Phosphorus Management for Potatoes

By Robert Mikkelsen

Economic rates of P fertilization are higher for potatoes than for many other crops due to shallow roots and sparse root hairs.

BMPs are outlined to minimize the risk of P losses from potato fields.

Potatoes are the most important root and tuber crop for humans, and a significant economic crop for many farmers. More than a billion people consume potatoes each day. For example, a typical American consumes over 60 kg (140 lb) of potatoes each year (fresh and processed), far more than any other vegetable. Potatoes are currently grown in more than 125 countries, with China and India leading in production.

Proper management of P for potato production is a critical aspect to success. Potatoes have a relatively high P demand and a root system that is not particularly well suited to P uptake. This topic was the subject of a special symposium that was recently published in the American Journal of Potato Research. This article summarizes some of their key conclusions. Readers should refer to the symposium proceedings for additional information and specific scientific references.

Potato Root Development

The essential role of P for plants is well known, but special attention is given to potatoes due to their relatively low P recovery and efficiency. Potatoes have a rather low total requirement for P (25 to 45 kg P/ha), but a high requirement for available P in the soil, indicating low uptake efficiency. Potatoes are also somewhat inefficient in taking up other nutrients. For example, potatoes require 6 to 9 times more available K in the soil to reach 90% of their yield potential than crops such as wheat or sugar beet.

Potatoes have a relatively shallow root system, with the majority of the roots found in the upper 30 cm (14 in.) of soil. Potato roots generally stop development between 60 to 90 days after planting, linked closely with the maturation of the crop canopy and the end of new leaf development. As the plants divert resources to tuber bulking, root systems begin to deteriorate, although the nutrient uptake requirement is still relatively high.

Potatoes have a relatively low total root length density (about one-fourth of that of wheat), and also have relatively few of the root hairs that are critical for P uptake. Root hairs account for 21% of the total potato root mass, compared with 30 to 60% in other crops. One study suggested that root hairs account for up to 90% of the total uptake by plants when the soil P concentration is low (**Figure 1**).

Phosphorus Fertilization

A review of the behavior of P fertilizer described the major reactions as sorption, precipitation and organic interactions.

Sorption refers to the adsorption of soluble P to the surface of soil minerals. These reactions include fast and reversible reactions through a ligand exchange. They also include the slower penetration of P below the mineral surface. The sorption capacity of soil has a strong influence on the amount of fertilizer P required to meet the nutritional needs of potatoes. Soil tests account for much of the sorbed P that will become available for plant uptake during the growing season.

Abbreviations and notes: P = phosphorus; BMPs = Best Management Practices.

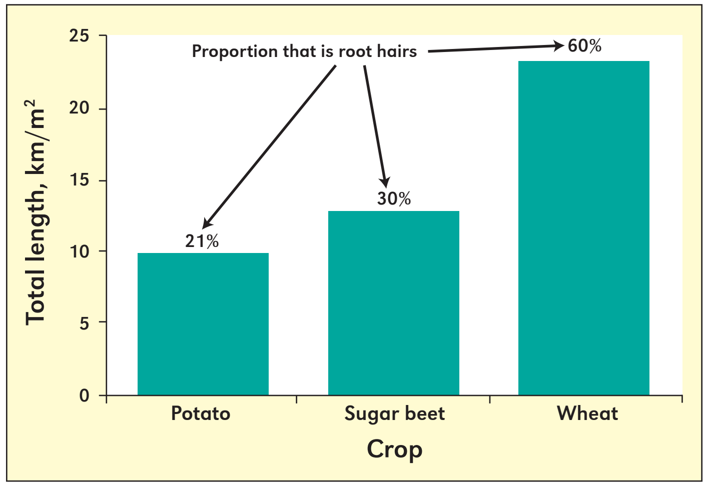

Figure 1. Relative root length and proportion of root hairs of three crop plants. From Thorton et al., 2014.

Precipitation occurs when added P fertilizer causes the soil solution to become over saturated with P and various solid minerals begin to form. The specific minerals that form and their persistence depends on many environmental and chemical factors. As time passes, the most soluble of these minerals may dissolve and less soluble minerals may recrystallize.

Organic P can contribute to potato nutrition. Much of the P added to soil in manures and composts is in the form of orthophosphate, initially behaving similarly to commercial P fertilizer. Soluble organic matter can inhibit P sorption in some soils and may also promote accumulation of organic P compounds, which can serve as a slow-release P source.

Placement of fertilizer P is critical for a potato plant to get the most benefit from its application, as the plant roots must grow into the soil zone influenced by the granule or droplet. Placing the fertilizer directly into the root zone increases the probability that a root will intercept the added nutrients. The failure of potato roots to intercept the fertilized micro-sites accounts for the relatively low first-year P recovery of 10% for broadcast fertilizer applications and 35% for banded applications. The unrecovered fertilizer P will contribute to the building of the general P concentration in the soil and can be used by succeeding crops.

Soil Testing

Soil testing is widely used to predict the need for additional fertilizer P to meet the demands of the potato crop. Although a variety of methods and extractants are used in different regions, they all determine if soluble P concentrations are below a critical level where additional P is required to achieve optimal yield. Soil testing should always be the first step in developing a P management program where it is available.

Plant tissue analysis is commonly performed to confirm P adequacy in the developing crop. Excellent resources exist to define the sufficiency of P concentrations during different stages of growth. When P deficiencies are found, in-season supplemental P applications are commonly made to alleviate any nutritional limitations.

The economically justified rates of P fertilization are much higher for potatoes than for many other crops. The positive yield response to P fertilizer often provides justification to applying P, even when the soil P concentrations are already high.


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Potato crop starting to flower, Tasmania.

Phosphorus Stewardship

Since many potato production fields often have relatively high soil P concentrations, they require special attention to prevent any off-field losses. Potato fields are at risk for loss of soluble P in surface runoff, particulate P with eroding soil, and P leaching in coarse-textured soils. Research has shown the need for special conservation efforts on fields of 6% slope or more. Implementing appropriate conservation practices in high-risk areas can minimize loss of P.

A seven-point recommendation of best management practices was suggested:

1. Begin a P management plan for potatoes with soil testing to determine the existing P concentration and establish the need for additional fertilization.
2. Base fertilizer P applications on calibrated potato response data. Excessive P fertilizer applications should be avoided for economic and environmental reasons.
3. Plan to apply a dose of P fertilizer at planting (with a minimum spacing from seed piece). Some potato-growing regions recommend only banded P fertilizer application, while other regions also use broadcast/incorporated P fertilization along with banded fertilizer.
4. The source of P fertilizer does not generally influence potato performance. Avoid placing ammonium-based P fertilizers too close to the seed piece at planting.
5. Monitor petiole P concentrations for determining the need for in-season fertilizer applications. In-season foliar P applications will not satisfy the nutritional requirement of a severely deficient crop. Check the chemical compatibility of fertilizer and irrigation water prior to fertigation.
6. Account for all P sources added to the field, including animal manures and composts.
7. Adopt appropriate conservation practices to minimize the loss of P to water, especially on vulnerable fields with a high risk of loss and with very high P concentrations. BC

P-deficient potato plants often appear stunted with dark blue/green leaf coloration.

Acknowledgement

The symposium papers listed below are published in Amer. J. of Potato Research (2014) Volume 91, Issue 2.

Fixen, P.E. et al. Potato Management Challenges Created by Phosphorus Chemistry and Plant Roots. pp.121-131.

Hopkins, B.G. et al. Improving Phosphorus Use Efficiency Through Potato Rhizosphere Modification and Extension. pp.161-174.

Rosen, C.J. et al. Optimizing Phosphorus Fertilizer Management in Potato Production. pp.145-160.

Ruark, M.D. et al. Environmental Concerns of Phosphorus Management in Potato Production. pp.132-144.

Thornton, M.K. et al. Improving Potato Phosphorus Use Efficiency in the Future. pp.175-179.

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