Changes in Iowa's Soil Test P and K Interpretations and Recommendations

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Research results from long-term and short-term experimentation in Iowa have been consistent in the response or lack of response of Iowa field crops to applications of fertilizer phosphorus (P) and potassium (K) at various soil test levels for P and K. Analyses of the research data have established critical soil test values for P and K and the most economic soil test range for P and K to maintain (Mallarino, Webb, and Blackmer, 1991a and 1991b; Mallarino and Blackmer, 1992 and 1994; Webb, Mallarino, and Blackmer, 1992). The economic returns to additions of fertilizer P and K at various soil test levels are shown in Fig. 1 and 2. As a consequence of the research, recommendations for P and K based on soil test results and the interpretation of soil test values have been revised. These have been implemented this fall of 1996. The recommendations are available in Pm-1688, General Guide for Crop Nutrient Recommendations in Iowa, that can be requested from Publications Distribution, Printing and Publications Building, Iowa State University, Ames, IA 50011.

SOIL TEST PROCEDURES

The soil tests for which interpretations are given are the Bray P_1 and the Olsen tests for P, the ammonium acetate test for K, the DTPA test for Zn, and the SMP buffer method for lime requirements. The Olsen test is the preferred test for P for soils with soil pH greater than 7.4. These tests, and that for soil pH, are among the tests prescribed for the North Central Region by the NCR-13 Regional Committee on Soil Testing and Plant Analysis. These and other tests are described in the North Central Regional Publication No. 221 (Revised), Recommended Chemical Soil Test Procedures for the North Central Region.

INTERPRETATION

The past system for interpretation of soil test values for P and K was one interpretation of soil test values regardless of soil or the crop to be grown. The soil test categories were very low, low, medium, high, and very high. The corresponding recommendation for P was adjusted for subsoil P, soil area (areas are the 12 major soil association areas in Iowa) and limiting physical factors of soil that severely limit crop yields. The corresponding recommendation for K was adjusted for subsoil K, soil area, natural internal drainage of the soil series (ranges from very poorly drained to well drained), yield limiting physical factors of soil, and sandy soils (sandy loams or loamy sands). The previous interpretations of soil test values are shown in Table 1 and the revised interpretations are shown in Table 2.

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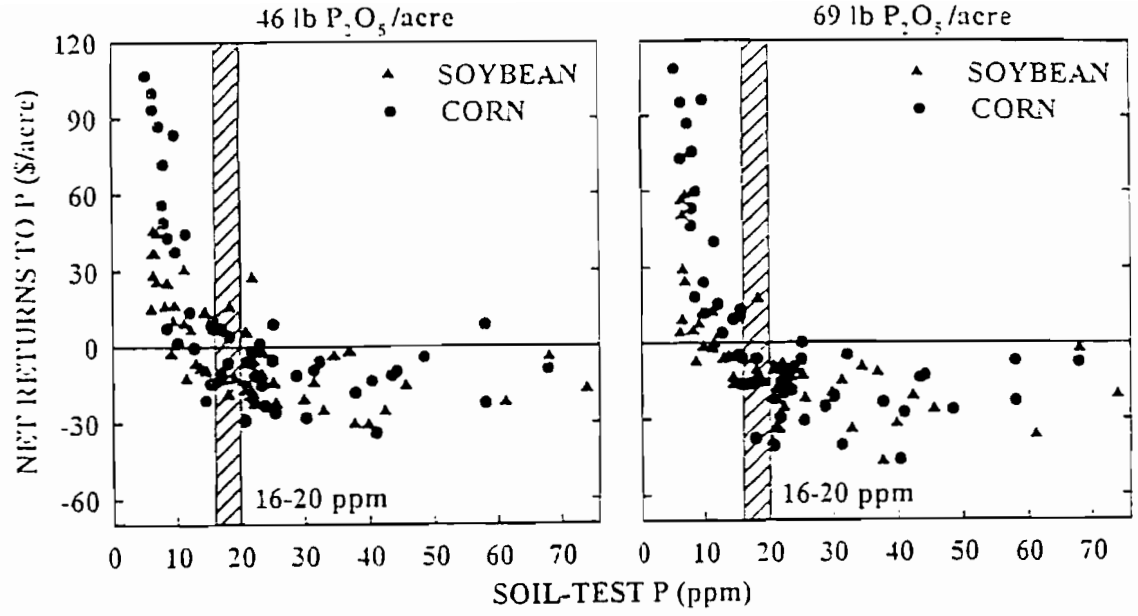

Fig. 1. Relationships between net returns to P fertilization and soil test P values for plots of two long-term trials. Average annual prices for each year that data were obtained were used for corn, soybean, and fertilizer P.

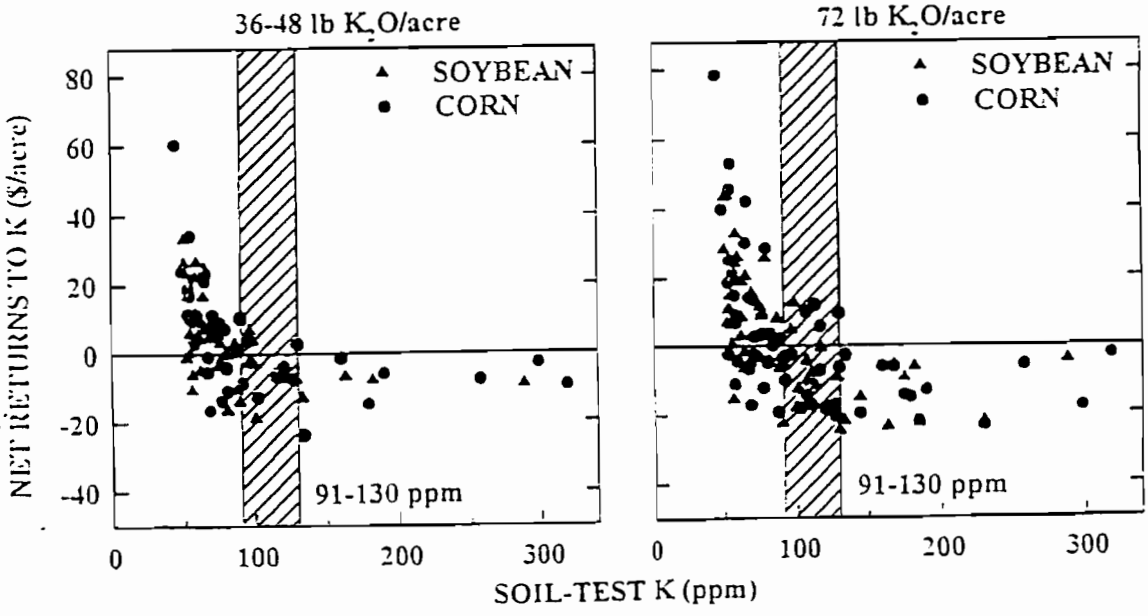

Fig. 2. Relationships between net returns to K fertilization and soil test K values for plots of three long-term trials. Average annual prices for each year that data were obtained were used for corn, soybean, and fertilizer K.

There are several major changes in interpretations. One revision is in the designation of soil test categories. The categories were very low, low, medium, high, and very high. The revised designated categories are very low, low, optimum, high and very high. The implication is that the optimum soil test category is the most profitable category for the producer to manage soil test levels in. The very high category designation pertains or applies only to the profitability of crop production when trying to maintain soil tests at this level.

Rather than adjusting the recommendations for subsoil P and K (termed nutrient supplying power of soils by some states), the revised interpretations are adjusted for subsoil P and K and there are only two subsoil categories, low and high for P and for K. The past system designated four levels of subsoil P; very low, low, medium and high. In the revised system the current very low will be low and the current low, medium and high subsoil P levels will be designated high. For K, the previous very low minus and very low plus will be low in the new system and the low, medium, and high subsoil K levels will be designated high in the new system.

Subsoil P and K levels are determined at the depth which provides the greatest range of soil test values for each nutrient. Subsoil P is determined by the Bray P_1 soil test for samples taken from the 30- to 42-inch depth. Subsoil K is determined by the ammonium acetate soil test for samples taken from the 12- to 24-inch depth. Subsoil P is designated low for subsoil test values of 8 ppm or less and high for values of 9 ppm or more. Subsoil K is designated low for subsoil test values of 50 ppm or less and high for values of 51 ppm or more. The effect of a high subsoil level of P or K is to require a lower concentration of that nutrient in the surface soil for optimum crop production.

Table 1. Previous interpretation of soil test values for surface soil samples.

Soil Test Classification	Soil Test Ranges Expressed in ppm	
	P	K
Very Low (VL)	7.5 or less	44 or less
Low (L)	8-15	45-84
Medium (M)	15.5-20	85-125
High (H)	20.5-30	126-188
Very High (VH)	30.5 or more	189 or more

The revised interpretation of soil test P values is adjusted for crop demand. In Iowa alfalfa and wheat are the high demand crops. The effect is to place higher soil test P values into lower soil test categories for wheat and alfalfa and these crops will receive a recommendation for P additions, whereas corn and soybean may not depending on the test level.

Table 2. Interpretation of soil test values for phosphorus (P) determined by Bray P_1 extractant or Olsen extractant and potassium (K) determined by ammonium acetate extractant for surface soil samples (6 to 7-inch deep cores).

	Bray P_1: Phosphorus (P)			Potassium (K)	
	Wheat, alfalfa	All crops except wheat, alfalfa		All crops	
		Subsoil P		Subsoil K	
Relative level*		Low	High	Low	High
			ppm		
Very low (VL)	0-15	0-8	0-5	0-60	0-40
Low (L)	16-20	9-15	6-10	61-90	41-80
Optimum (Opt)	21-25	16-20	11-15	91-130	81-120
High (H)	26-30	21-30	16-20	131-170	121-160
Very High (VH)	31+	31+	21+	171+	161+
	Olsen: Phosphorus (P)				
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+		

*The optimum soil test category is the most profitable to maintain.

The very high soil test category indicates that the nutrient concentration exceeds crop needs, and further additions of that nutrient very seldom produce a profitable yield response.

RECOMMENDATIONS

As stated before, the previous system adjusted recommendations for P and K additions for several factors. In the revised system the adjustments are simplified and the adjustments are made in the interpretation of soil test values. This simplifies the recommendation procedure.

The revised recommendations are given in Table 3 for corn grain, Table 4 for soybean, and Table 5 for alfalfa and alfalfa-grass hay production. Although not presented with this text, P and K recommendations also are revised for:

- Corn silage or sorghum silage production
- Oat grain and straw production with forage seeding
- Oat grain and straw production with no forage seeding
- Wheat production
- Sunflower
- Legume-grass pasture
- Tall cool-season grasses for pasture: bromegrass, orchardgrass, tall fescue, and reed canarygrass
- Warm season grasses for pasture and hay
- Bluegrass pasture
- Sorghum-sudan pasture

The format for presenting the recommendations has been changed. The soil test extractant, e.g., Bray P_1, is designated. This approach permits addition of other extractants when research supports such additions. The soil test values and interpretive categories are listed so that there is no misunderstanding as to the appropriate interpretation and recommendation. The P recommendations are not adjusted for any additional factors. The K recommendations are adjusted for soil texture for some crops. The sandy textured soils are loamy sands and sandy loams and these soils will receive a lower K recommendation than finer textured soils for corn grain, corn or sorghum silage, soybean, and oat with a forage seeding.

Major changes are the recommendations for the optimum and high soil test categories. The recommendation for the optimum category (corresponds to previous medium category) are based on crop removal using the values shown in Table 6 and is a so-called "maintenance" recommendation. Maintaining this category has been shown to be more profitable than maintaining higher soil test levels. The revised recommendations do not recommend P or K for the high and very high categories. Previously, the high soil test category received a "maintenance" recommendation. As the footnote for corn in Table 3 states, "Although P_2O_5 and K_2O are not recommended for the high soil test category, a small amount contained in 100 pounds of a common complete NPK grade, applied as a starter fertilizer banded to the side and below the seed row, may be advantageous under conditions of limited soil drainage, cool soil conditions, or crop residues on the soil surface. None is recommended for the very high soil test category."

There is a slight reduction in the amounts of P_2O_5 and K_2O recommended at the very low and low soil test categories in the revised recommendations. Soils that have a Corn Suitability Rating (CSR) of 30 or less are soils designated as having severe yield limiting factors and will receive recommendations of P_2O_5 and K_2O based only on crop removal regardless of soil test values. In the revised recommendations there is no adjustment for soil area for P_2O_5 and K_2O recommendations and there is no adjustment in the K_2O recommendation for natural drainage characteristic of a soil series.

Table 3. Phosphorus and potassium recommendations for corn grain production.

Phosphorus (P) Soil Test (ppm)*					
Soil Test Category:	Very Low	Low	Optimum	High	Very High
Bray P_1:					
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+
P_2O_5 to apply (lb/acre)					
	100	75	50	0	0

Potassium (K) Soil Test (ppm)*					
Soil Test Category	Very Low	Low	Optimum	High	Very High
Ammonium Acetate Extractable K:					
Low Subsoil K	0-60	61-90	91-130	131-170	171+
High Subsoil K	0-40	41-80	81-120	121-160	161+
K_2O to apply (lb/acre)					
Fine Textured	120	90	40	0	0
Sandy Textured	100	70	40	0	0

*The recommended amounts of P_2O_5 and K_2O for the optimum soil test category are based on nutrient removal for the reported yield. The amounts shown in the Table for the optimum soil test category are for 140 bu corn grain per acre, which will be used if no yields are given on information sheet.

Recommendation for soils with a corn suitability rating (CSR) of 30 or less will be based on expected crop yield and nutrient removal for soil test categories of optimum or lower.

Although P_2O_5 and K_2O are not recommended at high soil test category, a small amount equivalent to that contained in 100 pounds of a common complete NPK grade, applied as a starter fertilizer banded to the side and below the seed row, may be advantageous under conditions of limited soil drainage, cool soil conditions, or crop residues on the soil surface. None is recommended for the very high soil test category.

Table 4. Phosphorus and potassium recommendations for soybean production.

Phosphorus (P) Soil Test (ppm)*					
Soil Test Category:	Very Low	Low	Optimum	High	Very High
Bray P_1:					
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+
P_2O_5 to apply (lb/acre)					
	80	60	40	0	0

Potassium (K) Soil Test (ppm)*					
Soil Test Category:	Very Low	Low	Optimum	High	Very High
Ammonium Acetate Extractable K:					
Low Subsoil K	0-60	61-90	91-130	131-170	171+
High Subsoil K	0-40	41-80	81-120	121-160	161+
K_2O to apply (lb/acre)					
Fine Textured	90	75	65	0	0
Sandy Textured	80	65	65	0	0

*The recommended amounts of P_2O_5 and K_2O for the optimum soil test category are based on nutrient removal for the reported yield. The amounts shown in the Table for the optimum soil test category are for 45 bu soybean per acre, which will be used if no yields are given on information sheet.

Recommendation for soils with a corn suitability rating (CSR) of 30 or less will be based on crop yield and nutrient removal for soil test categories of optimum or lower.

Table 5. Phosphorus and potassium recommendations for alfalfa and alfalfa-grass hay production.

Phosphorus (P) Soil Test (ppm)*					
Soil Test Category:	Very Low	Low	Optimum	High	Very High
Bray P_1:					
All Subsoil P Levels	0-15	16-20	21-25	26-30	31+
Olsen P:					
All Subsoil P Levels	0-10	11-14	15-17	18-20	21+
P_2O_5 to apply (lb/acre)					
	110	80	60	0	0

Potassium (K) Soil Test (ppm)*					
Soil Test Category	Very Low	Low	Optimum	High	Very High
Ammonium Acetate Extractable K:					
Low Subsoil K	0-60	61-90	91-130	131-170	171+
High Subsoil K	0-40	41-80	81-120	121-160	161+
K_2O to apply (lb/acre)					
All Soil Textures	300	240	200	0	0

* 30 lb. P_2O_5 is recommended at seeding time regardless of soil test category. The recommended amounts of P_2O_5 and K_2O for the optimum soil test category are based on nutrient removal for the reported yield. The amounts shown in the Table for the optimum soil test category are for 5 ton per acre harvested yield, which will be used if no yields are given on information sheet.

Recommendations for soils with a corn suitability rating (CSR) of 30 or less will be based on nutrient removal of the expected crop yield for soil test categories of optimum or lower.

Table 6. The nutrient content of harvested crops used to calculate nutrient removal and recommended amounts of P_2O_5 and K_2O for optimum soil test category.

		Pounds per unit of yield	
Crop	Unit of Yield	P_2O_5	K_2O
Corn	bu	0.375	0.30
Corn silage	bu grain equivalent	0.55	1.25
Corn silage	ton, 65% H_2O	3.50	6.50
Soybean	bu	0.80	1.50
Oat and straw	bu	0.40	1.00
Oat straw	ton	5.0	33.0
Wheat	bu	0.60	0.30
Wheat straw	ton	4.0	25.0
Sunflower	100 lb	0.80	0.70
Alfalfa	ton	12.50	40.0
Red clover	ton	10.0	33.0
Vetch	ton	12.0	47.0
Smooth bromegrass	ton	9.0	47.0
Orchardgrass	ton	14.0	68.0
Tall fescue	ton	12.0	66.0
Timothy	ton	9.0	32.0
Perennial ryegrass	ton	12.0	34.0
Sorghum-sudan	ton	12.0	38.0
Switch grass	ton	12.0	66.0

Research is underway to determine if these recommendations should be modified for different methods of placement in no-till, ridge-till and conventional tillage systems. Until the current research indicates otherwise, the recommended amounts are for all tillage systems and methods of placement.

Placement of fertilizer with corn seed is not generally recommended, but if it is done, limit the amount of N + K_2O to 10 pounds or less per acre. If soils are sandy or dry, reduce the amount of N + K_2O by one-half. It is recommended that no fertilizer be placed in contact with soybean seed.

MICRONUTRIENTS

Iowa State University recommends only zinc for corn based on soil testing. The zinc soil test has been calibrated on Iowa soils. Zinc recommendations for corn are given in Table 7. Soil test procedures for the other micronutrients have not been calibrated because of either lack of or inconsistency of occurrence of deficiencies with the exception of iron deficiency on soybean. Iron deficiency on soybean occurs on high pH (calcareous) soils in central and north central Iowa and can be predicted by soil occurrence as shown in soil survey reports. Development of soybean varieties tolerant to low iron availability in calcareous soils has been an acceptable solution to the problem.

Table 7. Zinc recommendations for corn and sorghum production.

Zinc (Zn) Soil Test (ppm)			
Soil Test Category:	Low	Marginal	Adequate
DTPA Extractable Zn:			
	0-0.4	0.5-0.8	0.9+
	Zn to apply broadcast (lb/acre)		
	10	5	0
	Zn to apply in band (lb/acre)*		
	2	1	0

*Recommendation for amount to apply in band is based on other states' information.

Limestone

Limestone recommendations are given in pounds of pure fine calcium carbonate ($CaCO_3$) as given in Table 8. This recommendation is equal to pounds of effective calcium carbonate equivalent (ECCE) that is determined for all agricultural limestone sources in Iowa. Soil pH is to be used to determine whether or not to lime the soil. The SMP Buffer (also termed the Ohio Buffer) solution has been calibrated to determine the amount of lime to be applied to increase soil pH to a certain pH.

Recommendations are given to increase soil pH to 6.5 or to 6.9. Soil pH 6.0 is considered to be sufficient for grass pastures and grass haylands. Soil pH 6.9 is recommended for alfalfa. Soil pH 6.5 is considered to be sufficient for corn and soybean. Because of high pH subsoils in the Clarion-Nicollet-Webster, Galva-Primghar-Sac, Moody, Ida-Monona, Marshall, and Luton-Onawa-Salix soil associations, soil pH 6.0 is considered sufficient for corn and soybean grown in these soil associations, but when liming is required, lime is recommended to raise soil pH to 6.5.

The amount of limestone recommended is adjusted for the depth of tillage which determines the volume of soil to be neutralized. The depth for no-till is considered to be 2 to 3-inch depth unless specified otherwise.

Table 8. Lime recommendations, based on SMP Buffer Test, are given in pounds of pure fine calcium carbonate ($CaCO_3$) to increase soil pH from its present level to pH 6.5 or 6.9 for the depth of soil to be neutralized.

Buffer pH	Depth of soil to be neutralized							
	2 inch		3 inch		6 inch		8 inch	
	pH 6.5	pH 6.9	pH 6.5	pH 6.9	pH 6.5	pH 6.9	pH 6.5	pH 6.9
	$CaCO_3$ to apply (lb/acre)							
7.0	0	400	0	600	0	1,100	0	1,500
6.9	0	600	0	1,000	0	1,900	0	2,500
6.8	200	900	300	1,400	600	2,700	800	3,600
6.7	400	1,200	700	1,800	1,300	3,500	1,700	4,700
6.6	700	1,500	1,100	2,200	2,100	4,400	2,800	5,900
6.5	900	1,700	1,400	2,600	2,800	5,200	3,700	6,900
6.4	1,200	2,000	1,800	3,000	3,500	6,000	4,700	8,000
6.3	1,400	2,300	2,100	3,400	4,200	6,800	5,600	9,100
6.2	1,700	2,600	2,500	3,900	5,000	7,700	6,700	10,300
6.1	1,900	2,800	2,900	4,300	5,700	8,500	7,600	11,400
6.0	2,200	3,100	3,200	4,700	6,400	9,300	8,600	12,400
5.9	2,400	3,400	3,600	5,100	7,100	10,100	9,500	13,500
5.8	2,600	3,700	4,000	5,500	7,900	11,000	10,600	14,700
5.7	2,900	3,900	4,300	5,900	8,600	11,800	11,500	15,900

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