Managing P and S in your soil's nutrient bank

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Environmental concerns and regulations have brought changes to the both the phosphorus (P) and sulfur (S) economy of soils, which forces us to look for more efficient ways to cycle both nutrients on farms. Phosphorus, largely responsible for eutrophication of water bodies, is increasingly regulated in nutrient management plans. Additionally, there are global limits to P supply that make efficient P use essential. Sulfur, a component of acid rain, was rarely deficient in agricultural soils in the past because atmospheric deposition generally exceeded crop removal rates, but clean air regulations have brought lower S deposition and S deficiencies are emerging. This presentation will look at some possible ways to increase nutrient use efficiency for P and S by increasing overall soil health and using biological tools like cover crops.

Managing the soil's nutrient bank cannot be decoupled from managing overall soil health. This is especially evident for P. Traditional soil testing is not perfect for predicting crop response to P additions[1], and while it is advisable to follow soil test recommendations for P additions, physical and biological conditions of a soil that are not assessed in traditional soil tests can affect plant acquisition of P. Nonetheless, one of the most important factors influencing P availability, pH, is reported on most soil tests and is also one of the most easily managed aspects of a soil. A pH lower than 5.5 or greater than 7.3 increases the extent to which P is tightly bound to the mineral portion of soil and therefore maintaining pH within this range is critical to P management. Even with optimal pH, a soil's physical condition can limit P acquisition, especially when root growth is restricted by soil compaction, which is common on vegetable farms where heavy machinery and foot traffic are necessary for multiple field operations. Finally, biological activity influences P availability in multiple ways including overall microbial activity that can release P from organic matter, mycorrhizal associations that can increase effective rooting zones and increase P acquisition, and specific plant-soil interactions that can change the location and form of P in soil.

The biological components of crop-soil interactions and P dynamics are very complex and much is unknown. There is evidence, however, that certain management techniques including the use of some cover crops can increase P use efficiency in soils, thus reducing the amount of P fertilizer required for cash crop production. Not all cover crops increase P availability, however, and cover crop P uptake is not necessarily indicative of P availability to subsequent crops. For example, although white lupine (*Lupinus albus*) is known for its exceptional P uptake, it has been shown to decrease P availability after incorporation[2]. Therefore, if maximizing P availability is a goal of cover cropping, cover crops should be chosen carefully.

Anecdotal evidence that buckwheat (*Fagopyrum esculentum* Moench) increases soil P availability has been corroborated by some[3] but not all research reports. In one study, buckwheat had neither a positive nor negative effect on P availability for a subsequent crop while phacelia (*Phacelia tanacetifolia*) increased and ryegrass decreased available P[4]. Forage radish (*Raphanus sativus*), a non-mycorrhizal cover crop, has been shown to increase extractable P in the area directly around its taproot hole[5]. Results indicating that specific cover crops increase P availability to subsequent crops raise the possibility of precision cover cropping in place of or to complement fertilizer banding for the following crop.

Encouraging mycorrhizal associations that increase the effective rooting area and enhance P uptake is another biological strategy for efficient P cycling in agricultural soils. While there is little evidence to show that inoculation of soils with mycorrhiza is effective (unlike inoculation with *Rhizobia* for legume production), there is evidence that fallow periods are detrimental to indigenous mycorrhizal populations and crop P uptake[6]. Cover crops and careful crop rotation can increase indigenous mycorrhizal populations. For example, mycorrhizal cover crops interseeded with a non-mycorrhizal cash crop (cabbage) increased the mycorrhizal colonization and P uptake of the subsequent crop[7]. None of these biological management strategies is easy or well understood, but as nutrient management becomes more restrictive and P fertilizer harder to get, using the innate abilities of plants and microbes like mycorrhiza to increase P use efficiency will become more important.

Sulfur does not face the same global limitations as P, but some of the same strategies discussed for biological P management may be used for S management. The bulk of S in most agricultural soils is in organic matter, and biological activity is responsible for organic matter turnover and release of plant available sulfate. Therefore, total organic matter levels and biological activity are critical to S fertility. Sulfate is prone to leaching, however, so considerable amounts of plant-available S may be present below the rooting zone of many crops. Deep-rooted cover crops like forage radish or related cash crops like cabbage can capture this deep S, and crop rotations that include deep-rooted brassicas can increase overall S use efficiency. Forage radish cover crops increased sulfate-S on average 9 lb acre^{-1} compared to an oat cover crop (unpublished data).

Except in soils with excessive nutrient levels (which do exist!), there will always be a need to replenish P and S to the soil system because of crop removal. Most fertilizer recommendations exceed crop removal rates, however, which indicates that over time, a build-up of these nutrients will occur. Managing overall soil health and capitalizing on specific plant-microbe-soil interactions may provide a key to reducing fertilizer inputs.

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