A General Guide for Crop Nutrient and Limestone Recommendations in Iowa

Iowa State University
Extension and Outreach

PM 1688 Revised February 2023

Contents

General Guide for Crop Nutrient and Limestone Recommendations in Iowa

Introduction

This publication provides phosphorus (P), potassium (K), zinc (Zn), and lime recommendations based on soil testing for the major agronomic crops grown in Iowa. Interpretation of soil-test values and nutrient application recommendations are based on soil samples taken to a 6-inch depth. Research results from long-term and short-term field experiments have been used to determine the interpretation of soil-test values and the nutrient recommendations. Nutrients applied to meet the recommended amounts may be from inorganic sources, manure, or both. Manure nutrient concentrations are most accurately determined by laboratory analyses.

Nutrient recommendations are established based on different soil-test interpretation categories and amounts of nutrient to be applied according to the specific soil-test method, soil-test interpretation category, and crop or rotation.

Soil Test Interpretations

The soil test methods for which interpretations are given in this publication are the Bray P_1, Mehlich-3, and Olsen tests for P; the ammonium acetate and Mehlich-3 tests for K; the DTPA and Mehlich 3 tests for Zn; a 1:1 water-soil slurry for soil pH; and the SMP (Shoemaker-McLean-Pratt) or Sikora buffer pH methods for lime requirement. Soil sample handling procedures in the laboratory include testing of dried samples (at 95 to 105° F) and field-moist (undried) samples. There are two versions of the field-moist testing procedure; extraction of field-moist soil or extraction of a slurry made from field-moist soil plus water. Research has shown test results are similar with both field-moist methods.

Dry or field-moist soil testing does not affect the results for P by any method, so one set of interpretations are given for dry or field-moist testing procedures. Soil-test P interpretations for the Bray P_1 and Olsen are provided for the colorimetric analytical procedure because colorimetric analysis is the procedure used by most soil testing laboratories. Interpretations based on separate calibrations from field research are provided for the Mehlich-3 test using colorimetric or ICP (inductively coupled plasma) analytical methods because these give different results and different laboratories may use one method or the other. The Bray P_1 test is not recommended for soils with soil pH 7.3 or higher (due to free calcium carbonate) because often it underestimates plant-available P and, therefore, can return misleading low values. The Olsen P test has been recommended for calcareous soils for many years, but recent Iowa research has shown that both the colorimetric and ICP versions of the Mehlich-3 test can be used across all Iowa soils. Because the Bray P_1 and the colorimetric version of the Mehlich-3 test give similar results in non-calcareous soils, a common set of interpretations is provided for these two tests.

The ammonium-acetate and Mehlich-3 tests for K give similar test results, and the measurement of extracted K by ICP or other methods also give similar results. Therefore, a common set of interpretations is provided for these two K tests. In contrast to P, testing dried versus field-moist soil can produce greatly different K test results, so different interpretations based on field calibration research are provided for the dry or field-moist K testing procedures. The commonly used dry sample handling procedure is unreliable and not recommended for fine-textured soils classified as moderately poor to very poor drainage irrespective of tile drainage presence. Such soils are common in low landscape positions of the Des Moines Lobe from central to northcentral Iowa and less common in other areas.

All tests referred to in this publication are among the tests recommended for the North Central Region by the NCERA-13 Regional Committee on Soil Testing and Plant Analysis. These are described in the North Central Regional Publication 221 (Revised 2015) Recommended Chemical Soil Test Procedures for the North Central Region. All laboratory procedures have some inherent variability and thus soil-test results should be viewed as a potential range in values. The ranges in variation for routine soil test results produced within a laboratory are expected to be on the order of ±10% for soil test P and K, and ±0.1 pH unit. Laboratories should use field-response based interpretations for each test, and should be well aware of the increased error of plant-availability estimates when samples are analyzed by one method but an in-house factor is used to adjust and report results under a different test name.

Table 1. Interpretation of soil-test values for phosphorus (P) and potassium (K) determined using recommended sample handling procedures and analysis methods (6-inch deep soil samples). Samples analyzed either field-moist or in a slurry (not dried), or after drying at 95 to 105° F.

	PHOSPHORUS		POTASSIUM
	Alfalfa or Wheat	All Other Crops	All Crops
Relative Level	Bray P_1 or Mehlich-3 P		Ammonium-Acetate or Mehlich-3
	Field-Moist and Slurry or Dried Samples		Field-Moist or Slurry Samples
Very low (VL)	0-16	0-9	0-60
Low (L)	17-23	10-17	61-100
Optimum (Opt)	24-30	18-25	101-150
High (H)	31-40	26-34	151-200
Very high (VH)	41+	35+	201+
	Mehlich-3 ICP		Ammonium-Acetate or Mehlich-3
	Field-Moist and Slurry or Dried Samples		Dried Samples
Very low (VL)	0-21	0-16	0–125
Low (L)	22-32	17-27	126–170
Optimum (Opt)	33-44	28-40	171–220
High (H)	45-55	41-51	221-270
Very high (VH)	56+	52+	271+
	Olsen P		
	Field-Moist and Slurry or Dried Samples		
Very low (VL)	0-10	0-6	
Low (L)	11-15	7-10	
Optimum (Opt)	16-20	11-15	
High (H)	21-25	16-20	
Very high (VH)	26+	21+	

Soil Test Categories

Soil-test values are reported as parts per million (ppm) for a 6-inch soil sampling depth. Soil-test values for each P or K soil-test method have been classified into interpretive categories designated very low (VL), low (L), optimum (Opt), high (H), and very high (VH) and are shown in Table 1. For the P tests, one set of categories is used for wheat and alfalfa or alfalfa-grass mixtures, and another set is used for all other agronomic crops because wheat and alfalfa require higher soil P concentrations. The interpretation categories represent a decreasing probability of an economic yield response to applied nutrients. The percentage of P and K applications expected on average to produce a yield response within each soil test category is approximately 80% for very low, 55% for low, 25% for optimum, 5% for high, and <1% for very high. Based on prevailing input costs and expected yield increases, the optimum category is the category to maintain over time for long-term profitable crop production. The high and very high category indicate that the soil nutrient concentration exceeds crop needs, and additions of nutrients very seldom produce a profitable yield response.

Table 2 provides the crop nutrient concentrations per unit of yield for several Iowa agronomic crops, which should be used together with yield to estimate removal-based application rates for the optimum soil-test category.

Phosphorus and Potassium Recommendations

The nutrient recommendations in Tables 3 through 14 provide P and K applications for all soil-test interpretation categories for a single crop grown after soil sampling and also for a single application for the two-year corn-soybean rotation. Footnotes to each table provide useful information for the interpretations and recommended application rates.

The recommended amounts of P_2O_5 and K_2O for the very low and low soil-test categories will result in maximum yield in most conditions, provide very profitable crop responses in that year, and will gradually increase soil-test values after crop harvest because of significant residual effects from the applied P and K. Any post-harvest soil-test increase will vary greatly according to the many factors that influence yield levels and nutrient removal. Application rates greater than recommended for these low-testing categories will increase soil-test levels faster, but seldom will increase yield further. There is one set of P and K application rates (depending on the soil-test category) recommended for each crop across all Iowa soils.

Table 14 includes equations useful for variable-rate P and K application for corn, soybean, and the two-year rotation. These equations apply only for soil-test results within the very low and low categories. These equations extrapolate from soil test categories to soil-test results from 1 ppm to the uppermost value of the low category.

Increase in soil-test P or K values per unit of applied nutrient suggested in the Corn Belt have been on average for the corn-soybean rotation 16 to 18 pounds P_2O_5 to increase 1 ppm post-harvest soil-test P by the Bray P_1 or Mehlich-3 colorimetric tests (6-inch depth) and 8 to 10 pounds K_2O to increase 1 ppm soil-test K by the ammonium-acetate or Mehlich-3 tests using dried samples. However, research in Iowa and other states indicate that amounts needed actually vary from about 10 to 35 pounds P_2O_5 and 6 to 20 pounds K_2O, depending on many, and difficult to identify, conditions. Therefore, nutrient application rates higher than those included in this publication for the very low and low soil test categories are not recommended unless fertilizer and crops prices are very favorable, they are expected to become less favorable in the near future, and the field slope is not likely to result in large soil and P losses with erosion and surface runoff.

The P and K rates for the optimum soil-test category should be based on average nutrient removal in harvested crop parts (grain, silage, crop residues, or hay) or forage consumed and not recycled by grazing animals. The nutrient amounts shown in the tables for the optimum soil-test category should be adjusted to prevailing actual yield levels in a field or portions of fields (not a yield goal). The yield values provided in the footnotes to the recommendation tables are slightly higher than the state average in recent years and are only to be used when the actual yield level is unknown. The nutrient concentrations per unit of yield for several Iowa agronomic crops are given in Table 2. Those concentrations reflect approximately the upper seventy-fifth percentile of available data and are adjusted to an appropriate standard moisture basis for the crop portion harvested. The assumed standard moisture basis is 15% for corn grain, 13% for oats and soybean grain, 12% for wheat grain, 10% for sunflower grain, 65% for corn silage, 15% for hay and corn stover (at grain harvest time), and 10% for soybean or small grain straw.

Table 2. Nutrient concentrations to calculate removal amounts of P_2O_5 and K_2O in the optimum soil-test category.

Crop †	Unit of Yield and Moisture Basis	Pounds per Unit of Yield ‡	
		P_2O_5	K_2O
Corn	bushel, 15%	0.32	0.22
Corn silage	bushel grain equiv., 15%	0.44	1.10
Corn silage	ton, 65%	3.5	9.0
Corn stover	ton, 15%	4.8	18
Soybean	bushel, 13%	0.72	1.2
Soybean residue	ton, 10%	4.7	23
Oat	bushel, 13%	0.29	0.19
Oat straw	ton, 10%	6.4	36
Wheat	bushel, 12%	0.55	0.27
Wheat straw	ton, 10%	3.7	23
Sunflower	100 pounds, 10%	0.75	0.65
Alfalfa, alfalfa-grass	ton, 15%	13	43
Red clover-grass	ton, 15%	11	31
Trefoil-grass	ton, 15%	11	31
Smooth bromegrass	ton, 15%	7.9	41
Orchardgrass	ton, 15%	12	60
Tall fescue	ton, 15%	11	58
Timothy	ton, 15%	7.9	28
Perennial ryegrass	ton, 15%	11	30
Sorghum-sudan	ton, 15%	11	33
Switchgrass	ton, 15%	11	58
Reed canarygrass	ton, 15%	7.9	41

† Nutrients in corn stover, soybean residue, and small grain straw reflect content at grain harvest time approximating the proportion of cornstalks, cobs, stems, or leaves when baling immediately after harvest, but include little soil contamination. Nutrients in forages reflect content of good quality hay.

‡ Nutrient concentrations adjusted from a dry matter basis to a value suitable for multiplying by harvested crop yield, based on the standard moisture content of the crop component harvested. Values used to obtain appropriate nutrient removal estimates.

Economic and practical considerations suggest that a new soil test should be planned every two years for most cropping systems. Sampling every three or four years may be acceptable when fields are near optimum levels and maintenance fertilization is being used. For P and K applications between the soil testing years,

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

	Phosphorus Dry or Field-Moist and Slurry Soil Tests (ppm)				
Soil Test Category	**Very Low**	**Low**	**Optimum***	**High**	**Very High**
Bray P_1 and Mehlich-3 P	0–9	10–17	18–25	26–34	35+
Olsen P	0–6	7–10	11–15	16–20	21+
Mehlich-3 ICP P	0–16	17–27	28–40	41–51	52+
	P_2O_5 to apply (pounds/acre)**				
	120	85	67	0	0
	Potassium Soil Tests (ppm)				
Soil Test Category	**Very Low**	**Low**	**Optimum***	**High**	**Very High**
Ammonium Acetate and Mehlich-3 Extractable K					
Dry	0–125	126–170	171–220	221–270	271+
Field-moist and Slurry	0–60	61–100	101–150	151–200	201+
	K_2O to apply (pounds/acre)**				
	145	110	46	0	0

*The amounts of P_2O_5 and K_2O for the optimum category will maximize yield for most conditions but may not maintain soil-test values with yields higher than 210 bushels per acre. To maintain soil tests in the optimum category, application rates should be based on nutrient removal with harvested grain using the prevailing yield for the field or subfield areas and nutrient concentrations suggested in Table 2.

**Banded N-P or N-P-K starter fertilizer for the high and lower interpretation categories may be advantageous under conditions of limited soil drainage, cool soil, crop residues on the soil surface, or late planting dates with full-season hybrids.

Table 4. Phosphorus and potassium recommendations for soybean production.

	Phosphorus Dry or Field-Moist and Slurry Soil Tests (ppm)				
Soil Test Category	**Very Low**	**Low**	**Optimum***	**High**	**Very High**
Bray P_1 and Mehlich-3 P	0–9	10–17	18–25	26–34	35+
Olsen P	0–6	7–10	11–15	16–20	21+
Mehlich-3 ICP P	0–16	17–27	28–40	41–51	52+
	P_2O_5 to apply (pounds/acre)				
	100	70	50	0	0
	Potassium Soil Tests (ppm)				
Soil Test Category	**Very Low**	**Low**	**Optimum***	**High**	**Very High**
Ammonium Acetate and Mehlich-3 Extractable K					
Dry	0–125	126–170	171–220	221–270	271+
Field-moist and Slurry	0–60	61–100	101–150	151–200	201+
	K_2O to apply (pounds/acre)				
	145	110	84	0	0

*The amounts of P_2O_5 and K_2O for the optimum category will maximize yield for most conditions but may not maintain soil-test values with yields higher than 70 bushels per acre. To maintain soil tests in the optimum category, application rates should be based on nutrient removal with the harvested grain using the prevailing yield for the field or subfield areas and nutrient concentrations suggested in Table 2.

adjustments should be made to the recommended annual amounts. Available research data suggest that when recommended P and K amounts are applied to soils that test in the very low category, recommended amounts for the low category can be applied to subsequent crops until the next planned soil testing, but not for more than two years. When the recommended P and K amounts are applied to soils that test in the low category, recommended amounts for the optimum category can be applied to subsequent crops until the next planned soil testing. When soil tests are in the optimum category, the crop removal amount can be applied each year or twice the annual amount every two years. Annual P and K applications are recommended for coarse-textured soils (sandy, loamy sand, and sandy loam textural classes), for surface applications (when not injected, subsurface banded, or incorporated) to soils testing very low to minimize nutrient loss with surface runoff or subsurface drainage, and to avoid excessive nutrient uptake and removal when large nutrient amounts are applied at one time.

Phosphorus and K application in the high soil-test category seldom produces a profitable yield increase, and no recommendation is made for annual (one crop-year) application. However, if a multi-year application is planned (for example, consecutive corn and soybean crops), and it will be two years until the next soil sampling, one-half the estimated crop removal rate could be applied during that period. The very high category indicates that the nutrient concentration exceeds crop needs, and further additions of that nutrient very seldom produce a yield response. Therefore, no application is recommended except for typical low starter N-P or N-P-K rates applied at corn planting.

Table 5. Phosphorus and potassium recommendations for corn and soybean grain production (two-year rotation) with application before corn or soybean.

	Phosphorus Dry or Field-Moist and Slurry Soil Tests (ppm)				
Soil Test Category	**Very Low**	**Low**	**Optimum***	**High**	**Very High**
Bray P_1 and Mehlich-3 P	0–9	10–17	18–25	26–34	35+
Olsen P	0–6	7–10	11–15	16–20	21+
Mehlich-3 ICP P	0–16	17–27	28–40	41–51	52+
	P_2O_5 to apply (pounds/acre)**				
	190	135	117	0***	0
	Potassium Soil Tests (ppm)				
Soil Test Category	**Very Low**	**Low**	**Optimum***	**High**	**Very High**
Ammonium Acetate and Mehlich-3 Extractable K					
Dry	0–125	126–170	171–220	221–270	271+
Field-moist and Slurry	0–60	61–100	101–150	151–200	201+
	K_2O to apply (pounds/acre)**				
	245	175	130	0***	0

*The amounts of P_2O_5 and K_2O for the optimum category will maximize yield for most conditions but may not maintain soil-test values with yields higher than 210 bushel per acre of corn and 70 bu per acre of soybean. To maintain soil tests in the optimum category, application rates should be based on nutrient removal with harvested grain using the prevailing yield for the field or subfield areas and nutrient concentrations suggested in Table 2.

**For corn, banded N-P or N-P-K starter fertilizer for the high and lower interpretation categories may be advantageous under conditions of limited soil drainage, cool soil, crop residues on the soil surface, or late planting dates with full-season hybrids.

***In the high soil test category, consider applying one half or lower partial removal rate to the first crop if you plan to skip application for the second crop.

Table 6. Phosphorus and potassium recommendations for oat grain production.

	Phosphorus Dry or Field-Moist and Slurry Soil Tests (ppm)				
Soil Test Category	**Very Low**	**Low**	**Optimum***	**High**	**Very High**
Bray P_1 and Mehlich-3 P	0–9	10–17	18–25	26–34	35+
Olsen P	0–6	7–10	11–15	16–20	21+
Mehlich-3 ICP P	0–16	17–27	28–40	41–51	52+
	P_2O_5 to apply (pounds/acre)				
	70	60	25	0	0
	Potassium Soil Tests (ppm)				
Soil Test Category	**Very Low**	**Low**	**Optimum***	**High**	**Very High**
Ammonium Acetate and Mehlich-3 Extractable K					
Dry	0–125	126–170	171–220	221–270	271+
Field-moist and Slurry	0–60	61–100	101–150	151–200	201+
	K_2O to apply (pounds/acre)				
	75	45	15	0	0

*The amounts of P_2O_5 and K_2O for the optimum category will maximize yield for most conditions but may not maintain soil-test values with yields higher than 80 bushels per acre. To maintain soil tests in the optimum category, application rates should be based on nutrient removal with harvested grain using the prevailing yield for the field or subfield areas and nutrient concentrations suggested in Table 2.

Method of Application

The recommended amounts for P and K are based on yield responses to application in many tillage systems—from conventional-tillage to reduced-tillage and no-tillage systems. Research has shown that in most tillage systems equivalent crop responses are expected, with few exceptions, for broadcast, planter band, and deep band P and K applications. The exceptions are for K in ridge-tillage with corn and soybean where bands placed into the ridge provide higher yields than a broadcast application and for K in corn with no-tillage or strip-tillage for which deep banding (5 to 6 inch depth) can produce greater yield increases than broadcast or planter band applications. On average, however, the no-tillage or strip-tillage corn yield increase from deep K banding is not large and often may not pay for the increased application costs.

Application of banded N-P or N-P-K starter fertilizer for corn in all soil-test categories may be advantageous under conditions of limited soil drainage, cool soil, crop residues on the soil surface, or late planting dates with full season hybrids. However, yield increases from starter P or K are unlikely in soils testing very high or when the 2-year P and K rate for the corn-soybean rotation is applied before corn. Placement of starter fertilizer in the corn seed furrow should be limited to about 10 pounds or less of N + K_2O per acre to reduce the risk of decreased plant stand. 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.

Table 7. Phosphorus and potassium recommendations for wheat production.

	Phosphorus Dry or Field-Moist and Slurry Soil Tests (ppm)				
Soil Test Category	**Very Low**	**Low**	**Optimum***	**High**	**Very High**
Bray P_1 and Mehlich-3 P	0–16	17–23	24–30	31–40	41+
Olsen P	0–10	11–15	16–20	21–25	26+
Mehlich-3 ICP P	0–21	22–32	33–44	45–55	56+
	P_2O_5 to apply (pounds/acre)**				
	80	65	30	0	0
	Potassium Soil Tests (ppm)				
Soil Test Category	**Very Low**	**Low**	**Optimum***	**High**	**Very High**
Ammonium Acetate and Mehlich-3 Extractable K					
Dry	0–125	126–170	171–220	221–270	271+
Field-moist and Slurry	0–60	61–100	101–150	151–200	201+
	K_2O to apply (pounds/acre)**				
	85	60	15	0	0

*The recommended amounts of P_2O_5 and K_2O for the optimum soil test category are based on approximate nutrient removal for the harvested yield. The amounts shown in the table for the optimum soil test category are based on 55 bushels of wheat grain per acre. Nutrient removal amounts can be adjusted higher or lower for other yield levels

**Banded N-P or N-P-K starter fertilizer for the high and lower interpretation categories categories may be advantageous under conditions of limited soil drainage, cool soil, or thick soil residue cover.

Table 8. Phosphorus and potassium recommendations for sunflower production.

	Phosphorus Dry or Field-Moist and Slurry Soil Tests (ppm)				
Soil Test Category	**Very Low**	**Low**	**Optimum***	**High**	**Very High**
Bray P_1 and Mehlich-3 P	0–9	10–17	18–25	26–34	35+
Olsen P	0–6	7–10	11–15	16–20	21+
Mehlich-3 ICP P	0–16	17–27	28–40	41–51	52+
	P_2O_5 to apply (pounds/acre)				
	75	55	17	0	0
	Potassium Soil Tests (ppm)				
Soil Test Category	**Very Low**	**Low**	**Optimum***	**High**	**Very High**
Ammonium Acetate and Mehlich-3 Extractable K					
Dry	0–125	126–170	171–220	221–270	271+
Field-moist and Slurry	0–60	61–100	101–150	151–200	201+
	K_2O to apply (pounds/acre)				
	95	55	15	0	0

*The recommended amounts of P_2O_5 and K_2O for the optimum soil test category are based on approximate nutrient removal for the harvested yield. The amounts shown in the table for the optimum soil test category are based on 2,000 pound sunflower seed per acre. Nutrient removal amounts can be adjusted higher or lower for other yield levels.

Table 9. Phosphorus and potassium recommendations for corn silage or sorghum silage production.

	Phosphorus Dry or Field-Moist and Slurry Soil Tests (ppm)				
Soil Test Category	**Very Low**	**Low**	**Optimum***	**High**	**Very High**
Bray P_1 and Mehlich-3 P	0–9	10–17	18–25	26–34	35+
Olsen P	0–6	7–10	11–15	16–20	21+
Mehlich-3 ICP P	0–16	17–27	28–40	41–51	52+
	P_2O_5 to apply (pounds/acre)**				
	130	110	80	0	0
	Potassium Soil Tests (ppm)**				
Soil Test Category	**Very Low**	**Low**	**Optimum***	**High**	**Very High**
Ammonium Acetate and Mehlich-3 Extractable K					
Dry	0–125	126–170	171–220	221–270	271+
Field-moist and Slurry	0–60	61–100	101–150	151–200	201+
	K_2O to apply (pounds/acre)**				
	260	225	200	0	0

*The amounts of P_2O_5 and K_2O for the optimum category will maximize yield for most conditions but may not maintain soil-test values with yields higher than 22 tons per acre. To maintain soil tests in the optimum category, application rates should be based on nutrient removal with harvested silage using the prevailing yield for the field or subfield areas and nutrient concentrations suggested in Table 2.

**Banded N-P or N-P-K starter fertilizer for the high and lower interpretation categories may be advantageous under conditions of limited soil drainage, cool soil, crop residues on the soil surface, or late planting dates with full-season hybrids.

Table 10. Phosphorus and potassium recommendations for alfalfa and alfalfa-grass hay and pastures.

	Phosphorus Dry or Field-Moist and Slurry Soil Tests (ppm)				
Soil Test Category	**Very Low**	**Low**	**Optimum***	**High**	**Very High**
Bray P_1 and Mehlich-3 P	0–16	17–23	24–30	31–40	41+
Olsen P	0–10	11–15	16–20	21–25	26+
Mehlich-3 ICP P	0–21	22–32	33–44	45–55	56+
	P_2O_5 to apply (pounds/acre)				
	120	90	72	0**	0
	Potassium Soil Tests (ppm)				
Soil Test Category	**Very Low**	**Low**	**Optimum***	**High**	**Very High**
Ammonium Acetate and Mehlich-3 Extractable K					
Dry	0–125	126–170	171–220	221–270	271+
Field-moist and Slurry	0–60	61–100	101–150	151–200	201+
	K_2O to apply (pounds/acre)				
	290	250	235	0	0

*The amounts of P_2O_5 and K_2O for the optimum category will maximize yield for most conditions but may not maintain soil-test values with yields higher than 5.5 tons per acre. To maintain soil tests in the optimum category, application rates should be based on nutrient removal with harvested hay using the prevailing yield for the field or subfield areas and nutrient concentrations suggested in Table 2. For pastures, reduce the amount in all soil test categories for phosphorus to two-thirds and for potassium to one-half of the amount indicated for hay because more nutrients are returned to the soil when grazing.

** For soils that test in the high soil test P category, 40 lb P_2O_5 per acre is recommended at seeding time.

Table 11. Phosphorus and potassium recommendations for clover- and trefoil-grass hay and pastures.

	Phosphorus Dry or Field-Moist and Slurry Soil Tests (ppm)				
Soil Test Category	**Very Low**	**Low**	**Optimum***	**High**	**Very High**
Bray P_1 and Mehlich-3 P	0–9	10–17	18–25	26–34	35+
Olsen P	0–6	7–10	11–15	16–20	21+
Mehlich-3 ICP P	0–16	17–27	28–40	41–51	52+
	P_2O_5 to apply (pounds/acre)				
	85	65	40	0	0
	Potassium Soil Tests (ppm)				
Soil Test Category	**Very Low**	**Low**	**Optimum***	**High**	**Very High**
Ammonium Acetate and Mehlich-3 Extractable K					
Dry	0–125	126–170	171–220	221–270	271+
Field-moist and Slurry	0–60	61–100	101–150	151–200	201+
	K_2O to apply (pounds/acre)				
	185	145	100	0	0

*The amounts of P_2O_5 and K_2O for the optimum category will maximize yield for most conditions but may not maintain soil-test values with yields higher than 3.5 tons per acre. To maintain soil tests in the optimum category, maintenance application rates should be based on nutrient removal with harvested hay using the prevailing yield for the field or subfield areas and nutrient concentrations suggested in Table 2. For pastures, reduce the amount in all soil test categories for phosphorus to two-thirds and for potassium to one-half of the amount indicated for hay because more nutrients are returned to the soil when grazing.

Table 12. Phosphorus and potassium recommendations for tall cool-season grasses, warm-season perennial grasses, and sorghum-sudan hay and pastures.

	Phosphorus Dry or Field-Moist and Slurry Soil Tests (ppm)				
Soil Test Category	**Very Low**	**Low**	**Optimum***	**High**	**Very High**
Bray P_1 and Mehlich-3 P	0–9	10–17	18–25	26–34	35+
Olsen P	0–6	7–10	11–15	16–20	21+
Mehlich-3 ICP P	0–16	17–27	28–40	41–51	52+
	P_2O_5 to apply (pounds/acre)				
	95	65	40	0	0
	Potassium Soil Tests (ppm)				
Soil Test Category	**Very Low**	**Low**	**Optimum***	**High**	**Very High**
Ammonium Acetate and Mehlich-3 Extractable K					
Dry	0–125	126–170	171–220	221–270	271+
Field-moist and Slurry	0–60	61–100	101–150	151–200	201+
	K_2O to apply (pounds/acre)				
	175	135	100	0	0

*The amounts of P_2O_5 and K_2O for the optimum category will maximize yield for most conditions but may not maintain soil-test values with yields higher than 3.5 tons per acre. To maintain soil tests in the optimum category, maintenance application rates should be based on nutrient removal with harvested hay using the prevailing yield for the field or subfield areas and nutrient concentrations suggested in Table 2. For pastures, reduce the amount in all soil test categories for phosphorus to two-thirds and for potassium to one-half of the amount indicated for hay because more nutrients are returned to the soil when grazing.

Table 13. Phosphorus and potassium recommendations for bluegrass dominant pastures.

	Phosphorus Dry or Field-Moist and Slurry Soil Tests (ppm)				
Soil Test Category	**Very Low**	**Low**	**Optimum***	**High**	**Very High**
Bray P_1 and Mehlich-3 P	0–9	10–17	18–25	26–34	35+
Olsen P	0–6	7–10	11–15	16–20	21+
Mehlich-3 ICP P	0–16	17–27	28–40	41–51	52+
P_2O_5 to apply (pounds/acre)					
	45	35	20*	0	0
Potassium Soil Tests (ppm)					
Soil Test Category	**Very Low**	**Low**	**Optimum***	**High**	**Very High**
Ammonium Acetate and Mehlich-3 Extractable K					
Dry	0–125	126–170	171–220	221–270	271+
Field-moist and Slurry	0–60	61–100	101–150	151–200	201+
K_2O to apply (pounds/acre)					
	55	40	25*	0	0

*The amounts of P_2O_5 and K_2O for the optimum category will maximize yield for most conditions. However, estimates of yield and nutrient concentrations for grazed bluegrass pastures are scarce and unreliable and, therefore, consider the amounts as approximate estimates.

Micronutrient Recommendations

At this time Iowa State University provides micronutrient recommendations only for Zn for corn and sorghum based on soil testing. The DTPA soil test for Zn has been calibrated on Iowa soils, and recent research showed that the Mehlich-3 test for Zn extracts higher amounts than the DTPA test but both are well correlated. Zinc recommendations for corn and sorghum are given in Table 15. Soil test procedures for the other micronutrients have not been calibrated because of either lack of or inconsistent occurrence of deficiencies, with the exception of iron (Fe) deficiency on soybean. Iron deficiency on soybean occurs on high-pH (calcareous) soils but no Fe test has proved to be reliable in these soils. Soybean Fe deficiency can be predicted by calcareous soil types occurrence as shown in soil survey reports or soil pH testing. Development of soybean varieties tolerant to low Fe availability in calcareous soils is the most acceptable solution to the problem.

Table 14. Equations to determine the phosphorus (P) and potassium (K) application rates for corn, soybean, and the 2-year rotation using variable-rate technology for soil-test results within the very low and low soil-test categories (from 1 ppm to the upper end of the low category, see Table 1).†

Crop	Soil Test ‡	Equation
		Phosphorus
Corn	BP1 or M3P	lb P_2O_5/acre = 137.88 – (3.46 x ppm P) – (0.0335 x ppm P^2)
	M3P-ICP	lb P_2O_5/acre = 135.44 – (1.52 x ppm P) – (0.0351 x ppm P^2)
	Olsen	lb P_2O_5/acre = 138.88 – (4.61 x ppm P) – (0.197 x ppm P^2)
Soybean	BP1 or M3P	lb P_2O_5/acre = 114.26 – (2.59 x ppm P) – (0.0538 x ppm P^2)
	M3P-ICP	lb P_2O_5/acre = 112.19 – (1.01 x ppm P) – (0.0423 x ppm P^2)
	Olsen	lb P_2O_5/acre = 115.09– (3.46 x ppm P) – (0.219 x ppm P^2)
2 years	BP1 or M3P	lb P_2O_5/acre = 218.36 – (5.99 x ppm P)
	M3P-ICP	lb P_2O_5/acre = 219.35 – (3.72 x ppm P)
	Olsen	lb P_2O_5/acre = 223.45 – (10.07 x ppm P)
		Potassium
Corn	Moist	lb K_2O/acre = [(166.45 - (1.58 x ppm K)] / [(1 - (0.0059 x ppm K) - (0.000025 x ppm K^2)]
	Dry	lb K_2O/acre = [(167.30 - (0.96 x ppm K)] / [(1 - (0.0034 x ppm K) - (0.000012 x ppm K^2)]
Soybean	Moist	lb K_2O/acre = [(168.60 - (1.37 x ppm K)] / [(1 - (0.0038 x ppm K) - (0.000025 x ppm K^2)]
	Dry	lb K_2O/acre = [(167.00 - (0.85 x ppm K)] / [(1 - (0.0028 x ppm K) - (0.000009 x ppm K^2)]
2 years	Moist	lb K_2O/acre = [(276.80 - (2.01 x ppm K)] / [(1 - (0.0041 x ppm K) - (0.0000019 x ppm K^2)]
	Dry	lb K_2O/acre = [(277.55 - (1.37 x ppm K)] / [(1 - (0.0032 x ppm K) - (0.0000041 x ppm K^2)]

†The equations do not apply for soil-test results in the optimum category because rates based on nutrient removal should be applied that are calculated as the crop yield times the grain concentration per unit of yield (see Table 2).

‡BP1 = Bray P_1, M3P = Mehlich-3 colorimetric, M3P-ICP, Mehlich-3 ICP, Moist = ammonium-acetate or Mehlich-3 tests for field-moist and slurry soil tests, Dry = ammonium-acetate or Mehlich-3 tests for dried soil samples.

Limestone Recommendations

Soil pH is used to determine whether or not to lime soils, and a calibrated buffer pH method is used to estimate reserve acidity and the amount of lime required to increase soil pH to a desired value. The SMP and Sikora buffer pH methods provide estimates of reserve acidity, both have been calibrated for Iowa soils

Table 15. Zinc recommendations for corn and sorghum production.

	Zinc Soil Test (ppm)		
Soil Test Category	**Low**	**Marginal**	**Adequate**
DTPA Zinc	0–0.4	0.5–0.8	0.9+
Mehlich-3 Zinc	0-1.0	1.1-1.5	1.6+
	Zinc to apply broadcast (pounds/acre)		
	10	5	0
	Zinc to apply in band (pounds/acre)*		
	2	1	0

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

and produce the same test results. Therefore use the same interpretations for both tests. Lime recommendations in Table 16 are given in pounds of Effective Calcium Carbonate Equivalent (ECCE), for different soil buffer pH values, target soil pH, and depth of soil to be neutralized. Actual rates of limestone or other liming materials (such as pelleted limestone or water treatment plant residual materials) to apply should be calculated from the recommended ECCE rate (Table 16) of the product to be applied. The ECCE is determined for all agricultural limestone and other lime sources in Iowa following procedures established by the Iowa Department of Agriculture and Land Stewardship.

Recommendations are given to increase soil pH to 6.0, 6.5, or 6.9. Soil pH 6.9 is recommended for alfalfa or alfalfa-grass mixed hay or pastures. Soil pH 6.0 is sufficient for other forage legumes or legume-grass mixtures and grasses. For corn and soybean, soil pH 6.5 is considered to be sufficient in areas with low-pH subsoil, but 6.0 is sufficient in areas with high-pH (calcareous) subsoil within a four-foot depth of the surface. General soil association areas (which include several soil associations) with low or high subsoil pH have been summarized in Figure 1. The soil association areas with high pH subsoil are Clarion-Nicollet-Webster, Galva-Primghar-Sac, Moody, Monona-Ida-Hamburg, Marshall, and Luton-Onawa-Salix. Therefore, when liming is required for corn or soybean, lime is recommended to raise soil pH to 6.5 for fields in soil association areas with low subsoil pH, and to 6.0 in association areas with high subsoil pH.

The amount of lime material to be applied should be adjusted for the incorporation depth from tillage, which determines the volume of soil to be neutralized. The recommended sampling depth for soil pH analysis in no-tillage, strip-tillage, haylands, or pastures is 2 to 3 inches. It is very important that the laboratory knows the sampling depth. Samples taken from a 6-inch

Table 16. Lime recommendations based on SMP or Sikora buffer pH methods, given in pounds per acre of Effective Calcium Carbonate Equivalent (ECCE) to increase soil pH from its present level to pH 6.0, 6.5, or 6.9 for the soil depth to be neutralized.†

	Depth of Soil to be Neutralized								
	2 inches			**3 inches**			**6 inches**		
	Target Soil pH								
Buffer pH	**pH 6.0**	**pH 6.5**	**pH 6.9**	**pH 6.0**	**pH 6.5**	**pH 6.9**	**pH 6.0**	**pH 6.5**	**pH 6.9**
	Amount of Effective Calcium Carbonate Equivalent to Apply (pounds/acre) ‡								
7.0	0	0	400	0	0	600	0	0	1,100
6.9	0	0	600	0	0	1,000	0	0	1,900
6.8	0	200	900	0	300	1,400	0	600	2,700
6.7	0	400	1,200	0	700	1,800	0	1,300	3,500
6.6	0	700	1,500	0	1,100	2,200	0	2,100	4,400
6.5	100	900	1,700	100	1,400	2,600	200	2,800	5,200
6.4	300	1,200	2,000	400	1,800	3,000	800	3,500	6,000
6.3	500	1,400	2,300	700	2,100	3,400	1,400	4,200	6,800
6.2	700	1,700	2,600	1,000	2,500	3,900	2,000	5,000	7,700
6.1	900	1,900	2,800	1,300	2,900	4,300	2,500	5,700	8,500
6.0	1,000	2,200	3,100	1,600	3,200	4,700	3,100	6,400	9,300
5.9	1,200	2,400	3,400	1,900	3,600	5,100	3,700	7,100	10,100
5.8	1,400	2,600	3,700	2,200	4,000	5,500	4,300	7,900	11,000
5.7	1,600	2,900	3,900	2,500	4,300	5,900	4,900	8,600	11,800

† For corn and soybean, soil pH 6.5 is recommended in soil association areas without calcareous subsoil and soil pH 6.0 is recommended in areas with calcareous subsoil (see text and Figure 1). Soil pH 6.9 is recommended for alfalfa and alfalfa-grass mixtures in all soil association areas. Soil pH 6.0 is recommended for other forage legumes or legume-grass mixtures and grasses in all association areas.

‡ Amounts were derived from the following calibration equations and rounded to 100 pounds:

Pounds of ECCE to raise pH to 6.0 = [38619 - (5915 x Buffer pH)] x [Depth x 0.167]

Pounds of ECCE to raise pH to 6.5 = [49886 - (7245 x Buffer pH)] x [Depth x 0.167]

Pounds of ECCE to raise pH to 6.9 = [58776 - (8244 x Buffer pH)] x [Depth x 0.167]

depth for P and K testing could be used for lime requirement determination, but lime application rates should be adjusted to about one-half of the amounts recommended for a 6-inch depth. A footnote in Table 16 shows the equations derived from calibration data used to calculate the amounts of ECCE needed to raise soil pH to desired levels.

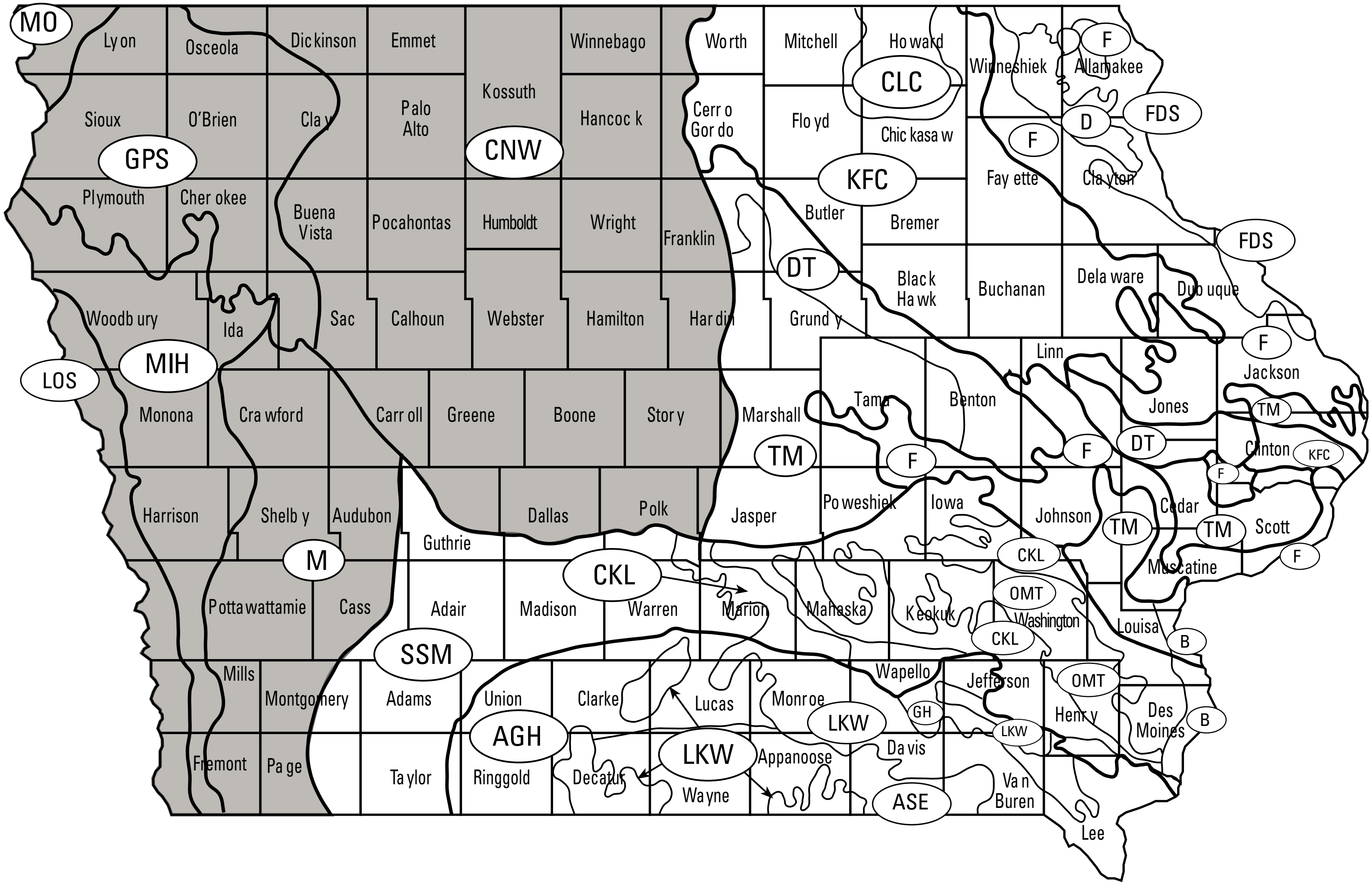

Figure 1. Map of Iowa delineating the 21 principal soil association areas with high(shaded area) or low subsoil pH. B designates the Mississippi bottomland.

AGH:	Adair-Grundy-Haig	D:	Downs	GH:	Grundy-Haig	MIH:	Monona-Ida-Hamburg
ASE:	Adair-Seymour-Edina	DT:	Dinsdale-Tama	KFC:	Kenyon-Floyd-Clyde	Mo:	Moody
CKL:	Clinton-Keswick-Lindley	F:	Fayette	LKW:	Lindley-Keswick-Weller	OMT:	Otley-Mahaska-Taintor
CLC:	Cresco-Lourdes-Clyde	FDS:	Fayette-Dubuque-Stonyland	LOS:	Luton-Onawa-Salix	SSM:	Shelby-Sharpsburg-Macksburg
CNW:	Clarion-Nicollet-Webster	GPS:	Galva-Primghar-Sac	M:	Marshall	TM:	Tama-Muscatine

Prepared by Antonio P. Mallarino, John E. Sawyer, Stephen K. Barnhart, and Mark A. Licht.

Department of Agronomy, Iowa State University.

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