Phosphorus Cycling on Organic Farms

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INTRODUCTION

All living things require phosphorus (P) to survive and thrive. P is found in the DNA, cell membranes, and energy storage compounds of every organism – from bacteria to bananas and from wheat to whales. In plants, P supports photosynthesis, root growth, flowering, and fruit and seed development, all of which are essential for producing healthy and abundant crops.

Soil P management is challenging for all farmers because of how P behaves in soil. Even when there is plenty of total P in soil, only a small amount is available to plants. Soil P that is exported in harvested products must be replenished from external sources. However, having too much P can cause environmental damage if it runs off into streams and lakes.

Organic farms face an extra challenge related to P management, since there are few suitable P inputs currently approved for use under organic standards. Some experts consider P management to be one of the biggest challenges facing the sustainability of organic crop production systems[1].

SOIL P IN A NUTSHELL

Elemental phosphorus (P) in soils, plants, and other organisms is always bonded to oxygen, forming phosphate ions (PO_4). Inorganic (or mineral) P compounds form when phosphate binds to soil minerals like calcium or iron. Phosphate can also bind to carbon and link to other elements to create organic (or biologically based) P compounds found in living, dead, and decomposing organisms, including soil organic matter.

All these P forms may be present in soil at the same time, creating a large pool of total P in soil with constant transformations between forms (*Figure 1*). However, only a tiny fraction of this P is dissolved in water at any time. Since plants need to "drink" their nutrients, they have direct access only to the P that is dissolved in water at that moment. Soil properties such as pH and clay content have a big influence on the solubility of P in the soil. Soil P is most soluble when soil pH is slightly acidic, around pH 6.5.

Generally, P does not move far in soil – only a few millimetres over a whole growing season – so plants have to go and get it. Some plants use extensive root systems to scavenge soluble P from the soil. Many plants associate with mycorrhizal fungi, which are even more effective scavengers than plant roots. Some plants also release substances from their roots to help extract less-soluble soil P from soil.

P or P_2O_5: What's the difference?

Fertilizer NPK analyses and many soil labs and agronomists refer to soil and fertilizer phosphorus as P_2O_5 or phosphate. A plant tissue analysis may report the results in elemental P (without the oxygen). In soil, fertilizers, and plants, P is never actually present as P_2O_5. However, it is important to understand how P_2O_5 fits into calculations of P budgets or P application rates. Be sure to consistently use either P_2O_5 or elemental P for such calculations.

To convert elemental P to P_2O_5, multiply by 2.3. To convert P_2O_5 to elemental P, multiply by 0.43. For example, a P_2O_5 application rate of 46 lb/ac is about 20 lb/ac of elemental P.

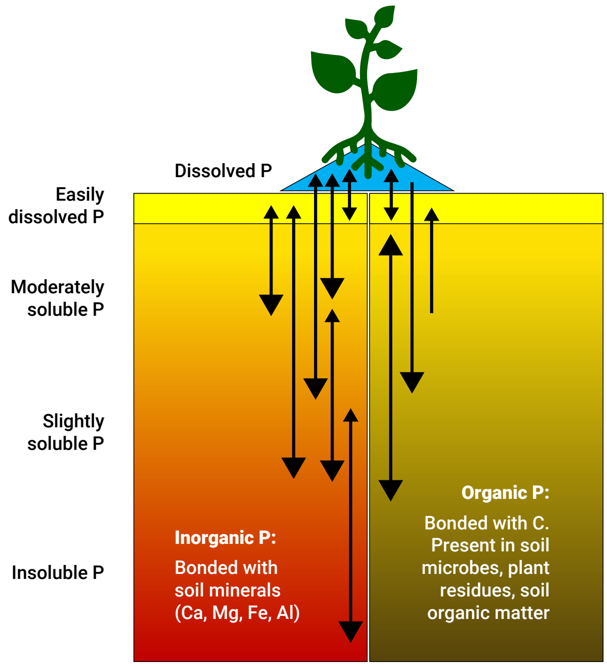

Figure 1. Pools of phosphorus in soil, including dissolved P, inorganic P with varying degrees of solubility, and organic P. Only dissolved P is immediately available to plants. A small amount of inorganic and organic P is easily transformed to soluble forms. Other transformations are constantly occurring. (Figure: J. Thiessen Martens)

PHOSPHORUS MANAGEMENT ON ORGANIC FARMS

Soil P management requires a long-term approach. On fields that have recently transitioned from conventional to organic production, crops may be able to rely on existing soil P reserves for a decade or more, depending on the initial soil P status and the crops grown. However, a P management plan can help correct early signs of P deficiency or prevent it altogether. On fields where plant-available P is already depleted, effective P management may be the most important step for restoring crop productivity.

Diagnosing P deficiencies

Diagnosing P deficiencies in organic systems requires a combination of observation and lab testing to help create a full picture of soil and crop nutrient status.

Young plants that are P deficient often have purple or red colouring (*Figure 2*), especially when the soil is cold. But even plants without the tell-tale purple leaves can be P deficient. General symptoms include delayed development, reduced flowering, poor root growth, and poor nodulation in legumes. However, these symptoms are hard to identify without a side-by-side comparison. If you have access to even a small amount of an approved P input, try applying it to a few strips in the field. Mark the strips well and observe the crop response over time.

Soil testing provides important information on soil P status. Organic fields can often be quite productive when a standard soil P test gives a rating of "low" (generally 5-8 ppm Olsen P). But a soil test that indicates a "very low" or "very deficient" rating (usually below 5 ppm Olsen P) is too low for most crops, even under organic conditions. Olsen P above 15 will not likely provide any additional benefit to crops and can pose a risk of P loss to the environment.

It is also important to test your soil pH, as this affects P solubility in the soil. Testing for other nutrients and properties such as salts can help to rule out other issues that may be causing poor crop growth.

If a P deficiency is suspected, a plant tissue test can provide more information. Tissue testing is best done in a legume-based green manure, at the early or full flowering stage. Collect samples of the whole plant from several places in the field, air-dry and cut into pieces, and send a sample to a lab for analysis of total plant tissue P. If the tissue P concentration is below 0.2%, a P deficiency is likely.

Making a P management plan

A good P management plan includes decisions on which P inputs to use, how much to apply, and when and where to apply it. There is no single best approach to P management because every farm is different, but following a few general principles can help.

Which P input?

A good starting point is to identify potential P inputs that are available, considering the pros and cons of each. Any P input used must be on the Permitted Substances List of the Canadian Organic Standard and must be approved by your certification body before it is applied.

Livestock manure or compost is one of the best sources of P and other nutrients. Be sure to have manure tested for nutrient content, as the P concentration can vary widely. There are a few other permitted P amendments available commercially, including alfalfa pellets, bone meal, and rock phosphate-based products. Rock phosphate and bone meal are generally only effective on soils with an acidic pH, but applying together with sulphur may help. When trying a new product, leave a check strip or two, so you can observe for yourself whether it was effective.

The costs of the product plus shipping and application are important to consider but remember that poor crop yields due to P deficiency also have a cost. Paying for P inputs is an investment in your farm.

How much P to apply?

The fertilizer recommendation from a standard soil test can provide guidance on how much P to apply, but is usually higher than what is needed for organic crops.

Another strategy for choosing a P application rate is to calculate a nutrient budget. A nutrient budget, much like a financial budget, adds up all the nutrients coming onto a field and subtracts those leaving the field. To calculate a nutrient budget, use the quantities of harvested products and P inputs multiplied by the P concentration of each item. A simple P budget is shown in *Table 1*. Charts of crop nutrient removals are available online or values can be obtained from lab analysis of grain and hay samples from your own farm. P removal from forage crops is very high and requires larger P additions than if only annual crops are grown. To balance your P budget, consider adding enough P to cancel out the deficit created by harvesting crops.

Given how scarce and expensive P inputs can be, it may not be possible to apply enough to balance P exports. In this case, it is important to create a strategy to make the best use of the P inputs available, especially when correcting P deficiencies that have already developed.

Table 1. A basic nutrient budget showing the removal of P from a field over a four-year rotation and the quantity of manure required to replace the P removed.

Year	Item	Quantity	P_2O_5 Concentration*	Total P_2O_5 removed/added
		Removals		
1	Alfalfa, hayed	3 ton/ac	15 lb/ton	45 lb/ac
2	Alfalfa, hayed	2 ton/ac	15 lb/ton	30 lb/ac
3	Wheat	30 bu/ac	0.6 lb/bu	18 lb/ac
4	Oats	50 bu/ac	0.26 lb/bu	13 lb/ac
	Total Removed			**106 lb/ac**
		Additions Needed		
	Beef cattle manure (wet basis)	**23 ton/ac**	**4.6 lb/ton**	**106 lb/ac**
Overall Balance				**0 lb/ac**

* Sources of P_2O_5 concentration values: **Crop Nutrient Uptake and Removal Chart**[2]; **Properties of Manure**[3]

Targeting certain crops is a good way to get the most benefit out of limited amounts of P inputs. Legume-based green manures and forages are especially sensitive to extreme P deficiencies and will not fix much N when deficient in P. For this reason, applying P to green manures can not only relieve P deficiency but can also help the legumes supply N to the following crop. Also, applying P inputs can stimulate weed growth, which may be easier to manage in a green manure crop than in a cash crop.

When and where to apply P?

If possible, apply P inputs in the spring, just before or at time of seeding. This gives the crop the best chance to use it and poses the least risk of P loss to the environment. Never apply any kind of P inputs on snow or frozen ground – much of it may be lost during spring snowmelt.

Because P does not move much in soil, it is important to get P inputs down into the soil rather than leaving them on the surface. Some products can be banded or injected. If applying on the soil surface, be sure to incorporate it into the soil as soon as possible. Placing P down into the soil also helps reduce P loss through surface runoff.

Coping with low soil P

Correcting soil P deficiencies can take time, but there are options to help cope with low soil P in the shorter term, especially on land where the deficiency is not very severe.

Choosing crops that are good at scavenging or mobilizing P from soil is important. Flax can do very well in fields with very low soil test P (3-4 ppm) because of its strong symbiotic relationship with mycorrhizal fungi. Soybeans also seem to perform well with very low soil test P. Other legumes, such as peas, hairy vetch, and alfalfa, tend to suffer at very low soil test P but can generally cope with soil test P classified as "low" (5-8 ppm)[4]. Most cereal crops are only moderately sensitive to P deficiency, but may suffer from N deficiency if the preceding green manure was P deficient. Brassica crops such as mustard tend to be very sensitive to P deficiency.

In soils with high organic matter content and biological activity, it may be possible to rely on the P released from the soil for a while. However, this is not a sustainable approach in the long term because it degrades soil organic matter.

SUMMARY

Phosphorus is often deficient on long-term organic fields without access to manure. Managing P on organic farms is tricky because of its complex reactions in soil and limitations on P inputs that can be used. Every farmer needs a long-term P management plan that includes knowing how to detect P deficiencies, deciding which P inputs to use to replace nutrients removed in harvested products, and choosing appropriate application practices. Applying P to fields that are deficient is an investment in the future of your farm, helping to support a sustainable and profitable operation built on healthy soils and crops.

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Figure 2. Spring-seeded fall rye with the typical purple leaf colour indicating P deficiency. (Photo: J. Thiessen Martens)

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