POTASSIUM MANAGEMENT, SOIL TESTING AND CROP RESPONSE

Antonio P. Mallarino and Ryan R. Oltmans
Department of Agronomy, Iowa State University, Ames

Introduction

New field research is conducted in Iowa as issues or questions arise to assure that nutrient management guidelines are up to date and to address new issues. This article briefly summarizes two major projects with potassium (K) whose results are useful to improve the efficacy of nutrient management and crop production. One project focused on correlating soil-test K methods with response of corn and soybean to fertilization and on obtaining better estimates of the concentration of K in corn and soybean plant parts. This research resulted in a significant update in fall 2013 of Iowa State University extension publication PM 1688 "A General Guide for Crop Nutrient and Limestone Recommendations in Iowa", which includes guidelines for P, K, lime, and micronutrients and had not been updated since 2002. The update included minor revisions to phosphorus (P), lime, and micronutrients guidelines but major changes to K guidelines. The updated publication is available in printed format and online (Mallarino et al., 2013). Preliminary information about this project was shared in a scientific journal article (Barbagelata and Mallarino, 2012) and in this conference (Mallarino, 2012). The other project focused on studying the P and K recycling to the soil from corn and soybean residues and impacts on soil-test values in order to better understand causes of short-term temporal soil-test variability and improve soil testing. Preliminary results for both P and K from a few sites were shared in this conference in 2011 (Oltmans and Mallarino, 2011). This article summarizes the completed research for K at many sites.

Potassium Soil-Test Procedures and Interpretation Categories

It has been known since the 1960s that drying of soil samples in the laboratory may change the amount of K extracted compared with moist soil analysis. Iowa research in the 1960s showed that soil-test K results from moist samples related better to crop K needs and response to fertilization. Therefore, a moist-based test for K was the only K test recommended by ISU during the 1970s and 1980s, it was among procedures recommended by the NCERA-13 regional soil testing committee, but was discontinued in 1988 because no other public or private laboratory adopted it. Detailed information about the history of the moist test, reasons for the new research, and results of new research conducted in the 2000s were shared before in this conference (Mallarino, 2012). The recent research confirmed results from the 1960s in that analyzing dried or field-moist soil does not change P soil-test results by any P test, doesn't affect much cations such as calcium, magnesium, and sodium, but can greatly affect K test results with both the ammonium-acetate and Mehlich-3 tests. The moist test can be performed either on field-moist samples or on a slurry of field-moist soil and water, and detailed procedures were included in an updated version of the NCERA-13 committee methods publication (Gelderman and Mallarino, 2012). Both versions of the moist test give similar results (Mallarino, unpublished).

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 correlations for the common test on dried samples and the moist test conducted from 2001 through 2006, and Fig.2 shows a similar comparison for field correlations conducted during 2011 and 2012.

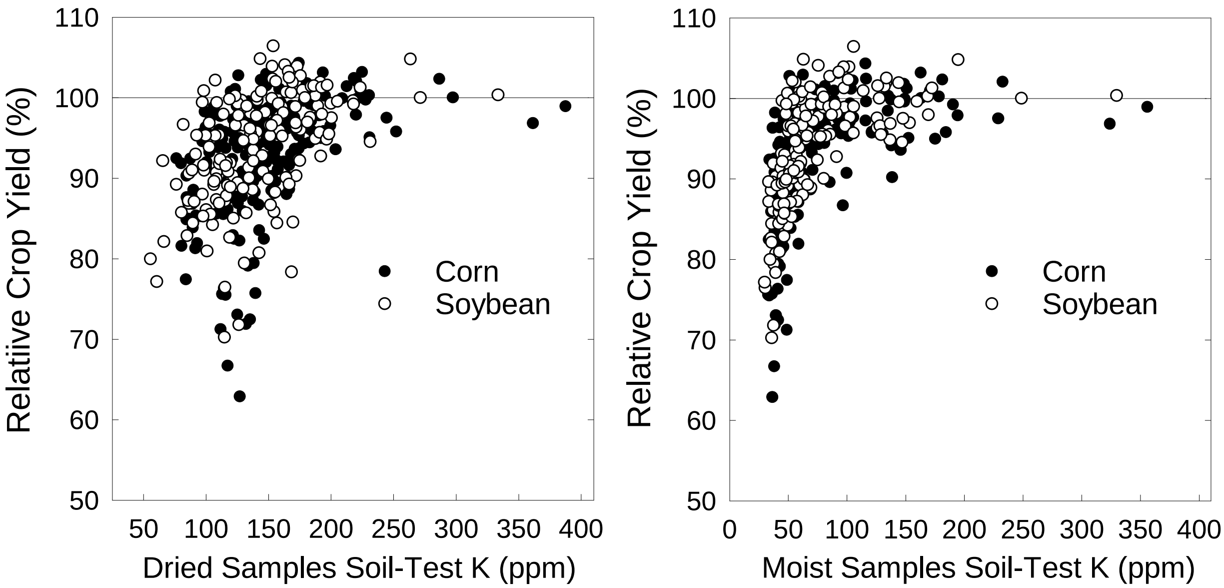

Fig. 1. Relationship between relative corn and soybean yield response to K and soil-test K measured on dried or field-moist samples for data collected from 2001 until 2006 (200 corn site-years and 162 soybean site-years).

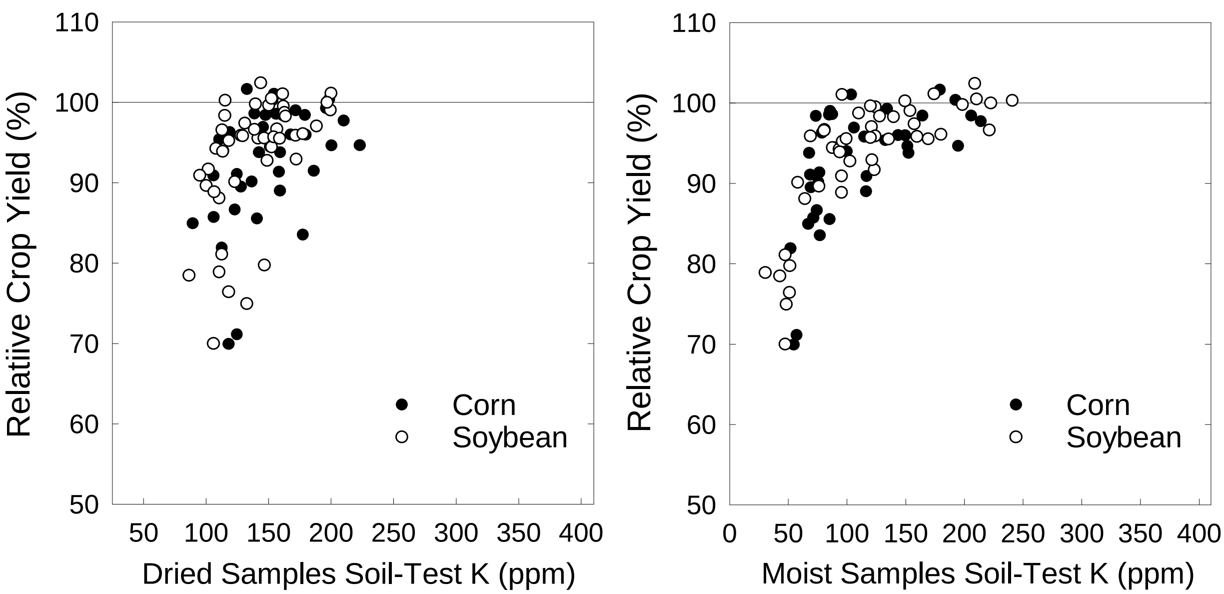

Fig. 2. Relationship between relative corn and soybean yield response to K and soil-test K measured on dried or moist (slurry procedure) samples for data collected in 2011 and 2012 (37 corn site-years and 46 soybean site-years).

The graphs 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 for a non-fertilized control treatment as the percentage of the yield for fertilization treatments that maximized. Both figures show that the moist soil-test for K has a tighter distribution of data points along the yield response range, which fits better with 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 (Mallarino, 2012). 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 crop K needs and minimizes the risk of under-fertilizing or over-fertilizing field or field areas.

These results were used to develop interpretations for the moist sample handling procedures and and to update interpretations for the common test based on dried samples. The research also confirmed results observed in the late 1990s in that we could not found support for a distinction that has been made since the late 1960s in Iowa for soil-test P and K interpretations according to subsoil levels. Interpretations for soils with high subsoil P or K (a very small area in the state) were lower than for soils with lower subsoil P and K levels, and sometimes could result in high risk of insufficient nutrient application to optimize yield. Therefore, interpretations for several P methods that were applicable to soil series with high subsoil P levels were dropped from the updated publication PM 1688 and the existing interpretations for soil series with low subsoil P levels now are recommended across all soils of the state (Mallarino et al., 2013). The P interpretations were not changed because new research indicated they are still appropriate in spite of increased crop yield levels.

The K interpretations for soils with high subsoil K levels also were dropped, but interpretations for all soils were changed based on the new research. Table 1 shows the new interpretation categories for K test results for the moist and dry sample handling procedures. The interpretation categories for K have been the same for all field crops, and this remained the same in the updated publication. Comparisons of soil-test K results have shown approximately similar values for the ammonium-acetate and Mehlich-3 test methods when using atomic absorption or ICP procedures to measure extracted K, so one set of interpretations is used for these methods. Data in Figs. 1 and 2 showed that there is very high uncertainty about the prediction of crop yield response by K tests based on dried samples, and that the old interpretation categories too often resulted in insufficient amounts of K application to optimize yield. Therefore, the new interpretations for the dried test have increased boundaries of all categories by 30 to 40 ppm. For example, the old optimum category (for which maintenance fertilization based on removal is recommended) was 131 to 170 ppm, whereas the updated category it is 171 to 200 ppm (formerly the high category).

Table 1. New interpretations of potassium soil-test results determined using two sample handling procedures for ammonium-acetate or Mehlich-3 methods.†

Relative Level	Field-Moist or Slurry Samples	Dried (35 to 40 C) Samples
	---------------- ppm K ----------------	
Very low (VL)	0 – 50	0 – 120
Low (L)	51 – 85	121 – 160
Optimum (Opt)	86 – 120	161 – 200
High (H)	121 – 155	201 – 240
Very high (VH)	156+	241+

† 6-inch deep soil samples.

New Crop Nutrient Concentrations for Estimating Removal

In Iowa, as in many other states, 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 a yield increase is about 25% and where the magnitude of the expected increase is small. Table 2 shows the new suggested crop P and K concentrations in harvested crops. The nutrient concentrations can be obtained by chemical analysis of the harvested material or from the table, which provides concentrations from prior analysis of many samples. The suggested concentrations were changed because lower grain nutrient concentrations have been observed in Iowa and other states in recent years, and more information is available.

Table 2. Suggested phosphorus and potassium concentrations in harvested corn and soybean parts to estimate removal.

Crop and plant part †	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

† Selected crops from publication PM 1688 (Mallarino et al., 2013). Nutrients in corn and soybean residue reflect content at grain harvest time and include little soil contamination.
‡ Nutrient concentrations were adjusted from a dry matter basis to a value suitable for multiplying by crop yield, based on the standard moisture content of the crop component harvested.

It is important to note that the suggested nutrient concentrations have been adjusted from dried-based data so they can be directly multiplied by crop yield expressed using commonly used moisture content standards. The yield level that should be used for the calculation of nutrient 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 level. 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 level information. Some default crop yield levels were increased, mainly corn yield, to reflect increasing yields over time (not shown). The yield levels are levels slightly higher than observed state averages in recent years and the abnormally low yields due to drought mainly in 2012 were excluded. We must emphasize that the prevailing yield level should be provided to the laboratory for a more accurate maintenance recommendation.

Potassium Removal and Leaching From Residue in Corn and Soybean

Soil and crop samples for this study were collected from K fertilization trials for corn and soybean that were located at several fields of six research farms. There were 12 soil series across all sites, and there were 33 corn site-years and 14 soybean site-years. The trials included several fertilization treatments replicated four times, but for this study we sampled treatments with non-limiting K and P fertilization rates. Plant samples were taken from all four replications of the treatments. Physiological maturity (PM) samples for corn included aboveground vegetative plant parts, cobs, and grain from six plants per plot. For soybean, samples included aboveground vegetative plant parts (including pod shells) and grain from a 15-ft^2 area of each plot. Plant tissue samples were dried, weighed, and analyzed for total K and P concentrations. At grain harvest, five residue samples were collected from each plot. The corn samples included residue of 10 plants and the soybean samples included residue collected from a 50-ft^2 area. The samples were placed in mesh plastic bags on top of non-tilled ground, and were removed at roughly 45 day intervals from harvest until spring. The plant tissue and residue samples were dried, weighed, ground, and analyzed for total K and P concentrations.

Figure 3 shows that for both crops the amount of K remaining in vegetative plant tissue at PM (excluding grain) or residue after harvest decreased following an exponential decay trend to a minimum over time for averages across sites. The decrease was similar with or without K fertilization, although the overall K levels remaining were greater for the fertilized treatment.

In soybean, the greatest amount of K loss from tissue occurred between PM and grain harvest. On average across both K treatments, the amount of K remaining in residue at harvest was 46% of the amount in vegetative tissue at PM, and the amount remaining in residue by early December was 41% of the amount at harvest. The K loss from vegetative tissue between PM and grain harvest can be attributed to leaf drop to the ground that we did not recover and K leaching from the plant as leaves and stems tissue senesced. Additional K losses from residue from December until early April were smaller, because much less K remained in the residue and there was frozen or snow covered soil until the middle of March. By early April, only 12% of the total K in soybean vegetative plant parts at PM remained in the residue.

In corn, the decrease over time of the amount of K remaining in vegetative tissue (excluding grain) or residue was more gradual than in soybean and showed a significant decrease early the following spring. A cubic polynomial model fit significantly better ($P \leq 0.10$) than exponential decay, quadratic, or linear models. As in soybean, however, the largest decrease in amount of K remaining was greater from PM to mid-December. On average across both K treatments, the amount of K remaining in corn residue at harvest was 67% of the amount at PM, and the amount remaining in residue by early December was 76% of the amount at harvest. By early April, and on average for both K treatments, 31% of the total K at PM still remained in the corn residue, which was much greater than for soybean at this last sampling date (12%). We believe that the different type of plant and residue for corn and soybean and the different distribution of K within the plant (as shown before) and known proportionally larger accumulation of K in cornstalks than in leaves explain the more gradual K loss from tissue for corn than for soybean.

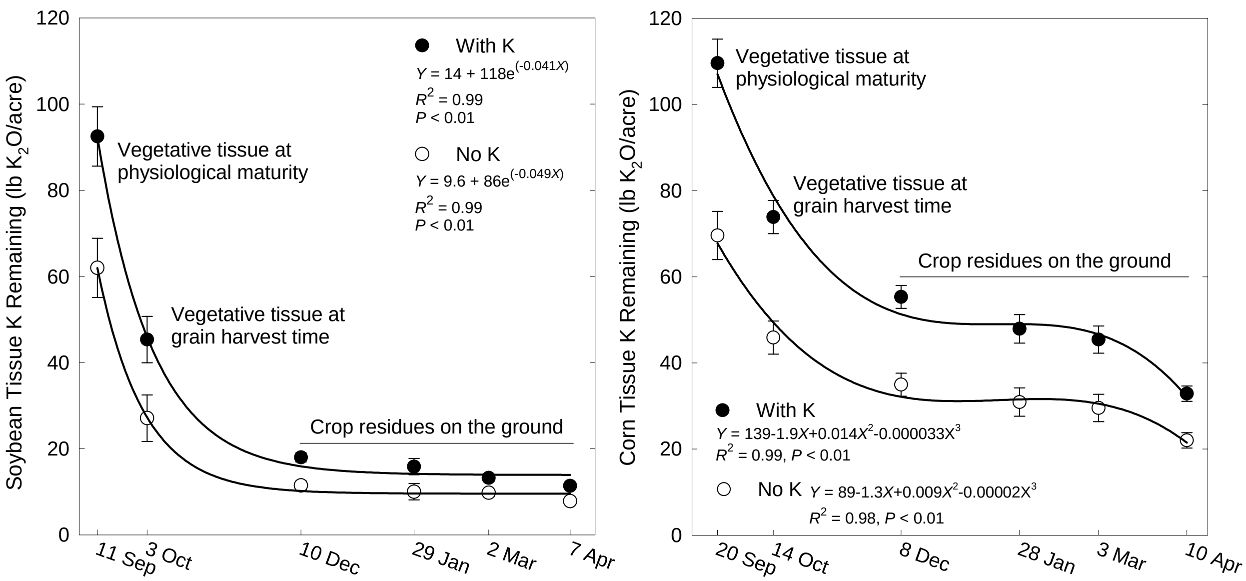

Figure 3. Potassium accumulation in soybean and corn vegetative tissues or residues over time for two K treatments (means across 14 site-years for soybean and 33 site-years for corn). Vertical lines indicate confidence intervals ($P = 0.10$)

Figure 4 show that precipitation occurring from PM to early April explained a considerable proportion of the tissue K loss variation over time. The K concentration or K remaining in crop tissue decreased exponentially to a minimum as precipitation increased across all site-years and tissue sampling dates. The relationship was better for soybean than for corn, however, and also there was a sharper K decrease for soybean. According to the models fit, with the maximum observed precipitation, the amount of K remaining in residue was 7% for soybean and 25% for corn. Late in the season K accumulates mainly in cornstalks instead of leaves and unless cornstalks are affected by disease or insects should be difficult for rainfall to leach out K. Also, dried soybean stems and leaves break more easily during grain harvesting and threshing. Therefore, less rainfall was probably needed to affect a large K loss from soybean plant tissue and residue than for corn.

Figure 5 shows that the amount of K lost from crop residue explained a significant proportion of the difference in STK from grain harvest until early April across all sampled site-years. However, there was large unexplained variability, mainly for data from corn residue. The data in the figure suggest that there was no clear difference between crops and no clear relationship between K loss and STK difference for K loss values below approximately 40 lb/acre.

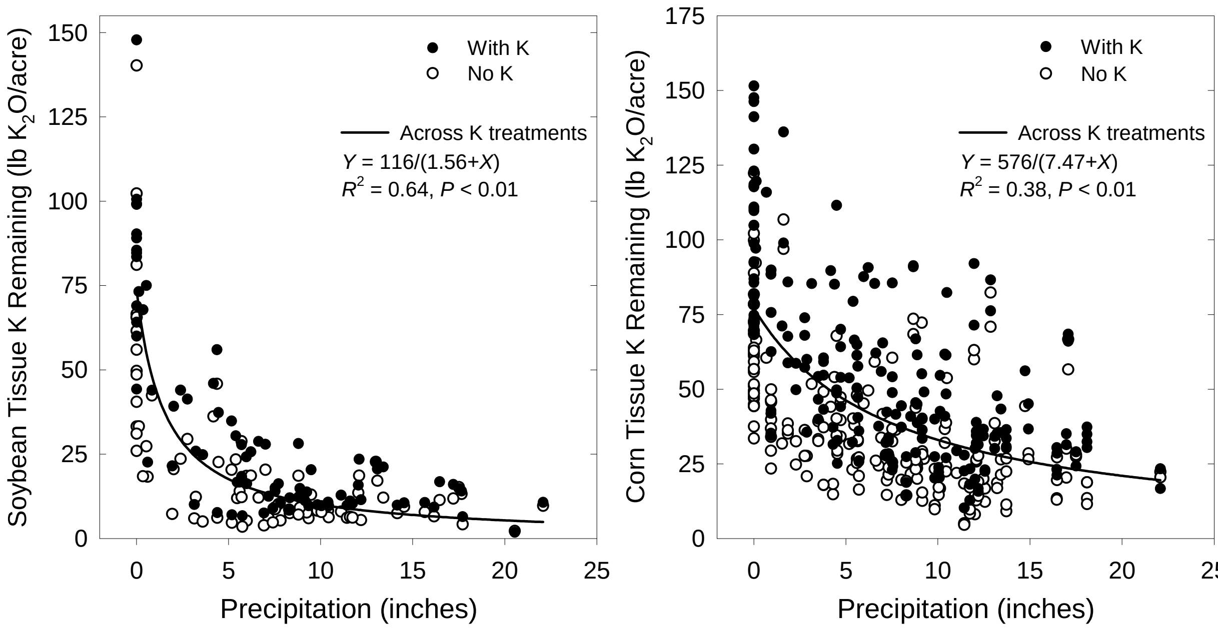

Figure 4. Relationships between K remaining in soybean and corn vegetative tissues or residues and precipitation across all site-years and sampling periods.

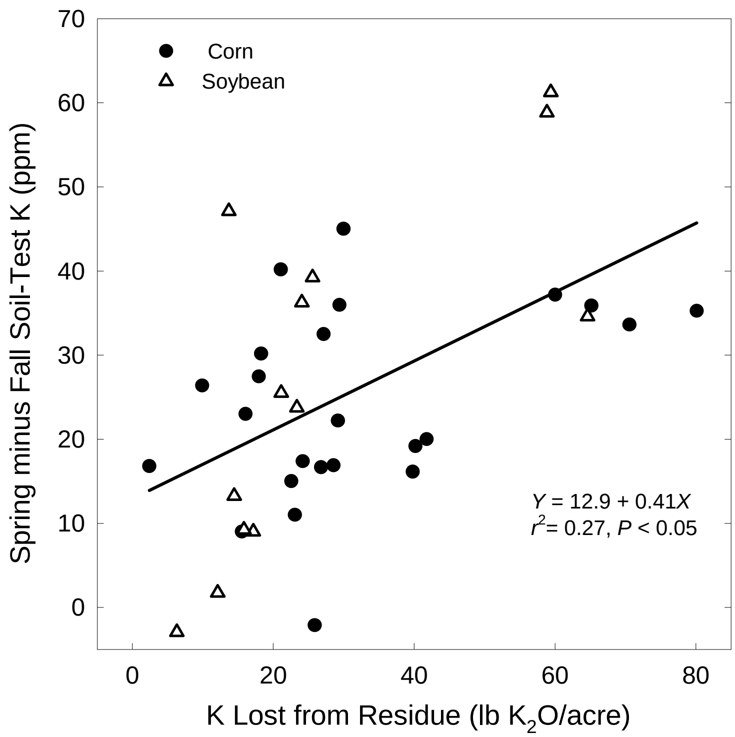

Figure 5. Relationship between the change in soil-test K between fall and spring and the amount of K lost from crop residues from grain harvest to early April of the following year.

The results showed that K recycling to the soil from crop residue occurs much sooner than was assumed and can greatly affect soil-test K results in samples collected at different times from harvest to the following spring. The effects on test results vary with the crop residue and with both amount and distribution of rainfall. It is clear, however, that early fall is a very unstable period to sample and analyze soils for K, although in practice is a convenient time for soil sampling due to various reasons.

References Cited

Barbagelata, P.A., and A.P. Mallarino. 2013. Field correlation of potassium soil test methods based on dried and field-moist soil samples for corn and soybean. Soil Sci. Soc. Am. J. 77:318-327.

Gelderman, R.H. and A.P. Mallarino. 2012. Soil Sample Preparation. Chapter 1, Revised October 2012. p. 1.1-1.4 In: Recommended chemical soil test procedures for the North Central region. North Central Regional Publ. No. 221 (Rev.). Missouri Exp. Stn. Publ. SB 1001. Univ. of Missouri. Columbia. Published online http://ncera-13.missouri.edu/pdf/sb1001_updatedOct2012.pdf.

Mallarino, A.P. 2012. Testing field-moist soil for potassium and other nutrients -- what's it all about? p. 26-36. In 42nd North-Central Extension-Industry Soil Fertility Conf. Proceedings. Nov. 14-15 2012. Vol. 28. Des Moines, IA. International Plant Nutrition Institute, Brookings, SD.

Mallarino, A.P., Sawyer, J.E., and S.K. Barnhart. 2013. General guide for crop nutrient recommendations in Iowa. Publ. PM 1688 (Rev.). Iowa State. Univ. Extension.

Oltmans, R.R., and A.P. Mallarino. 2011. Phosphorus and potassium removal and leaching from residue in corn and soybean. p. p. 197-202. In North-Central Extension-Industry Soil Fertility Conf. Proceedings. Nov. 16-17. Vol. 27. Des Moines, IA.

PROCEEDINGS OF THE

44^{th}

NORTH CENTRAL
EXTENSION-INDUSTRY
SOIL FERTILITY CONFERENCE

Volume 30

November 19-20, 2014
Holiday Inn Airport
Des Moines, IA

PROGRAM CHAIR:

James L Camberato
Purdue University
915 W State St.
West Lafayette, IN 47907
(765) 496-9338
jcambera@purdue.edu

PUBLISHED BY:

International Plant Nutrition Institute
2301 Research Park Way, Suite 126
Brookings, SD 57006
(605) 692-6280
Web page**: www.IPNI.net**

ON-LINE PROCEEDINGS:

http://extension.agron.iastate.edu/NCE/