Update to Iowa phosphorus, potassium, and lime recommendations

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Introduction

This article highlights revisions to Iowa State University (ISU) soil-test interpretations and application guidelines for phosphorus (P), potassium (K) and lime in the updated ISU extension publication PM 1688 “A General Guide for Crop Nutrient and Limestone Recommendations in Iowa”. The previous update to this publication was in 2002. Field research is conducted as issues or questions arise to assure that nutrient management suggestions are up to date. This research has indicated that some recommendations should not be changed, but that others needed significant changes to optimize nutrient management to improve the profitability and sustainability of crop production. The updated publication is available in printed format and online at http://store.extension.iastate.edu/ItemDetail.aspx?ProductID=5232.

What was not changed?

The recommendations that did not change will not be reviewed in this article and are summarized in the following points.

1. The general concept of P and K recommendations is to achieve long-term profitability and reduced risk of yield loss while maintaining or improving the sustainability of nutrient and crop management. This is attained by emphasizing crop response-based fertilizer applications for the low-testing classes and recommending removal-based maintenance based on estimated crop removal with harvest for the optimum soil test class.
2. Soil-test interpretation categories for the Bray-P1, the colorimetric version of the Mehlich-3 test, and the ICP (inductively-coupled plasma) were not changed since research done since 2001 indicates they are appropriate in spite of increased yield levels, mainly of corn.
3. The amounts of P and K recommended for grain production in the very low and low soil test interpretation categories, which are based on crop response (not buildup) remain the same, since results of response trials in many fields have shown that soil-test levels needed to optimize yield have not changed in spite of the higher yield levels.
4. The soil pH considered sufficient for grain and forage crops were not changed since a very large research project conducted in many years with corn and soybean confirmed previous recommendations about optimum pH levels.
5. Interpretations for micronutrients, which currently include only recommendations for zinc (Zn) in corn or sorghum, were not changed. Ongoing research with corn and soybean studying several micronutrients applied to soil or foliage has not been completed.

What was changed?

The most significant changes were to include interpretations for a moist-based test for K (with field-moist or slurry analysys), changes to soil-test interpretations categories for K using dried soil samples, and adjustments to crop nutrient concentrations and default crop yields needed to estimate nutrient removal for maintaining soil-test levels in the optimum category.

Changes to soil-test interpretation categories

Table 1 shows the new interpretation categories for P and K soil-test results by several methods and for various crops. The most significant interpretations changes are summarized in the following points.

1. Eliminated soil-test interpretations for soil-test P and K results for soil series with high subsoil P and K. Soil-test methods field calibration research since the 2000s for corn and soybean showed no clear differences in soil-test requirements between soils classified as having low or high subsoil P and K levels (requirements were lower for soil series with high subsoil P and K) that were established in the 1960s. Earlier research, during the 1990s could not fully confirm the value of this classification, but results of the recent research were clearly showed that using the lower soil-test levels suggested for soils with high subsoil K sometimes could limit crop yield. Therefore, the soil-test P interpretations that were not changed are the ones that before were recommended for soils with low subsoil P and K.
2. There was a minor adjustment to interpretation categories for the Olsen P test. Research in recent years has shown that the upper boundary levels for the categories low, optimum, and high for this P test were too high by one to two ppm. As in the previous version of the publication, the Olsen and both versions of the Mehlich-3 test (colorimetric or IP determination of extracted P) are recommended across all Iowa soils. However, the Bray-1 test is not recommended for high pH, calcareous soils (> pH 7.3) because in these soils it tends or under-estimate crop-available P.
3. There was a significant change of interpretations for the commonly used analysis of soil K based on laboratory-dried soil samples by the ammonium-acetate and Mehlich-3 extraction tests. Research conducted since the early 2000s have shown that there is very high uncertainty about the prediction of crop yield response by K tests based on dried samples, and also showed that the old interpretation categories too often resulted in insufficient amounts of K application to optimize yield. Therefore, the new research-based interpretations have increased the boundaries of all categories by 30 to 40 ppm. For example, the old optimum category (for which maintenance fertilization is recommended) was 131 to 170 ppm, whereas the updated category it is 171 to 200 ppm (formerly the high category).
4. The updated publication re-introduces a moist-based test for K (with new interpretations) that was the only K test recommended by ISU during the 1970s and 1980s. Detailed information about the history of the moist test, reasons for its renewed adoption, comparison of amounts of K extracted, and early field research results were shared in last year's conference.

Research during the 1960s and 1970s and additional research since the early 2000s have shown that analyzing dried or field-moist soil does not change P soil-test results by the Bray-P1, Mehlich-3, or Olsen P tests. Therefore, the soil-test interpretations provided for the P tests are the same for analysis of dried or moist soil samples. However, extracting K from undried soil samples or after drying the samples in the laboratory can greatly affect K test results with both the ammonium-acetate and Mehlich-3 tests (these two tests give similar results no matter the sample handling procedure). The moist test can be performed either on field-moist samples or on a slurry made with field-moist soil and water, and both versions give similar results. Therefore, the updated publication provides different interpretations for K testing of moist or dried samples.

Field calibration research has indicated that the moist K test is more reliable than the test based on dried samples because it is a better predictor of crop K fertilization needs. There were two periods of field calibration research, one from 2001 until 2006 that was based on the field-moist version of the test and a recent one during 2011 and 2012 that was based on the slurry-version of the test. In both periods soil analyses were done at the ISU Soil and Plant Analysis Laboratory. Figure 1 shows results of field calibrations for the commonly dry test and the moist test conducted from 2001 through 2006, and Figure 2 shows a similar comparison for field calibrations conducted during 2011 and 2012.

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)	0–15	0–8	0–50
Low (L)	16–20	9–15	51–85
Optimum (Opt)	21–25	16–20	86–120
High (H)	26–35	21–30	121–155
Very high (VH)	36+	31+	156+

Relative Level	Mehlich-3 ICP		Ammonium-Acetate or Mehlich-3
	Field-Moist and Slurry or Dried Samples		*Dried Samples*
Very low (VL)	0–20	0–15	0–120
Low (L)	21–30	16–25	121–160
Optimum (Opt)	31–40	26–35	161–200
High (H)	41–50	36–45	201–240
Very high (VH)	51+	46+	241+

Relative Level	Olsen P	
	Field-Moist and Slurry or Dried Samples	
Very low (VL)	0–9	0–5
Low (L)	10–13	6–9
Optimum (Opt)	14–16	10–13
High (H)	17–19	14–18
Very high (VH)	20+	19+

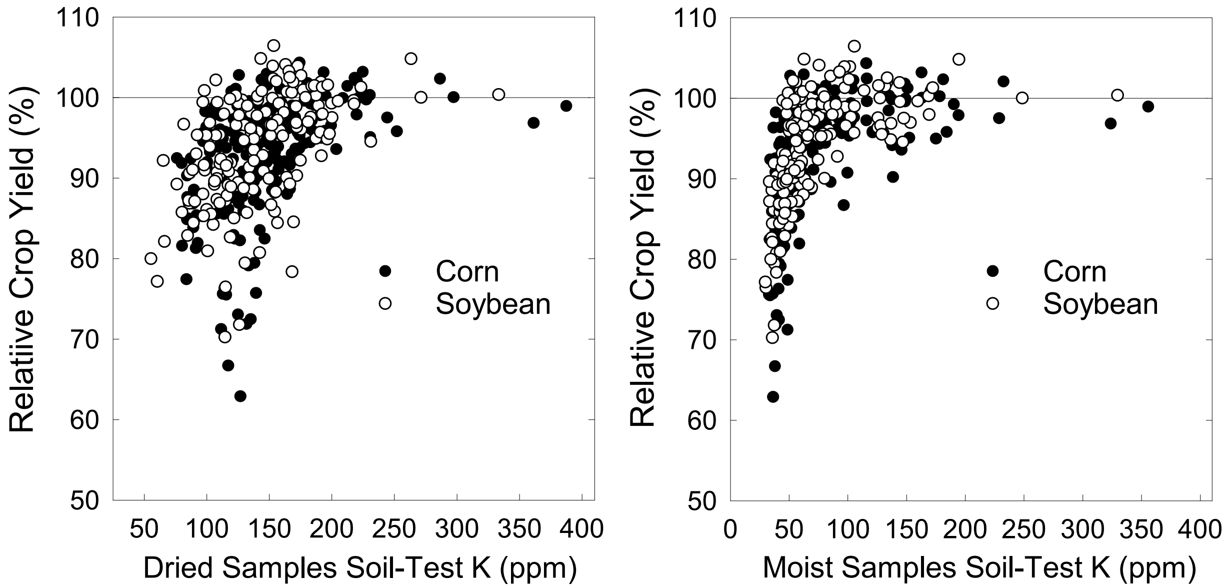

Figure 1. Relationship between relative corn and soybean yield response to K and soil-test K measured on dried or field-moist samples for data collected from 2001 until 2006 (200 corn site-years and 162 soybean site-years).

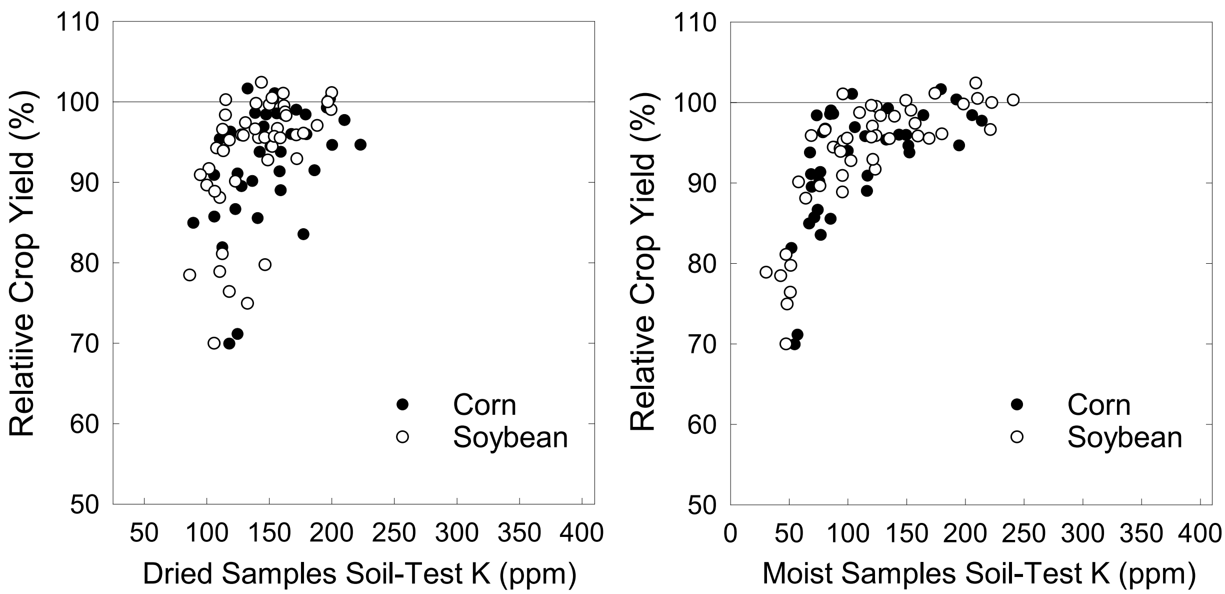

Figure 2. Relationship between relative corn and soybean yield response to K and soil-test K measured on dried or moist (slurry procedure) samples for data collected in 2011 and 2012 (37 corn site-years and 46 soybean site-years).

The graphs in both figures combine data for corn and soybean because the relationship between the relative yield response and soil-test results was similar for both crops. Relative yield expresses the yield of a non-fertilized control as the percentage of the yield with non-limiting fertilization. Both figures show that the moist test has a much tighter distribution of data points which fits better the expected relationship between soil-test results and yield response to nutrient application.

The amounts of K extracted can differ greatly between moist and dried samples, and the differences change greatly across soil series, soil-test K levels, and soil conditions related to drainage and moisture content cycles. There is no numerical factor that can be used to transform test results between moist and dried testing procedures across all conditions. Therefore, laboratories should not transform soil-test results obtained by one procedure to express values by the other procedure. When switching to the new moist test, the K test results may be lower, approximately similar, or higher than results based on the dried test. The moist test will tend to be lower at the lower soil K levels and in soils with fine textures and poor drainage, but may be similar or even higher at high soil K levels, in well-drained soils, or dry soil sampling seasons.

Although the new interpretations have reduced the risk of yield loss when using the dry K test, we encourage use of the moist test because it performs better at predicting the needed fertilization rate, and minimizes the risk of under-fertilizing or over-fertilizing field or field areas.

Changes to suggested crop P and K concentrations and default yield levels

The amount of P and K removed with harvest is used in addition to soil-test results to determine the fertilizer rate needed to maintain soil-test values in the optimum interpretation category. This category has been defined as the soil-test range in which the probability of crop a yield increase is about 25% and where the magnitude of the expected yield increase is small. So maintaining this soil-test level is recommended based on estimates of the amounts of P and K removed with harvest. The amount of P and K removed with harvest is determined by the yield level and the nutrient concentration in the harvested crop portion (grain, silage, residue, or forage) and the yield level.

The yield level that should be used for the calculation of removal should a reasonable estimate of the expected yield level based on prevailing yield in a field or portions of a field. It should not be a yield goal, since no research in Iowa or other states suggest that a certain P or K rate should be applied to achieve a desirable yield. Default yield levels are suggested in the publication so that soil testing laboratories still can make a fertilizer recommendation for test results within the optimum category when they do not get yield information with the soil sample submitted for analysis. Some default crop yield levels were increased, mainly corn yield, to reflect increasing yields over time. The provided default yield levels are levels slightly higher than observed state averages in recent years (excluding the abnormally low yields due to drought). We must emphasize that the prevailing yield level should be provided to the laboratory for a more accurate maintenance recommendation.

Table 2 shows the new suggested crop P and K concentrations in harvested crops. The nutrient concentration needed to estimate P and K removal together with the yield level can be obtained by chemical analysis of the harvested material or from tables that provide concentrations from prior analysis of many samples. The suggested concentrations were changed because of several reasons. One reason was that in recent years lower grain nutrient concentrations have been observed in Iowa and other states of the Corn Belt in samples from research studies. A second reason was that several research projects conducted in recent years have resulted more and better information of nutrient concentrations for many crops and harvested plant parts. Therefore, the suggested nutrient concentrations better reflect the observed concentrations and have been adjusted so that they can be directly multiplied by yield expressed using common moisture content standards.

Table 2. Nutrient concentrations to calculate removal with crop harvest and amounts of P_2O_5 and K_2O for the optimum soil-test category.

Crop †	Unit of Yield and Moisture Basis	Pounds per Unit of Yield ‡	
		P_2O_5	K_2O
Corn	bu, 15%	0.32	0.22
Corn silage	bu grain equiv., 15%	0.44	1.10
Corn silage	ton, 65%	3.5	9.0
Corn stover	ton, 15%	4.8	18
Soybean	bu, 13%	0.72	1.2
Soybean residue	ton, 10%	4.7	23
Oats	bu, 13%	0.29	0.19
Oats straw	ton, 10%	6.4	36
Wheat	bu, 12%	0.55	0.27
Wheat straw	ton, 10%	3.7	23
Sunflower	100 lb, 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 grains 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.

Changes to suggested P and K application rates

The changes to some soil-test interpretation categories (P by the Olsen test and for K tests) do not necessarily result in changes to the recommended P and K application rates for each category. However, there were some changes to the amounts of fertilizer recommended for some crops. The most relevant changes are summarized by the following points:

1. The update publication includes a table with recommended amounts of P and K fertilizer applied once for two-year corn-soybean rotations. The criterion for determining the needed amounts of fertilizer is the same that was included in the text portion of the old publication, but no table was presented before.
2. Adjustments were made to P and K amounts recommended for corn silage and some forages when soil-test results are in the very low or low categories. Usually the amounts recommended were increased.
3. Changes to the suggested default yield goal and nutrient concentrations in harvested crops resulted in changes to the amounts recommended for the optimum soil-test category, for which maintenance based on removal is recommended. The new amounts recommended changed significantly mainly corn grain, corn silage, and alfalfa or alfalfa-grass mixtures. The new application rates cannot be possibly shown in this short article.
4. The publication includes equations to calculate P and K application rates that are useful for variable-rate application for corn, soybean and the two-year rotation. The equations allow for calculating the application rate for each nutrient and testing method for soil-test results ranging from 1 ppm (lowest value of the very low category) to the upper end of the low category. 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. These are not buildup equations. Nutrient application rates higher than those included in this publication for the very low and low 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.

Lime recommended for soil association areas with calcareous subsoil

Previous recommendations in the publication PM 1688 indicated that soil pH 6.5 was sufficient for corn and soybean in soil association areas with low subsoil pH, but that 6.0 was sufficient in areas with high (calcareous) subsoil pH. However, a target pH of 6.5 was suggested for all areas when calculating the amount of lime to apply. This apparent incongruence could be justified since a long-term approach is reasonable for soil pH and lime management in some situations (for example, with save land tenure) but it created confusion. Therefore, the new publication recommends targeting pH 6.0 for areas classified as having calcareous subsoil when calculating the lime requirement. The classification of Iowa soil association areas according to subsoil pH was not changed. The updated publication also includes the equations based on buffer pH test results used to determine the amount of lime needed to raise soil pH to desirable values that are useful for variable rate lime application.