CASE STUDY - P IN POTATO PRODUCTION

MARCH 2022

Soil Wealth NURTURING CROPS

Integrated Crop Protection PROTECTING CROPS

IMPROVING P UPTAKE EFFICIENCY OF POTATOES IN P-FIXING SOILS

KEY MESSAGES

- ✔ **Potatoes have low phosphorus (P) uptake efficiency compared to most other crops**
- ✔ **Potatoes require available P throughout the growing season**
- ✔ **P uptake is highly correlated to root length and distribution as well as root health**
- ✔ **In the soil, polymers and organic molecules can keep P in solution**
- ✔ **Soil microorganisms can contribute to increased P availability**

PHOSPHORUS AVAILABILITY AND UPTAKE

You cannot escape the theory, and you would not want to – it can provide you with a clear view through the mist of misleading claims. (GRDC)

Potatoes are considered to have a low phosphorus (P) uptake efficiency compared to most other crops. It is well documented that generally only about 5-25% of fertiliser P is taken up, depending on variety and conditions. Therefore, P fertiliser inputs are commonly high. This is costly and may lead to P losses to the environment (Ruark et al. 2014). Even in P-fixing soils such as ferrosols – which fix P as insoluble aluminium and iron phosphates due to low pH and high aluminium and iron levels – losses can still occur via surface runoff and soil erosion.

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A large, healthy root system is the most important plant attribute for effective nutrient and especially P acquisition, particularly from P-fixing soils. In potato crops, poor root systems can be due to:

- Poor seed quality and health; physiologically old seed
- Compaction; cloddiness
- Poor soil microbiology; low organic matter
- Poor drainage; excess irrigation; waterlogging
- Low soil temperature
- High soil-borne disease pressure
- Adverse rootzone conditions, especially during crop establishment (low pH, high EC)
- Low level of available calcium in the rootzone
- Low level of available phosphorus in the rootzone (e.g. in P-fixing soils)
- Variety (for instance Russet Burbank has a poor root system compared to Innovator).

Another important factor is the distribution of P throughout the rootzone.

P availability is highly correlated with improved root development; when $H_2PO_4^-$ increases in the soil, plant roots can spread extensively (Balemi 2009, Faucon et al. 2015). This in turn leads to an enhanced exploration of the soil for water and nutrients. The yield quality is enhanced and disease resistance improved with appropriate P availability (Fernandes et al. 2017, Rosen & Bierman 2008).

Plants obtain their P from the soil solution in the form of the anions $H_2PO_4^-$ and HPO_4^{2-}. The $H_2PO_4^-$ form is dominant in acid solutions (pH < 7), and HPO_4^{2-} is dominant in alkaline solutions. In most soils a substantial proportion of the soil solution P is present in the form of soluble organic-P compounds. However, it is still debated how much these forms contribute to

plant nutrition. It has been shown that potato plants can absorb soluble organic phosphates (Havlin et al. 2016). Roots and also mycorrhiza hyphae release mildly acid exudates, which break the bond between locked up phosphates and allow uptake. This partly explains the relationship between root mass, root health and P uptake. The microbial biomass represents a relatively small but labile, available pool of soil P which varies significantly depending on the microbial population and its turnover.

Some soil microorganisms, particularly bacteria, solubilise P in the rhizosphere, increasing P availability to the plant (Gupta et al. 2014, Lucy et al. 2004).

Improving P availability and uptake efficiency can be achieved by keeping P in the soil solution and available for root uptake. This can be achieved by protecting it from forming insoluble aluminium, iron and also manganese phosphates in acid soils and calcium phosphates above pH 6.4 (P-fixing). This protection can be accomplished with the use of polymers, for instance to create polyphosphate, or via organic compounds that bond to complex anions. Humic and fulvic acids have been used to complex P-anions. Leonardite is a mineraloid produced by surface oxidation of lignite (a precursor to brown coal). It is comparable to soil humic acid and bioactive due to its molecular structure and can thus be very effective in 'protecting' P from being fixed.

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It is important for potato production that P availability and uptake during the growing season match the crop's need. The below diagram (see Figure 1) shows the general distribution of P in potato plants (%) relative to total P at maturity for Russet Burbank. It illustrates the increasing P uptake requirement after planting and explains why a preplant application of an easily fixable P-source (standard granular fertiliser) may not be suitable to provide adequate amounts of available P for the crop over the whole growing season.

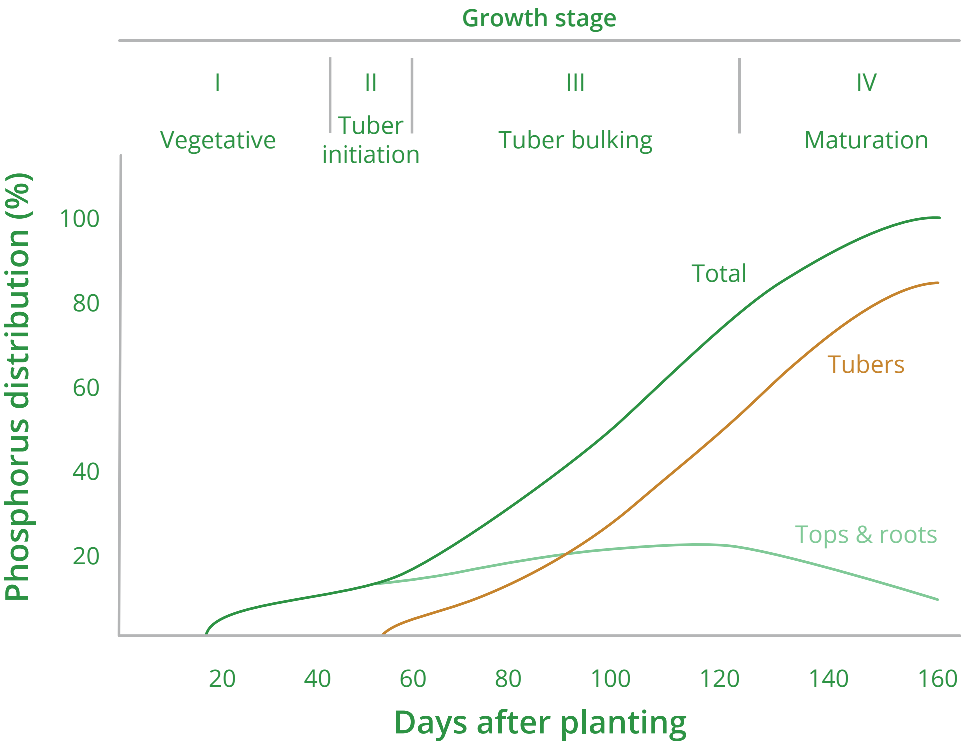

Figure 1: Potato P requirement/distribution during growth stages

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EVALUATION OF A NEW LIQUID PHOSPHORUS (P) FERTILISER

Research question:

Can the standard P application rate to processing potatoes (Russet Burbank) on a P-fixing soil be reduced using a specially formulated liquid P product?

A replicated trial was conducted in north-west Tasmania at the Forthside Vegetable Research Station during the 2020/21 season on a ferrosol soil to evaluate P-availability and impact on crop performance of a new liquid P fertiliser formulated with leonardite.

Treatments included five fertiliser treatments with:

- decreasing rates of total applied phosphorous as follows: 260 – 181 – 142 – 115 - 69 kg/ha achieved via:
    - decreasing P application rates of an industry standard dry NPKS fertiliser granular blend (11-13-19-1) as follows: 2000 – 1359 – 1000 – 750 – 350 kg/ha total blend
    - increasing rates of liquid P alongside the granular fertiliser as follows: 50 – 100 – 150 – 200 L/ha
- Rates of N, K, and S were kept constant at 220, 380 and 20 kg/ha respectively in all treatments; to achieve this, the required rates of a granular blend that did not contain P were applied together with the decreasing rates of the 11-13-19-1 blend.

The five treatments described in Table 1 were repeated with the addition of a biostimulant that was applied to the furrow separately from other liquids (P fertiliser and standard fungicides) at 20 L/ha. This biostimulant has previously been shown to improve root health and distribution.

The liquid P product analysis and properties were: 9.1 : 11.9 : 00 + 0.26% Zinc + 7.8% 'Reacted Carbon Technology' (Leonardite); the liquid product has a low salt index and pH of 6.3. The mineral component is derived from anhydrous ammonia, urea-ammonium nitrate (UAN), phosphoric acid and zinc sulphate.

The biostimulant contained: <1.00% w/v micro-organisms as well as, 1×10^3 colony forming units/mL of each of *Bacillus licheniformis*, *Bacillus megaterium* and *Bacillus pumilus* in a culture based medium of 99.00% w/v.

Table 1: Initial treatments detailing nutrients applied and subsequent treatments with biostimulant addition

Treatment	NPKS granular fertiliser (11-13-19-1) (kg/ha)	Liquid P (L/ha)	Total applied P (kg/ha)	Change in P vs treatment 1	Biostimulant (L/ha)
1	2000	0	260	-	20
2	1359	50	181	-30%	20
3	1000	100	142	-45%	20
4	750	150	115	-56%	20
5	350	200	69	-73%	20

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Findings and discussion

The soil at the trial site was low in P based on the 0-10 cm soil test (see Table 2). Colwell P indicated an adequate level but the PBI clarified that not all of the P may be available to the crop. All other tests showed that P levels were low (Mehlich 3 and DGT) and the P fixing capacity of the soil was high (PBI, PSR).

Marketable crop yield and tuber number were equivalent for all treatments. Treatments did not have a significant effect on tuber diseases. There was a trend for increasing misshapen tubers with decreasing phosphorous rate, with a significantly greater number of misshapen tubers at the lowest applied phosphorous rate of only 69 kg/ha compared to the highest and middle rates of 260 kg/ha and 142 kg/ha respectively. The relationship between tuber shape and P uptake needs to be further investigated.

Specific gravity of harvested tubers was very similar for all treatments that did not receive the biostimulant, regardless of phosphorous treatment. Where the biostimulant was applied there appeared to be a goldilocks effect with specific gravity increasing with decreasing phosphorous rate to 142 kg P/ha and then decreasing with decreasing rate after this point.

Dry tissue and sap petiole analysis revealed a general trend for decreasing phosphorous in sap and dry ash nutrients with decreasing application rate of phosphorous. The biostimulant generally caused an increase in phosphorous levels at 34 days after planting but the trend was not consistent at later testing dates. These results may have been due to the very low soil P levels; i.e. the crop may have needed additional P at this site. The commercial rates were used however to simulate industry standards, which mostly rely on recipe based approaches rather than site-specific management.

Figure 2: Control treatment (left) and comparable treatment with liquid P showing increased root and tuber development at 7 weeks post planting (right).

Table 2: P soil test results using different analytical methods

P test to 10 cm	Unit	Result	Desirable	Rating
Mehlich 3 P	mg/kg	28.5	40-90	very low
Mehlich 3 PSR	P saturation index	0.02	>0.06 <0.23	low = P-fixing
Colwell P	mg/kg	160	60-120	adequate
PBI + Col P	P buffer index	723	<100	high = P fixing
DGT-P	µg/L	31	50-70	low

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Summary

The results indicate that reducing the overall P rate to 142 kg/ha via applying half of the standard granular fertiliser rate of 2000 kg/ha plus 100 L/ha of the liquid P formulation may be a good approach in this low P and P-fixing soil. The addition of a biostimulant may be of advantage in soils with lower organic carbon levels. The trial site had 4% organic carbon in 0-10 cm.

Next steps would be to trial reducing granular P rates and using the liquid, more available P source to replace some of it in commercial crops using a site-specific approach. The commercial trials would also consider the results from the 2020/21 field trials. These trials conducted in several commercial crops in the Ballarat region and Northwest Tasmania showed improved tuber set (see Figure 2) and yield increases when granular P was partially replaced with the new liquid formulation.

A further consideration would be to apply some of the liquid P during the growing season rather than at planting to provide for the increasing crop demand. The biostimulant is expected to be beneficial on sites where organic carbon levels have declined, indicating a drop in microbial activity and/or diversity.

REFERENCES AND USEFUL RESOURCES

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Resources

Plant Analysis Guide - https://www.soilwealth.com.au/resources/articles-and-publications/plant-analysis-for-vegetable-crops-a-practical-guide-to-sampling-analysis-and-interpretation/

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