate at pH 7.**

Soil Test Procedures - Midwest

- **Recommended for the North Central Region by the NCR-13 Regional Committee**
- **Phosphorus**
  - **Bray P1 ***
  - **Mehlich-3**
  - **Olsen**
- **Potassium**
  - **Ammonium Acetate ***
  - **Mehlich-3**

* **Used for Tri-State Fertilizer Recommendations**

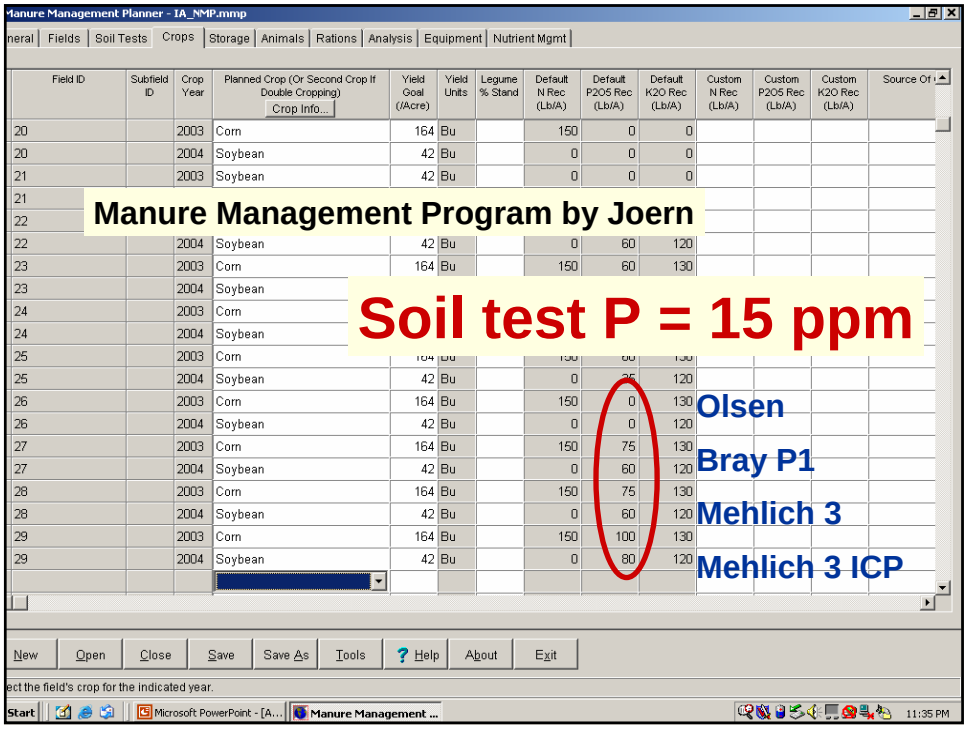
Examples of Different Extractants and Their Optimum Sufficiency Ranges for Corn

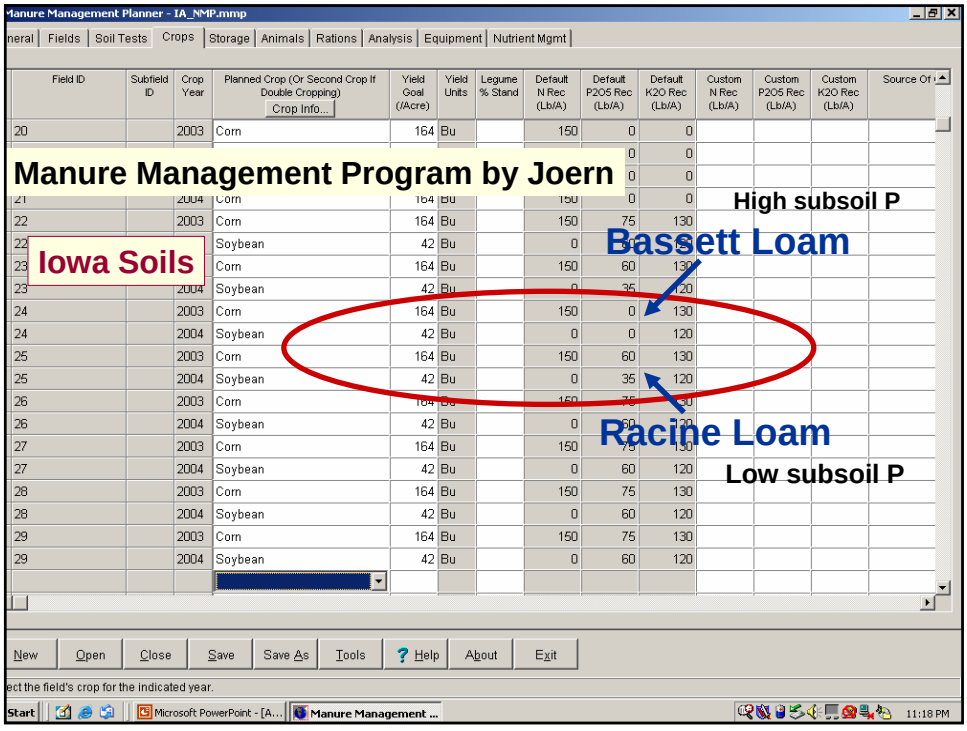
Nutrient	Optimum Sufficiency Range (ppm)	Extractant
Phosphorus	11 - 15	Mehlich-3
	11 - 15	Bray P1
	21 - 30	Mehlich-3 - ICP
	8 - 11	Olsen
Potassium	111 - 150	NH_4OAc (pH 7.0)
	111 - 150	Mehlich-3

Iowa State University, 2002 (assumes high P & K in subsoil)

Important Points

- Soil Test Values are indices; not the amount of available nutrient present in the soil.
- Soil Test Values relate to the probable response that might be expected if fertilizer is added – is there adequate P & K such that applying fertilizer will not change the yield?





Soil Test Values

- Inherent variability due to soil sampling (representative sample is critical)
- Inherent variability due to laboratory procedures
  - Phosphorus +/- 10%
  - Potassium +/- 10%
  - pH +/- 0.1 pH unit

Soil Test Numerical Values

- Reported in parts per million (ppm)
- Sometimes reported in lb/A assuming an acre-furrow-slice of soil weighs 2,000,000 lbs
  (Thus, ppm x 2 = lb/A)
- Values classified into interpretive categories:
  - Very Low (VL)
  - Low (L)
  - Optimum (Opt)
  - High (H)
  - Very High (VH)

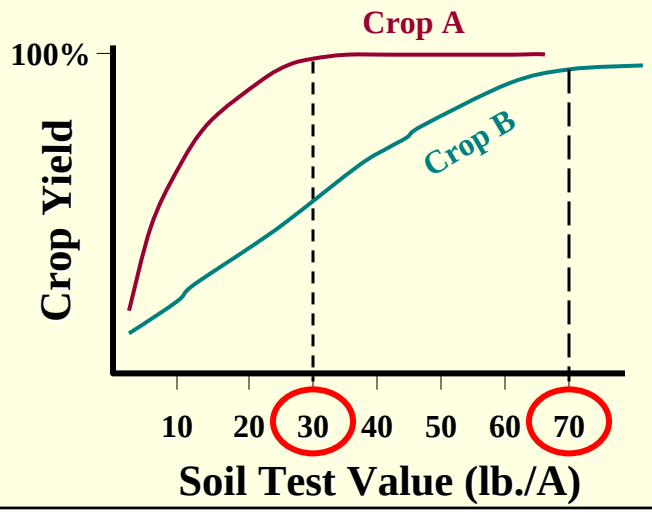
Decreasing probability of economic response to applied nutrients

Soil Test Numerical Values:

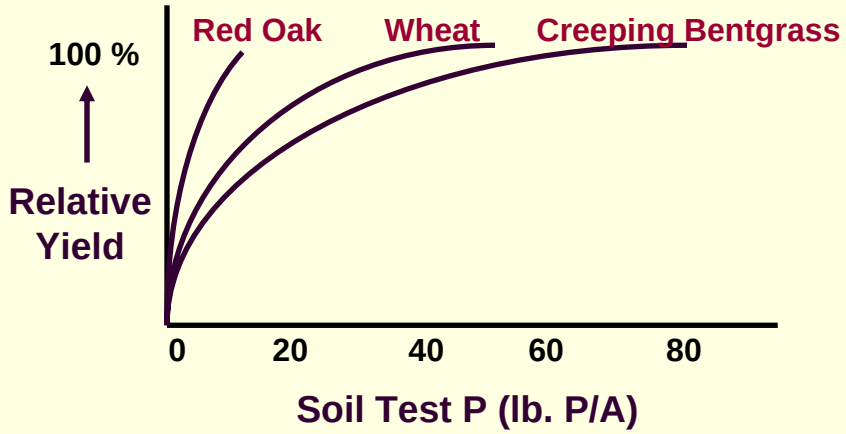
The percentage of P & K applications expected on the average to produce a yield response within each soil test category:

Very Low	(VL)	80%
Low	(L)	65%
Optimum	(Opt)	25%
High	(H)	5%
Very High	(VH)	<1%

Correlating Soil Test Values to Specific Crops

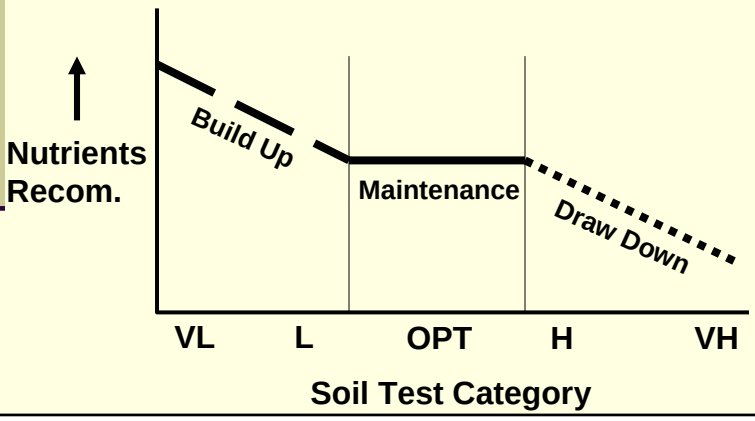


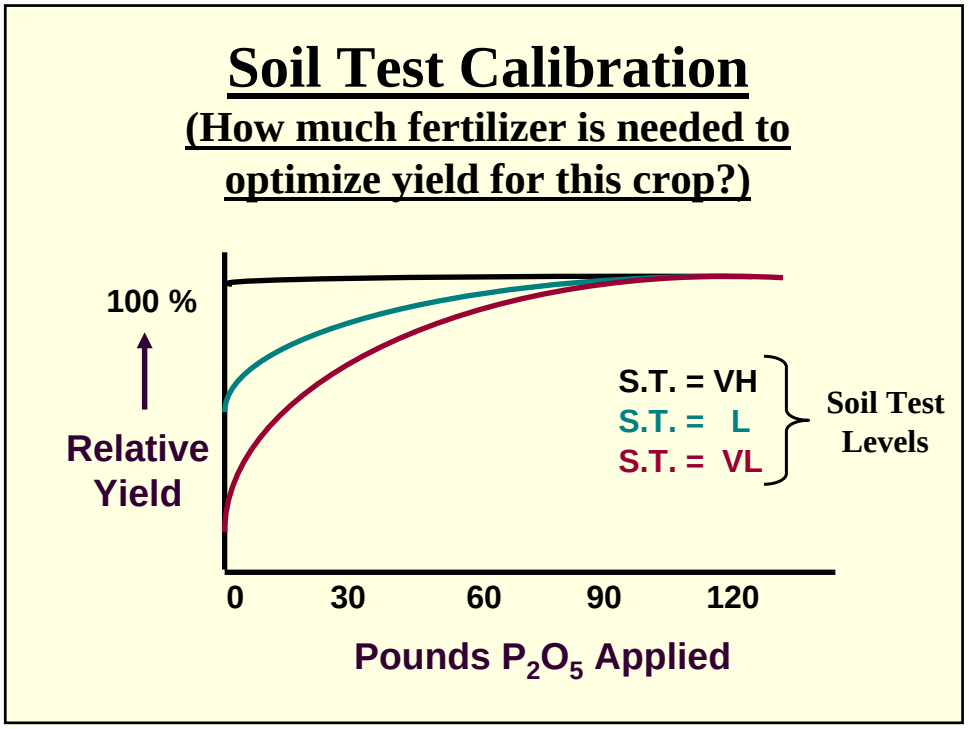
Soil Test Correlation - Varies by plant species

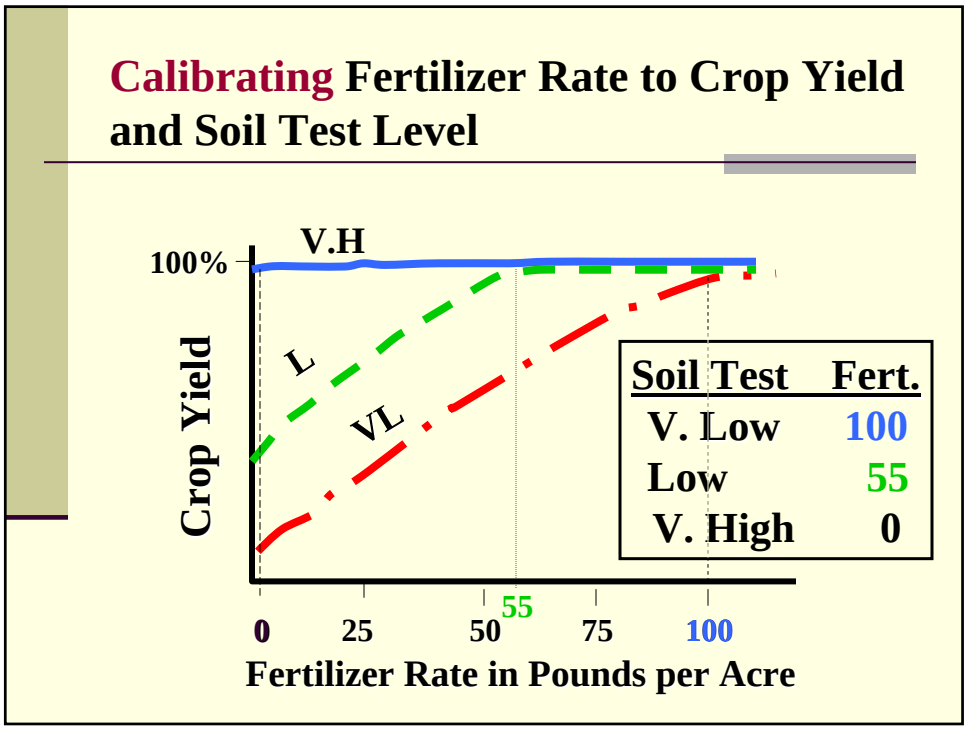


Nutrient Recommendations Based on Soil Tests:

- Structured so that soil tests move toward optimum level



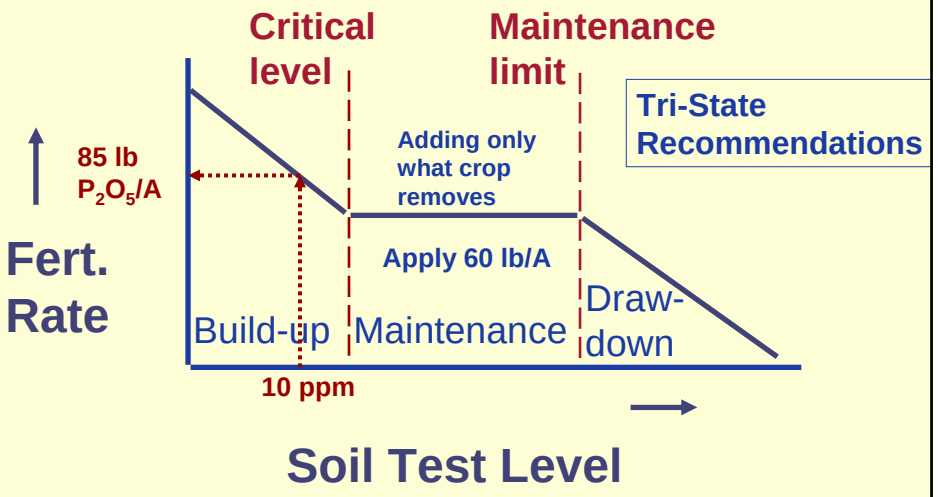




Example of P_2O_5 Fertilizer Recommendations for Corn

ppm P Soil Test	Rating	---Yield Potential (bu/A)--- 100	120	140	160	180
		---------- (pounds P_2O_5 per acre)----------				
5	Deficient	85	95	100	110	115
10	Deficient	60	70	75	85	90
15-30	Adequate	35	45	50	60	65
35	High	20	20	25	30	35
40	Very High	0	0	0	0	0

Nutrient Build-up and Maintenance Concept



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5	Deficient	85	95	100	110	115
10	Deficient	60	70	75	85	90
15-30	Maintenance	→			60	65
35	High	20	20	25	30	35
40	Very High	0	0	0	0	0

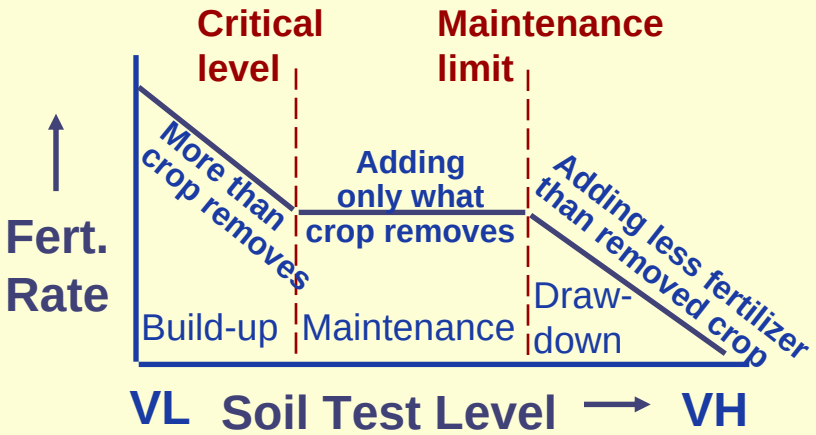
Critical Levels for Phosphorus

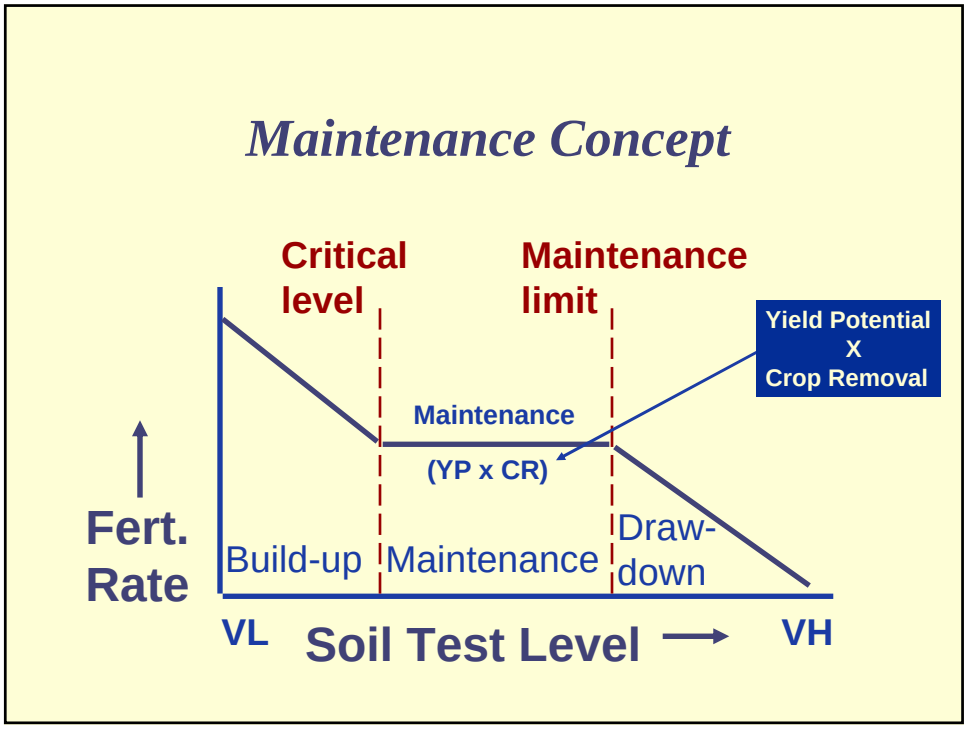
Crop	ppm P	(lb P/acre)
Corn	15	(30)
Soybean	15	(30)
Wheat	25	(50)
Alfalfa	25	(50)

Response of Corn to Varying P Soil Test Values – Purdue Data

Bray P1 Soil Test Values lb/ A	Bray P1 Soil Test Values ppm	Corn Yield Bu / A
20	10	142
41	20	152
58	29	155
119	59	153
30	15	Critical Level

Nutrient Build-up and Maintenance Concept





Nutrients Removed in Harvested Portion of Agronomic Crops

Crop	Unit of yield	Nutrient removed per unit of yield	
		P_2O_5	K_2O
		- - - - lb./unit - - - -	
Corn grain	bu/acre	0.37	0.27
Corn silage	tons/acre	3.30	8.00
Soybeans	bu/acre	0.80	1.40
Wheat grain	bu/acre	0.63	0.37
Wheat straw	bu/acre	0.09	0.91
Alfalfa	tons/acre	13.00	50.00

Phosphorus Maintenance Equation

Designed to keep soil test constant

lb P_2O_5/acre to apply

= (YP x CR)

180 bu/acre corn grain example

= (180 x 0.37)

= 66 lb P_2O_5/acre

Tri-State Phosphorus Rec… Corn Grain

Phosphorus Maintenance Equation
Designed to keep soil test constant

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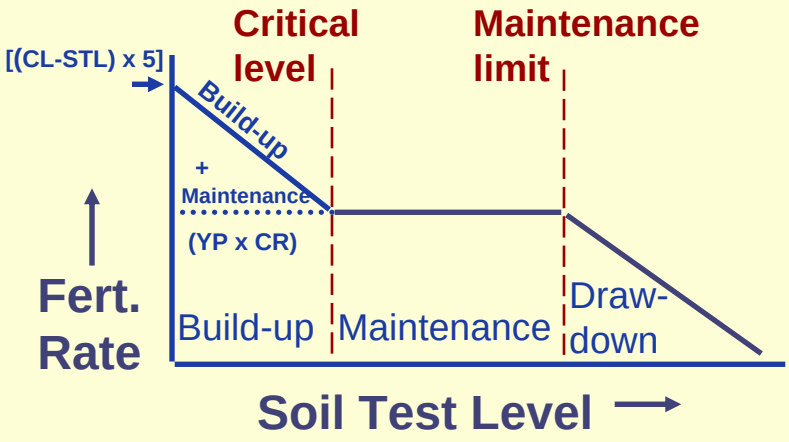
= (YP x CR)

180 bu/acre corn grain example
= (180 x 0.37)
= 66 lb P_2O_5/acre

Soil test	…tial (bu/acre)					
- - ppm					P_2O_5/acre - - - - - - -	
Critical level →	5				110	115
	10				85	90
	15-30	35	45	50	0	65
	35	20	20	25	30	35
	40	0	0	0	0	0

Maintenance

Nutrient Build-up and Maintenance Concept



Phosphorus Build-up Equation

Designed to reach critical level in four years

lb P_2O_5/acre to apply

= [(CL-STL) x 5] + (YP x CR)

= Build-up + Maintenance

Nutrients Removed in Harvested Portion of Agronomic Crops

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		P_2O_5	K_2O
		- - - - lb./unit - - - -	
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Wheat grain	bu/acre	0.63	0.37
Wheat straw	bu/acre	0.09	0.91
Alfalfa	tons/acre	13.00	50.00

Phosphorus Build-up Equation

70 bu/acre wheat example

STP = 15 ppm / CL = 25 ppm

Build-up + Maintenance

[(25-15) x 5 + (70 x 0.63)]

= 50 + 44

= 94 lb P_2O_5/acre

In four years we will apply 200 lb P_2O_5/acre in excess of crop removal to increase soil test by 10 mg P/kg, so it takes 20 lb P_2O_5/acre in excess of crop removal to increase soil test by 1 ppm

Phosphorus Build-up Equation

70 bu/acre wheat example

[(25-15) x 5 + (70 x 0.63)]

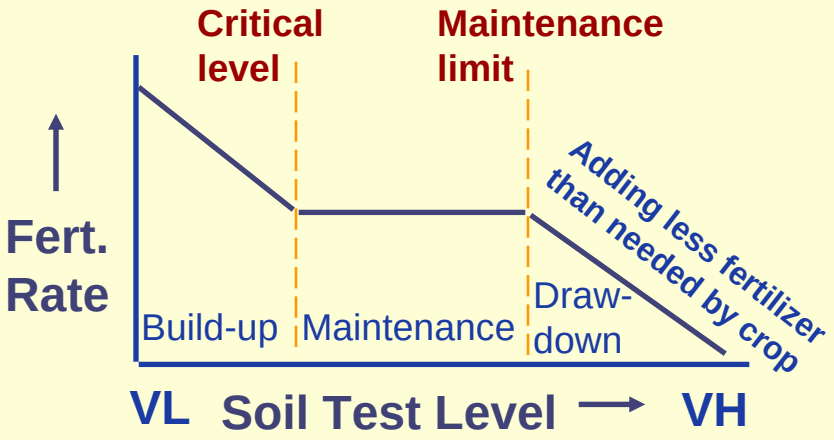
= 50 + 44

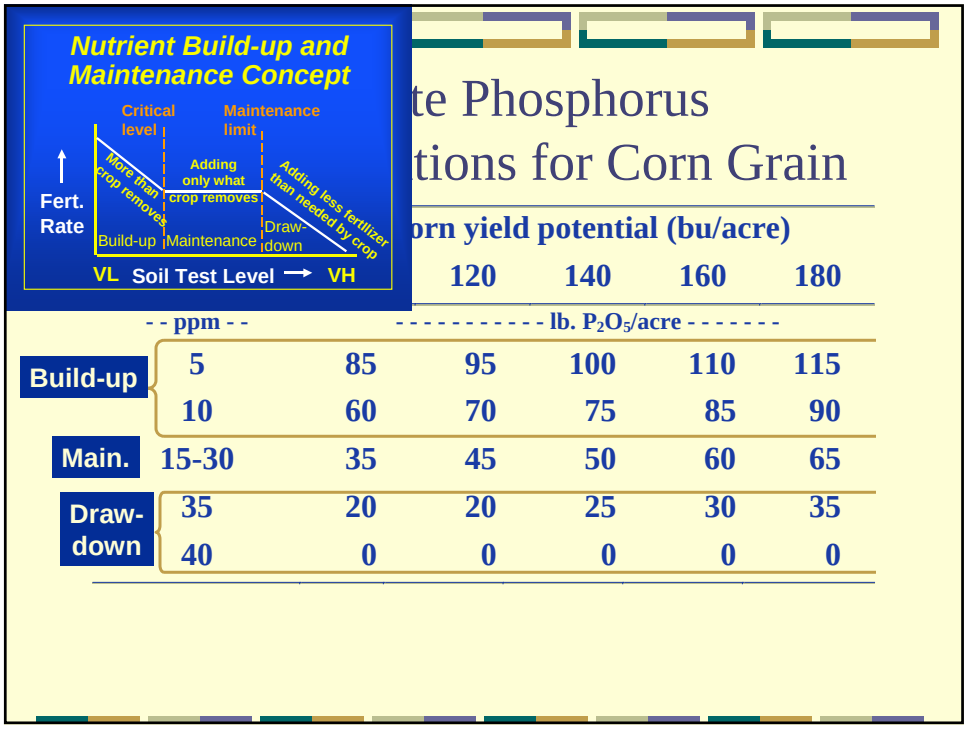
= 94 lb P_2O_5/acre

e Phosphorus
dations for Wheat

	eat yield potential (bu/acre)				
	60	70	80	90
-- ppm --	- - - - - - - - - - lb. P_2O_5/acre - - - - - - - -
15	80	90	95	100	105
20	55	65	70	75	80
25-40	30	40	45	50	55
45	15	20	20	25	30
50	0	0	0	0	0

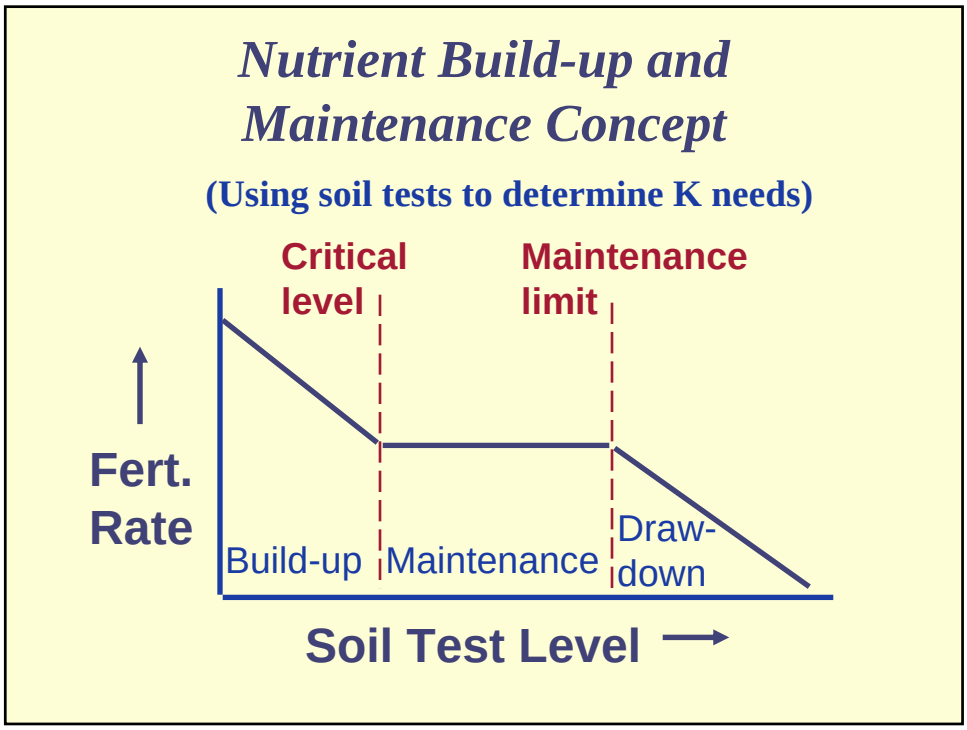
Nutrient Build-up and Maintenance Concept





te Phosphorus
tions for Corn Grain

		orn yield potential (bu/acre)				
		120	140	160	180	
	- - ppm - -	- - - - - - - - - - lb. P_2O_5/acre - - - - - - -				
Build-up	5	85	95	100	110	115
	10	60	70	75	85	90
Main.	15-30	35	45	50	60	65
Draw-down	35	20	20	25	30	35
	40	0	0	0	0	0



Critical Soil Test Levels (CL) for Various Agronomic Crops

Crop	Critical soil test levels				
	P	K at CEC[1]			
		5	10	20	30
	ppm (lb/acre)	ppm (lb/acre)			
Corn	15 (30)[2]	88 (175)	100 (200)	125 (250)	150 (300)
Soybean	15 (30)	88 (175)	100 (200)	125 (250)	150 (300)
Wheat	25 (50)	88 (175)	100 (200)	125 (250)	150 (300)
Alfalfa	25 (50)	88 (175)	100 (200)	125 (250)	150 (300)

Potassium (K)

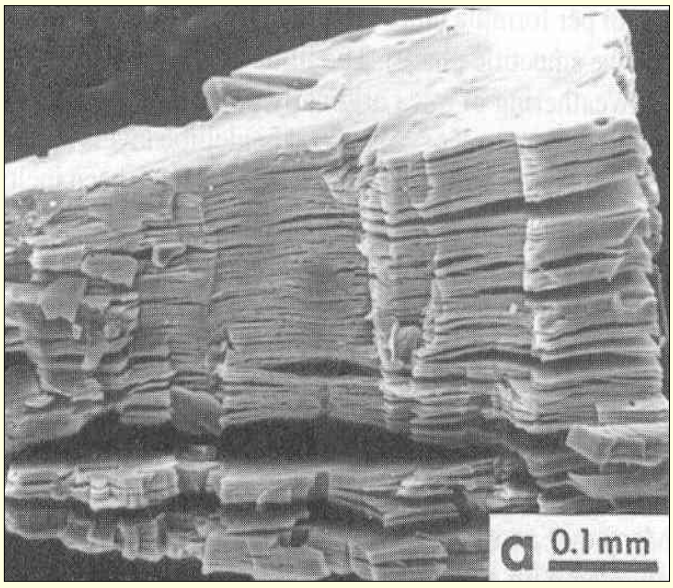
(75 + (2.5 x CEC))

for corn, soybean, wheat and alfalfa

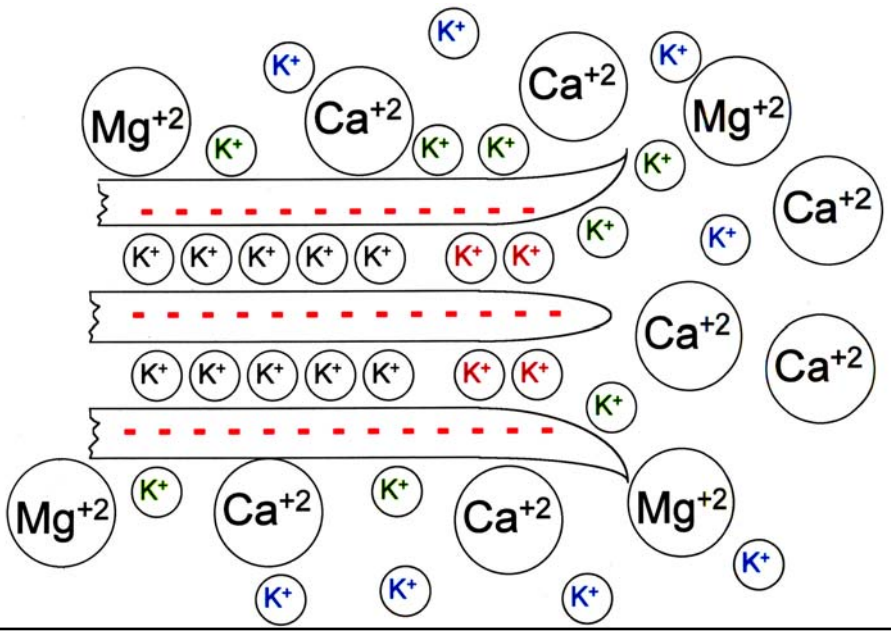
Potassium Critical Levels

- **Critical Soil Test Levels increase as Soil CEC increases**
  - **CEC = 5 Critical S.T. Level = 88 ppm**
  - **CEC = 10 Critical S.T. Level = 100 ppm**
  - **CEC = 20 Critical S.T. Level = 125 ppm**
  - **CEC = 30 Critical S.T. Level = 150 ppm**
- **Fertilizer Rates increase as Soil CEC increases for a specified yield goal (Tied to high 2:1 clays and K fixation)**

2:1 Clay Mineral with Interlayer K



Interlayer Potassium – Very dynamic



Tri-State Potash Recommendations for Corn Grain (CEC = 10)

	Corn yield potential (bu/acre)				
Soil test level	100	120	140	160	180
- - ppm - -	- - - - - - - - - - lb. K_2O/acre - - - - - - -				
25	160	165	170	175	180
50	120	125	135	140	145
75	85	90	95	100	105
100-130	45	50	60	65	70
140	25	25	30	35	35
150	0	0	0	0	0

Tri-State Potash Recommendations for Corn Grain (CEC = 30)

	Corn yield potential (bu/acre)				
Soil test level	100	120	140	160	180
- - ppm - -	- - - - - - - - - - lb. K_2O/acre - - - - - - -				
75	235	240	245	250	255
100	170	175	185	190	195
125	110	115	120	125	130
150-180	45	50	60	65	70
190	25	25	30	30	35
200	0	0	0	0	0

Nutrients Removed in Harvested Portion of Agronomic Crops

Crop	Unit of yield	Nutrient removed per unit of yield	
		P_2O_5	K_2O
		- - - - lb./unit - - - -	
Corn grain	bu/acre	0.37	0.27
Corn silage	tons/acre	3.30	8.00
Soybeans	bu/acre	0.80	1.40
Wheat grain	bu/acre	0.63	0.37
Wheat straw	bu/acre	0.09	0.91
Alfalfa	tons/acre	13.00	50.00

Potassium Maintenance Equation

Designed to keep soil test constant

lb K_2O/acre to apply

(Non-forage crops)

= (YP x CR) + 20

140 bu/acre corn grain example

= (140 x 0.27) + 20

= 58 lb K_2O/acre

Maintenance rate is not CEC dependent

Tri-State Potash Recommendations for Corn Grain (CEC = 10)

	Corn yield potential (bu/acre)				
Soil test level	100	120	140	160	180
- - ppm - -	- - - - - - - - - - lb. K_2O/acre - - - - - - -				
25	160	165	170	175	180
50	120	125	135	140	145
75	85	90	95	100	105
100-130	45	50	60	65	70
140	25	25	30	35	35
150	0	0	0	0	0

Potassium Build-up Equation

Designed to reach critical level in four years

lb K_2O/acre to apply

= [(CL-STL) x (1 + (0.05 x CEC))]+(YP x CR) + 20

= [Build-up] + harvested nutrients + 20

In four years the build-up portion of the equation will increase current soil test level to the critical level. Build-up portion is CEC dependent to account for soil buffer capacity.

Nutrients Removed in Harvested Portion of Agronomic Crops

Crop	Unit of yield	Nutrient removed per unit of yield	
		P_2O_5	K_2O
		- - - - lb./unit - - - -	
Corn grain	bu/acre	0.37	0.27
Corn silage	tons/acre	3.30	8.00
Soybeans	bu/acre	0.80	1.40
Wheat grain	bu/acre	0.63	0.37
Wheat straw	bu/acre	0.09	0.91
Alfalfa	tons/acre	13.00	50.00

Potassium Build-up Equation

50 bu/acre soybean, STK = 75 mg/kg, CEC = 10

CL = 100

lb K_2O/acre to apply:

= [(CL-STL) x (1 + (0.05 x CEC))]+(YP x CR) + 20

= [(100-75) x (1 + (0.05 x 10))] + (50 x 1.4) + 20

= (25 x 1.5) + 70 + 20

= 37.5 + 90

= 130 lb K_2O/acre

In four years we will apply 150 lb K_2O/acre (37.5 x 4) in excess of maintenance rate to increase soil test by 25 mg K/kg, so it takes 6 lb K_2O/acre in excess of maintenance rate to raise soil test by 1 mg K/kg at CEC of 10

Potassium Build-up Equation

50 bu/acre soybean, STK = 75 mg/kg, CEC = 10

lb K_2O/acre to apply:

= [(CL-STL) x (1 + (0.05 x CEC))]+(YP x CR) + 20

= [(100-75) x (1 + (0.05 x 10))] + (50 x 1.4) + 20
= (25 x 1.5) + 70 + 20
= 37.5 + 90

= 130 lb K_2O/acre

ecommendations (CEC = 10)

ld potential (bu/acre)

			50	60	70
			- - lb. K_2O/acre - - - - - - -		
			205	215	230
50	135	150	165	180	195
75	100	115	130	140	155
100-130	60	75	90	105	120
140	30	40	45	50	60
150	0	0	0	0	0

Soil Testing Confusion:

- Soils sampled at different times, from different depths, and samples not truly representative of the area of interest.
- Nutrient stratification as a result of tillage practices.
- Making fertilizer recommendations based on laboratory procedures for which the recommendations were not developed.
- Changes in lab protocol which are now correlated to “old” fertilizer recommendation data.
- Recommendations are sometimes extrapolated to other crops without field studies being done on the soils and under climatic conditions where the crop is grown.

Things to Remember !!!

- **Be sure soil test procedures are calibrated to the recommendations being made.**
- **Be sure recommendations have been developed for the soils and region in which you work.**
- **Keep records of soil test data and fertilization practices to observe changes over time.**
- **Don't underestimate the value of farmer fertility trials – understanding local conditions, management practices, and other factors influencing yields.**