

Evaluation of soil phosphorus derivation methods for use in agriculture

Omid Pourzargham Faradonbeh¹, Hossein Bagheri^{1*} and Reza Zafarian²

¹Department of Agriculture, Chaloos Branch, Islamic Azad University, Chaloos, Iran

²Department of Animal Science, Chaloos Branch, Islamic Azad University, Chaloos, Iran

Abstract

The aim of this review was to compare the conventional chemical derivations of soil with the ion-sink extraction methods. Efficacy of the ion-sink methods especially the resin membranes which extract soil available P in a similar manner as plant roots does and it can be employed for a variety of soil types irrespective of their properties. In contrast to chemical derivations, this has been designed for specific soil types. Resin membranes does not alter the chemical composition of the soil and therefore give a close estimate of soil-available P. Results show that the chemical nature of the extracting affect the ability of the method to detect changes in the solubility of soil P that are not related to the total concentration of P in the soil. Water extraction was found to be sensitive to physicochemical changes in soil solutions, and could be recommended for estimating short-term changes in P solubility.

Keywords: Derivations; chemical; ion-sink; phosphorus

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Introduction

Being an essential nutrient for plant growth, the estimation of plant available phosphorus (P) has a long history. In the beginning of the 20th century the scientific community was interested in developing a chemical extraction method for predicting the crop responses to P fertilization. Since then, knowledge concerning soil P has increased greatly and the methods used for its characterization have developed further to produce more detailed information on soil P forms (Kurtz, 1953).

Availability of P for plant utilization is not a function of its concentration in the soil, but rather on the rate of its release from the soil surface into the soil solution. P is considered the most unavailable and inaccessible of all mineral nutrients (Holford, 1997). Extraction methods used in evaluating P status of soils include extraction with water, weak acids, bases, salts and anion exchange resin. These conventional P derivations may not give a clue on the

level of available P for plant absorption as the chemicals used for the extraction may solubilise non-labile P. This may leads to P fixation by aluminium and ferrous oxides (FeO) and hence unavailable for plant use (Mallarino, 1997). Moreover, these chemical derivations are not applicable over all soil types. Inadequate use of any chemical extractant over a different soil can result to the buffering of the extractant and dissolution of non-labile P (Myers et al., 2005). Ion-sink methods usually employed in P extraction include anion and cation exchange resin membranes, resin bags, FeO coated filter papers or strips. The efficacy of soil P testing method must be directed towards its ability to extract P in a similar manner as plant roots does and at the growth stage where plants requires P most for growth and development. Ion sink test has been employed by other authors (Chardon et al., 1996; Bache and Ireland, 1980; Raven and Hossner, 1993; Buehler et al., 2002) in extracting available soil-P. These soil P testing methods can be employed over

Corresponding author: Hossein Bagheri, Department of Agriculture, Chaloos Branch, Islamic Azad University, Chaloos, Iran. Email: Bagheri_hm2000@yahoo.com

soils with variety of physical and chemical properties (Sharpley et al., 1994).

Plant available phosphorus in the soil

It is also referred to as labile P. The concentration of available P is always low because of continuous plant uptake. This is further complicated by the slow replenishment of the extracted P from the soil solution by the labile pool which is dictated by the soil P equilibria (Holford, 1997). This is however, favoured by an application of P amendment source like fertilizers or manure. The concentration of available P pool is dictated by the prevailing soil conditions at a particular time and the ability of the crop to extract the P from the soil solution. It is therefore a quantity or extensive parameter (Raven and Hossner, 1993; Holford, 1997). Even though, most people use available P synonymously with P availability, they are not the same because P availability is an intensive parameter and does not predict the amount or concentration of available P (White and Beckett, 1964).

Maintenance of plant-available P in the soil is very imperative to avoid over exploitation of soil P which will lead to P deficiency and consequently, low plant yield. This maintenance is a function of the concentration of P in the labile pool and how readily it is released into the soil solution from the solid phase. This in turn depends on the P buffering capacity of the soil (Holford, 1997), even though, P buffering capacity may not be directly related to P desorption ability of soils as observed by Raven and Hossner (1993). P is released at a faster rate from the labile pool into the soil solution at lower buffering capacity. These include the amount of or concentration of P in the soil solution; the amount of P in the replenishment source that enters into equilibrium with the soil solution phase and P buffering capacity of the soil.

Comparison of chemical derivations with ion-sink derivations

Even though, almost every P extraction methods have problems, some are more effective than others. Chemical derivations are designed for soils with particular characteristics and their application over other soils with different properties may lead to inefficiency with a consequence of solubilising P making it prone to fixation by sesquioxides. This lead to a difficulty in interpretation of the test result (Myers et al., 2005). This underscores the use of acid derivations for soil P extraction. Standard extraction methods used in extracting organic P are tedious and time consuming as they require separate extraction periods. Mineral dynamic may be altered with ignition method as a result of high temperature which may

lead to a change in the level of extractable P in the soil (Soltanpour et al., 1987).

The use of exchange membrane resins is employed using either the Batch or miscible displacement technique. The Batch technique involves the use of wide soil to solution ratio, which varies the concentration in the solution, and the quantity of desorbed P as the reaction proceeds (Sparks, 1985). If there is no adequate mixing of solution with the ion exchanger, a limited rate of reaction may occur (Sparks, 1985). This may also lead to a change in the surface chemistry of the colloids and the breakdown of soil particles (Barrow and Shaw, 1977). Another problem with the batch technique is that measurement at initial time steps of the reaction is not possible (Carski and Sparks, 1985). This is because majority of batch technique requires centrifugation to separate the solid from the liquid, which normally takes place after the completion of most exchange reactions (Sparks, 1985). With miscible displacement technique, there can be error in dilution which can lead to error of interpretation (Ogwada and Sparks, 1986) by altering the concentration of the soil (Sparks, 1999). This is more pronounced in colloids having low ion absorbing power (Carski and Sparks, 1985). Also, dispersion of soil colloids may not be fully achieved (Sparks, 1999). Even though, anion exchange resins extracts more P than FeO coated papers, the additional P extracted may not be available (Robinson and Sharpley, 1994). FeO coated papers are not so much available in the market (Myers et al., 2005). Soil particles can contaminate the FeO coated papers during shaking (Chardon et al., 1996) which can lead to error in estimating desorbable P (Uusitalo and Yli-Halla 1999). This can however, be minimized by the use of CaCl_2 solution as the background electrolyte which tend to minimize soil dispersion (Myers et al., 2005). But this can lead to reduction in the amount of P extracted (Koopmans et al., 2001). With all the mentioned disadvantages of the FeO coated papers, ion-sink methods especially when anion exchange membrane is used, are still regarded as the best method of plant-available P extraction technique. Its major advantage is its capability to extract P from variety of soil type irrespective of the properties of the soil (Sharpley et al., 1994). It extracts P from the soil in the same manner as Plant roots do (Raven and Hossner, 1993). Anion exchange resin membranes does not alter the chemical and physical characteristic of the soil, it quite simulates the soil aqueous solution. Furthermore, the resin membranes can be re-used for several times without losing its extracting power (Schoenau and Huang, 1991). This property makes it relatively cheaper than the FeO coated papers. The problem associate with the pH of the soil solution can be overcome by charging the resin

with either HCO_3^- or Cl^- . HCO_3^- is used for charging the resin when the soil is alkaline and calcareous (Delgado and Torrent, 2001), while Cl^- is used for acidic soils (Agbenin and Raji, 1999). When Cl^- resin is used, the Cl^- accumulates in solution thereby inhibiting the exchange reaction (Myers et al., 2005). An important aspect of resin use that needs standardization is the resin strip size and its total surface area.

Phosphorus cycling in agricultural fields

In soil, P is constantly cycling, mediated by the biological P requirements of all living organisms. When soil is harnessed for agricultural production, the natural cycling will be disturbed by fertilizer additions and removal of nutrients with harvesting. For long term sustainability of cropping, adequate amounts of P through fertilization are needed. Guggenberger et al. (2000) found that fertilization increased the labile Po pool, but the type of fertilizer seemed not to have any importance and Otabbong et al. (1997) concluded that in soils well supplied with available P, fertilizer additions especially increase the Po concentration. Mc Lauchlan (2006) reviewed the impacts of agricultural practices on soil properties and concluded that tillage and harvesting tend to decrease concentrations of organic matter and nutrients in soil. Due to the fairly close relationship between organic C and Po (Bünemann et al., 2006), management practices increasing soil organic matter are expected to increase soil Po concentrations. Compared to conventionally tilled soil in no-tilled fields, organic C and available P have been found to be enriched in surface soils (Muukkonen et al., 2007). According to Muukkonen et al. (2007), the accumulation of organic C may enhance availability of P in clay soils due to the competition between organic anions and $\text{PO}_4\text{-P}$ for the same sorption sites. In addition to fertilization and tillage-induced changes in Pi and Po, the P cycle in agricultural fields is subjected to seasonal changes. In fertilized soils, the seasonal variation in P has been suggested to result from physicochemical changes in soil induced by management practices, such as fertilization, but in non-fertilized soils, it is attributable to biological cycling of P (Styles and Coxon, 2007). As the weather gets warmer in the spring, the accumulated labile Po is mineralized along with the increased microbial activity and the solubilised P will meet the needs of the fast growing plants (Chen et al., 2003). Turner and Haygarth, (2000) reported springtime maximum in P leaching and suggested the increase to originate from microbial biomass. In the boreal zone, the growing season is shorter than at lower latitudes, and during the winter months the soil is at least part of the time frozen and the biological activity in soils is minimal. In incubation studies, freezing has been found

to increase the solubility of soil P, especially in high organic matter soils, however, freeze-thaw studies have been criticised because of unnatural freezing rates and minimum temperatures (Henry, 2007).

Conclusion

The chemical nature of the extracting affects the ability of the method to detect changes in the solubility of soil P that are not related to the total concentration of P in the soil. Water extraction was found to be sensitive to physicochemical changes in soil solutions, and can be recommended for estimating short-term changes in P solubility. However, this sensitivity can be a disadvantage in agronomic soil testing that aims to describe soil P status over the longer term. The sensitivity of the method used to detect changes in P solubility plays a key role in the interpretation of results obtained at different times of the year. Myers et al. (2005) concluded that anion exchange resin was the best of all the extraction methods applied over 24 soils. Further, it is concluded that the use of anion exchange resin membrane may be the best soil extracting provided that the size and dimension of the resin strips is standardized to avoid disparity in the amount of P extracted when different sizes were used.

References

- Agbenin, J.O. 2003. Extractable iron and aluminum effects on phosphate sorption in a Savanna Alfisol. *Soil Science Society of America Journal*, 67:589-595.
- Agbenin, J.O. and Raji, B.V. 2001. Kinetics and Energetics of phosphate release from tropical soils determined by mixed ion-exchange resin. *Soil Science Society of America Journal*, 5:1108-1114.
- Bache, B.W and Ireland, C. 1980. Desorption of phosphate from soils using anion exchange resins. *Journal of Soil Science*, 31:297-306.
- Barrow, N.J. 1979. The description of desorption of phosphate from soils. *Journal of Soil Science*, 30: 259-270.
- Barrow, N.J. and Shaw, T.C. 1977. Factors affecting the rate of phosphate extracted from soils by anion exchange resin. *Journal of Soil Science*, 18:309-323.
- Buehler, S., Oberson, A. , Rao, I.M. , risen and D.K. 2002. Sequential phosphorus extraction of a ^{32}P -labeled Oxisol under contrasting agricultural systems. *Soil Science Society of America Journal*, 66:868-877.
- Bunemann, E.K., Heenan, D.P., Marschner, P. and McNeill, A.M. 2006. Long-term effects of crop rotation, stubble management and tillage on soil phosphorus dynamics. *Australian Journal of Soil Research*, 44:611-618.

- Carski, T.H. and Sparks, D.L. 1985. A modified miscible displacement technique for investigating adsorption-desorption kinetics in soils. *Soil Science Society of America Journal*, 49:1114-1116.
- Chardon, W.J., Menon, R.J. and Chien, S.H. 1996. Iron oxide impregnated filter paper (Pi test): A review of its development and methodological research. *Nutrient Cycling Agronomy ecosystem*, 46:41-51.
- Chen, C.R., Condon, L.M., Davis, M.R. and Sherlock, R.R. 2003. Seasonal dynamics of soil phosphorus and associated microbial properties under adjacent grassland and forest in New Zealand. *Forest Ecology and Management*, 177:539-557.
- Delgado, A. and Torrent, J. 2001. Comparison of soil extraction procedures for estimating phosphorus release potential of agricultural soils. *Commun. Soil Science and Plant Analysis*, 32:87-105.
- Fox, F.J. and Kamprath, E.J. 1970. Phosphate sorption isotherms for evaluating the phosphate requirements of soils. *Soil Science Society of America*, 34:902-907.
- Guggenberger, G., Christensen, B.T. and Rubæk, G. 2000. Isolation and characterization of labile organic phosphorus pools in soils from the Askov long-term field experiments. *Journal of Plant Nutrition and Soil Science*, 163:151-155.
- Henry, H. 2007. Soil freeze-thaw cycle experiments: Trends, methodological weaknesses and suggested improvements. *Soil Biology and Biochemistry*, 39: 977-986.
- Koopmans, G.F., Van Der Zeeuw, M.E., Romkens, P.F.M.A., Chardon, W.J. and Oenema, O. 2001. Identification and characterization of phosphorus rich sandy soils. *Netherlands Journal of Agriculture Science*, 49:369-384.
- Kurtz, L.T. 1953. Inorganic phosphorus in acid and neutral soils. *Soil and Fertilizer Phosphorus in Crop Nutrition*, 25: 59-88.
- Mallarino, A.P. 1997. Interpretation of soil phosphorus tests for corn in soils with varying pH and calcium carbonate content. *Journal of Production Agriculture*, 10:163-167.
- McLauchlan, K. 2006. The nature and longevity of agricultural impacts on soil carbon and nutrients: A review. *Ecosystems*, 9: 1364-1382.
- Mehlich, A. 1984. Mehlich 3 soil test derivations: A modification of Mehlich 2 extractant. *Commun. Soil Science Plant Analysis*, 15: 1409-1415.
- Morgan, M.F. 1941. Chemical soil diagnosis by the universal test system. *Conn. Experiment Station Bulletin*, p:450.
- Muukkonen, P., Hartikainen, H., Lahti, K., Särkelä, A., Puustinen, M. and Alakukku, L. 2007. Influence of no-tillage on the distribution and lability of phosphorus in Finnish clay soils. *Agriculture, Ecosystems, and Environment*, 120:299-306.
- Myers, R.G., Sharpley, A.N., Thien, S.J. and Pierzynski, G.M. 2005. Ion-Sink phosphorus extraction methods applied on 24 soils from the continental USA. *Soil Science Society of America Journal*, 69:511-521.
- Ogwada, R.A. and Sparks, D.L. 1986. Kinetics of ion exchange on clay minerals and soils: 1. Evaluation of methods. *Soil Science Society of America Journal*, 50:1158-1162.
- Ottobong, E., Persson, J., Iakimenko, O. and Sodovnikova, L. 1997. The Ultuna long-term organic matter experiment: II. Phosphorus status and distribution in soils. *Plant and Soil*, 195:17-23.
- Raven, K.P. and Hossner, L.R. 1993. Phosphate desorption quantity-intensity relationships in soil. *Soil Science Society of America Journal*, 57:1505-1508.
- Robinson, J.S. and Sharpley, A.N. 1994. Effect of organic phosphorus on the sink characteristics of iron oxide-impregnated filter paper. *Soil Science Society of America Journal*, 58:758-761.
- Schoenau, J.J. and Huang, W.N. 1991. Anion-exchange membrane, water and sodium bicarbonate extractions as soil tests for phosphorus. *Commun. Soil Science Plant Analysis*, 22:465-492.
- Sharpley, A. 2008. Phosphorus management in Nordic-Baltic agriculture reconciling productivity and environmental protection. Seminar conclusions, discussion, and recommendations. In: Rubæk, G. (ed.). *NJF Report*, 4:9-14.
- Soltanpour, P.N., Fox, R.L. and Jones, R.C. 1987. A quick method to extract organic phosphorus from soils. *Soil Science Society of America Journal*, 51: 255-256.
- Sparks, D.L. 1985. Kinetics of ionic reactions in clay minerals and soils. *Advances Agronomy*, 38:231-266.
- Sparks, D.L. 1999. Kinetics and mechanisms of chemical reactions at the soil mineral/water interface. In: DL Sparks (ed.) *Soil physical chemistry. 2nd ed. CRC Press, Boca Raton, Florida*, Pp: 135-191.
- Styles, D. and Coxon, C. 2006. Laboratory drying of organic-matter rich soils: Phosphorus solubility effects, influence of soil characteristics, and consequences for environmental interpretation. *Geoderma*, 136:120-135.
- Turner, B.L. and Haygarth, P.M. 2000. Phosphorus forms and concentrations in leachate under four grassland soil types. *Soil Science Society of America Journal*, 64:1090-1099.
- Uusitalo, R. and Yli-Halla, M. 1999. Estimating errors associated with extracting phosphorus using iron oxide and resin methods. *Soil Science Journal*, 28:1891-1897.
- White, R.E. and Beckett, P.H.T. 1964. Studies on the phosphate potentials of soils. *Plant and Soil Journal*, 20:1-16.