

Selection of an Appropriate Phosphorus Test for Soils

M.A. Elrashidi (e-mail: moustafa_elrashidi@usda.gov), Soil Survey Laboratory, National Soil Survey Center

Phosphorus and Eutrophication

Phosphorus (P) is an essential element for plant growth and is often applied to agricultural land to increase crop production. Animal waste generally has a high concentration of P. Livestock feedlots and cattle grazing on grassland can introduce substantial amounts of P-rich manure to the environment. Nonpoint sources of P, such as surface runoff and subsurface leaching from agricultural land and livestock operations, are major contributors to eutrophication in freshwater bodies. Eutrophication has been linked to a variety of ecological and health problems, ranging from increased growth of undesirable algae and aquatic weeds to fish kills and human illness.

Phosphorus Loss from Soil

Phosphorus is lost from agricultural land to surface water bodies in sediment-bound and dissolved forms. Sediment-bound P includes P associated with minerals and organic matter. Dissolved P constitutes 10 to 40 percent of the P transported from most cultivated soils to water bodies through runoff and seepage (Sharpley et al., 1992). Surface runoff from grassland, forest, and uncultivated soils carries little sediment and carries dominantly dissolved forms of P. Unlike sediment-bound P, dissolved P is readily bioavailable and thus is the main cause of eutrophication. A concentration of P above 0.02 ppm in lake water generally accelerates eutrophication (Sharpley et al., 1999). This concentration is much less than the P concentration in soil solution of cultivated soils and leads us to an important question regarding the relationship between P in soil and surface runoff. Selection of an appropriate soil test is essential for understanding this relationship and for identifying nonpoint sources of P contamination from agricultural land.

Soil Phosphorus Tests

Many chemical solutions have been proposed to extract potential forms of P in soils. Water probably was the first extractant that researchers applied to measure P in soils. The small amounts of soil P extracted by water (mainly P in dissolved forms) and difficulties related to chemical analysis limit the use of water as an extractant.

Bray and Kurtz (1945) suggested a combination of HCl and NH_4F to remove easily acid soluble P forms, largely Al- and Fe-phosphates. In 1953, Mehlich introduced a combination of HCl and H_2SO_4 acids (Mehlich 1) to extract P from soils in the north-central region of the U.S. Sulfate ions in this acid solution can dissolve Al- and Fe-phosphates in addition to P adsorbed on colloidal surfaces in soils. In the early 1980s, Mehlich modified his initial soil test and developed a multi-element extractant (Mehlich 3) which is suitable for removing P and other elements in acid and neutral soils. Mehlich 3 extractant (Mehlich, 1984) is a combination of acids (acetic [HOAc] and nitric [HNO_3]), salts (ammonium fluoride [NH_4F] and ammonium nitrate [NH_4NO_3]), and the chelating agent ethylenediaminetetraacetic acid (EDTA).

Olsen et al. (1954) introduced 0.5 M sodium bicarbonate (NaHCO_3) solution at a pH of 8.5 to extract P from calcareous, alkaline, and neutral soils. This extractant decreases calcium in solution (through precipitation of calcium carbonate), and this decrease enhances the dissolution of Ca-phosphates. Moreover, this extracting solution removes dissolved and adsorbed P on calcium carbonate and Fe-oxide surfaces.

The concept of P-sink was applied to measure the amount of soil P which can be released in response to such sink. An anion exchange resin (AER) and Fe-oxide impregnated paper (IIP) were used (in a water matrix) as a P-sink to determine available P in a wide range of soils. Recent publications describe AER (Sharpley, 2000) and IIP (Chardon, 2000) methods.

Selecting an Appropriate Test

When extracting solution is added to soil, there are four basic reactions by which P is removed from the solid phase: 1) dissolving action of acids, 2) anion replacement to enhance desorption, 3) complexing of cations binding P, and 4) hydrolysis of cations binding P. Therefore, the selection of a P soil test depends on the chemical forms of P in the soil.

One can conclude that for acid and neutral soils, Al- and Fe-phosphates are the primary source of P. A soil extractant that removes these minerals along with dissolved and adsorbed forms should be a good choice. Either Bray 1 or Mehlich 3 can be used successfully. Mehlich 3 may be preferable, since it can also remove available forms of macronutrients (Ca, Mg, K, and Na) and micronutrients (Cu, Zn, Fe, and Mn) for analyses of these soils.

Calcium phosphates are the main P minerals in alkaline and calcareous soils, whereas neutral and slightly acid soils (pH 6 to 7) may contain both Ca- and Al-phosphates. The NaHCO₃ extractant (Olsen et al., 1954) can remove Ca-phosphates and phosphate adsorbed on surfaces of calcium and magnesium carbonates along with Al-phosphates and is considered the most suitable P test for these soils.

A water extract removes dissolved forms of P but very little of the adsorbed and mineral forms. It is suitable for both acid and calcareous soils. The amount of P extracted is small for most soils, and may not reflect all forms of labile P. A P-sink in a water matrix can remove more P from soil than water extract alone. As an alternative to water, either the AER or IIP method can be used to measure bioavailable P in soils.

The soil properties affecting selection of the appropriate P test and recommended methods are outlined in the table that follows.

Soil properties affecting selection of the appropriate phosphorus test and recommended methods.

Soil	pH	Minerals	Methods
Acidic	< 6.0	Al-P, Fe-P, and Mn-P	Bray 1, Mehlich 1, Mehlich 3, Water, IIP, and AER
Slightly acid to slightly alkaline	6.0 to 7.2	Al-P, Fe-P, Mn-P, Mg-P, and Ca-P	Bray 1, Mehlich 1, Mehlich 3, Olsen, Water, IIP, and AER
Alkaline, calcareous	> 7.2	Ca-P and Mg-P	Olsen, Water, IIP, and AER

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For more information, call the Soil Survey Lab at (402) 437-5006 or e-mail judy.kisch@usda.gov.