TOPSOIL THICKNESS INFLUENCE ON PHOSPHORUS AND POTASSIUM AVAILABILITY AND CROP RESPONSE

R. E. Spautz and N. R. Kitchen[1]

INTRODUCTION

Soil testing to estimate nutrient availability and fertilizer needs is a widespread management practice for cropping systems in the United States, as well as in other countries. The purpose of soil testing is to simulate the ability of the plant roots to uptake these various nutrients critical for normal growth. Crops generally uptake a small amount of phosphorus (P) compared to potassium (K). The portion of soil P that is readily available for plant growth maybe limiting due to the small quantities of P in soil and its tendency to complex with soil components such as iron and aluminum oxides to form insoluble compounds. As pointed out by Bray (1961) for the law of limiting nutrient, an amount of nitrogen (N) (a mobile nutrient) can be adequate for only one yield of a given size and composition, while a given amount of P and K (relatively immobile nutrients) can be sufficient for widely varying yields. The dilemma then is understanding plant growth and yield potential as mediated by availability of two nutrients (P and K).

Plant roots explore for exchangeable K and adsorbed P; thus, reduction of topsoil thickness (topsoil thickness defined here as the depth from the surface to the top of the Bt horizon) generally reduces the volume of fertile soil for root growth, total K and P supply, and storage of plant available water (Frye et al. 1982). Engelstad et al. (1961) examined the effect of topsoil thickness to determine if N could substitute for topsoil on Marshall silt loam soils in Iowa where positive correlation between topsoil thickness and yield was found. They conclude that climatic factors (rainfall) influenced the degree of substitution more than N. More recently researchers Mielke & Schepers, (1986); Thompson et al.(1991) have reported that the effect of topsoil scalping and added fertilizer on crop growth is reduction in topsoil thickness reduced yields, and that once gone, cannot be replaced by fertilizers.

Soil sampling depth for routine nutrient availability assessment is most often prescribed for the plow layer (0 to 15.0 cm (0-6 in.) or 0 to 20 cm (0-8 in.)) for cropping systems using some type of tillage (James & Wells, 1990). As pointed out by Randall (1980) concentrations of available P and K are more uniform throughout the plow layer with conventional tillage compared to conservation tillage methods of chisel, disk only, or no-till. Thus, for routine sampling for conventional tilled soils the plow layer sample depth is considered satisfactory for determining

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[1] Randall E. Spautz is Graduate Research Assistant, Dept. of Soil and Atmospheric Sciences: University of Missouri-Columbia, MO; Newell R. Kitchen is Soil Scientist, Cropping Systems and Water Quality Research Unit, USDA-Agriculture Research Service, Columbia, MO 65211.

the level of soil acidity and immobile nutrients. While not universally encouraged, a prevailing thought in sampling conservation-till or no-till fields is to sample at a shallower depth than the for conventional tillage to monitor the surface acidity and buildup of immobile nutrients.

A premise of precision farming variable-rate fertilizer applications in cropping systems is there exists spatial variability in soil nutrient supply to crop plants. This premise is currently extended only in practice to various locations within a field (e.g. as measured with grid soil sampling). Variability in nutrient quality may also be significant when considering the variation in root zone across the landscape as opposed to relying only on the surface 6 inches. The research question we're addressing is can a more accurate prediction of P and K availability be made by considering topsoil thickness. Topsoil thickness could especially be helpful in fertility recommendations for soils highly variable in topsoil thickness parameter (e.g. claypan soils in Missouri range from a few inches to over 4 ft.).

OBJECTIVES

The overall objective of this research was to investigate the relationship of topsoil thickness and soil nutrient availability for the Mexico-Putman association soils of Central Missouri. Specifically the objectives were to: (1) determine and/or evaluate the relationship between topsoil depth and soil test P and K nutrient availability for the Mexico-Putman association of claypan soils, and (2) determine the responsiveness of crops to added P and K fertilizer as affected by topsoil thickness and surface nutrient availability. Only objective 1 is reported in this paper.

MATERIALS AND METHODS

Soil samples were taken from 80 sites within 16 fields on Mexico-Putman soil association fields located in Central Missouri. Mexico-Putman soils were formed in loess over Kansan glacial till. These soils are somewhat poorly drained and clay content, bulk density, and acidity increases with depth. Each soil sample (field site) consisted of four core subsamples that were taken within a 3.0 m diameter. Depth of each core sub samples was taken at six segments: (0 to 15 cm.). (15 to 30 cm.). (30 to 45 cm.). (45 to 60 cm.), (60 to 76 cm.), and (76 to 90 cm.). The thickness of topsoil was measured for each site using the four core sub samples and averaged.

After collection. each representative soil sample was air dried, crushed to pass a screen (2.0 mm), and analyzed for available P and K. Available P was analyzed using the Bray P1 method. Available K was analyzed using the method 1.0 N ammonium acetate extraction described by the University of Missouri Soil testing lab (Brown & Rodiques, 1983). Analysis of variance and regression statistics were computed using the SAS statistical package (SAS. 1991).

Statistical Analysis

Analysis of variance and regression analysis was performed to test significance ($P < 0.10$) of topsoil thickness and sample depth effects for the following hypotheses:

H1: Available P and K in 0 to 15, 15 to 30, 30 to 45, 45 to 60, 60 to 76, and 76 to 90 cm. samples is a function of topsoil thickness.

H2: Available P and K in the 0 to 90 cm. depth is a function of topsoil thickness.

Multiple regression procedure using topsoil thickness and sample depth for testing H1 and topsoil thickness for H2. Only significant regression parameters (F-test $P< 0.10$) were included in the final regression equations. The following regression model was used for H1:

$$Y = B_0 + (\Delta B_1\, DTC) + (\Delta B_2\, DTC^2) + (\Delta B_1\, D) + (\Delta B_2 D) + (\Delta B_1\, DTC * D) + (\Delta B_2\, DTC^2 * D) + (\Delta B_2\, D^2 * DTC) + (\Delta B_2\, DTC^2 * D^2).$$

Y = expected value of Y due to the independent factors,
B_0 = Y axis intercept without DTC and D,
$\Delta B_{(1\,\&\,2)}$ = linear and quadratic slope correction coefficients.
DTC = topsoil thickness.
D = sampling depth.

RESULTS AND DISCUSSION

Relationship of P and K Availability to Topsoil Thickness and Sampling Depth

Regression equations for available P and K are listed in Table 1. Regression models were developed [Eq. 1 & 2] to show the distribution of available P and K with sampling depth and topsoil thickness. While topsoil thickness and sampling depth parameters were significant in explaining P and K variability, model R^2 values were still relatively low. Graphical representation of the equation 1 (Fig.1) shows that the availability of P decreases slightly at sampling depth 1 to 3 and increases slightly from 3 to 6 sampling depths. This trend is prevalent with an increase in topsoil thickness. The model shows an increase in available P with an increase in topsoil thickness for all sampling depths.

Regression model [Eq. 2] shows the distribution of available K with sampling depth and topsoil thickness. Figure 2 shows a decrease in available K with an increase in depth of sampling and topsoil thickness. These results indicate that the amount and type of clay may attribute to the availability of K in the soil. Thompson et. al. (1992) found the clay content decreased as topsoil thickness increased in Mexico soils. Average clay content of the upper 100 mm of soil was 38, 25, 22 and 19% for topsoil thickness of 0, 125, 250, and 374 mm, respectively. The principal clay minerals in the clay pan soil are of the 2:1 montmorillonitic group, which is characterized by an expanding crystal lattice. Soil K can easily become temporally or permanently fixed within the matrix of the lattice through hydration and dehydration transformations.

Table 1. Regression models and statistical significance (DTC = depth to claypan or topsoil thickness: D = sampling depth).

H1

[1] $$\begin{aligned} \text{P kg/ha} = {} & 50.331 - (0.3726\ \text{DTC})^{*} + (0.0156\ \text{DTC}^{2})^{***} \\ & - (21.711\ \text{D})^{***} + (3.760\ \text{D}^{2})^{***} - (0.0893\ \text{DTC D})^{***} \\ & - (0.0021\ \text{DTC}^{2}\ \text{D})^{**} \end{aligned} \qquad R^2 = 0.397$$

[2] $$\begin{aligned} \text{K kg/ha} = {} & 437.85 + (0.5598\ \text{DTC})^{***} - (0.0252\ \text{DTC}^{2})^{**} \\ & - (93.527\ \text{D})^{***} + (10.026\ \text{D}^{2})^{***} + (0.00037\ \text{DTC D}^{2})^{*} \end{aligned} \qquad R^2 = 0.177$$

H2

[3] $$\text{P kg/ha/90cm} = 103.93 + (0.0089\ \text{DTC}^{2})^{**} \qquad R^2 = 0.044$$

[4] $$\begin{aligned} \text{K kg/ha/90 cm} = {} & 1347.232 - (3.843\ \text{DTC})^{***} \\ & - (0.0193\ \text{DTC}^{2})^{*} + (1417.721\ \text{Group})^{**} \end{aligned} \qquad R^2 = 0.631$$

*** significant F-test at $P < 0.001$. ** significant F-test at $P < 0.05$.
* significant F-test at $P < 0.10$.

Total Root Zone P and K Availability to Topsoil Thickness

Regression equations for total available P and K are listed in Table 1. Equation 3 (with very low R^2) is represented in Fig. 3. This figure illustrates that total available soil P increases slightly as topsoil thickness increases.

Equation 4 is represented in Fig. 4. These curves show a significant but slight decrease in total available K with an increase in topsoil thickness. Also, total available K was expressed as having a significant grouping effect where fields 5, 6, and 7 were significantly different ($P < 0.01$) than the other fields. Fields 5, 6, and 7 were adjacent to each other. Results may indicate that the mineralogy of the parent material in this group exhibit relatively higher levels of K.

CONCLUSION

The relationship between available soil P and K. topsoil depth. and sampling depth were examined on Mexico-Putman association soils. While topsoil thickness was significant in explaining some of the variability in P and K availability. total variability among fields was high thereby questioning whether the topsoil thickness measurement can improve prediction of the P and K nutrient pool.

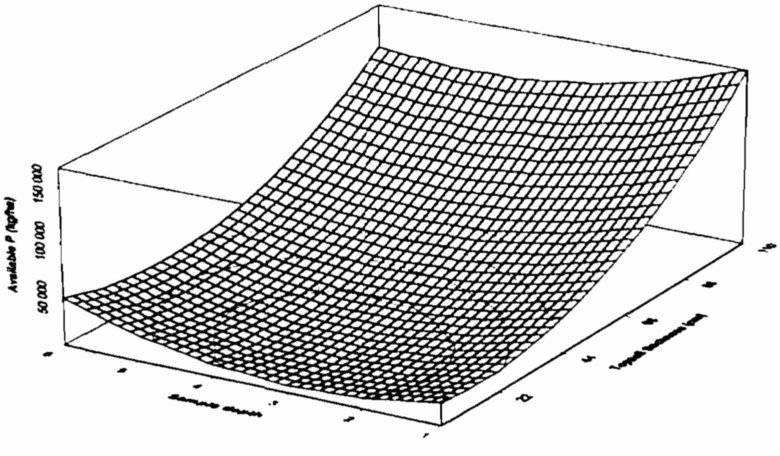

Figure 1. Regression model for available P (kg/ha) distribution with topsoil thickness (cm) and sampling depth class taken at 15 cm. segments on claypan soils.

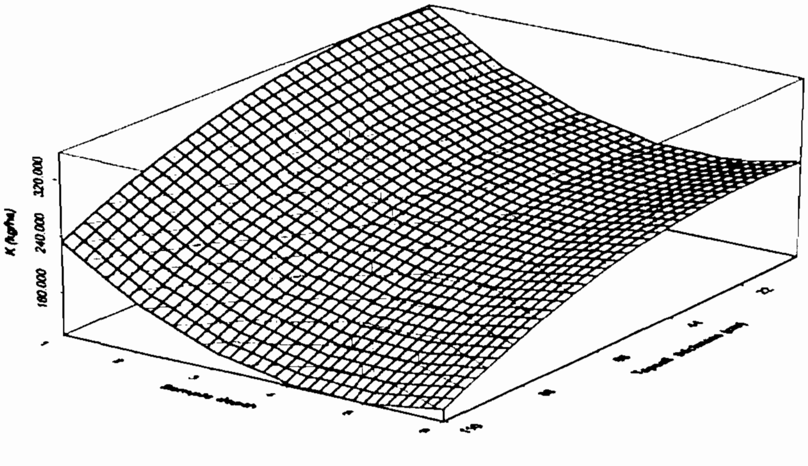

Figure 2. Regression model for available K (kg/ha) distribution with topsoil thickness (cm) and sample depth class taken at 15 cm. segments on claypan soils.

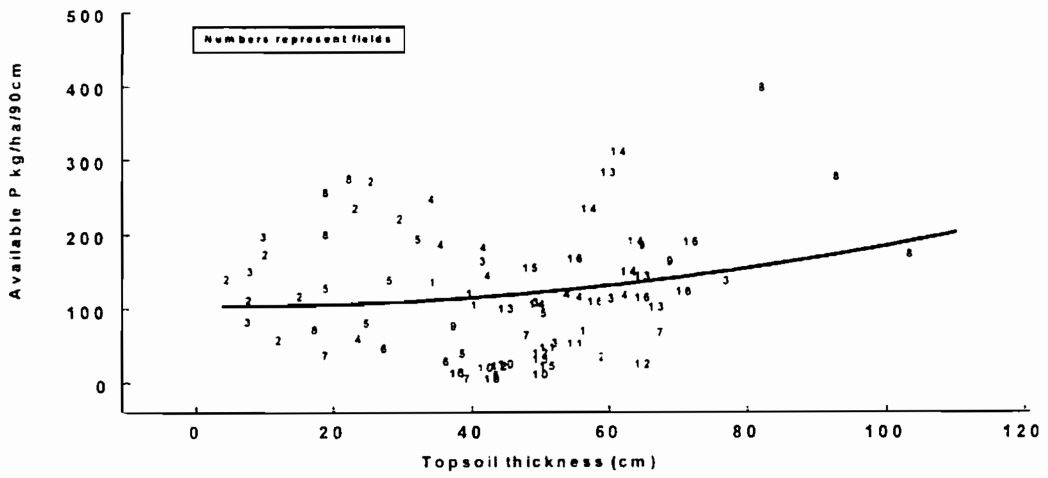

Figure 3. Distribution of total available P (kg/ha) with topsoil thickness (cm) on claypan soils for 16 fields.

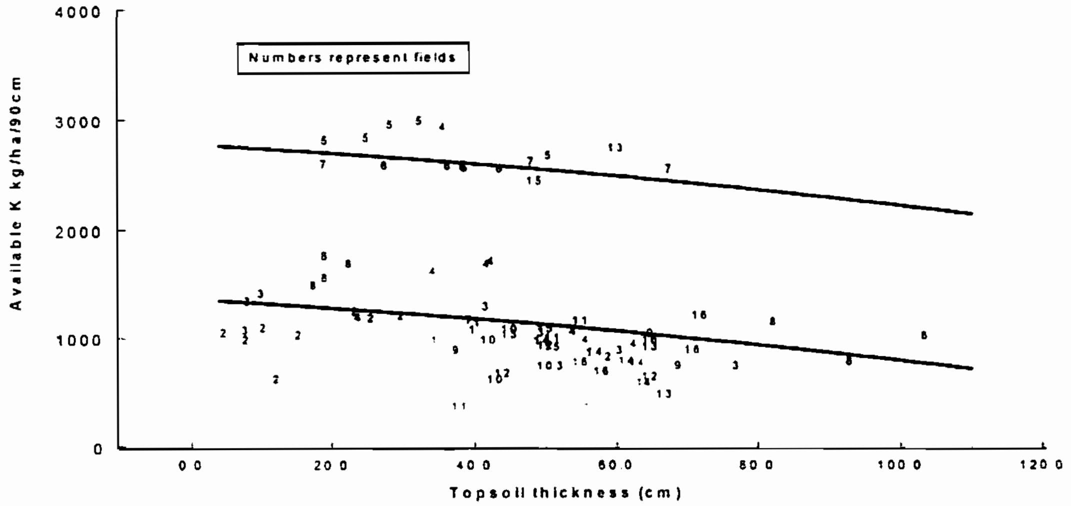

Figure 4. Distribution of total available K (kg/ha) with topsoil thickness (cm) on claypan soils for 16 fields.

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Dr. Gary Hergert
University of Nebraska-Lincoln
Institute of Agriculture and Natural Resources
West Central Research & Extension Center
Route 4, Box 46A
North Platte, NE 69101