Phosphorus in Mississippi Soils

MISSISSIPPI STATE UNIVERSITY EXTENSION

Soil phosphorus (P) management has both economic and environmental implications. Phosphorus is essential for plant growth. It stimulates root and shoot growth, promotes vigorous seedling growth, and advances maturity. It is integral to the conversion of solar energy to the chemical energy that plants need to synthesize sugars, starches, and proteins (Maathuis, 2009; Schachtman, Reid, & Ayling, 1998).

This publication examines phosphorus in soils, plant uptake, soil fertility and testing, and management of phosphorus fertilizers.

Phosphorus in Soils

Phosphorus exists in soils in organic and inorganic forms. Organic forms of phosphorus are found as decomposed plant material and other organic materials, or closely absorbed to soil solids (Dodd & Sharpley, 2015; Menezes-Blackburn, Jorquera, Greiner, Gianfreda, & De La Luz Mora, 2013; Schachtman et al., 1998). Recent research has shown that the role of soil organic phosphorus in soil fertility is greater than once believed (Dodd & Sharpley, 2015).

Because of its particular chemistry, phosphorus forms very strong bonds with soil solids, which fix phosphorus in relatively unavailable forms (Sims & Pierzynski, 2005). In this regard, phosphorus does not behave like nitrogen (N) in the form of nitrate (NO_3^-), which also has a negative charge but does not form insoluble complexes.

Flooded soils provide other phosphorus management challenges in Mississippi. Phosphorus becomes more available in flooded soils, but less so as the soil dries out. This fixation is more extensive and less reversible under alternating flooding-draining regimens, such as crop-rotation systems, than in continuously flooded or continuously moist situations. Supplemental phosphate may be needed for subsequent crops grown in rotation with rice because of this fixation.

Phosphorus Uptake by Plants

The form of inorganic phosphorus in soils is pH-dependent and is negatively charged in most soils. The form used by plants at common soil pH in Mississippi soils is $H_2PO_4^-$, although HPO_4^{2-} will be present and used at pH levels greater than 7 (Sims & Pierzynski, 2005).

Some soils in Mississippi, including many in the Blackland Prairie region, have pHs greater than 7. This variation leads to challenges in nutrient management within the state for crop production.

The absolute quantity of these ions present in the soil and available for uptake at any one time is very small. The amount that is dissolved and accessible in the soil solution is in equilibrium with solid phase phosphorus. The solid phase consists of both the organic and inorganic forms in the soil.

Crops generally need more phosphorus than is normally dissolved in the soil solution for optimal growth; therefore, this phosphorus "pool" must be replenished many times during the growing season. The soil's ability to do this is key to the soil's plant-available phosphorus status.

Nutrient Management

Management of nutrients in the landscape should be guided by the four Rs: The **right amount** of the **right fertilizer**, at the **right place** and at the **right time** (Bruulsema, Peterson, & Prochnow, 2019; Johnston & Bruulsema, 2014). Plants use only 10 to 30 percent of phosphorus fertilizer the year of application. The remainder largely remains in the soil in forms unavailable to plants (Syers, Johnston, & Curtin, 2008).

The diverse soils in Mississippi have unique phosphorus chemistry differences. The soils in the alluvial flood plain of the Delta traditionally have very high amounts of soil-test measurable phosphorus. The soils of the Blackland Prairie (Northeast Mississippi) often have high pHs and phosphorus nutrient management challenges. Many soils in south-central Mississippi have elevated soil-test phosphorus levels due to long-term application of poultry litter.

Soil Testing for Phosphorus

Determining the right rate depends on soil testing. If the soil phosphorus level is not adequate for optimal crop growth, supplemental fertilization may be necessary to ensure adequate amounts are available. You should base the need for supplemental phosphorus on soil-test recommendations. Information on soil testing in Mississippi is available for farmers (MSU Extension Information Sheet 346) and homeowners (MSU Extension Information Sheet 1294). Soil testing measures the ability of a soil to provide phosphorus to the soil solution for plant use, but it does not measure the total quantity of available phosphorus. In other words, the soil tests provide an index of phosphorus in soils that is related to the phosphate fertilizer needs of the crop. The relationship between the phosphorus index determined by a soil test and phosphate fertilizer requirements is developed through research. Plant phosphorus uptake and yield are related to measured quantities of phosphorus in soil.

Different soil-testing laboratories use different solutions to extract phosphorus from a soil sample. These different techniques can result in very different numeric values reported by different laboratories. This increases the importance of the index concept. Direct comparison of phosphorus levels between laboratories is very difficult unless they use the same procedures, solutions, techniques, and indices.

Indices commonly used to report soil-test phosphorus levels are very high, high, medium, low, or very low (**Table 1**). Each category should reflect the probability of response to phosphate fertilizer application. Crops grown on soils with a very high phosphorus index normally should not respond to phosphate fertilizer application, but crops on very low phosphorus soils should usually respond.

Phosphate Fertilization

In general, no fertilizer phosphorus is recommended for soils testing in the high or very high indices using MSU Extension procedures. Several fertilizer options are available if a soil test recommends phosphate be added to maximize plant growth (**Table 2**). Nitrogen is also a major ingredient of some materials.

Phosphorus needs of plants are most critical in the earliest growth stages. If the pH is between 6 and 7 and the soil has a low risk of erosion, you can apply phosphorus in the fall for cotton or grain production. However, fall-applied phosphorus on soils that are later flooded for duck habitat may be unavailable to crops the following year.

Phosphorus movement within soil is limited (Sims & Pierzynski, 2005). Because of this, corn and grain sorghum may benefit from phosphorus fertilization in a band near planted seed. Roots do not grow to fertilizer, but, when a root system meets localized phosphorus (or nitrogen) fertilizer, the roots will proliferate in that area. Placing fertilizer bands below and near the seed enhances the possibility of roots finding the fertilizer. Increased rooting because of the fertilizer-induced proliferation improves early plant vigor by more efficiently using all nutrients in the rooting zone.

Research with soybeans has not indicated a similar response to fertilizer placement. This is probably because of the different root systems of soybeans and grain crops.

Table 1. MSU Extension Service Soil Testing Laboratory soil-testing indices for phosphorus for all crops.

Soil Test Levels (pounds per acre)	MSU Extension Soil Test Index (based on Mississippi soil-test extractant)
0–18	very low
19–36	low
37–72	medium
73–144	high
greater than 144	very high

Table 2. Common phosphorus-containing fertilizers.

	N	P_2O_5	K_2O
Ammonium polyphosphate	10	34	0 (liquid)
Ammonium polyphosphate	16	62	0 (dry)
Diammonium phosphate	18	46	0
Monoammonium phosphate	11	48	0
Ordinary superphosphate	0	20	0
Triple superphosphate	0	46	0

Most forage crops develop many small roots close to the soil surface. These crops can efficiently use annual broadcast fertilizer applications to established stands. The preferred management before seeding forages is to broadcast and incorporate phosphorus fertilizer at the recommended rate. After establishment, you can apply phosphorus fertilizer annually at rates required to meet crop needs and to minimize environmental impact.

Because phosphorus does not readily move within soils, placement of phosphate fertilizers is a major management decision in crop-production systems. There is no ideal placement for all crops. Decisions about phosphate fertilizer placement depend on the intended crop, soil-test phosphorus level, and environmental considerations.

Animal manures and bedding materials contain significant amounts of phosphorus in organic forms. After microbes convert phosphorus from the organic forms, it is subject to the same fate as inorganic fertilizer phosphorus when applied to soils.

Detailed information on commercial fertilizer recommendations, options, and management is provided in MSU Extension Publication 2647 *Nutrient Management Guidelines for Agronomic Crops Grown in Mississippi* and Publication 2500 *Inorganic Fertilizers for Crop Production*.

Environmental Concerns

Phosphorus movement off agricultural land to surface waters may speed algal growth in water bodies. These algae ultimately die and decay in the water. This process may reduce oxygen levels and ultimately impact aquatic populations.

Research has shown that most phosphorus transported within a landscape is attached to moving sediment. Since phosphorus is closely attached to solid soil materials, erosion control helps to limit phosphorus movement to surface waters.

Best management practices (BMPs) are simple, low-cost, common-sense ways to minimize phosphorus movement (Lizotte, Knight, Locke, & Bingner, 2014; Osmond, Shober, Sharpley, Duncan, & Hoag, 2019). Information on BMPs for fertilizer applications is available in Extension Publication 2647 *Nutrient Management Guidelines for Agronomic Crops Grown in Mississippi*. Use the best combination of these for your situation.

Some situations may require more extensive nutrient management planning, such as animal feeding operations. The Mississippi Phosphorus Index Risk Assessment Tool may be used to evaluate the potential for phosphorus to move in the landscape. Note that this is not the same index illustrated in **Table 1**.

The risk assessment tool incorporates site-specific soil conditions and applied management practices in the evaluation. Soil-test phosphorus levels, soil permeability, field slopes, animal byproduct application rates, distance to surface water, and other factors are used to determine the probability of nutrient movement in the landscape. Evaluations are done on a field-by-field basis, usually by county Natural Resource Conservation Service office personnel and private technical service providers.

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