Characterizing the effects of excessive phosphorus rates on soil test phosphorus

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Applications of poultry litter, swine slurry, lagoon sludge and other manures can result in phosphorus applications that exceed agronomic need. Some lagoon sludge material can have an nitrogen:phosphorus (N:P) ratio substantially less than 1 whereas N:P ratio of harvested crops typically run 4:1 to 8:1.

Applying these rich phosphorus materials based on crop N needs can result in P application rates that exceed crop removal by a factor of 10 or more.

Rapid increase in soil test P from high rates of applied P may be beneficial to crop yields on P deficient soils. Previous research has shown P application rate and soil test P are typically are linearly related in the agronomic range.

The objective of this research was to see if high rates of P application create conditions likely to result in higher P losses from agricultural fields.

Methods and Materials

Phosphorus was applied to established fescue stands at three locations.

- Mexico soil (Fine, smectitic, mesic Aeric Vertic Epiaqualfs), University of Missouri South Farm, Columbia MO.
- Lagonda soil (Fine, smectitic, mesic Aquertic Argiudolls), University of Missouri Forage Systems Research Farm, Linneas MO.
- Creldon soil (Fine, mixed, active, mesic Oxyaquic Fragiudalfs), University of Missouri Southwest Research Center, Mt. Vernon MO.

Phosphorus was surface-applied as ammonium polyphosphate (AP) solution at the rate of 0, 67, 111, 177, 892, and 2,231 kg P ha-1. Treatments were replicated three times in a randomized block design. Plots were 3.3 m^2 and any plot down-slope from another plot was separated by 14 m of fescue sod. Plots were mowed every 2 to 4 weeks during the growing season with a mulching mower returning all forage growth to the surface of the plot.

Soil samples were taken 31, 198, 408 and 607 days after P application on the Mexico and Lagonda soils and 31, 195 and 580 days after application on the Creldon soil. Only the 0 P control and the highest 3 P rates were sampled on the last sampling date.

Two sets of 20 cores were removed from each plot at each sampling. Sampling depth was 15 cm. The first set of cores were placed in a bucket, mixed well and subsampled. The second set of cores was divided into three, 5-cm sections (0 to 5 cm, 5 to 10 cm and 10 to 15 cm). The 4 samples from each plot were dried to a constant weight at 35°C, pulverized with a chain flail mill and analyzed for Bray-1 P concentration.

Results and Discussion

Agronomic P rates

In this experiment, two consecutive sampling times with the same slope in the relationship of added ammonium polyphosphate versus Bray-1 soil test was interpreted as evidence that Bray-1 soil test levels had equilibrated. Added P equilibrated with the soil (0- to 5-cm increment) in less than 30d for the Lagonda and Creldon soils and in less than 199 days for the Mexico soil according to this standard (Fig. 1). The slope value of the surface soil at equilibration was significantly affected by soil type (P=0.02). Orthogonal contrasts indicated the Lagonda soil was significantly more responsive to added P than the Mexico (P=0.10) and the Creldon (P=0.01) soils.

Surface applied P increased B1-STP in layers of soil below the surface (data not shown). Mean effect of 1 kg ha-1 added P was to raise Bray-1 soil test P 0.2 ug g-1 in the 0- to 5-cm layer, 0.012 ug g-1 in the 5- to 10-cm layer and 0.005 ug g-1 in the 10- to 15-cm layer. There was evidence that added P moved into the soil layers below the surface after the first sampling date. The highest values for B1-STP in the 2 sub-surface layers were observed on the last sampling date (198 d for the Creldon; 408 d for the Lagonda and Mexico).

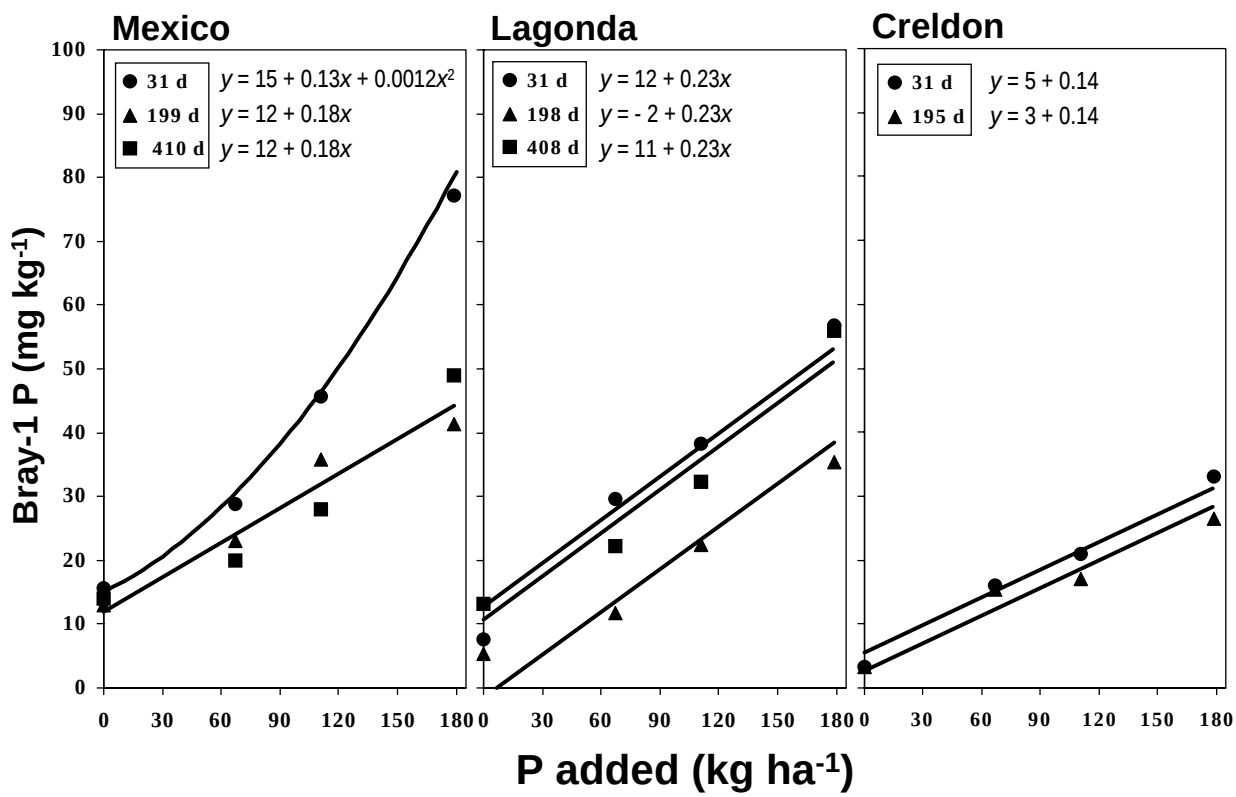

Figure 1. The effect of agronomic rates of ammonium polyphosphate, soil type and sampling date on Bray-1 soil test phosphorus in the surface 0- to 5-cm soil depth.

Excessive P rates

Response to high rates of P addition resulted in a linear response in Bray-1 soil test P in the 0- to 5-cm soil depth (Fig. 2). Initially, high rates of P resulted in higher soil test values than predicted by agronomic rates. Agronomic rates (see Fig. 1) were projected to the high rates applied (see dotted line in Fig. 2). By the last sampling date all soil test levels matched the levels predicted by agronomic rates (Fig. 2). Phosphorus movement below 5 cm was greater than predicted by agronomic rates and increased with time (data not shown).

There was evidence that soils differ in the speed of equilibration with these high rates. There was little change in slope coefficient between 408 and 604 d in the Lagonda soil implying these soils were approaching equilibrium and the equilibrium was similar to what was predicted by agronomic response. Regression analysis indicated the slope coefficient continued to decrease from day 410 to day 607 in the Mexico soil implying it was taking longer to equilibrate.

The rate of equilibration for the excessive rates of P was substantially slower than what had been observed with agronomic rates of P. Agronomic rates equilibrated within 31 days and did not exceed 200 days. Equilibration exceeded 200 days on all soils with excessive rates. These results imply that excessive rates increase the potential for phosphorus loss from such fields because they maintain a higher than predicted soil test P level for an extended period of time.

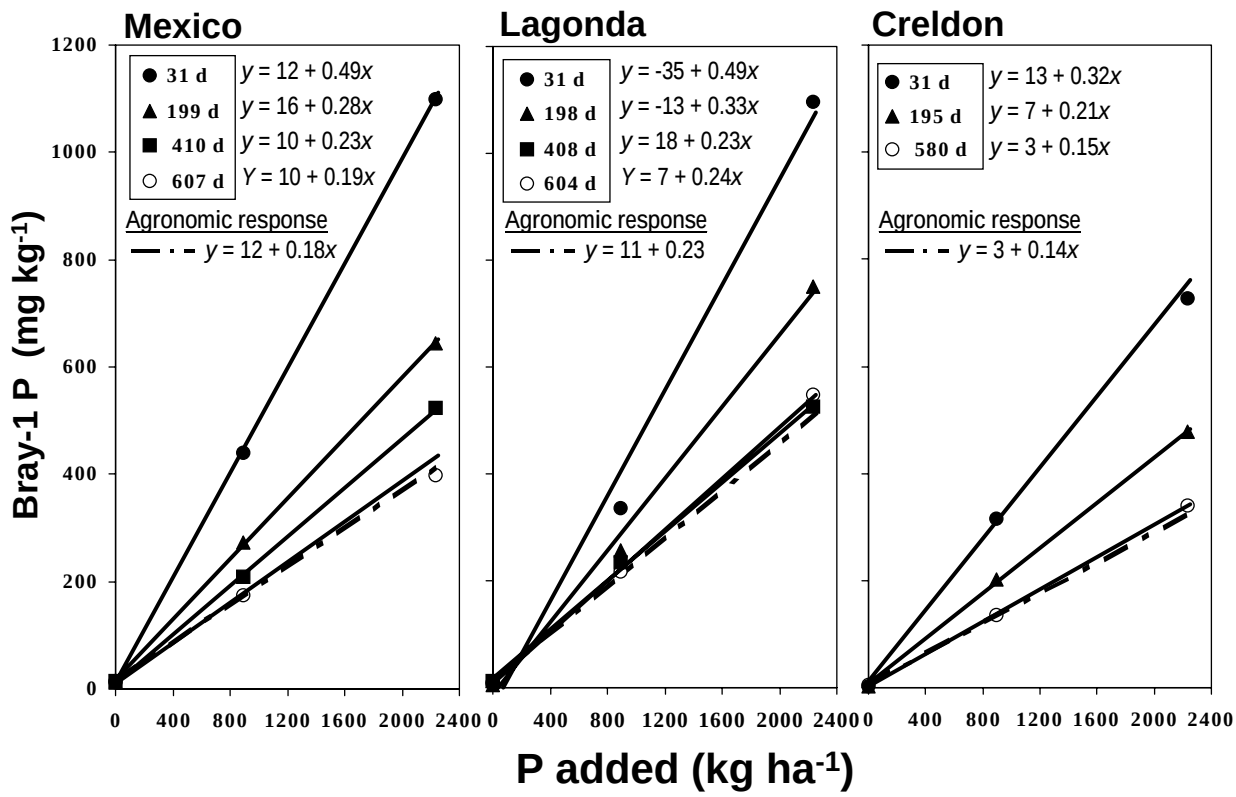

Figure 2. The effect of high rates of ammonium polyphosphate rate, soil type and sampling date on Bray-1 soil test phosphorus in the surface 0- to 5-cm soil depth. Agronomic response was based on the last sampling date in Fig. 1.

Soil sampling depth effect

A 15-cm (6-inch) taken too soon after a surface P application of both agronomic (Fig. 3A) and excessive (Fig. 3B) rates will lead to erroneous estimates of soil test P levels, Initially, 15-cm cores under estimated Bray-1 soil test P. Eventually the phosphorus in the soil equilibrates eliminating the effect (Fig. 3). It takes substantially longer for the effect to disappear with excessive rates of P.

The effect is likely due to soluble P in the surface soil being fixed during sample processing with lower layers. On soils where the three layers are sampled separately, the surface soil rich in recently applied P is kept separate from the low-P subsoil. In the 15-cm core the three regions of soil are mixed allowing the soluble P in the surface soil to react with the lower-P sub-surface soil while the sample is being transported and air dried.

The implication of these results is that shallow cores are needed to accurately characterize surface soil test phosphorus levels for a significant period after excessive P applications.

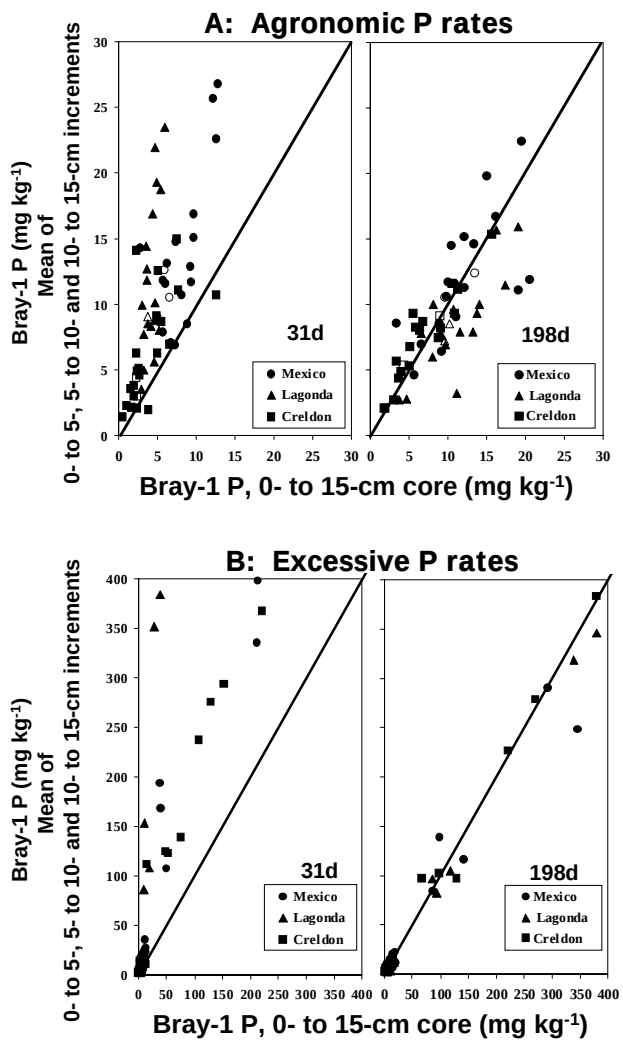

Figure 3. Bray-1 soil test phosphorus of 0- to 15-cm cores versus the mean value of the 0- to 5-cm, 5- to 10-cm, and 10- to 15-cm cores.

Conclusions

Agronomic rates of P caused a linear increase in soil test P although soils differed in time needed to reach their equilibration point.

High P rates required substantially longer periods to equilibrate and resulted in higher levels of soil test P below 5 cm than was predicted by agronomic rates. The equilibration period was less than 31 days for agronomic rates on 2 of 3 soils but greater than 195 days for all soils at high P rates. During the equilibration period there was a greater risk to water quality from a large application on a smaller field than smaller applications spread over a larger area.

We recommend phosphorus application rates not exceed in a single application the amount needed to raise Bray-1 soil test P 30 mg P kg-1 in the surface 5 cm of the soil or 20 mg P kg-1 in the surface 15 cm of soil. These guidelines would allow building soil test phosphorus from almost any soil test level up to or exceeding the agronomic optimum with one P application.