Phosphorous nutrition of crops: a sustainable approach

by Antonio Abboud

Generally speaking, P fertilizer efficiency use indices are very low, which means that a large portion of the P added as fertilizers is lost rapidly by either chemical or physical removal from the available P pool in the plant-soil system. The total amount of P absorbed by crops is much less than the amounts added as fertilizers.

Plants can only absorb P when in phosphate ion form, although organic forms can also be absorbed to some extent. When in solution, these ions undergo several physicochemical transformations that, in most cases, turn them into forms that are less available to plants.. These transformations are referred as immobilization or fixation reactions and they are highly dependent on pH.

Phosphate ions can react with different elements, forming various insoluble products in the soil. In low pH sites, aluminum and iron are the most important elements responsible for the immobilization of P. Under neutral and alkaline conditions, different calcium compounds are responsible for these reactions. Soil organic matter also plays an important role. Some organic compounds can function as adsorption sites where phosphate ions are held with different strengths; others can compete with phosphate ions for adsorption sites, resulting in less immobilization of phosphate ions.

When first applied, P fertilizers are highly soluble and available, but there is a rapid decrease in availability. This is one of the reasons why P fertilizers are applied at seeding time, and localized along the area that will be exploited by the young roots. Also, some plants like maize, have a high demand for P at the early phases of development, which reinforces the use of this practice.

This approach is useful under situations where one single crop is considered. A certain amount of fertilizer is applied every year so that the soluble pool reaches a certain level during a certain period of time for that particular crop. As stated before, most of this fertilizer will be 'lost, as it is transformed into unavailable forms which accumulate in the soil. Under a monocrop system this phenomena will be even more dramatic, since the same crop is able to absorb nutrients from one same site, with one single intensity overthe same period of the life cycle.

Soil Erosion

Intensive monocrop systems are a major cause of soil erosion, which carries with it, fertilizer wastes. When they reach aquatic ecosystems they can have a major impact on eutrophication.

P fertilizers are a non-renewable resource; the phosphate rocks (the source for soluble Pfertilizer production) are restricted to some parts of the globe, hence the supply is not limitless. Strategies to cut the current excesses and misuses of this resource will help, not only to maintain the resource itself, but also, will contribute to decrease the fossil energy consumption to produce these fertilizers.

Because of the low solubility of phosphates in the soil solution and the relatively high concentrations required by plants, P absorption rates by the roots are faster than the diffusion of the phosphate ions in the soil solution. This causes a barrier at the soil root interface, normally known as the root depletion zone.

To overcome this barrier, two basic approaches could be considered: (i) increase the amount of phosphate ions in solution by artificial means, e.g. soluble fertilizers; (ii) increase the rate of phosphate ions release, through the manipulation of the soil, e.g. liming, organic fertilization, improvement of structure by tillage methods, irrigation, etc. The first approach is at the simpler level where the soil is a mere carrier of nutrient coming from fertilizer; the second one is also straightforward but soil dynamics are taken into account.

The soil is not an inert substrate nor are the plants a passive sink of nutrients. Provided the first and second approaches have already been adopted, to some extent, in most agricultural soils, the exploration of a third approach can give us opportunities to improve P nutrition, without the addition of inputs. We are now talking about increase of nutrient use efficiency rather than maximization of yields through addition of inputs.

Changing Environment

Plants can change their surrounding environment in a variety of ways. They can also respond to soil constraints by physiological changes that are not completely understood. They can as well interact with soil organisms that will help them to overcome nutrient shortages. This ability to modify the surrounding environment is genetically controlled and different species and even varieties within the same species, differ on these features. Because many of our crop varieties were selected under a high supply of nutrients, negative selection for some of these traits may have occurred. In fact, in a lot of cases, wild types of cultivated plants have a higher ability to survive under nutrient stress conditions than their cultivated relatives.

An important mechanism that can contribute to improving P nutrition is rhizosphere acidification. Most plants can, under certain conditions, acidify their rhizosphere. This acidity produced around the roots will modify the solubility of different soil P fractions. In general, legumes like clover, alfalfa and faba beans, can produce acidity when they are fixing nitrogen. However, if these same species receive nitrogen fertilizers this acidification will not occur. Research data have shown that legumes fixing nitrogen can take up more P than those that had been fertilized with nitrates.

Another group of plants that are known to be very efficient on taking up P from the soil, are the cruciferae such as rapeseed and oil radish. These plants have a higher percent of P in their tissues than many crops and they are also rhizosphere acidifying species. Buckwheat is another example of an efficient species on P uptake and is also a rhizosphere acidifier.

Plants can produce enzymes known as phosphatases that are able to breakdown some organic P compounds. Some research results show that these enzymes can contribute, to P nutrition, provided the organic substrate are present. Although there is a great deal of organic P in most soils, those that have been receiving intensive management, like high fertilization levels and mechanization, are those with lower levels of organic matter. In situations like that, the enzyme would be ineffective.

Beneficial Association

Another component of the soil plant system are the mycorrhizal associations. Most cultivated plants are associated with mycorrhizal fungi. These organisms are found in most soils around the globe and many plant species can not survive without them. Among the benefits from this association, increases in P absorption are the most studied. Intensive management and P fertilization can cause reduction in the presence of these associations. Tillage can reduce root infection by mycorrhrizae fungi through the disruption of hyphal network in the soil. P fertilization can have a short term effect by reducing infection on crops, as well as a possible negative long term one, by changing the mycorrhizal composition in the soil, both quantitatively and qualitatively.

Some species of plants are able to increase the mycorrhizal inocula potential after they are harvested. In a crop rotation system, alternation with such species could contribute to improving infection on the next crop. Different weeds can be a good source of mycorrhizal propagules. On the other hand, non-host species such as canola, mustard, buckwheat, oil radish coup reduce it. Although some studies have shown that some species are better than others, further research is needed to confirm that in specific locations.

These are some examples of fields that could be explored for a more efficient use of the soil P. Although we are talking about P nutrition specifically, other aspects of plant nutrition and soil conservation are involved.

The selection of species and varieties for these desirable traits discussed above, should be intensified. Trials with different combinations of such plants, in different situations of tillage and management are needed in specific areas until those systems can be manipulated, By adopting a mixed farming system in which crop rotations, cover crops, low tillage, less pesticides, organic fertilizers and green menu ring coexist, we will automatically enable our system to function, in a way, that all the mechanisms described above could contribute somewhat for the nutrition of the crops. In this case, less fertilizers would be required and problems of soil erosion and water quality, minimized.

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