Differentiating and Understanding the Mehlich 3, Bray, and Olsen Soil Phosphorus Tests

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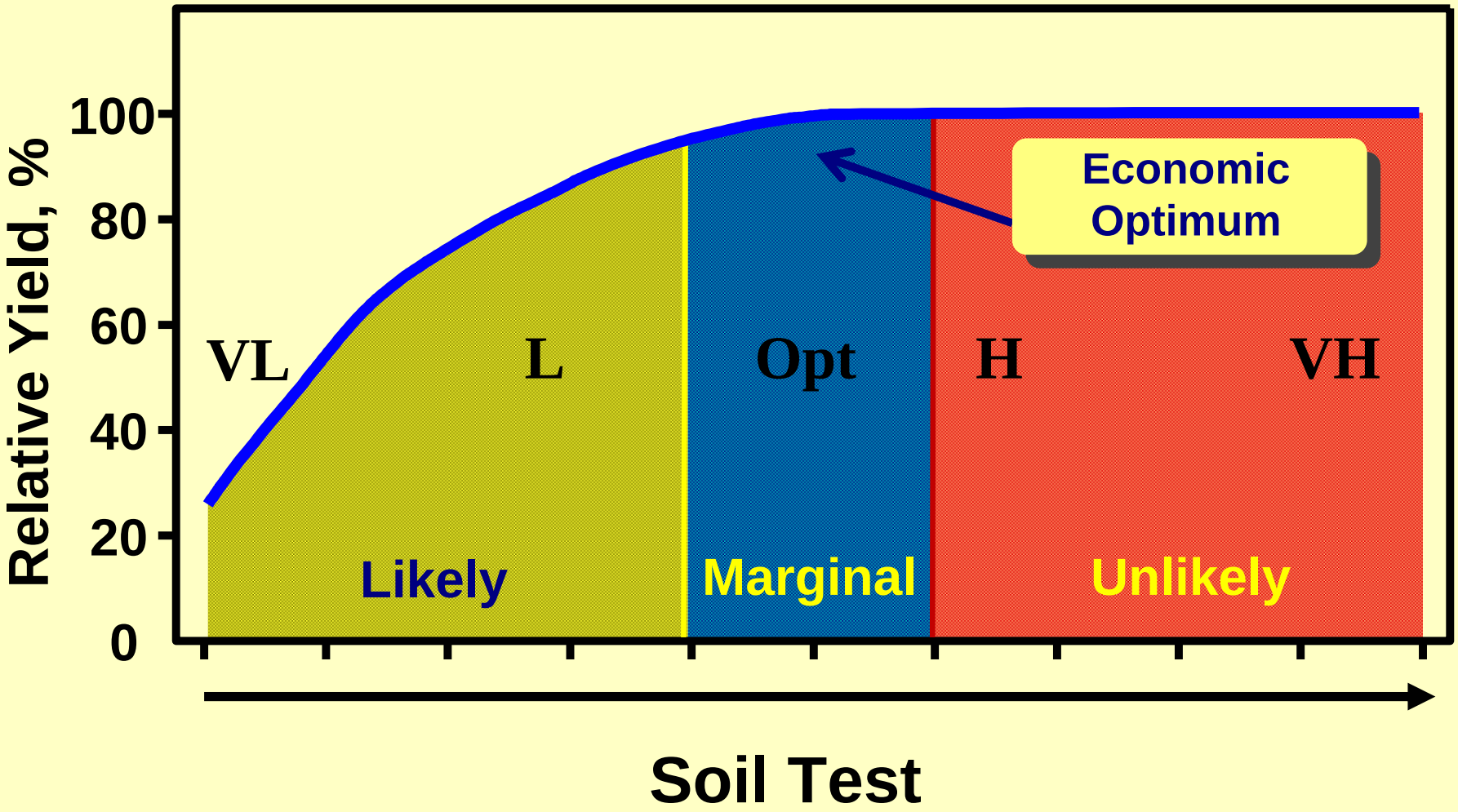
The Four Components of Soil Testing

- Field Sampling
- Extraction and Chemical Analysis
- Interpreting the Analytical Results
- Making the Fertilizer Recommendation

What are the Laboratory Components in a Soil Test Method

- Soil preparation and sampling
- Extractant
- Extraction procedure
- Chemical analysis method (measurement)
- *(Result interpretation)*

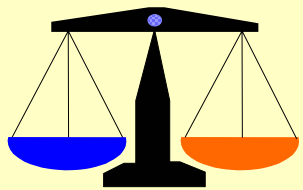
Soil Test Interpretation
Index of Availability and Crop Response



Laboratory Method for Phosphorus

- Grind soil
- Measure 2 g soil into 50 ml flask (125 ml for Olsen)
- Add 20 ml extraction solution (40 ml for Olsen)
- Shake for 5 minutes (30 min for Olsen)
- Filter though filter paper
- Determine P concentration by colorimetric procedure -- Ascorbic Acid Method

NCR 221 (Rev.)



Phosphorus Test Extractants

- **Bray 1-P Extractant (Bray & Kurtz, 1945)**
  - **0.025 M HCl; 0.03 M NH_4F**
- **Mehlich-3 Extractant (Mehlich, 1984)**
  - **0.2 N acetic acid; 0.25 N NH_4NO_3; 0.015 NH_4F; 0.013 N HNO_3; 0.001 M EDTA**
- **Olsen Extractant (Olsen et al., 1954)**
  - **0.5 M $NaHCO_3$**

P Extraction with Dilute Acid Fluoride (Bray)

- **Acid soils**
  - **Fluoride ion promotes P desorption by decreasing aluminum activity by forming aluminum - fluoride complexes**
- **Highly calcareous soils**
  - **Acid neutralized by calcium carbonate and CaF_2 is formed**
  - **This is when Bray results in false low values**

P Extraction with Dilute Acids and Fluoride (Mehlich)

- **Acid soils**
  - **Similar to Bray**
- **Highly calcareous soils**
  - **? Variety and stronger acids than Bray**
  - **? More buffered solution**

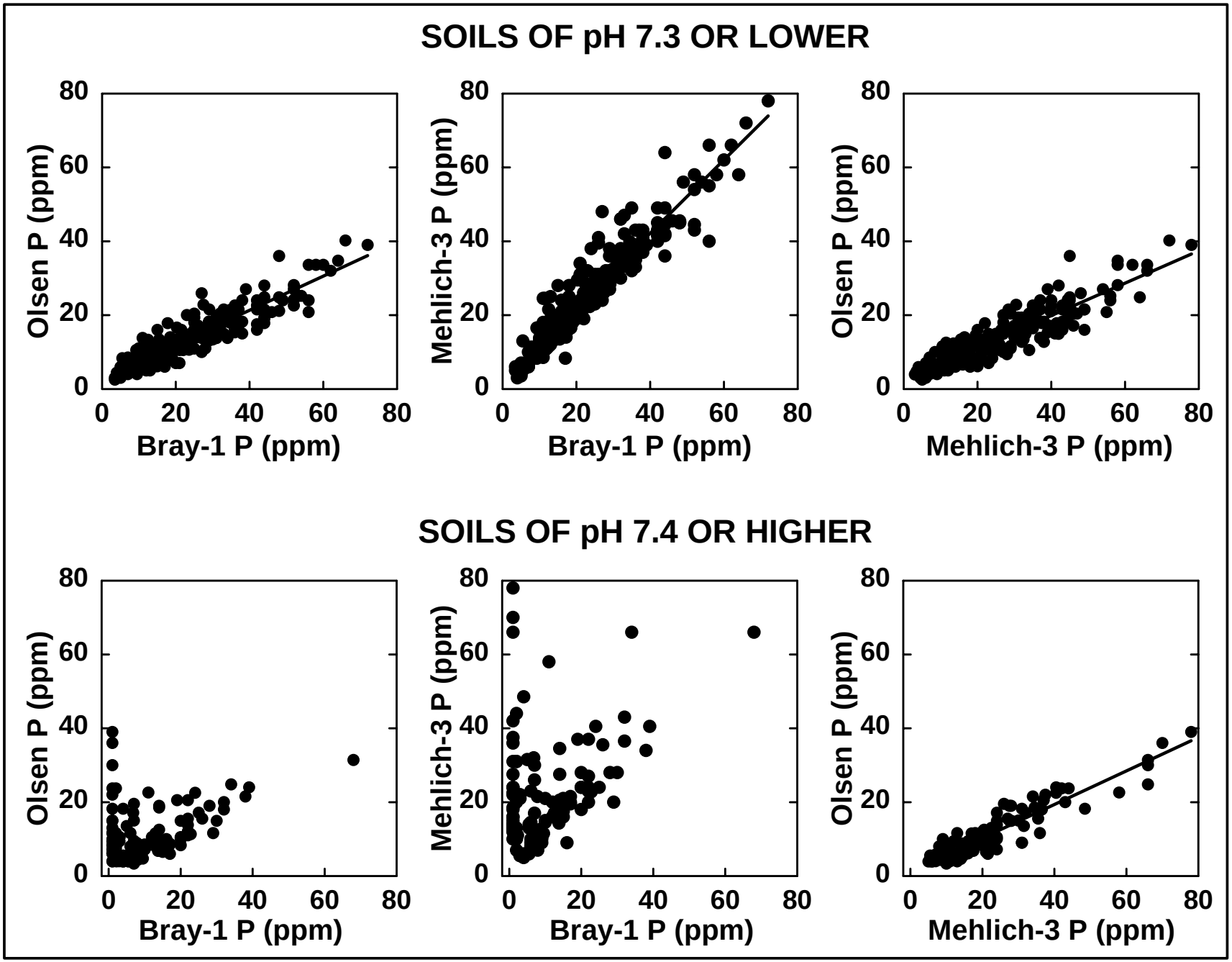
P Extraction with Buffered Alkaline Solution (Olsen)

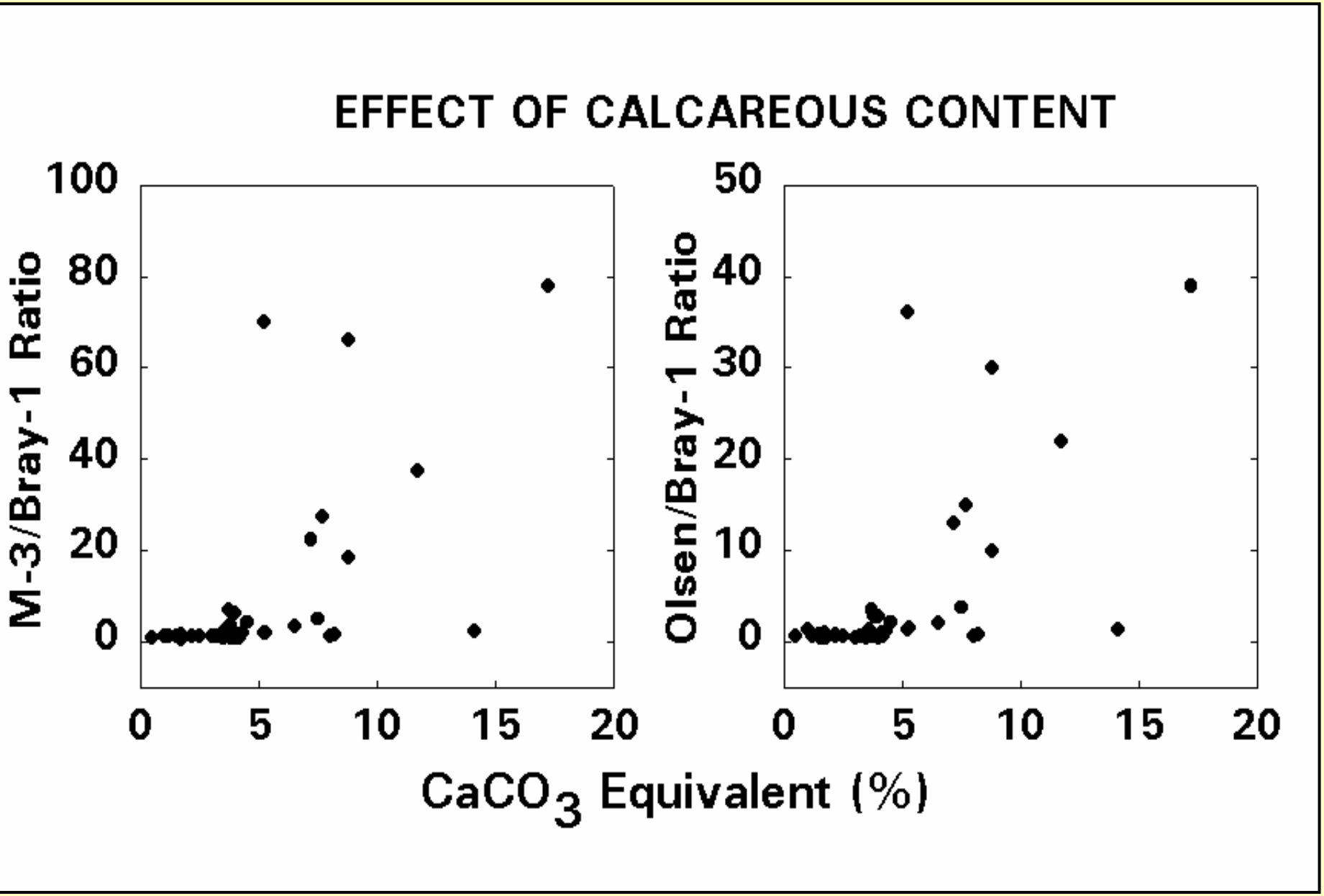
- $NaHCO_3$ solution decreases concentration and activity of Ca^{2+} and Al^{3+} and increases P solubility

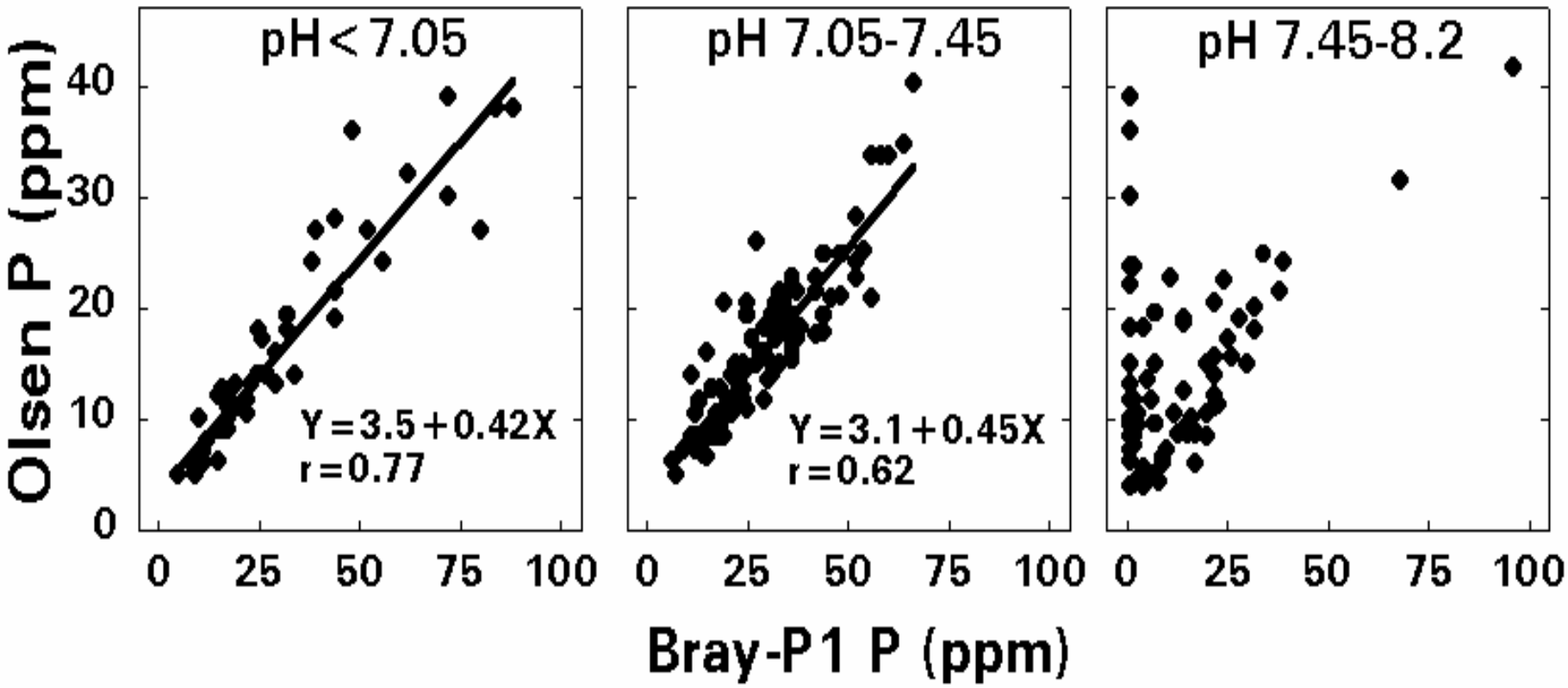
Phosphorus Soil Test Reproducibility

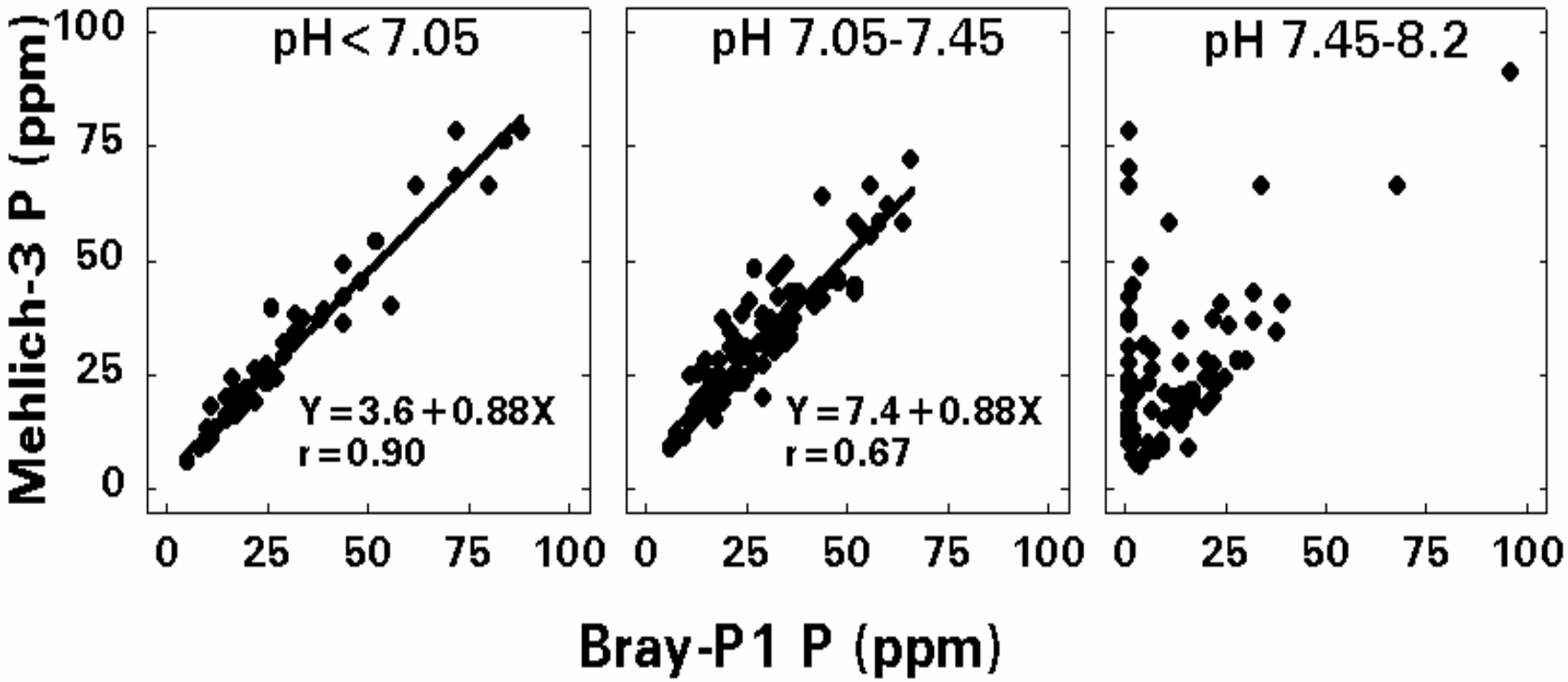
- **Bray 1-P**
  - ± 10% (dry soil basis)
  - 1 ppm detection limit
- **Mehlich 3**
  - ± 10% (dry soil basis)
  - 1 ppm detection limit
- **Olsen**
  - ± 12% (dry soil basis)
  - 2 ppm detection limit

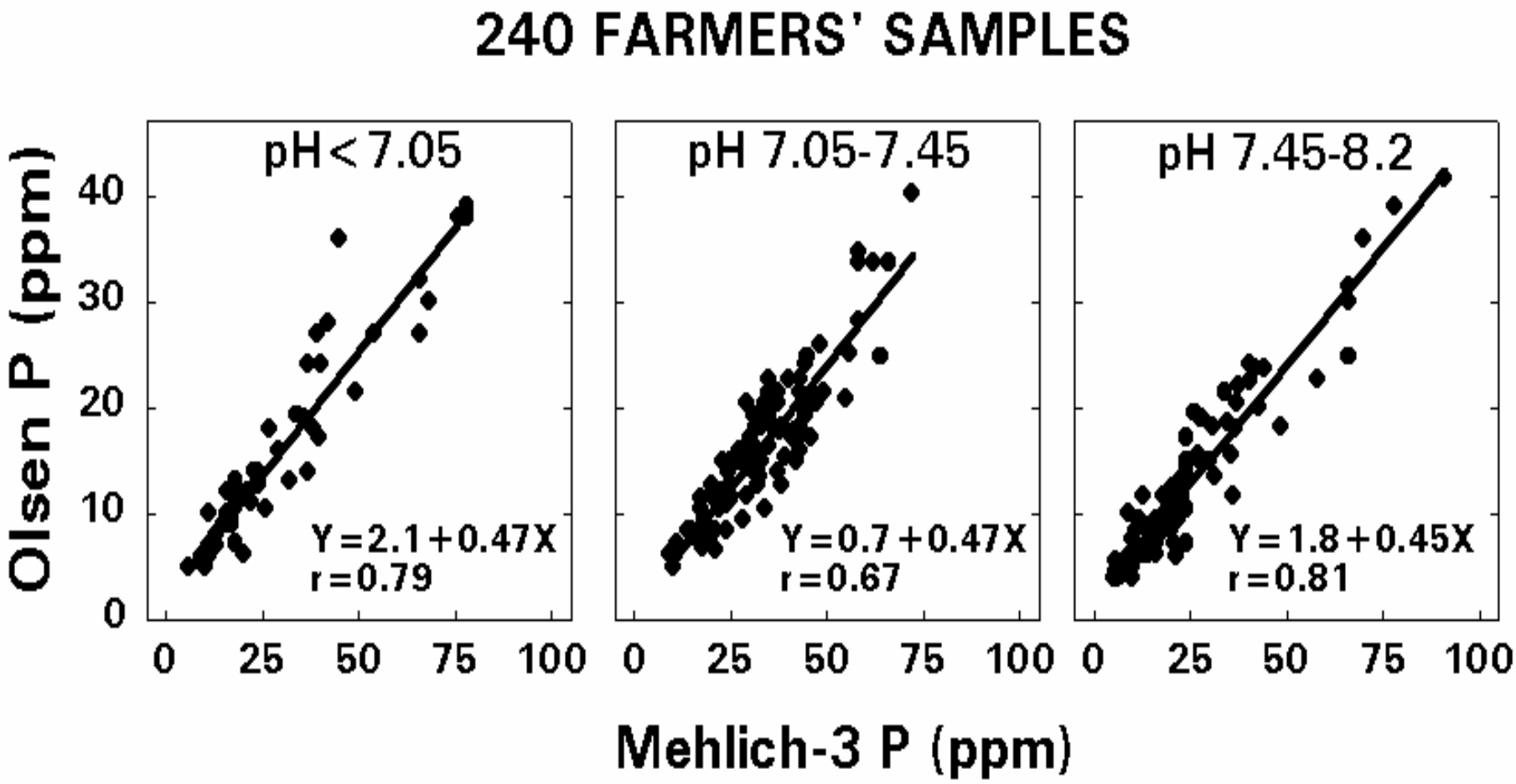
NCR 221 (Rev.)

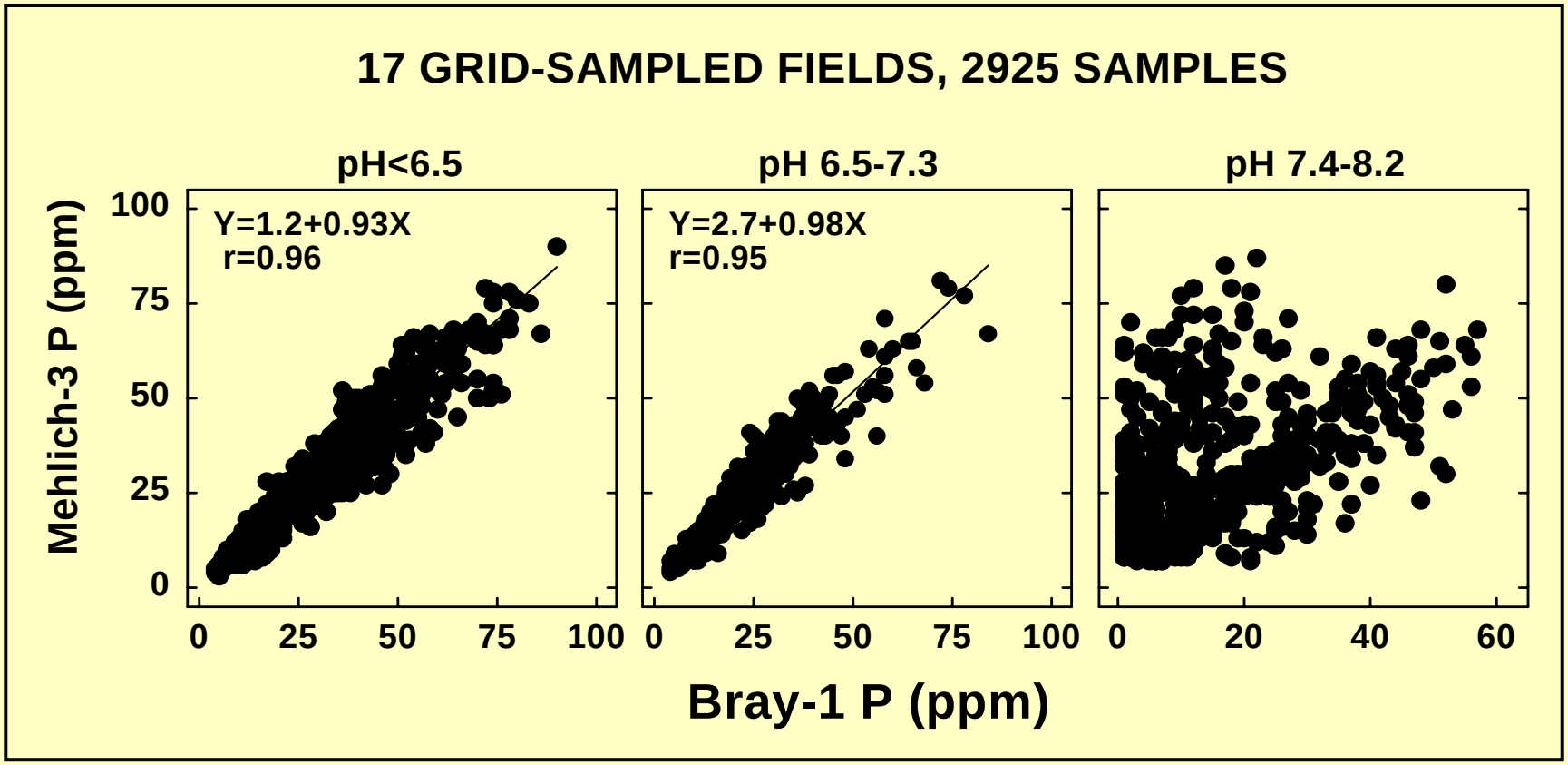

SOILS OF pH 7.3 OR LOWER
Olsen P (ppm)
Bray-1 P (ppm)
Mehlich-3 P (ppm)
Bray-1 P (ppm)
Olsen P (ppm)
Mehlich-3 P (ppm)
SOILS OF pH 7.4 OR HIGHER
Olsen P (ppm)
Bray-1 P (ppm)
Mehlich-3 P (ppm)
Bray-1 P (ppm)
Olsen P (ppm)
Mehlich-3 P (ppm)
0
20
40
60
80

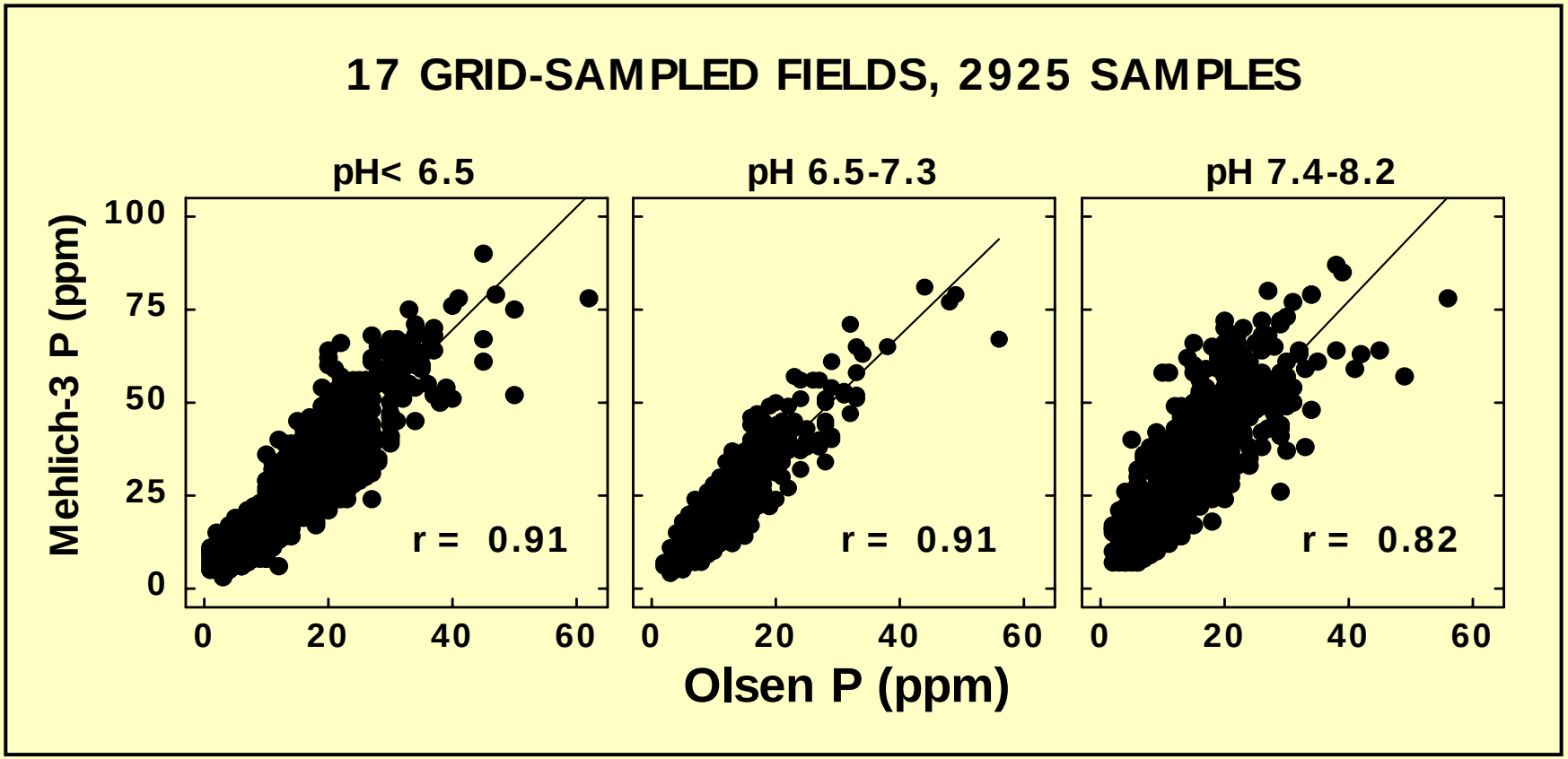

EFFECT OF CALCAREOUS CONTENT
M-3/Bray-1 Ratio
100
80
60
40
20
0
Olsen/Bray-1 Ratio
50
40
30
20
10
0
0
5
10
15
20
0
5
10
15
20
CaCO3 Equivalent (%)


240 FARMERS' SAMPLES
pH < 7.05
pH 7.05-7.45
pH 7.45-8.2
Olsen P (ppm)
0
10
20
30
40
Y = 3.5 + 0.42X
r = 0.77
Y = 3.1 + 0.45X
r = 0.62
0
25
50
75
100
Bray-P1 P (ppm)

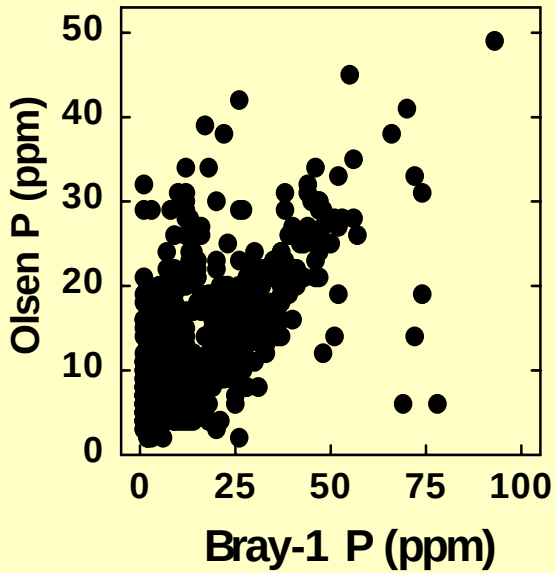

240 FARMERS' SAMPLES
pH < 7.05
pH 7.05-7.45
pH 7.45-8.2
Y = 3.6 + 0.88X
r = 0.90
Y = 7.4 + 0.88X
r = 0.67
Mehlich-3 P (ppm)
Bray-P1 P (ppm)
0
25
50
75
100

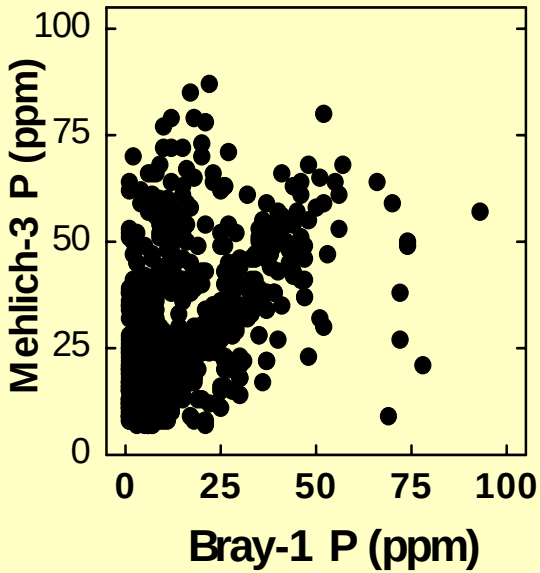

240 FARMERS' SAMPLES
pH < 7.05
pH 7.05-7.45
pH 7.45-8.2
Olsen P (ppm)
0
10
20
30
40
0
25
50
75
100
Y = 2.1 + 0.47X
r = 0.79
Y = 0.7 + 0.47X
r = 0.67
Y = 1.8 + 0.45X
r = 0.81
Mehlich-3 P (ppm)

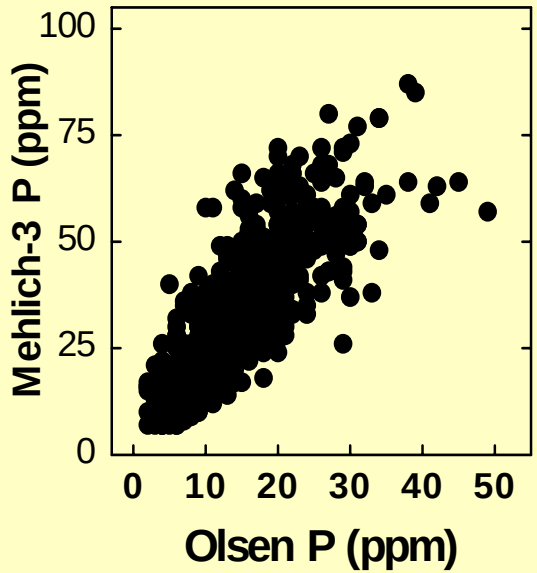

17 GRID-SAMPLED FIELDS, 2925 SAMPLES
pH<6.5
pH 6.5-7.3
pH 7.4-8.2
Y=1.2+0.93X
r=0.96
Y=2.7+0.98X
r=0.95
Mehlich-3 P (ppm)
Bray-1 P (ppm)
0
25
50
75
100
0
20
40
60

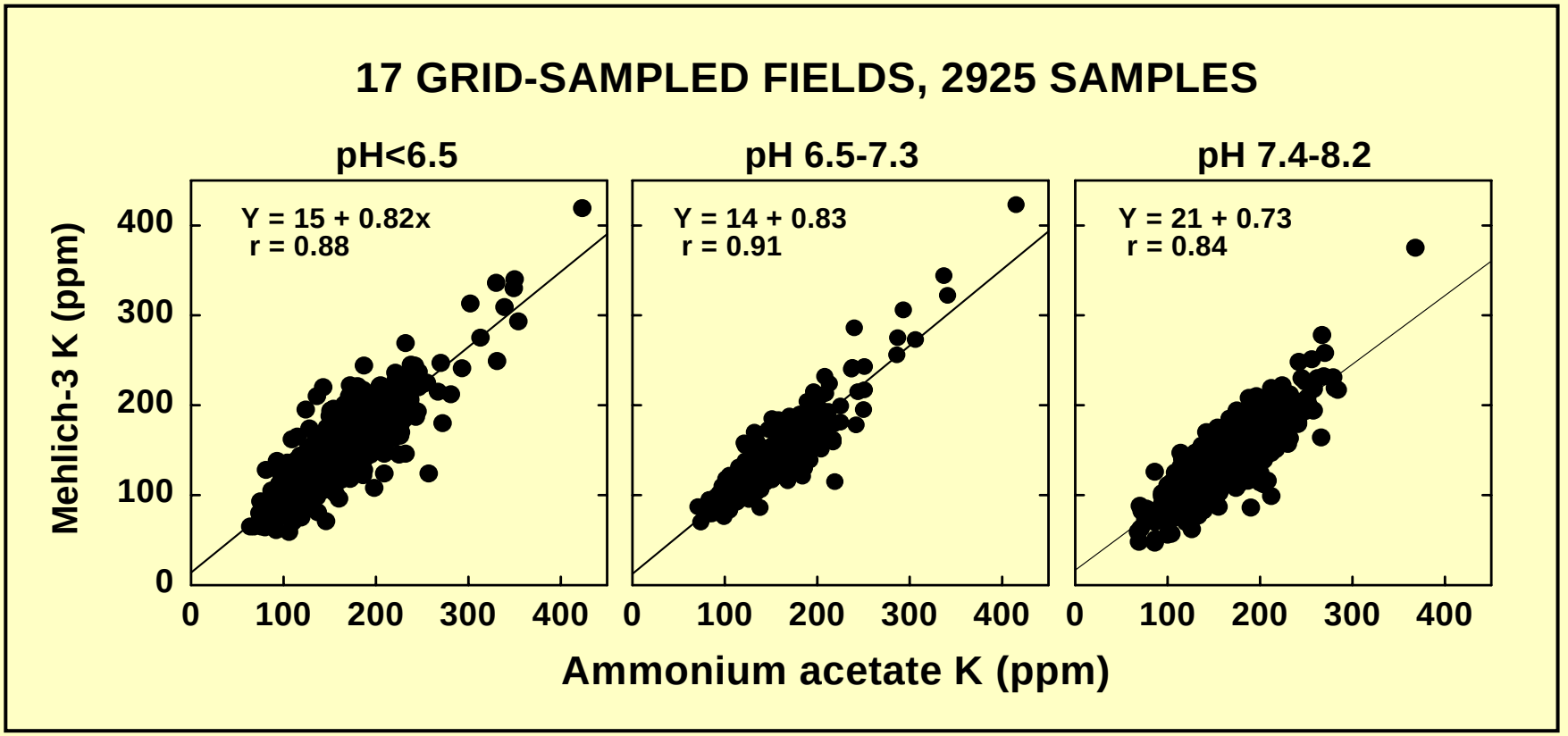

17 GRID-SAMPLED FIELDS, 2925 SAMPLES
pH< 6.5
pH 6.5-7.3
pH 7.4-8.2
Mehlich-3 P (ppm)
100
75
50
25
0
r = 0.91
r = 0.91
r = 0.82
0
20
40
60
Olsen P (ppm)

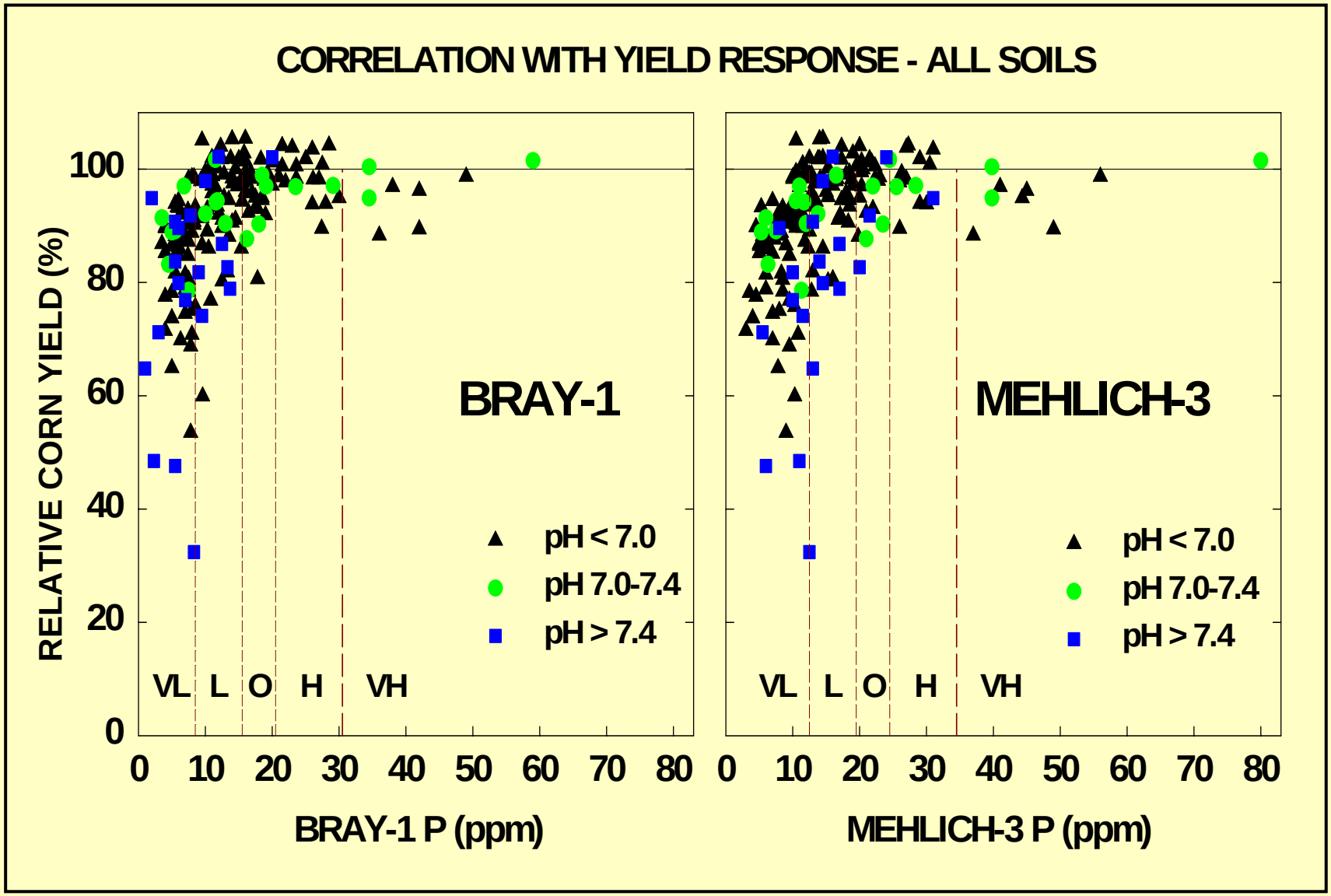
544 SAMPLES OF pH 7.4 TO 8.2

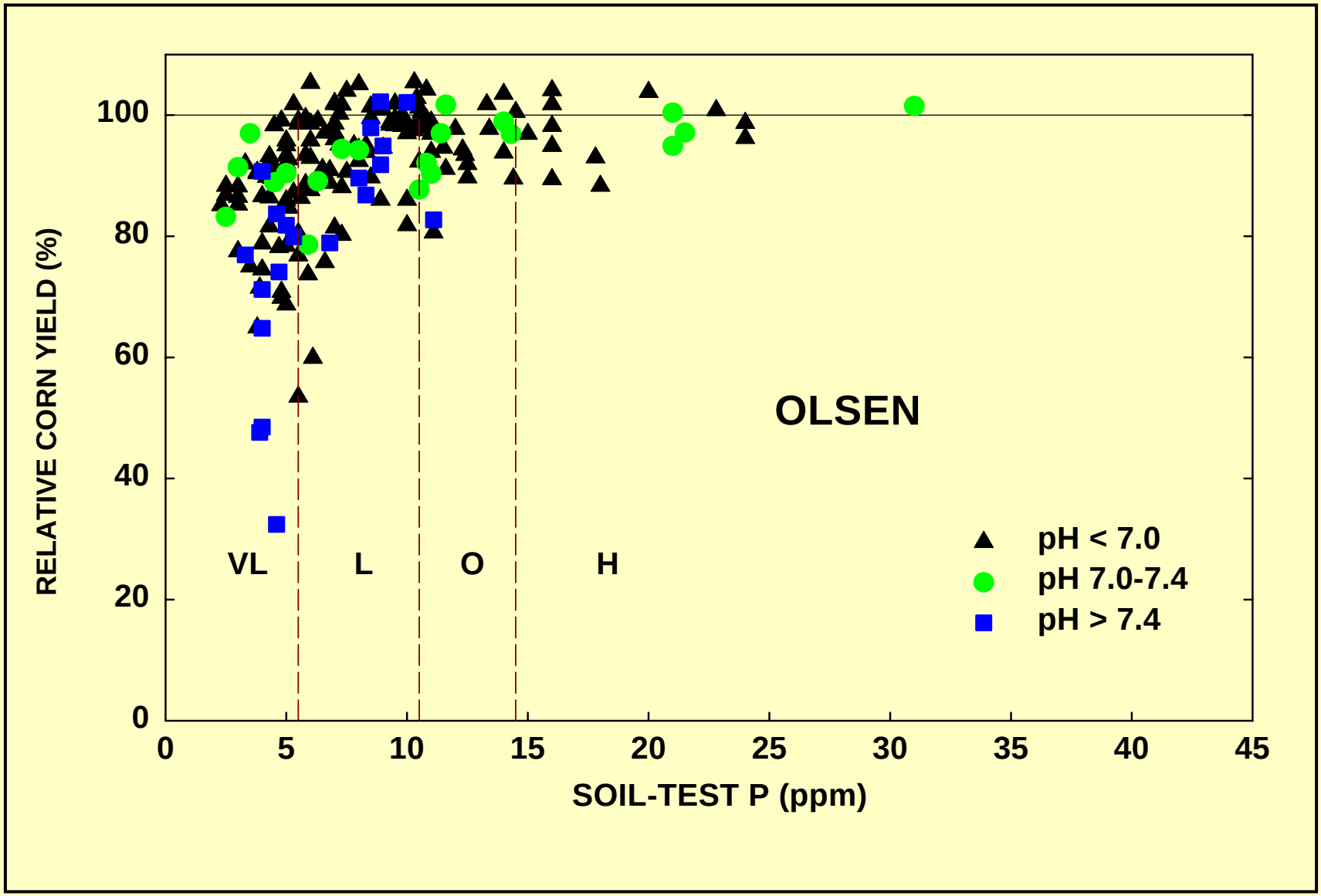


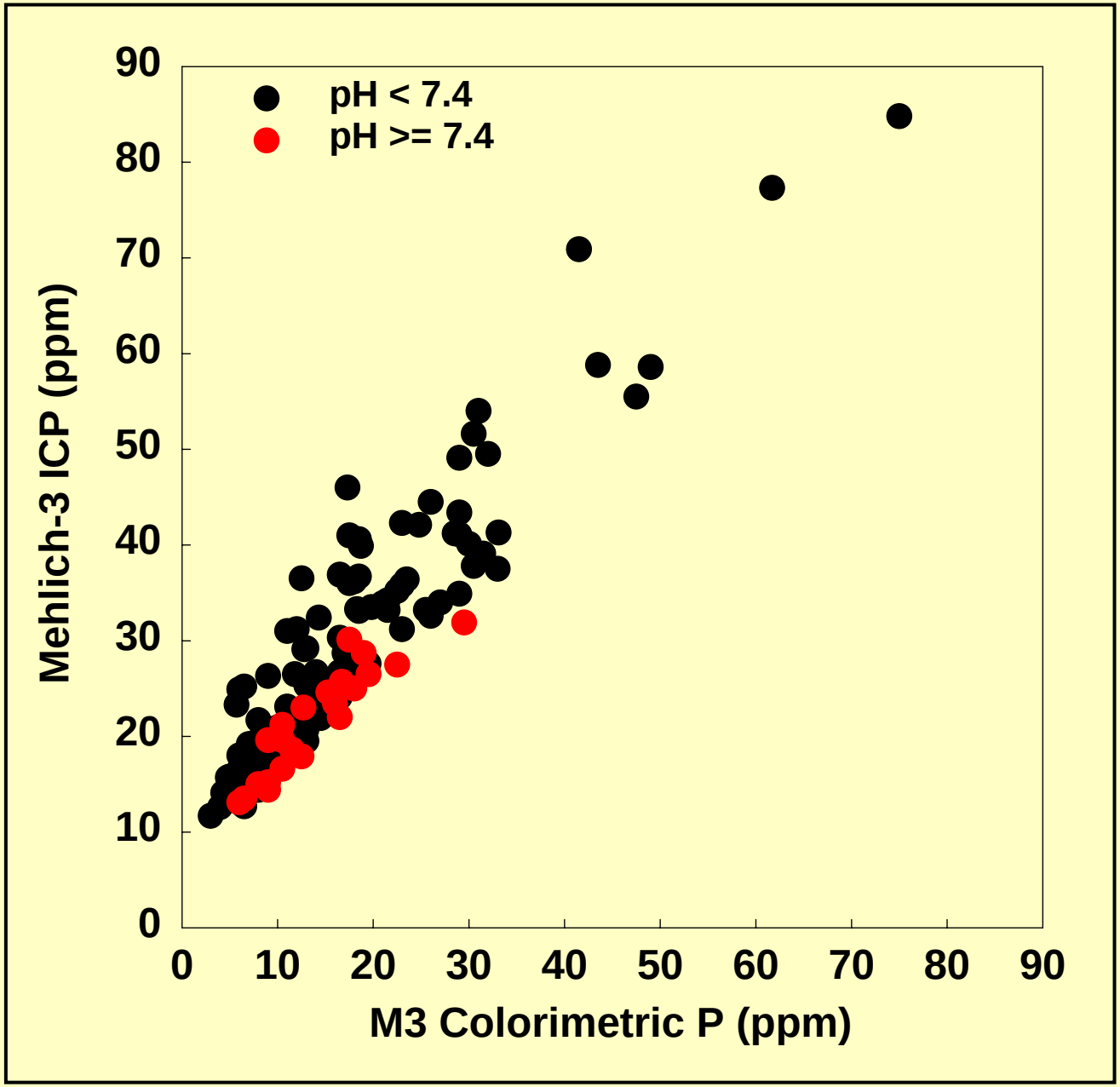


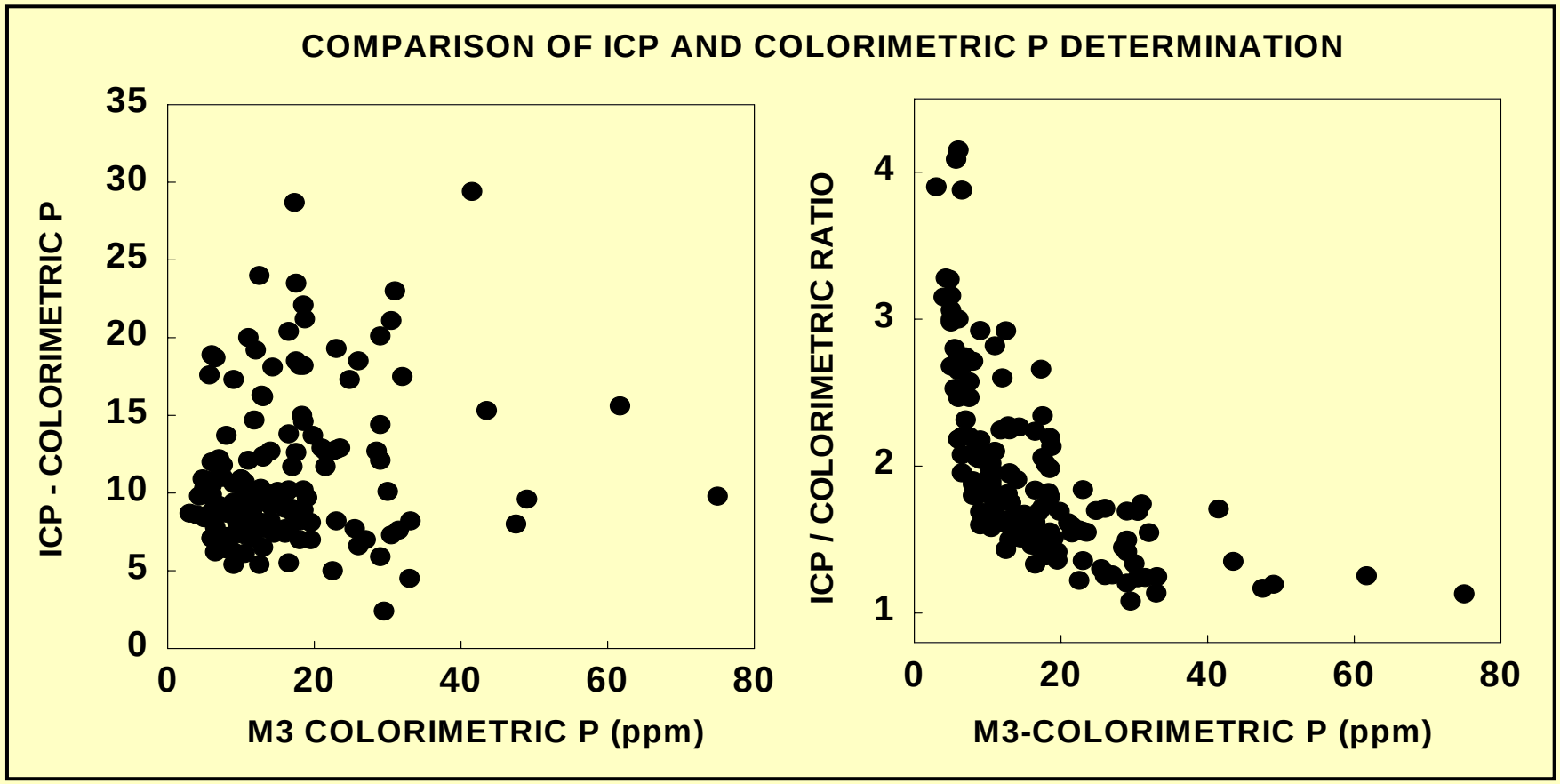



17 GRID-SAMPLED FIELDS, 2925 SAMPLES
pH<6.5
pH 6.5-7.3
pH 7.4-8.2
Y = 15 + 0.82x
r = 0.88
Y = 14 + 0.83
r = 0.91
Y = 21 + 0.73
r = 0.84
Mehlich-3 K (ppm)
Ammonium acetate K (ppm)
0
100
200
300
400

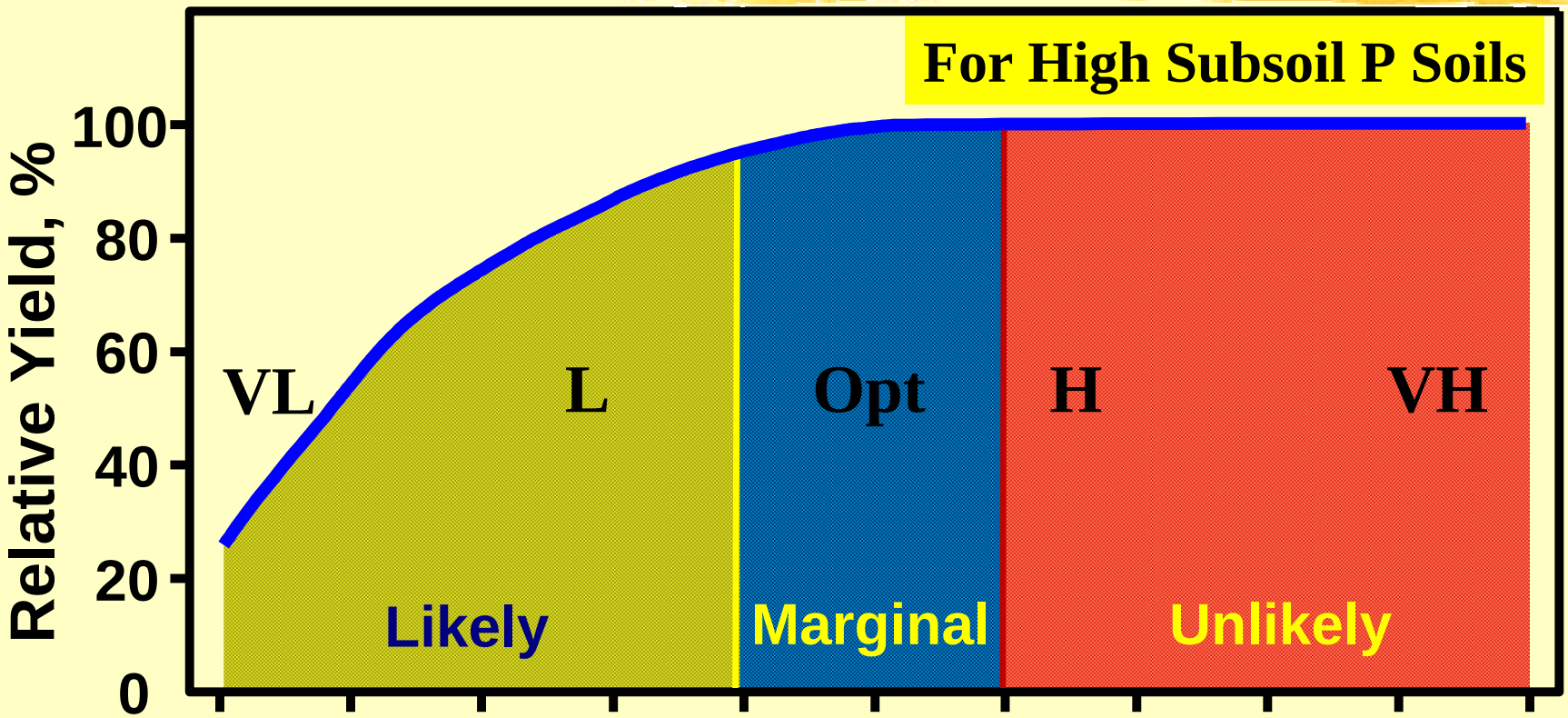

CORRELATION WITH YIELD RESPONSE - ALL SOILS
RELATIVE CORN YIELD (%)
0
20
40
60
80
100
BRAY-1
pH < 7.0
pH 7.0-7.4
pH > 7.4
VL
L
O
H
VH
0
10
20
30
40
50
60
70
80
BRAY-1 P (ppm)
MEHLICH-3
pH < 7.0
pH 7.0-7.4
pH > 7.4
VL
L
O
H
VH
0
10
20
30
40
50
60
70
80
MEHLICH-3 P (ppm)


RELATIVE CORN YIELD (%)
100
80
60
40
20
0
0
5
10
15
20
25
30
35
40
45
SOIL-TEST P (ppm)
OLSEN
VL
L
O
H
pH < 7.0
pH 7.0-7.4
pH > 7.4


pH < 7.4
pH >= 7.4
Mehlich-3 ICP (ppm)
M3 Colorimetric P (ppm)
0
10
20
30
40
50
60
70
80
90


COMPARISON OF ICP AND COLORIMETRIC P DETERMINATION
ICP - COLORIMETRIC P
0
5
10
15
20
25
30
35
0
20
40
60
80
M3 COLORIMETRIC P (ppm)
ICP / COLORIMETRIC RATIO
1
2
3
4
0
20
40
60
80
M3-COLORIMETRIC P (ppm)

Soil Test Interpretation
Index of Availability and Crop Response



Bray:	0	6	11	16	21+
Mehlich 3:	0	6	11	16	21+
Olsen:	0	4	8	12	16+

Soil Test Interpretation
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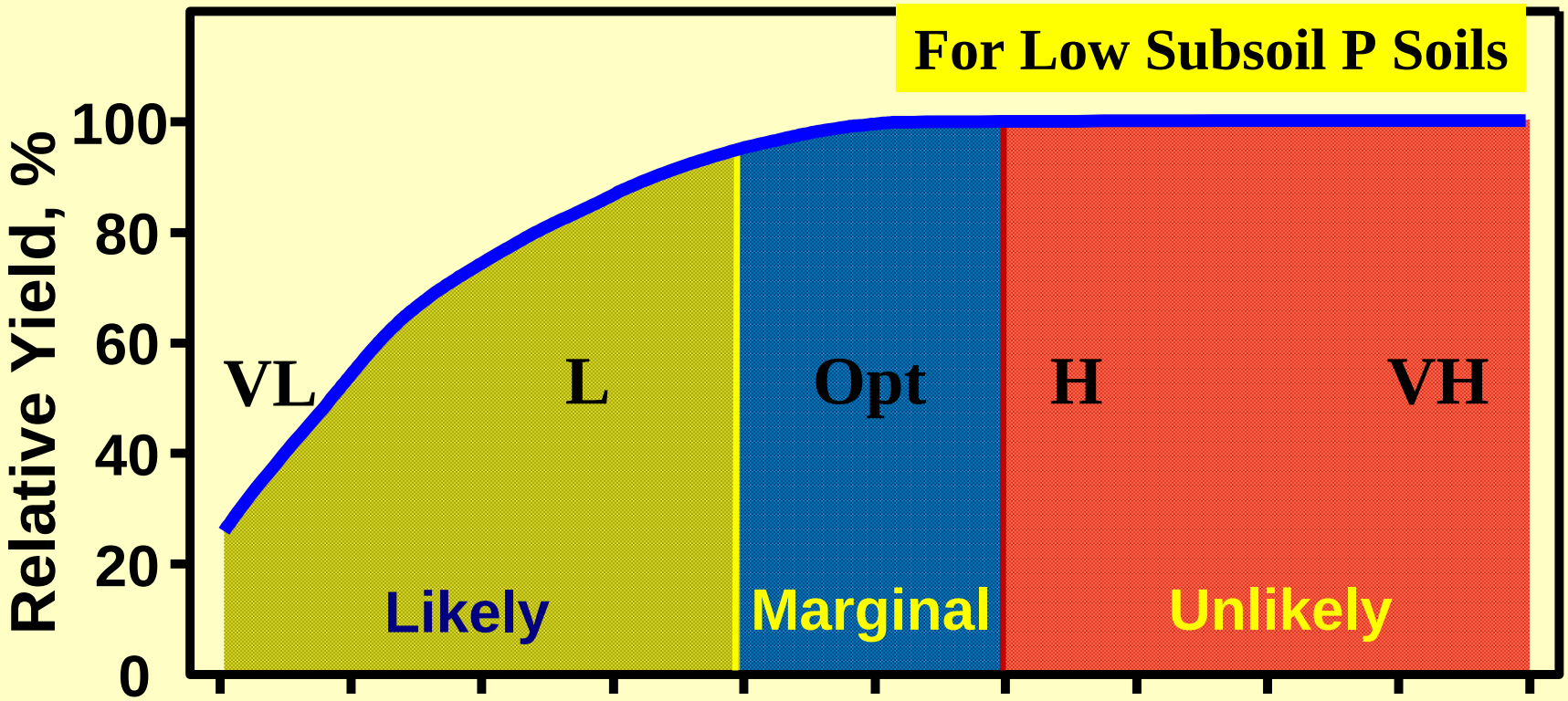

Bray:	0	9	16	21	31+
Mehlich 3:	0	9	16	21	31+
Olsen:	0	6	11	15	21+

Iowa State University Interpretations for P Soil Tests

Bray P_1 and Mehlich-3: Phosphorus (P)

	Wheat Alfalfa	All crops except wheat and alfalfa	
		Subsoil P	
Relative Level		**Low**	**High**
		ppm	
Very Low (VL)	**0 –15**	**0 – 8**	**0 – 5**
Low (L)	**16 – 20**	**9 – 15**	**6 – 10**
Optimum (Opt)	**21 – 25**	**16 – 20**	**11 – 15**
High (H)	**26 – 30**	**21 – 30**	**16 – 20**
Very High (VH)	**31 +**	**31 +**	**21 +**

Pm-1688 General Guide for Crop Nutrient Recommendations in Iowa

Iowa State University Interpretations for P Soil Tests

	Olsen: Phosphorus (P)		
	Wheat Alfalfa	All crops except wheat and alfalfa	
		Subsoil P	
Relative Level		Low	High
		ppm	
Very Low (VL)	0 –10	0 – 5	0 – 3
Low (L)	11 – 14	6 – 10	4 – 7
Optimum (Opt)	15 – 17	11 – 14	8 – 11
High (H)	18 – 20	15 – 20	12 – 15
Very High (VH)	21 +	21 +	16 +

Pm-1688 General Guide for Crop Nutrient Recommendations in Iowa

Iowa State University
Subsoil P and K Determination

- **P -- Bray P-1 test**
  - **30 to 42 inch depth**
    - **Low ≤ 8 ppm**
    - **High ≤ 9 ppm**
- **K -- Ammonium acetate test**
  - **12 to 24 inch depth**
    - **Low ≤ 50 ppm**
    - **High ≤ 51 ppm**

Iowa State P Interpretations and Recommendations for Corn Grain

	Phosphorus Soil Test (ppm)				
Soil Test Category:	**Very Low**	**Low**	**Optimum***	**High**	**Very High**
Bray P_1 and Mehlich-3 P:					
Low Subsoil P	0-8	9-15	16-20	21-30	31+
High Subsoil P	0-5	6-10	11-15	16-20	21+
Olsen P:					
Low Subsoil P	0-5	6-10	11-14	15-20	21+
High Subsoil P	0-3	4-7	8-11	12-15	16+
Mehlich-3 ICP:					
Low Subsoil P	0-15	16-25	26-35	36-45	46+
High Subsoil P	0-10	11-20	21-30	31-40	41+
	P_2O_5 to apply (lb/acre)				
	100	**75**	**55**	**0**	**0**

PM-1688 General Guide for Crop Nutrient and Limestone Recommendations in Iowa

Iowa State K Interpretations and Recommendations for Corn Grain

	Potassium Soil Test (ppm)				
Soil Test Category:	**Very Low**	**Low**	**Optimum***	**High**	**Very High**
Ammonium Acetate and Mehlich-3 Extractable K:					
Low Subsoil K	0-90	91-130	131-170	171-200	201+
High Subsoil K	0-70	71-110	111-150	151-180	181+
	K_2O to apply (lb/acre)				
Fine Textured	**130**	**90**	**45**	**0**	**0**
Sandy Textured	**110**	**70**	**45**	**0**	**0**

PM-1688 General Guide for Crop Nutrient and Limestone Recommendations in Iowa

Current Iowa State University Suggestions on Use of P Soil Tests

- **Bray 1-P**
  - **If soil pH is less than 7.4**
- **Olsen**
  - **If soil pH is above 7.4**
  - **If soil pH is above 5.0**
- **Mehlich 3**
  - **Any soil**

Mehlich 3 Extraction of Ca, Mg, K and Estimation of CEC

- In acid and neutral soils
  - Similar to ammonium acetate extraction
- In calcareous soils
  - Not the same, especially for Ca
  - Same problem with CEC estimation as with ammonium acetate extraction

Mehlich 3 Extraction of Zn or Other Elements

- Not recommended by NCR 13 committee
- Not recommended for use in Iowa
  - In Iowa -- still use DTPA extraction for Zn