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SPATIAL VARIABILITY OF PLANT ANALYSIS PHOSPHORUS LEVELS

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ABSTRACT: Plant samples were taken from a corn field at an early and later sampling dates in an 82.5 ft. grid. The samples were analyzed for phosphorus (P) using both an acid-digest method and a simple acetic-acid extraction. Values for P composition were compared to soil Bray PI levels taken from the same locations. Mapping from the plant analysis methods and soil PI values were compared. Acid-digest P levels were significantly correlated with soil P levels at each sampling. Acetic acid extracts were significantly correlated with soil P only at the late sampling. Acetic acid and acid-digest P were strongly correlated with each other at the early sampling and also significantly correlated at the late sampling. Plant analysis using both methods may be useful in mapping relative P uptake levels throughout a field, but the levels may or may not be related to soil PI levels. Some ground truthing with soil sampling may be neccessary to interpret plant analysis P before fertilizer application is directed.

INTRODUCTION

Many studies concerning the spatial distribution of plant available nutrients have used soil testing as the basis for mapping. (Beckett, 1971; Dow and James, 1973; Assmus, et al., 1985; Warrick, et al., 1986; Miller et al., 1988). Far more soil samples are taken by growers and industry than plant samples (Jones, 1985). Soil

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samples can be taken at nearly every time of year, while plant samples can only be taken during crop growth. Plant samples are often calibrated to specific stages of crop growth, making timing critical (Jones and Case, 1990).

Soil sampling has an advantage of convenience and mobility over plant sampling, since soil samples can be taken using a vehicle when the crop is short in height or before and after harvest. A vehicle can be used early in the growing season for plant sampling, but later in the growing season the plant sampler often must walk. Walking can make plant sample collection slow, tedious and expensive. Plant sample preparation in the laboratory traditionally reguires strong acids to degrade plant tissue and free elements for analysis. Most soil testing procedures require less caustic extractants, making soil testing somewhat safer for technicians and less expensive to perform.

Plant analysis has two advantages over soil testing. First, plant analysis is more universal across geographic regions. Many crops have critical plant nutrient levels established from which the recommendations made are valid for wide areas (Jones and Case, 1990) while soil testing procedures and recommendations are more regionalized (Fixen and Grove, 1990). Secondly, whereas a crop fertilizer response based on soil testing results may be misleading because of soil nutrient interactions, soil physical factors and environmental factors (Allan et al., 1993; Coos et al., 1993), plant analysis results reflect effective availability and nutrient uptake by the crop (Munson and Nelson, 1990).

There is little information concerning using plant analysis as a basis for making site-specific decisions. The objective of this study was to determine how well plant analysis of P levels agreed with soil test P levels and how well field maps prepared with the plant analysis correlate to fertility parameters developed with soil test mapping. A rapid method of plant P extraction and detection was tested which did not use a strong acid digest and could easily and cheaply be performed by many soil testing laboratories.

MATERIALS AND METHODS

A 40 acre field was sampled each year from 1990-1992 for both soil and plant chemical properties in an 82.5 ft. grid. The field is located northwest of Thomasboro, IL and has been described by Peck, 1991 in great detail. The major soil types within the field are Drummer silty clay loam (fine-silty, mixed, mesic Typic Haplaguolls) and Harpster silty clay loam (Fine-silty mesic Typic

Calciaguolls). A map of the soil types within the Thomasboro tract is shown in Figure 1.

Soil samples were taken in the fall of each year from 1990-1992. Five 7 inch deep soil cores were collected from each sampling site with one core in the center of each plot and the other four cores taken from the corners of a 16-foot square surrounding the central core. The five cores were placed in a common bag, dried at 36°C, pulverized, and analyzed for Bray PI (Knudsen and Beegle, 1988). The field was planted to corn each year.

Each year, two plant samplings were taken. The first was obtained when the corn was in the five-leaf stage. Plants were removed at the soil level, being careful not to contaminate the plants with soil. Ten plants were taken for each sample. The second sampling was done when most of the field was in the early tassle stage. The leaves below and opposite the ear of ten corn plants were removed with a sharp knife. All samples were dried in a forced air oven at 80°C, ground to pass a 60-mesh screen, and stored in polyethylene bags.

The plant samples were digested using a CEM microwave oven. From 0.2 to 0.5 g. of plant tissue were weighed and placed in a microwave bomb. Ten mL of concentrated nitric acid was added to the bomb under a hood and allowed to stand for 10 minutes. Five mL of concentrated HCl was then added to the bomb which was then capped and torgue sealed to manufacturers specifications. The microwave was then programmed to high output for 6 minutes, followed by 12 minutes at low output. The bombs were allowed to cool and the resulting clear solution decanted into nalgene storage bottles. The digest was then analyzed by indictively coupled plasma emission spectrometry (ICP) for P.

In 1990, a quick method was used to analyze for relative plant P (Rauen et al., 1987). Using 100-mL polyethylene bottles with screw caps as extracting vessels, 0.1 g. of ground plant tissue was placed in the bottle. Fifty mL of 2% v/v acetic acid was added to the bottle and shaken at 80 cycles per minute for 5 minutes. The extract was filtered through Whatman Number 2 filter paper. The P was analyzed using PB and PC solution as in a Bray PI test, and then color read on the photometer at 660 nm.

Data from soil and plant analysis was analyzed for geostatistical relationships using GS+ software program (Gamma Design Software, Plainwell, MI). Mapping was performed with the program Surfer (Golden Software, Inc., Golden, CO). The maps were constructed by first using the inverse distance squared method to

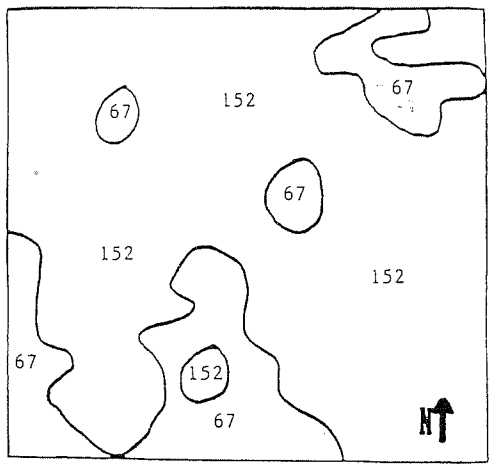

FIGURE 1. Thomasboro soil type map (67 = Harpster silty clay loam; 152 = Flanagan silt loam).

estimate values at unsampled locations, then contouring the field to illustrate areas of like plant concentration ranges. Inverse distance has been shown to be a valid method to estimate unsampled values within a regularly spaced grid (Isaaks and Sristava, 1989; Wollenhaupt et al., 1994).

RESULTS AND DISCUSSION

A summary of statistics for soil and the acid-digest plant analysis from 1990-1992 is shown in Table 1. The data from each sampling was also subjected to geostatistical analysis to determine whether samplings were spatially variable. The spatial statistics from each sampling are shown in Table 2. A variogram model can be fit to each set of data and is highly correlated to the data, which confirms that each sampling is spatially variable. The high value of the nugget in relation to the sill with the late sampling using the acid-digest shows that a large portion of the variability within the field at that late sampling date is not described by the model.

The 1990 Thomasboro soil P map is shown in Figure 2. The major features of the soil P map are a low P area in the south central area, low P areas in the north-

TABLE 1. Means and standard deviations of Thomasboro 1990-1992 acid-digest plant analysis and soil P levels.

Data	1990 Mean	1990 St.Dev.	1991 Mean	1991 St.Dev.	1992 Mean	1992 St.Dev.
Soil P, lbs/A.	56	29.4	54	29.3	57	33
5th Leaf P %	0.54	0.09	0.49	0.07	0.39	0.06
Ear Leaf P %	0.34	0.03	0.25	0.03	0.24	0.03

TABLE 2. Geostatistical summary of acid-digest and acetic acid plant analysis data.

Data	Kurtosis	Skewness	Transform	Model	r^2	Nugget	Sill	Nugget % of sill
Early sampled, acid-digest	2.593	-0.368	None	Spherical	0.550	0.0013	0.0092	14.1
Late sampled, acid-digest	3.849	0.267	None	Spherical	0.811	0.00052	0.00105	49.5
Early sampled, acetic acid	2.388	-0.353	None	Exponential	0.998	0.00145	0.00523	27.7
Late sampled, acetic acid	3.161	-0.082	Log	Spherical	0.762	0.0134	0.0362	36.2

west and east, and high P levels in the southeast, northeast and western portions of the field. Only mapping from the 1990 data set are shown in this paper. For the mapping from 1991 and 1992 data sets, see Franzen, 1993. Since fertilizer P was not applied in any year of this study, P levels changed little between 1990 and 1992 and patterns of P levels within the field were also similar from year to year from both soil P and plant P mapping.

In Figure 3, the 1990 acid-digested early sampled P concentration map shows lower P levels in the northwest, and a low P area stretching from the south boundary north to the central region. Correlations of early sampled acid-digest plant P with soil P from 1990-1992 are significant (Table 3). Late sampled 1990 acid-digested plant P in Figure 4 shows the low P area in the northwest and high P in the

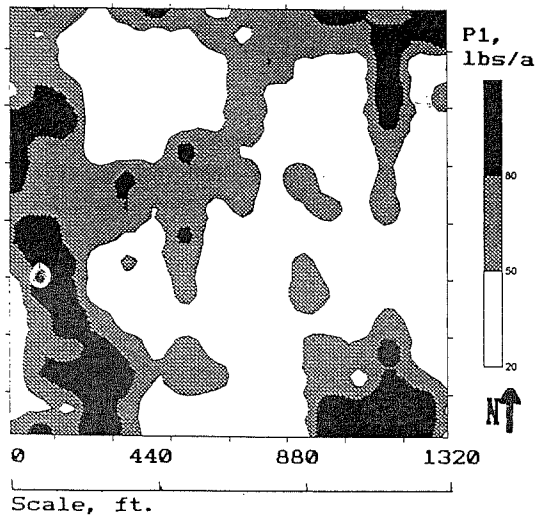

FIGURE 2. Soil P levels, 1990.

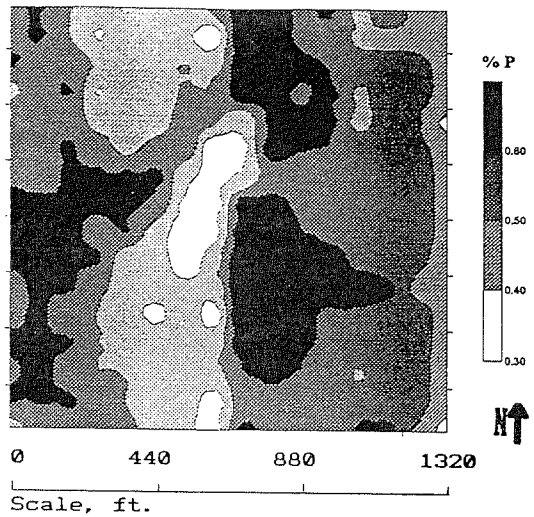

FIGURE 3. Early sampled 1990 plant P levels, acid digest.

TABLE 3. Correlations (r) between soil and plant analysis P levels, Thomasboro, 1990-1992.

Comparisons	1990	1991	1992
Soil P with early sampled P	0.210*	0.145*	0.202*
Soil P with late sampled P	0.362*	0.382*	0.409*
Early sampled P with late sampled P	0.072	0.255*	0.379*

Significant at the 5% probability level.

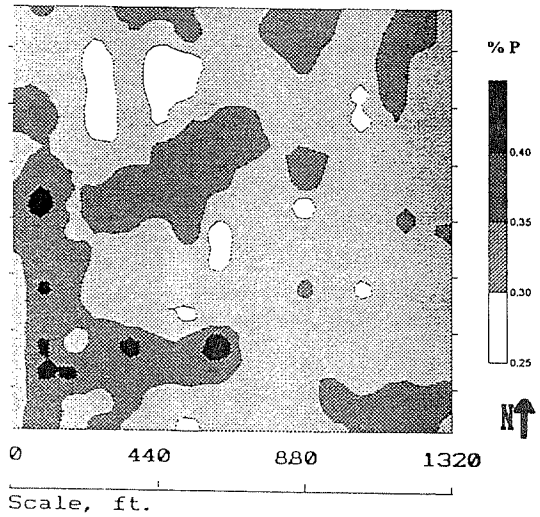

FIGURE 4. Late sampled 1990 plant P levels, acid digest.

southwest. Soil P was more strongly correlated with late sampled plant P than early sampled P from 1990-1992 (Table 3). The early sampled P was not significantly correlated with late sampled plant P in 1990, but was correlated in 1991 and 1992.

Although acid digestion with ICP plant tissue analysis from 1990 through 1992 was correlated with soil test P, the procedure is relatively expensive to use for analysis of the large numbers of grid samples needed to represent fertility levels within a field. The equipment and procedure is not practical for many smaller laboratories across Illinois and other states. Many laboratories, however, have photometers which could be used with the acetic acid extraction for P as previously described.

In 1990, acetic acid extraction was performed on both plant samplings. Correlations between the acid digest and acetic acid extraction derived P in 1990 are shown in Table 4. Figure 5 displays early sampled P concentrations from acetic acid extraction. There is an area of low P area in the northwest, south and eastern regions of the field. The late sampled P extracted using acetic acid (Figure 6) shows low P areas in the northwest, east and south portions of the field, similar to areas shown in the acid-digest analysis map.

Early sampled P from the acetic acid extraction was not significantly correlated with soil P, however, early P from acetic acid extracts were correlated with the early sampled plant P from the acid-digest and ICP analysis. Late sampled P from the acetic acid extracts was significantly correlated with both soil P and late sampled acid-digest and ICP analysis.

CONCLUSION

Plant samples were taken in an 82.5 ft. grid from two growth stages of corn in a forty-acre field for each of three years and analyzed by using an acid digest and ICP detection and/or a simple weak acid extraction. All samplings were found to be spatially variable. Plant analysis P was correlated with soil P levels in all six comparisons using acid-digest and one of two comparisons using the weak acid extraction technique. A P analysis map from acid digests of plant samples and from the acetic acid extract ions contained many of the same high and low P level features as the soil P map.

Acetic acid plant-P extraction was compared to acid digest and ICP-P analysis. The acetic acid extraction was significantly correlated to acid-digest P levels in three out of four comparisons. The early sampled acetic acid and acid-digest procedures

TABLE 4. Correlation of plant P levels using acetic acid extraction compared with strong acid digest, 1990.

Comparison	r^2
Soil P with early sampled acetic acid P	0.104
Soil P with late sampled acetic acid P	0.298*
Early sampled acetic acid P early sampled acid digest P	0.863*
Late sampled acetic acid P with late sampled acid digest P	0.336*
Early sampled acetic acid P late sampled acetic acid P	0.127

*Significant at the 5% probability level.

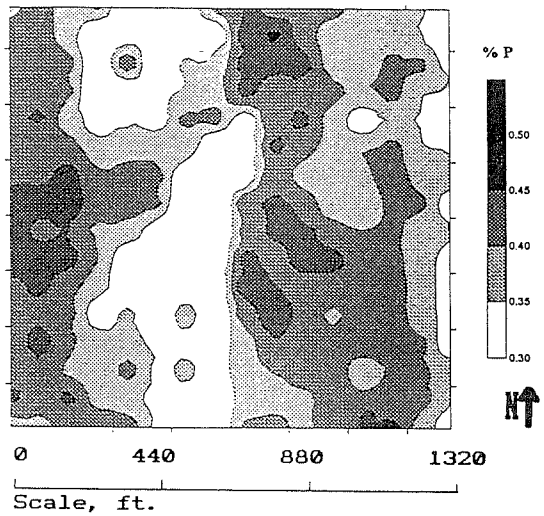

FIGURE 5. Early sampled 1990 plant P levels, acetic acid extraction.

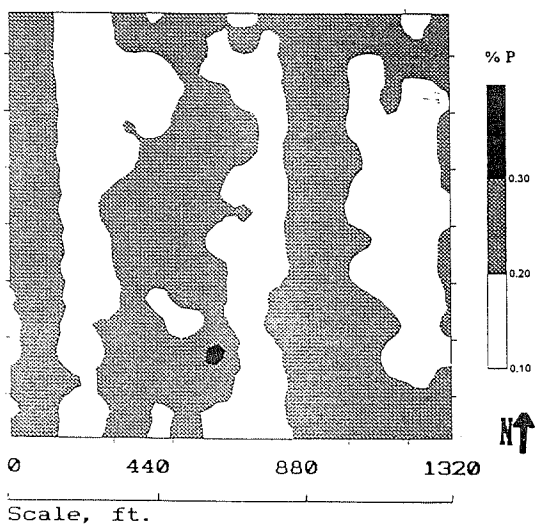

FIGURE 6. Late sampled 1990 plant P levels, acetic acid extraction.

were much more highly correlated than the later plant sampling. This may be because of the greater concentration of P as free orthophosphate at early crop growth than later in the growing season (Rauen et al., 1987).

Looking toward the future, although soil testing is still the preferred manner for determining the fertility status of Illinois farms, there may come a time when plant analysis is also used. Fertility trials in certain cultural systems such as ridge-tillage find that soil testing does not always predict crop uptake. Perhaps plant analysis would be a better indicator. Acetic acid plant tissue extraction can successfully identify high or low P levels in a field. Sampling could possibly be accomplished during a field operation such as a herbicide application or cultivation. Timing of sampling may be less of a concern if sufficiency levels were available for several more growth stages.

This study shows that plant analysis, using both a traditional digest and a rapid extraction method, can map similar P features as soil test maps for P. If plant samples are taken in a grid comparable to soil samples, to give a basis for a geo-

statistical analysis, plant analysis for P, using either of the two methods discussed, should define areas which describe relative levels of fertility in a field. Some soil sampling will be neccessary, however, before plant analysis of P levels is used to direct variable-rate fertilization.

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