EFFECTS OF SAMPLING TIME, SOIL MOISTURE CONTENT, AND EXTRACTANT ON SOIL TEST POTASSIUM LEVELS

L.F. Vitko, C.A.M. Laboski, and T.W. Andraski
University of Wisconsin-Madison, Madison, WI

Abstract

An accurate prediction of plant-available potassium (K) requires a thorough understanding of the mechanisms that might impact soil test K. A three year field study was developed to determine relationships between soil test potassium (STK) levels and time of soil sampling, soil moisture content, and extractant. Five field sites were established in 2006 throughout Wisconsin at Arlington, Hancock, Marshfield, and Lancaster Agricultural Research Stations, and a private farm in Fond du Lac county each representing a unique pedogenic region of the state. The sites were cropped for three years in a corn-soybean-corn rotation. Plot treatments included seven different K fertilizer rates (0, 75, 150, 225, 300, 375, 450 kg K_2O ha^{-1}) and two different harvest methods (grain or silage). Soil samples were collected eleven times in the three years, just before planting, during the growing season, and after harvest. In 2006 and 2007, soil samples were split into three subsamples to undergo different drying methods (moist, air, and oven dry at 35°C) and analyzed for extractable K by both Bray-1 and ammonium acetate. In 2008, soil samples were oven-dried and analyzed by Bray-1 only.

Soil test potassium levels were found to be significantly affected by time of soil sampling in the silage harvested plots at Arlington, Hancock, and Marshfield where no K was applied and at Arlington and Lancaster for the highest K rate and in the grain harvested plots at Hancock, Marshfield, and Fond du Lac at both the highest K and no K applied rates. Consistent increases in soil test potassium levels from fall to spring occurred at Hancock, while changes in STK levels from fall to spring at other locations were more sporadic, if present at all. In general, the Bray-1 extractant was found to be more sensitive to drying method than the ammonium acetate extractant. Air-drying was not found to change Bray-1 STK levels compared to oven-drying (at all locations except Fond du Lac), but leaving soils moist significantly decreased Bray-1 STK levels compared to air or oven-drying them (at all locations except Hancock). The slope of the regression line for Bray-1 STK verses ammonium acetate STK was not found to change when samples were air-dried compared to when they were oven-dried, but was found to change at Arlington and Hancock when samples were left moist. Generally, the slope of the regression line for Bray-1 STK verses ammonium acetate STK for a given drying method was found to be different for Arlington and Hancock compared to the other locations.

Introduction

Soil tests are an important tool to guide farmers in determining an appropriate fertilizer application rate. The interpretation of potassium soil test results are complicated by the fact that soil test potassium levels are known to fluctuate throughout the year (Blakemore, 1966; Childs and Jencks, 1967; Liebhart and Teel, 1977). Therefore the time of soil sampling may impact fertilizer recommendations. Major factors thought to affect potassium soil test levels include soil mineralogical composition and soil moisture. Soils high in 2:1 type clay minerals (micas and vermiculites) have the ability to fix potassium (trap it in the interlayer) or release potassium depending on the soil potassium level and soil moisture status (Goulding, 1987). If fluctuations in soil test K levels could be attributed to a particular time of the year or to particular weather/environmental conditions, then the results of soil tests might be more appropriately interpreted.

Soil testing labs typically oven dry (at relatively low temperatures) soil samples before analysis. Although this might be more convenient for the testing labs, it might not be the best indication of available potassium for certain soil types. Drying of soils has been found to cause net fixation or release of potassium. Fixation of potassium has been found to occur when K fertilizer is added to soil prior to drying (McLean and Simon, 1958; Badraouri and Bloom, 1989) and release of potassium has been found to occur when no K is added to the soil prior to drying (Leubs et al., 1956; Jones et al., 1961). Fixation has also been found to occur when the initial exchangeable K level is high, while release was found to occur when the initial exchangeable K level is low (Cook and Hutcheson, 1960). Potassium released by oven drying has been found to release more K than air drying (Kadrekar and Kibe, 1973). It would be beneficial to determine if the soils of Wisconsin behave similarly with drying or if the method of drying does not significantly affect soil test potassium levels.

The state of Wisconsin uses the Bray-1 extractant (.025M HCl and .03M NH_4F at pH 2.60) to estimate plant-available potassium, whereas much of the U.S. and the world uses neutral 1M ammonium acetate to extract potassium (Novozamsky and Houba, 1987). The Bray-1 extractant is generally considered to be a weaker extractant than ammonium acetate (Peters, 2009); however, the relationship may change depending on soil type and environmental conditions. Because ammonium acetate is widely used, it is important to understand for purposes of comparison how relationships between Bray-1 STK and ammonium acetate STK might behave differently under different conditions.

The objectives of this study are as follows:

- Determine if time of sampling affects soil test potassium levels.
- Evaluate whether drying method (moist, air-dried, oven-dried) affects Bray-1 extracted potassium or ammonium acetate-extracted potassium.
- Determine if relationships between Bray-1 and ammonium acetate extractants change under different drying methods or locations.

Materials and Methods

Field plots were established in the spring of 2006 at Arlington, Hancock, Lancaster, and Marshfield Agricultural Research Stations, and a private farm in Fond du Lac County. These five locations represent five pedogenically unique mineral soils of Wisconsin as described in Laboski et al. (2006). The soil names, initial Bray-1 soil test K and P levels, organic matter content, pH, previous crop, and N fertilizer rates for each location are presented in Table 1.

The duration of the experiment was three growing seasons, 2006-2008. The experimental design is a split- plot with four replications and with corn harvest method as the whole plot factor (grain and silage) and potassium fertilizer rate as the subplot factor. All locations received seven different rates (0, 75, 150, 225, 300, 375, 450 kg K_2O ha^{-1}) except Fond du Lac, which received only 4 rates (0, 75, 150, 225 kg K_2O ha^{-1}). Potassium fertilizer was preplant surface broadcast and subsequently incorporated to a depth of 20 cm in the spring of 2006. No additional fertilizer was applied in 2007 or 2008.

The sites were cropped to corn in 2006, soybean in 2007, and corn again in 2008. Tillage was spring or fall chisel, except at Hancock which was moldboard plowed. Plot size was 3.0 m in width (except at Hancock which was 3.6 m in width) and 10.6 m in length. Best pest management practices were followed at each location.

For the corn grain harvest plots, soil samples were collected a total of 11 times at each location for the three year duration of the experiment. Soil sampling occurred five times in 2006, four times in 2007, and twice in 2008. In 2006, soil was sampled late April/ early May (prior to fertilizer application), June, July, September, and after harvest in October. In 2007, soil was sampled before planting in May, twice during the growing season in June and August, and after harvest in October. In 2008, soil was sampled before planting in May and after harvest in October/ November. The corn silage harvest plots were sampled prior to planting and after harvest each year. The different locations were not all sampled on the same day for each sampling event, but were all sampled from within a few days of each other to within 2 weeks of each other.

Six soil cores, 0-20cm depth, were collected from each plot and mixed to make a composite sample. Soil samples were homogenized and sieved to 2mm. For the grain harvest treatment, soil samples from each plot were split to undergo different drying methods in 2006 and 2007. A third of the sample was kept moist, a third was air-dried, and a third was oven-dried at 35°C. Soil samples from 2008 were oven-dried. Soil potassium was extracted with Bray-1 on all soils samples. Ammonium acetate extractable K was determined on samples from the grain harvest plots for all sampling dates in 2006 and the first two sampling dates in 2007. Extraction and analysis of potassium followed procedures outlined in Peters (2009) and Warncke and Brown (1998). In 2006 and 2007 potassium was determined using atomic absorption flame spectroscopy, while ICP-OES was used in 2008.

The effect of sampling time on STK levels was determined for the 0 K rate and highest K rate silage and grain harvested plots at each location (for oven-dried, Bray-1-extracted soil samples) using a repeated measures ANOVA model in PROC MIXED of SAS (SAS Inst., Inc., Cary, NC). Contrasts were used to determine if soil test K levels differed significantly between fall and spring. The effect of drying method at each location was evaluated with an ANOVA model in PROC MIXED of SAS. Pairwise comparisons were made for the drying methods using the PDIFF procedure of SAS. The relationship between Bray-1 STK and ammonium acetate STK for each location and drying method was evaluated with regression analysis using PROC REG of SAS. Indicator variables were used to test whether the slopes of the regression lines differed by drying method or location.

Results and Discussion

Effect of time on STK

Soil test potassium levels were found to be significantly affected (*P*<0.05) by time of soil sampling in the silage harvested plots at Arlington, Hancock, and Marshfield where no K was applied; at Arlington and Lancaster for the highest K rate; and in the grain harvested plots at Hancock, Marshfield, and Fond du Lac at both the highest K and no K applied rates (Figure 1). For some treatments, fluctuations in STK were quite large but were not statistically significant because of variability between replicates.

Spring STK levels were found to be significantly greater (*P*<0.05) than fall STK levels at Hancock for the 0 and high K rates in silage harvested plots and for the high K rate grain harvested plots. From 2006 to 2007 potassium soil test levels increased 18, 14, and 20 mg kg^{-1} and in 2007-2008 potassium soil test levels increased 8, 22, and 20 mg kg^{-1} for the silage harvested 0 K rate, silage harvested high K rate, and grain harvested high K rate, respectively. This amounts to a 20-45% increase in soil test K levels from fall to spring. Spring soil test K levels were significantly (*P*<0.05; -29 mg kg^{-1}) less than fall soil test K levels at Arlington in 2006-2007 and were significantly (*P*<0.05; 10 mg kg^{-1}) greater than fall STK at Lancaster in 2007-2008 for the high K rate in silage harvested plots. Soil test potassium levels were not significantly different between fall and spring for the other locations and treatments.

Effect of drying method on STK

Drying method had more of an effect on Bray-1 STK than ammonium acetate STK (Table 2). With the exception of Hancock, moist Bray-1 STK was found to be significantly less than air and oven-dried Bray-1 STK. Fond du Lac was the only location in which oven drying significantly increased Bray-1 STK relative to air drying. Moist ammonium acetate STK was significantly less for Lancaster and Fond du Lac compared to air and oven-dried ammonium acetate STK. Marshfield, on the other hand, had significantly greater moist ammonium acetate STK compared to oven-dried ammonium acetate STK, as well as significantly greater air-dried ammonium acetate STK compared to oven-dried ammonium acetate STK. Drying method did not significantly affect ammonium acetate STK levels at Arlington or Hancock. The non significance of drying method for either STK extraction at Hancock is attributed to the relatively low clay content and relatively low soil test K levels.

Relationships between Bray-1 STK and ammonium acetate STK

Air-dried and oven-dried soil samples were not found to have significantly different slopes of regression for Bray-1 STK verses ammonium acetate STK (Table 3). Leaving soil samples moist compared to air or oven-drying them did significantly change the slope of the regression line for Bray-1 STK verses ammonium acetate STK at Arlington and Hancock, but not at Lancaster, Marshfield, or Fond du Lac.

For a given drying method, Hancock and Arlington were found to have significantly different slopes of regression for Bray-1 STK verses ammonium acetate STK compared to the other locations, while Lancaster, Marshfield, and Fond du Lac were not found to have different slopes of regression. For air and oven- dried soil samples, Arlington was not found to have a different regression slope than Fond du Lac.

Conclusions

When interpreting the results of soil tests, it is important to consider that time of soil sampling may impact STK levels. The lack of a simple relationship between STK levels and time make it difficult to generalize or predict how STK levels may change in a given year, at a given location. Increases in soil test potassium levels from fall to spring were observed consistently at Hancock but changes in STK between fall and spring were only observed intermittently at other locations, if present at all. Future work will evaluate whether fluctuations in STK levels can be linked to changes in weather patterns.

The results of this study indicate that the Bray-1 extractant is more sensitive to drying method than the ammonium acetate extractant. At most locations, air-drying did not significantly change Bray-1 STK levels compared to oven-drying, but leaving soils moist was found to significantly decrease Bray-1 STK levels compared to air or oven-drying them. Further, the relationship between Bray-1 STK and ammonium acetate STK varied depending on drying method and location.

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Table 1. Selected characteristics of soils and field sites.

		Initial Soil Test Values†					N rate	
Location	Soil name	K	P	pH	OM	2005 crop	2006	2008
		--mg kg^{-1}--			-%-		---kg ha^{-1}---	
Arlington	Plano silt loam	123	33	6.7	4.0	Soybean	135	179
Hancock‡	Plainfield sand	40	97	6.6	0.8	New seeding red clover	224	241
Lancaster	Fayette silt loam	70	12	6.9	2.7	August alfalfa after oats	179	179
Marshfield	Withee silt loam	111	32	7.1	3.4	Soybean	135	123
Fond du Lac	Kewaunee clay loam	95	17	7.6	3.2	Soybean	135	135

†Bray-1 extracted K and P. K, P, pH, and OM determined for air-dried soils sampled in the spring of 2006, 0-20cm in depth.
‡ Irrigated.

Table 2. Effect of drying method on Bray-1 and ammonium acetate K concentrations at each location averaged over all K application rates and sampling dates

Comparison	Location	Difference in STK between drying methods	
		Bray-1	Ammonium acetate
		——— mg kg^{-1} ———	
Air-dried – moist	Arlington	17.6*	-4.4
	Hancock	-2.3	3.9
	Lancaster	11.8*	8.7*
	Marshfield	12.7*	-7.1
	Fond du Lac	19.1*	20.2*
Moist – oven-dried	Arlington	-15.7*	5.9
	Hancock	-1.0	-4.6
	Lancaster	-12.2*	-9.1*
	Marshfield	-14.5*	20.2*
	Fond du Lac	-24.9*	-25.3*
Air-dried – oven-dried	Arlington	1.9	1.5
	Hancock	-3.3	-0.7
	Lancaster	-0.4	-0.4
	Marshfield	-1.8	13.1*
	Fond du Lac	-5.8*	-5.0

* indicates significantly different (*P*<0.05)

Table 3. Linear regression relationship between Bray-1 STK (x) verses ammonium acetate STK (y) for each drying method and location.

Drying method	Location	Slope	Intercept	R^2	Comparison of locations†	Comparison of drying methods‡
Moist	Arlington	1.608	-14.461	0.912	a	a
	Hancock	0.854	-2.412	0.863	c	b
	Lancaster	1.284	0.392	0.826	b	a
	Marshfield	1.360	9.011	0.796	b	a
	Fond du Lac§	1.245	15.416	0.748	b	a
Air-dried	Arlington	1.446	-3.695	0.839	a	b
	Hancock	1.000	-2.995	0.944	c	a
	Lancaster	1.191	6.193	0.890	b	a
	Marshfield	1.280	14.605	0.775	b	a
	Fond du Lac	1.336	2.506	0.564	ab	a
Oven-dried	Arlington	1.399	0.023	0.833	a	b
	Hancock	0.947	-5.460	0.952	c	a
	Lancaster	1.259	-0.082	0.866	b	a
	Marshfield	1.294	-1.227	0.838	b	a
	Fond du Lac	1.238	16.132	0.551	ab	a

† Locations within a drying method with the same letter are not significantly (P<0.05) different.
‡ Drying methods at a given location with the same letter are not significantly (P<0.05) different.
§ At Fond du Lac n=336 compared to n=588 at the other locations.

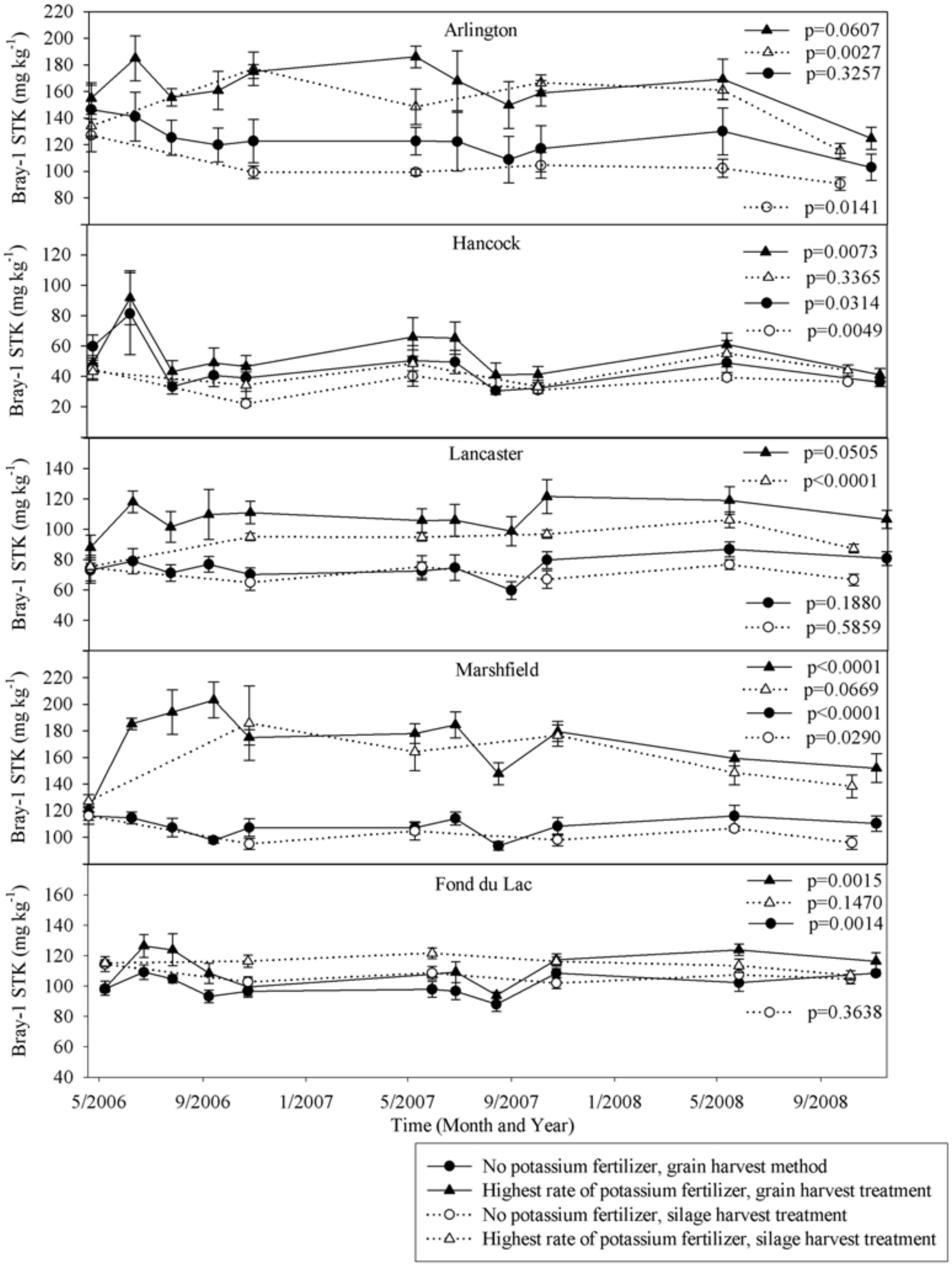

Figure 1. 2006-2008 oven-dried Bray-1 soil test potassium (STK) levels for fertilized (450 kg K_2O /ha at all locations except Fond du Lac, which had 225 kg K_2O /ha) and unfertilized plots harvested as grain or silage at 5 Wisconsin locations. P-values are given for the effect of time on Bray-1 STK.

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Program Chair:

John Lamb
University of Minnesota
St. Paul, MN 55108
(612) 625-1772
JohnLamb@umn.ed

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