P and K Fixation by Missouri Soils: Final Report

Peter Scharf, Randy Miles, and Manjula Nathan
Division of Plant Sciences and Dept. of Soil, Environmental, and Atmospheric Sciences, University of Missouri

Objectives:

- Evaluate whether P and K fixation differ widely between Missouri soils.
- If differences are found, determine whether these differences can be predicted by soil region and by easily measured chemical properties of soils.
- Consider whether the buildup component of University of Missouri fertilizer recommendations should be modified to account for differences between soils.
    - Currently, one buildup equation is applied to all Missouri soils, even though soil properties are known to vary widely in Missouri.

Procedures:

- Forty-two Missouri soils were collected for this study, representing many major agricultural soil types (see map and table).
- Laboratory incubations of these soils with and without fertilizer were carried out to see how much soils differed in the size of the soil test increase from fertilization.
    - Each soil received three treatments:
        - P fertilizer added (215 lb P_2O_5/acre)
        - K fertilizer added (300 lb K_2O/acre)
        - no fertilizer added
    - All soils were incubated moist (water was added periodically to maintain soil moisture at field capacity) in the laboratory for three months, then they were sampled and dried.
- Increase in soil test P and soil test K was calculated for all soils as the (soil test with P or K addition) minus the (soil test with no fertilizer added).
- Analysis of covariance was used to determine whether soil region or soil properties consistently affect the size of the soil test increase.
    - Soil regions used were Bootheel, Claypan, Loess & Drift, Osage Plains, Ozarks, and River Bottom.
    - Soil properties measured and related to soil test increase were:
        - initial soil test levels
        - % sand, silt, and clay
        - % organic matter
        - pH and neutralizable acidity
        - extractable iron and aluminum

Results for potassium:

- K was added to the soils at a rate equivalent to 300 lb K_2O/acre. This K rate resulted in increases in soil test K values ranging from 98 to 240 lb K/acre (Table 1). This range matches well with the current University of Missouri equation, which predicts that 300 lb K_2O/acre will raise soil test K values by about 100 lb/acre on low-testing soils and 200 lb K/acre on very high-testing soils. However, when used by itself, the initial soil test K value was a very poor predictor of how much soil test K would increase. Only when combined with the region that the soil came from and the amount of clay in the soil were predictions somewhat accurate.
- Soil test K increased less in soils with higher clay content. The clay component of the soil is responsible for the process of K fixation (tie-up in forms not available to crops).

We may need to recommend more K for soils with higher clay contents. This is partly accounted for by current University of Missouri recommendations, which recommend higher soil test K target levels for soils with higher CEC (cation exchange capacity) values, which are closely related to clay content. The end result is that more K is recommended on soils with more clay.

- The only clearly distinguishable regional effect is that soil test K increased more for Ozark soils (average increase = 182 lb K/acre) than for other Missouri soils (average increase = 151 lb/acre). Lower K rates may be appropriate during the buildup period in the Ozarks compared to other regions. We had suspected that we might get this result based on lower concentrations of 2:1 type clays (K-fixing) in Ozark soils.
- Other regions were fairly similar to each other in terms of average soil test K increase observed.
- By combining initial soil test K, clay content, and soil region, we are able to explain 56% of the variability in how much soil test K increased.

Results for phosphorus:

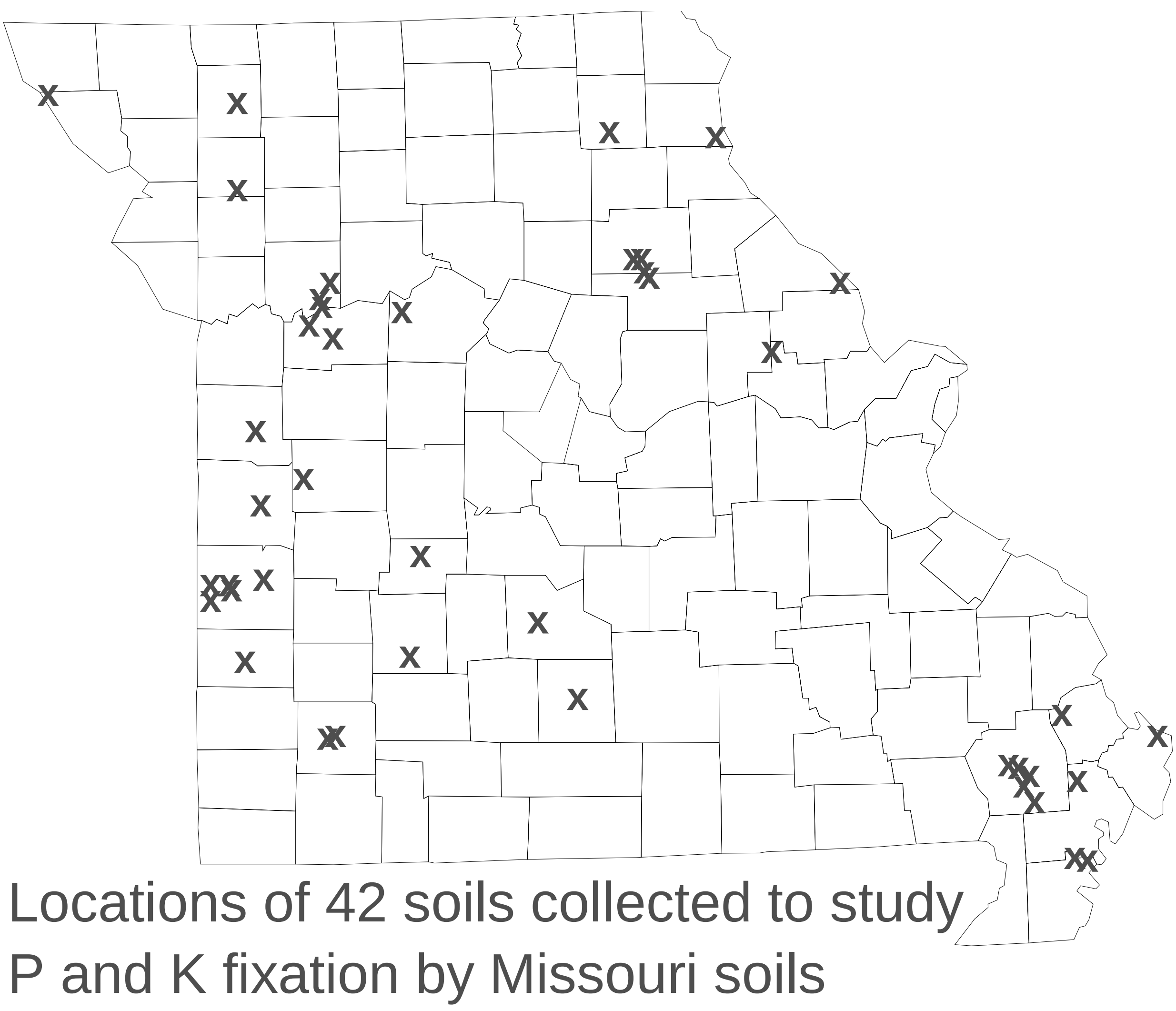
- P was added to the soils at a rate equivalent to 215 lb P_2O_5/acre. This P rate resulted in increases in soil test P values ranging from 23 to 76 lb P/acre (see table). This range is higher than the current University of Missouri equation, which predicts that 215 lb P_2O_5/acre will raise soil test P values by about 15 lb/acre on low-testing soils and 45 lb P/acre on very high-testing soils.
- We found weak support for the concept (built into current Missouri recommendations) that a given fertilizer rate gives a larger increase in soil test P on high-testing soils than on low-testing soils. When used by itself, the initial soil test P value explained only 7% of the variation in the size of the increase in soil test P.
    - Although this concept is widely believed, it should be interpreted cautiously. Several other recent studies have found that when different P rates are applied, each increase in the amount of P added gives the same increase in soil test P.
    - For soils above 40 lb P/acre soil test value in this study there was no relationship between initial test value and soil test increase.
    - For soils below 40 lb P/acre, average increase in soil test P was 80% of the increase observed in soils above 40 lb P/acre.
- The combination of initial soil test P value, the region that the soil came from, the amount of clay in the soil, and the neutralizable acidity of the soil explained 58% of the variation in the size of the increase in soil test P.
- As with K, soil test P increased less in soils with higher clay content. The clay component of the soil is responsible for the process of P fixation, which is tie-up in forms not available to crops. We may need to recommend more P for soils with higher clay contents. Currently we do not have a system in place to account for differences in soil clay content in our P recommendations.
- The most clearly distinguishable regional effect is that soil test P increased less for claypan region soils (average increase = 33 lb P/acre) than for other Missouri soils (average increase = 50 lb P/acre). This is true even after correcting for clay contents of all soils, indicating that there is some property of claypan soils in addition to high clay content that results in lower soil test P increases. Higher P rates may be appropriate for claypan soils (relative to other soil regions), at least during the buildup phase of management.
- Another likely regional effect is that soil test P increased more for Ozark soils than for

soils from other regions. When we started this experiment, we thought that the opposite might be true due to the clay minerals in these soils, which are the most highly-weathered clays found in Missouri. Highly-weathered clay minerals in tropical parts of South America are known to bind P tightly, making it unavailable to plants, but this does not appear to be true for the Ozarks.

- We also thought that Osage Plain soils might need more P for the same reason. We found weak evidence that this might be true, but the effect is small: average soil test increase for Osage Plain soils was 43 lb P/acre, and for Bootheel, Loess & Drift, and River Bottom soils combined it was 49 lb P/acre.
- Another key finding was that the more neutralizable acidity a soil has, the lower the increase in soil test P. This was expected and has been part of our Extension teaching for some time–good lime management helps applied P to be more available. For most parts of Missouri, economics probably favor good lime management rather than applying more P to compensate for inadequate liming.

Outcomes:

- We will bring up with the Soil Fertility Working Group the possibility of changing the University of Missouri K buildup equation based on our results to reflect regional differences.
- We will bring up with the Soil Fertility Working Group the possibility of changing the University of Missouri P buildup equation based on our results:
  - to reflect that the soil test P increases that we found were larger than what would be predicted by current University of Missouri buildup equations
  - to incorporate regions, soil texture, and possibly soil neutralizable acidity
- Results of this study were used in planning greenhouse experiments to understand how soil properties affect the plant’s reaction with fertilizer. Emphasis was placed on studying differences in soil regions and soil clay contents.



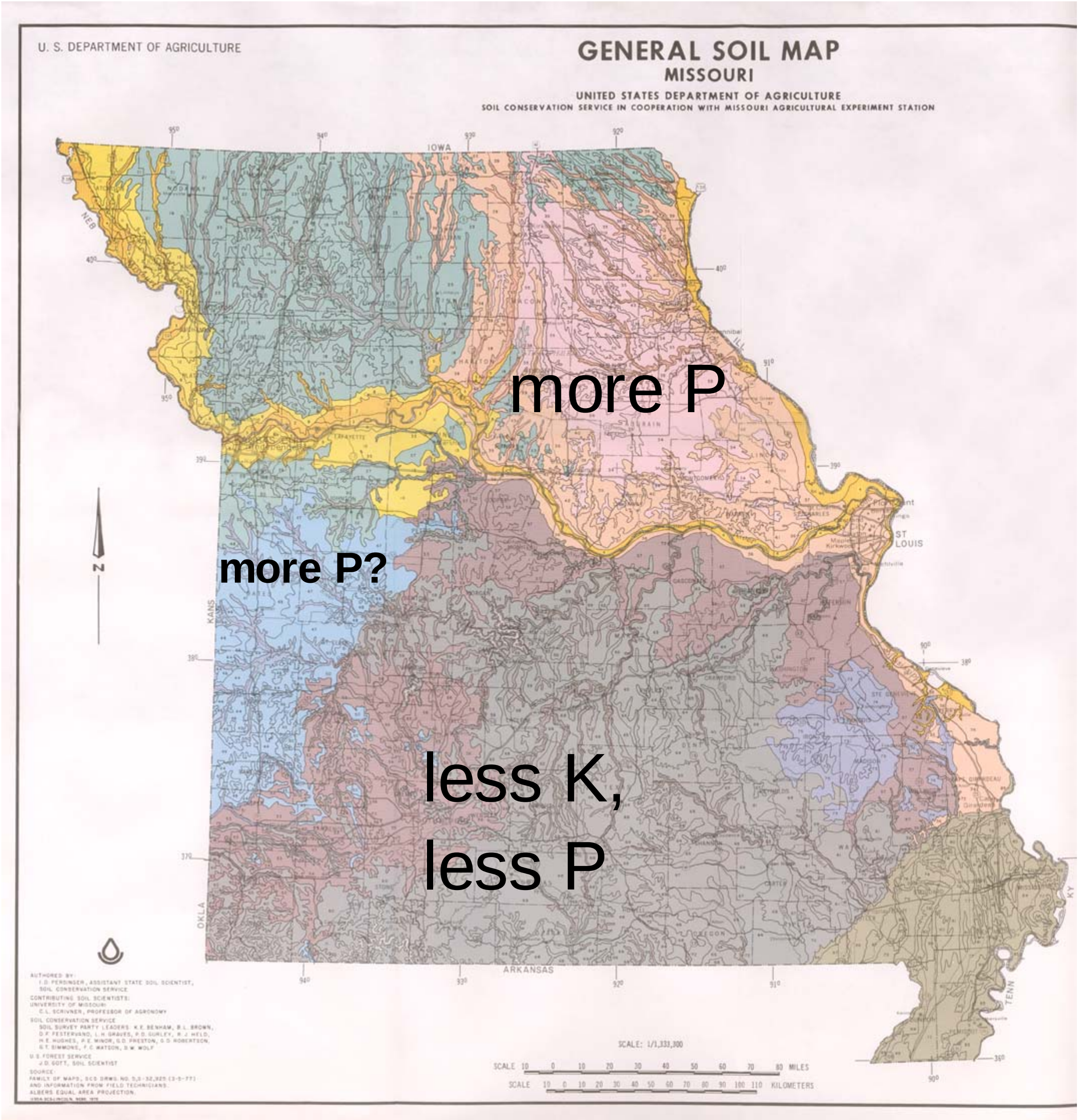
Locations of 42 soils collected to study P and K fixation by Missouri soils

Table 1. Increase in soil test K for 42 Missouri soils with K added at a rate of 300 lb K_2O/acre.

Region	Soil Type	Increase in soil test K lbs/acre
Bootheel	Commerce Silty Clay Loam	98
Claypan	Mexico Silt Loam 1	105
Loess and Drift	Lagonda Silt Loam	107
Bootheel	Portageville Clay	111
Loess and Drift	Marshall Silt Loam	115
Claypan	Putnam Silt Loam 1	117
Loess and Drift	Grundy Silt Loam 1	120
Osage	Barden Silt Loam 1	125
Osage	Barco Loam 1	126
Bootheel	Sharkey Silty Clay Loam	127
Osage	Kenoma Silt Loam	131
Bootheel	Sharkey Clay	132
Bootheel	Loring Silt Loam 1	132
Bootheel	Commerce Silty Clay Loam 1	133
Claypan	Mexico Silt Loam 2	134
Claypan	Mexico Silt Loam 3	136
Osage	Barden Silt Loam 2	139
Claypan	Putnam Silt Loam 2	140
Osage	Barden Silt Loam 3	140
Bootheel	Loring Silt Loam 2	141
Claypan	Mexico Silt Loam 4	142
Ozarks	Cedargap Cherty Silty Loam	142
River Bottom	Haynie Silt Loam	147
Osage	Barco Loam 2	148
River Bottom	Westerville Silt Loam	150
Loess and Drift	Sharpsburg Silt Loam	152
Loess and Drift	Grundy Silt Loam 2	152
Ozarks	Huntington Silt Loam	153
River Bottom	Leta Silty Clay	154
Osage	Hartwell Silt Loam	158
Bootheel	Lilbourn Sandy Loam	163
Loess and Drift	Higginsville Silt Loam	164
Osage	Osage Clay	165
Ozarks	Viraton Silt Loam	167
Osage	Parsons Silt Loam	173
Bootheel	Lilbourn Fine Sandy Loam	177
Ozarks	Goss Gravelly Silt Loam	179
Ozarks	Keeno Cherty Silt Loam	179
Ozarks	Creldon Silt Loam	198
Ozarks	Clarksville Very Cherty Silt Loam	198
Loess and Drift	Haig Silt Loam	221
Claypan	Putnam Silt Loam 3	240

Table 2. Increase in soil test P for 42 Missouri soils with P added at a rate of 215 lb P_2O_5/acre.

Region	Soil Type	Increase in soil test P lbs/acre
Bootheel	Sharkey Clay	23
Claypan	Mexico Silt Loam 3	28
Bootheel	Loring Silt Loam 2	29
Loess and Drift	Lagonda Silt Loam	30
Claypan	Putnam Silt Loam 1	31
Osage Plains	Barco Loam 2	33
Bootheel	Loring Silt Loam 1	34
Claypan	Mexico Silt Loam 4	35
Claypan	Putnam Silt Loam 2	36
Bootheel	Portageville Clay	36
Osage Plains	Barco Loam 1	37
Osage Plains	Hartwell Silt Loam	37
Claypan	Putnam Silt Loam 3	38
Osage Plains	Barden Silt Loam 1	39
Osage Plains	Osage Clay	40
Osage Plains	Kenoma Silt Loam	43
Claypan	Mexico Silt Loam 1	44
Loess and Drift	Grundy Silt Loam 1	44
Ozarks	Viraton Silt Loam	45
River Bottom	Westerville Silt Loam	49
Ozarks	Keeno Cherty Silty Loam	50
Loess and Drift	Marshall Silt Loam	51
Loess and Drift	Sharpsburg Silt Loam	51
Ozarks	Creldon Silt Loam	52
River Bottom	Haynie Silt Loam	52
Osage Plains	Barden Silt Loam 2	52
Ozarks	Clarksville Cherty Silty Loam	53
Ozarks	Huntington Silt Loam	53
River Bottom	Leta Silty Clay	54
Osage Plains	Barden Silt Loam 3	54
Bootheel	Commerce Silty Clay Loam 1	56
Ozarks	Cedargap Cherty Silty Loam	58
Bootheel	Sharkey Silty Clay Loam	58
Bootheel	Commerce Silty Clay Loam 2	59
Loess and Drift	Haig Silt Loam	64
Loess and Drift	Grundy Silt Loam 2	64
Ozarks	Goss Gravelly Silt Loam	64
Bootheel	Lilbourn Fine Sandy Loam	66
Loess and Drift	Higginsville Silt Loam	68
Osage Plains	Parsons Silt Loam	70
Bootheel	Lilbourn Sandy Loam	76



Map of Missouri soil regions with regional differences in fertilizer needs for soil test buildup as suggested by this research. The claypan region soils required more P than soils from other regions to produce the same soil test increase. This may also be true for the Osage Plains soils. Ozark soils, on the other hand, required less K and probably less P than soils from other regions to produce the same soil test increase. Regional differences in the soil test buildup equations are probably justified.