CHANGES IN EXTRACTABLE PHOSPHORUS IN AMENDED SOILS DURING A GROWING SEASON

R.C. Schwartz and J.M. Bell
USDA-ARS, Bushland, TX
rschwart@cprl.ars.usda.gov (806)356-5762

ABSTRACT

Recent studies indicate that soil extractable P and P in runoff are greatest immediately after fertilizer and manure applications. Our objective was to evaluate changes in Mehlich 3– and water– extractable P in soils amended with cattle (*Bos taurus*) manure and monoammonium phosphate (MAP) throughout a single growing season. Cattle manure and MAP were applied at a rate of 184 and 300 kg P ha^{-1}, respectively, on a Pullman clay loam (Fine, mixed, superactive, thermic Torrertic Paleustoll). Unfertilized checks were included for P extractability comparisons. Grain sorghum (*Sorghum bicolor* (L.) Moench) was planted after fertilizer applications and received supplemental irrigation (180 mm). Soil samples (0-150 mm) were collected prior to fertilizer applications and periodically throughout the growing season. Changes in Mehlich 3– and water– extractable P with time exhibited a rapid initial increase after fertilizer applications followed by seasonal fluctuations and a decline 15 weeks after planting. Because of higher P applications rates, MAP –amended plots exhibited greater Mehlich 3 and water P extractabilities as compared to manure amended plots. However, at an average Mehlich 3–extractable P level of 161 mg kg^{-1}, water extractable–P averaged 39% greater ($P<0.05$) for MAP amended as compared to manure amended plots. This fertilizer source dependency would limit the use of the Mehlich 3 extractant in making satisfactory P loss vulnerability assessments.

INTRODUCTION

Soil P enrichment from repeated applications of manures and inorganic fertilizers can increase environmental risks associated with elevated concentrations of dissolved P in runoff. Customarily, increases in soil P concentrations are detected using agronomic soil P tests (e.g. Mehlich 3) so that crop nutrient requirements can also be assessed. Agronomic soil P tests are often correlated with environmental soil tests such as water–extractable P and in some cases with soluble P in runoff (Sims et al., 2002; Pote et al., 1996). However, these relationships may be altered when soils are amended with manure or fertilizer P. In amended soils incubated for eight weeks, Schwartz and Dao (2005) showed that manure and KH_2PO_4 P sources differed with respect to their relationships between agronomic soil test– and water– extractable P. Moreover, in recently amended soils Sharpley et al. (2001) found that dissolved P in runoff was not related to Mehlich 3–extractable P but, rather, a function of the source and quantity of P applied three weeks earlier. Because water–extractable P is closely related to dissolved P in overland flow (McDowell and Sharpley, 2001; Pote et al., 1999), delineating the seasonal response of both water extractable and Mehlich 3 P under field conditions would help ascertain the dynamics of P response after application and the resultant influence on environmental assessments of soil P status. We initiated a study in 2005 to investigate the effects of scraped cattle manure and MAP fertilizer applications on the dynamics of Mehlich 3 and water extractable soil P throughout a growing season.

MATERIALS AND METHODS

The study was carried out in 2005 on border irrigation plots on Pullman clay loam near Bushland, TX. The plots were cropped in continuous grain sorghum with supplemental irrigation and no fertilizer P since 2000. Three fertility treatments (manure, MAP, and an unfertilized check) were established within a randomized block design with three replications. Experimental plots (100 m × 9.1 m) were leveled and subdivided with earthen berms to facilitate flood irrigation. Each experimental plot was further subdivided into three subplots (upper, middle, and end of the field) to check for within-plot variability due to the potential for variable water and manure application rates within a plot. Bulk samples of manure from freshly scraped pens were obtained from a beef cattle feed yard located near Amarillo, TX. Manure and synthetic fertilizers were applied on 27 May, 2005 prior to sorghum establishment. Urea + MAP were broadcast to achieve 300 kg P ha^{-1} + 212 kg N ha^{-1} using a drop spreader. Cattle manure (total P of 4.23 ± 0.50 g kg^{-1} and dissolved reactive P of 0.25 ± 0.02 g kg^{-1}, oven dry weight basis) was applied using a beater-style box spreader. The spreader was calibrated to uniformly apply pre-weighed manure piles into each plot at a rate of 62 Mg ha^{-1} with a resultant application rate of 184 ± 22 kg total P ha^{-1}. All fertilizers were incorporated using an offset disc at a depth of 0.15 m.

Grain sorghum (DeKalb 44)[1] was sown 8 June, 2005 at a rate of 148 000 seed ha^{-1} and a row spacing of 0.76 m with a vacuum seeder. Weed control was achieved using an offset disk and row cultivator. Border plots were flood irrigated on 15 July (76 mm) and on 29 July (102 mm). Soil samples were collected at the 0-15 cm depth increment prior to fertilizer applications, periodically throughout the growing season, and after sorghum harvest. Six soil samples were collected from each subplot and composited. Bulk soil samples were air-dried, sieved (2 mm) and stored at -8°C until required for analyses. Selected properties of the Pullman soil are given by Schwartz and Dao (2005).

Phosphorus was extracted from soils with deionized water (2 g soil in 20 mL, shaken end over end for 30 minutes, centrifuged at 3800 rpm at 25 minutes) and Mehlich 3 extractant (Mehlich, 1984; 2 g soil in 20 mL, shaken end over end for 5 minutes). Water suspensions were filtered through Whatman No. 42 filter paper and Mehlich 3 suspensions were filtered through Whatman No. 2 filter paper. Manure samples ground to pass through a 0.5 mm sieve were digested with sulfuric acid and hydrogen peroxide for determination of total P (Richards, 1993). Dissolved reactive P in manures was determined by shaking 4 g manure in 40 mL deionized water end over end for 2 h, centrifuging at 6,000 rpm for 20 minutes, and filtering with a vacuum through a 0.45 Φm membrane filter (Self-Davis and Moore, 2000). Dissolved molybdate reactive P in extracts and digests was determined using a modified colorimetric molybdate-blue method of Murphy and Riley (1962) in conjunction with an autoanalyzer (EPA, 1983).

Mixed linear model analysis (Littell, 1996; SAS, 1999) with fertilizer treatment as fixed effects and plot replicates as random effects were used to analyze soil data. A first-order autoregressive covariance structure was used to model temporal correlations in random errors of the longitudinal data.

[1] The mention of trade or manufacturer names is made for information only and does not imply an endorsement, recommendation, or exclusion by USDA-ARS.

RESULTS AND DISCUSSION

Temporal trends in Mehlich 3–extractable P show a rapid initial increase after fertilizer applications followed by seasonal fluctuations and a significant (*P*<0.05) decline after DOY 262 (Fig 1a). After fertilizer applications, Mehlich 3 extractabilities of MAP amended soils were significantly greater than those of manure amended soils (*P*<0.05) except on DOY 206 (P=0.4261). There was a tendency for P extractabilities of manure amended plots to increase even after several months whereas MAP amended plots tended to decrease after the first sampling date. An exponential decline in extractable soil phosphorus following fertilizer applications as inferred by the model proposed by Karpinets et al. (2004) is not evident in these results. In particular, irrigations tended to induce short-term fluctuations in extractable P possibly as a result of leaching soluble P forms, changes in the sampling depth due to soil reconsolidation, and or stimulation of increased microbial activity that promoted mineralization of organically-bound P.

Changes in water–extractable P throughout the season (Fig. 1b) were most pronounced for MAP amended soils. However, temporal trends of water–extractable P mirrored the seasonal changes observed for Mehlich 3–extractable P for all treatments. After the first sampling date, water–extractable P significantly (*P*<0.05) varied with respect to fertilizer source as unamended < manure < MAP.

Greater Mehlich 3 P extractabilities of MAP amended as compared to manure amended plots is a direct result of higher P application rates. For the manure amended plots, Mehlich 3–extractable P increased by 61 mg kg^{-1} which represents 65% of the total P applied assuming that all added P remained in the surface 0.15 m soil depth and a bulk density of 1.3 Mg m^{-3}. Schwartz and Dao (2005) found similar extraction efficiencies (68%) for the Pullman soil amended with scraped manure and incubated for eight weeks. The average extraction efficiency for the MAP amended plots was 55%, significantly lower than the 79% reported for KH_2PO_4 by Schwartz and Dao (2005), probably because of leaching of soluble P by a ~100 mm precipitation event immediately after planting.

The functional relationship between water– and Mehlich 3– extractable P was strongly dependent on the P source (Fig. 2). For example, at an average Mehlich 3–extractable P level of 161 mg kg^{-1}, water–extractable P averaged 39% greater (*P*<0.05) for MAP amended as compared to manure amended plots. Similar source dependent relationships were also found by Schwartz and Dao (2005) for several soils, fertilizer sources, and extractants and may be a result of organic and inorganic P sources contributing to different soil P pools.

CONCLUSIONS

Manure and MAP additions to soils increased extractable P levels in soils that were easily detectable under field scale conditions. Data from these field results suggest that prediction of within-season fluctuations in extractabilities would be problematic without taking into account P transport. However, the increase in extractable P expected from P additions was predictable for manure amendments and could be useful for nutrient management planning, especially since the change in Mehlich 3– extractable P in response to P additions tends to be linear for a wide range of extractabilities (Schwartz and Dao, 2005).

Because water–extractable P is closely linked to dissolved P in overland flow (Pote et al., 1999), the fertilizer source dependent relationship between Mehlich 3– and water– extractable P has important implications for P management. When planning fertilizer applications to achieve a given Mehlich 3 threshold level, application of soluble inorganic fertilizer such as MAP would substantially increase the potential losses of P to runoff compared with organic fertilizers. In addition, the source dependency would also limit the use of the Mehlich 3 extractant in making suitable P loss vulnerability assessments either solely or within a P-index framework.

ACKNOWLEDGEMENTS

We gratefully acknowledge the laboratory and field assistance of Ms. Mandy McCarthy, Mr. John Rogers, and Mr. Duncan Vernon.

REFERENCES

EPA, 1983. Methods for chemical analysis for water and wastes. EPA/6/4-79-020. US Govt. Printing Office, Washington, D.C.

Littell, R.C., G.A. Milliken, W.W. Stroup, and R.D. Wolfinger. 1996. SAS System for Mixed Models. SAS Institute Inc., Cary, NC.

McDowell, R.W. and A.N Sharpley. 2001. Approximating phosphorus relsease from soils to surface runoff and subsurface drainage. J. Environ. Qual. 30:508:520.

Mehlich, A. 1984. Mehlich III soil test extractant: A modification of Mehlich II extractant. Commun. Soil Sci. Plant Anal. 15:1409-1416.

Murphy, J. and J.P. Riley. 1962. A modified single solution method for the determination of phosphate in natural waters. Anal. Chim. Acta 27:31-36.

Pote, D.H., T.C. Daniel, D.J. Nichols, P.A. Moore, Jr., D.M. Miller, and D.R. Edwards. 1999. Seasonal and soil-drying effects on runoff phosphorus relationships to soil phosphorus. Soil Sci. Soc. Am. J. 63:1006:1012.

Pote, D.H., T.C. Daniel, A.N. Sharpley, P.A. Moore, Jr., D.R. Edwards, and D.J. Nichols. 1996. Relating extractable soil phosphorus to phosphorus losses in runoff. Soil Sci. Soc. Am. J. 60:855-859.

Richards, J.E. 1993. Chemical characterization of plant tissue. In (M.R. Carter, Ed.) Soil Sampling and Methods of Analysis. Lewis Publishers, Boca Raton, FL.

SAS Institute. 1999. SAS/STAT Online Dcoumentation, Version 8. SAS Institute, Inc., Cary, NC.

Schwartz, R.C. and T.H. Dao. 2005. Phosphorus extractability of soil amended with stockpiled and composted cattle manure. J. Environ. Qual. 34:970-978.

Self-Davis, M.L. and P.A. Moore, Jr. 2000. Determining water soluble phosphorus in animal manure. P. 74-76. In G.M. Pierzynski (ed.), Methods of Phosphorus Analysis for Soils, Sediments, Residuals and Waters. Southern Cooperative Series Bulletin #396, North Carolina State University, Raleigh, NC.

Sharpley, A.N., R.W. McDowell, J.L. Weld, and P.J.A. Kleinman. 2001. Assessing site vulnerability to phosphorus loss in an agricultural watershed. J. Environ. Qual. 30:2026-2036.

Sims, J.T., R.O. Maguire, A.B. Leytem, K.L. Gartley, and M.C. Pautler. 2002. Evaluation of Mehlich 3 as an agri-environmental soil phosphorus test for the mid-Atlantic United States of America. Soil Sci. Soc. Am. J. 66:2016-2032.

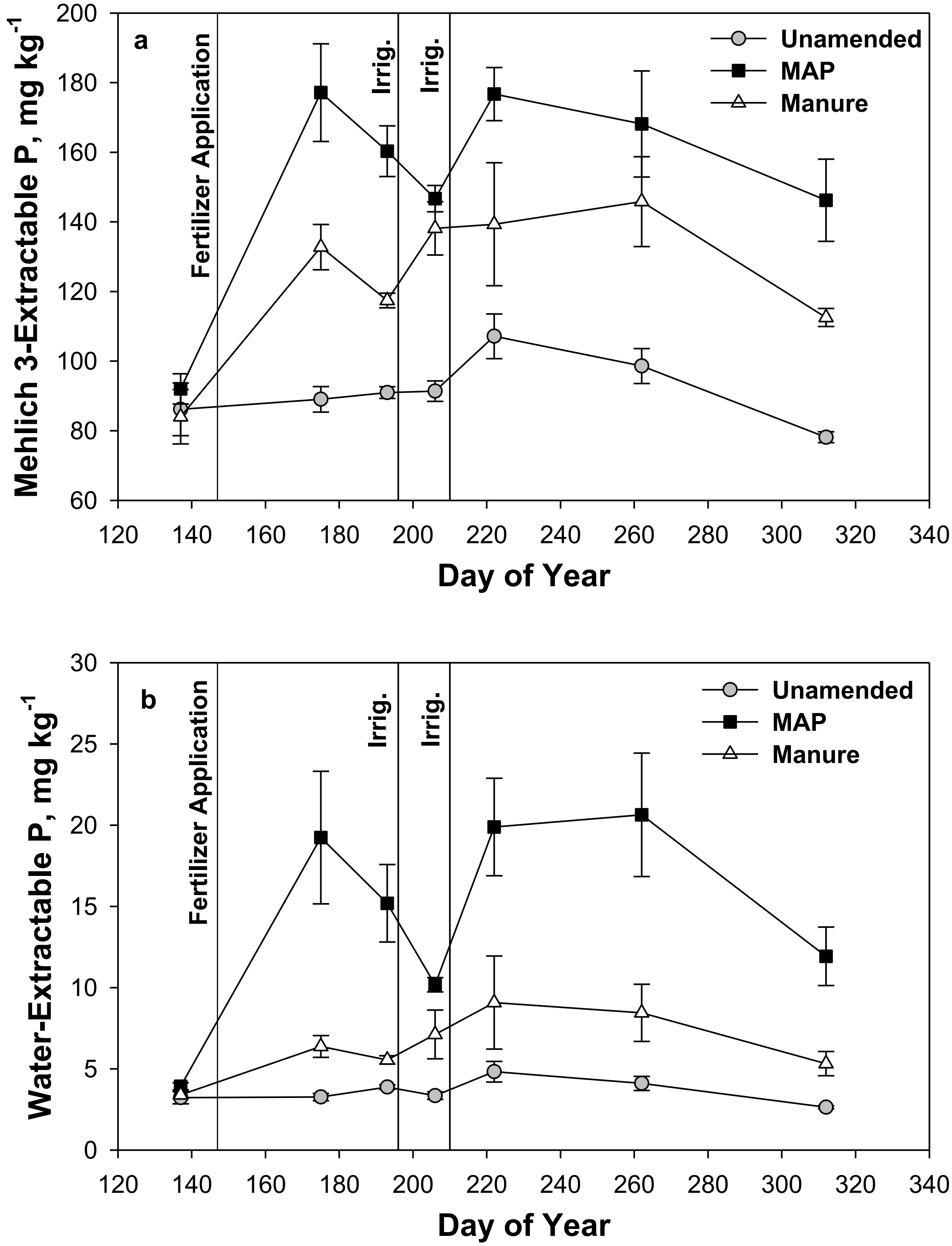

Fig. 1. Trends in (a) Mehlich 3– and (b) water– extractable P for different fertilizer sources throughout the growing season. Horizontal bars are ± 1 standard error (*n* = 3).

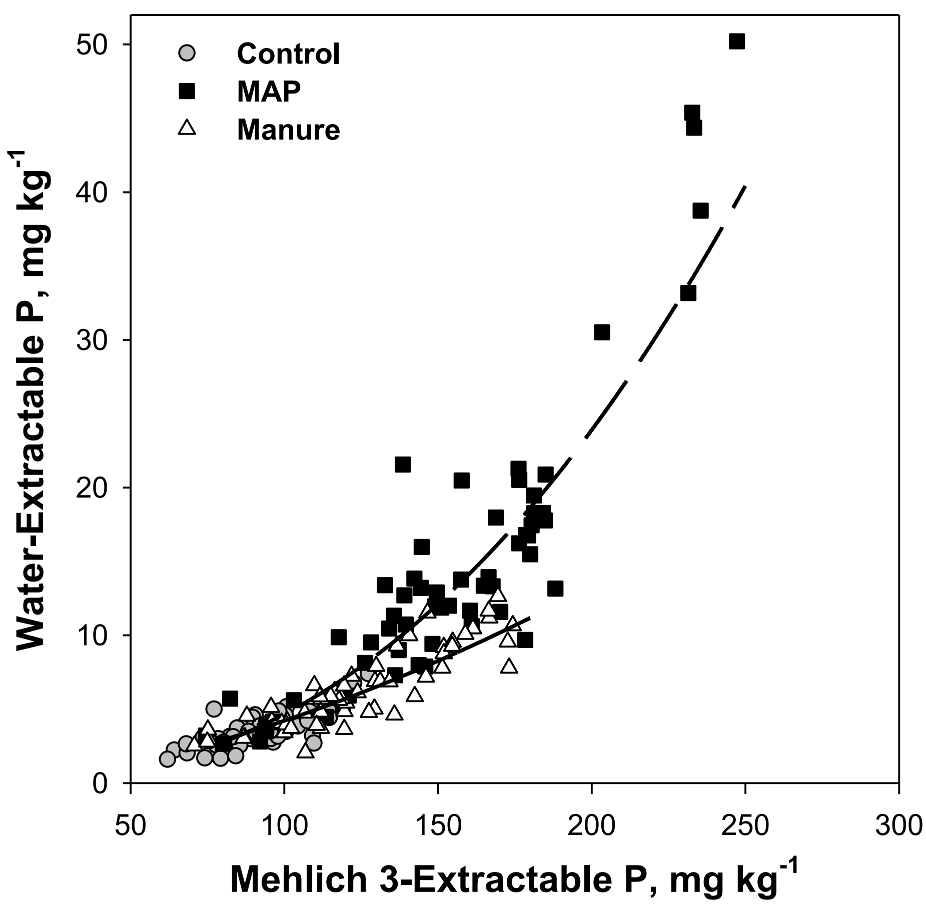

Fig. 2. Trends in Mehlich 3– with water– extractable P for different fertilizer sources. Lines are fitted power functions ($y = ax^b$) for MAP (dashed) and manure (solid).