

Review

Soil-phosphorus extraction methodologies: A review

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Soil available phosphorus has been measured using chemical extractants and ion-sink methods comprising of resin membranes and FeO coated filter papers or strips. This study compared the conventional chemical extractants such as Bray-1, Olsen, and Mehlich-3 etc with the ion-sink extraction methods. Investigations from researchers have shown the efficacy of the ion-sink methods especially the resin membranes which extract soil-available P in a similar manner as plant roots does. It can be employed for a variety of soil types irrespective of their properties. In contrast to chemical extractants that is designed for specific soil types. Resin membranes does not alter the chemical composition of the soil and therefore gives a close estimate of soil-available P. Economically, resin membrane strips can be used and re-used several times without losing its extraction power. The size and dimension of the resin strips should be standardized to avoid disparity in the amount of P extracted when different sizes were used for same soils.

Key words: Phosphorus, extractants, chemical, ion-sink.

INTRODUCTION

Availability of phosphorus (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. Phosphorus 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. Many authors (Morgan, 1941; Bray and Kurtz, 1945; Watanabe and Olsen, 1965; Fox and Kamprath, 1970; Barrow, 1979; Mehlich, 1984) have designed P-testing methods using chemical extractants to determine soil-available P. These conventional P extractants may not give a clue on the level of available P for plant absorption as the chemicals used for the extraction may solubilize non-labile P. This may lead to P fixation by Al and Fe oxides and hence unavailable for plant use (Mallarino, 1997). Moreover, these chemical extractants are not applicable over all soil types. Inadequate use of any chemical extractant over a different soil it was designed for can result to the buffering of the extractant and dissolution of non-labile P (Myers et al., 2005). Bray-1 and Mehlich-3 extractants are designed to extract P from non-calcareous soils (Bray and Kurtz, 1945; Mehlich, 1984); whereas Olsen extraction method is meant for soils characterized by calcareous nature (Watanabe and Olsen, 1965).

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 soils with variety of physical and chemical properties (Sharpley et al., 1994). Ion-sink methods usually employed in P extraction include anion and cation exchange resin membranes, resin bags, FeO coated filter papers or strip. 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.

Plant-available phosphorus in the soil

The term available-P is often used to express the amount of soil P in solution which can be extracted or mined by plant roots and utilized by the plant for growth and development during its life cycle. 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). Phosphorus is released at a faster rate from the labile pool into the soil solution at lower buffering capacity. Holford (1997) reported 3 important soil components controlling the supply of P from the labile pool to replenish crop extraction. 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.

Factors affecting extractable-soil phosphorus

Several soil properties have been reported to influence the availability of P for plant use and also P extracted by chemical extractants. Such properties include extractable Fe, Al and Mn oxides, clay content of the soil, CaCO_3 , organic matter, soil pH and P-sorption capacity of the soil. Most important of these in tropical soils is amorphous and crystalline Fe oxides as well as citrate-bicarbonate extractable Fe and Al oxides (Agbenin, 2003). These properties have been reported by Kuo et al. (1988) to strongly influence P-sorption potential of soils. Chemical extractants used for P extraction may lead to solubilization of non-labile pool thereby influencing its fixation by sesquioxides or Ca complexes (Mallarino, 1997). Phosphate availability in submerged soils is rather not affected by Fe and Al oxides because of reduction of Fe^{3+} phosphate to Fe^{2+} phosphate which is soluble. However, P fractionation can't be done in wet soil directly before drying. This drying creates an aerobic situation and the P is converted to insoluble Fe^{3+} phosphate.

Comparison of chemical extractants with ion-sink extractants

Even though, no P-extraction method is not without a problem, some are more effective than others. Chemical extractants are designed for soils with particular charact-

eristics and their application over other soils with different properties may lead to inefficiency with a consequence of solubilizing 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 extractants 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 break down 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 plant-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 simulate the soil aqueous solution. Further more, they 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 (Agbenin and Raji, 1999; Delgado and Torrent, 2001), while Cl^- is used for acidic soils (Agbenin and Raji, 1999).

Sibbesen (1978) observed that the use of HCO_3^- -resin is more advocated than Cl^- -resin because plant roots accumulate bicarbonate in the rhizosphere leading to an increase in rhizosphere pH in acid to neutral soils and a decrease in rhizosphere pH in calcareous soils. 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. Different authors have used different sizes ranging from 9 x 62 mm to 25 x 62.5 mm which has led to disparity in the amount of P extracted.

Conclusion

Sibbesen (1978) evaluated some P extraction methods and concluded that anion exchange resin was the best and all the chemical extractants with the exception of sodium bicarbonate performed worst. In evaluating the Bray-1, Mehlich-3, Olsen and the ion-sink methods that involved anion exchange resin and FeO-coated papers, Myers et al. (2005) concluded that anion exchange resin was the best of all the extraction methods applied over 24 soils. They further concluded that the use of anion exchange resin membrane may be the best soil extractant 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.

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