Phosphorus Efficient Potatoes

Tim George, Lawrie Brown, Jane Wishart, Jacqueline Thompson, Gladys Wright, Gavin Ramsay, John Bradshaw, Philip White

Phosphorus (P) is a mineral nutrient required by plants and its management in soil is critical to ensure a sustainable and profitable agriculture that has minimal impact on the environment. Although soils contain large amounts of P, only a small proportion is immediately available to plants. For this reason, P-fertilisers are commonly used to maintain agricultural productivity. However, intensive use of P-fertilisers has resulted in the accumulation of P in soils, albeit in forms that are poorly available to plants. The movement of this P to water-courses is of environmental concern. Our objective is to improve the economic and environmental sustainability of agriculture by using fertilisers more efficiently.

Potatoes require large P-fertiliser inputs. One way to reduce these inputs is to cultivate genotypes that use P efficiently, either because they require less P in their tissues or because they yield with smaller P input. These abilities are affected by many factors, but rooting characteristics (such as increased rate of growth, specific root length, and density and length of root hairs) and rhizosphere biochemical processes (such as the exudation of organic acids and enzymes) are of fundamental importance. Understanding the physiological and genetic control of changes in these characteristics as a natural response to P deficiency may provide opportunities to improve the acquisition of soil and fertiliser P by plants in conventional and organic systems.

Our initial approach has been to screen core collections for tissue P efficiency (PUEt) in tuber yield (Figure 1). This work has demonstrated significant differences in PUEt between commercial varieties and, importantly, between parents of SCRI genetic mapping populations. In a Defra-funded collaboration with Dr John Hammond (Warwick HRI) we have screened these populations for PUEt and identified chromosomal regions (QTL) affecting this trait.

We have also assessed the ability of potatoes to explore the soil volume, by screening genotypes for rooting characteristics in the field (Figure 2). We found significant differences in root length between commercial

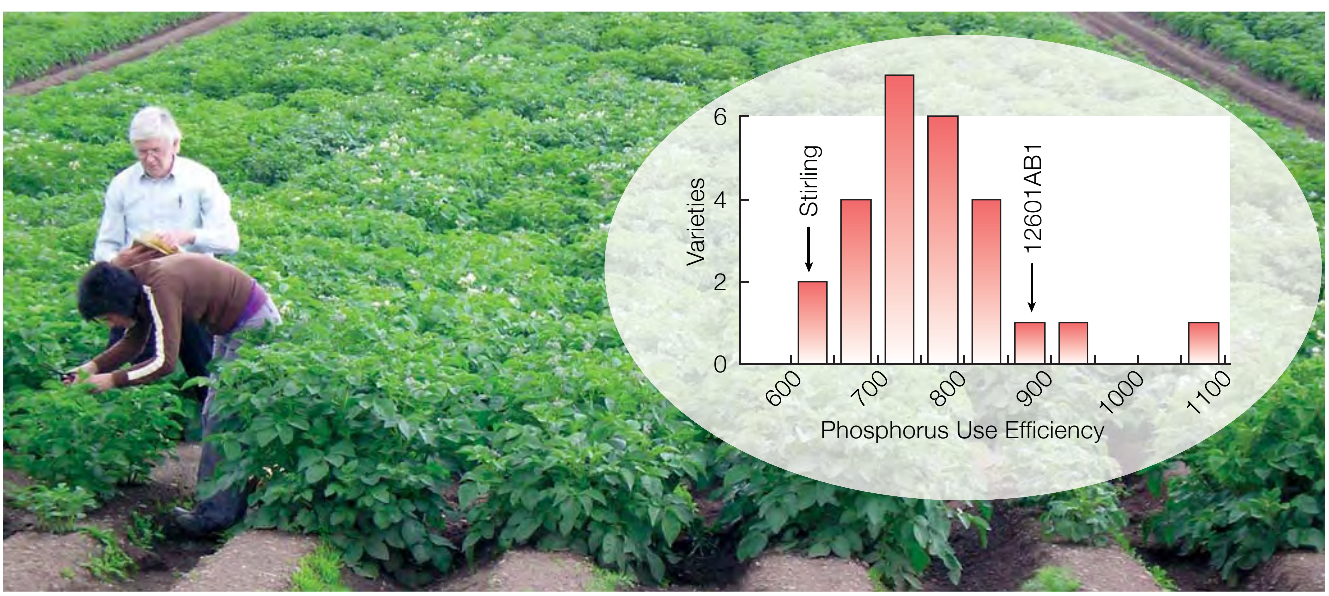

Figure 1 Screening genetic mapping populations of potatoes for P-use efficiency in the field is identifying the genetic basis of traits that will deliver varieties that allow sustainable reduced-input agricultural production. Inset: Phosphorus Use Efficiency (g DM / g P) determined in tubers of a core collection of 26 commercial potato varieties trialled in the field at SCRI in 2006. Data are means of two replicate plots each containing eight plants at 40 cm spacing. Stirling and 12601AB1 are parents of a *Solanum tuberosum* genetic mapping population.

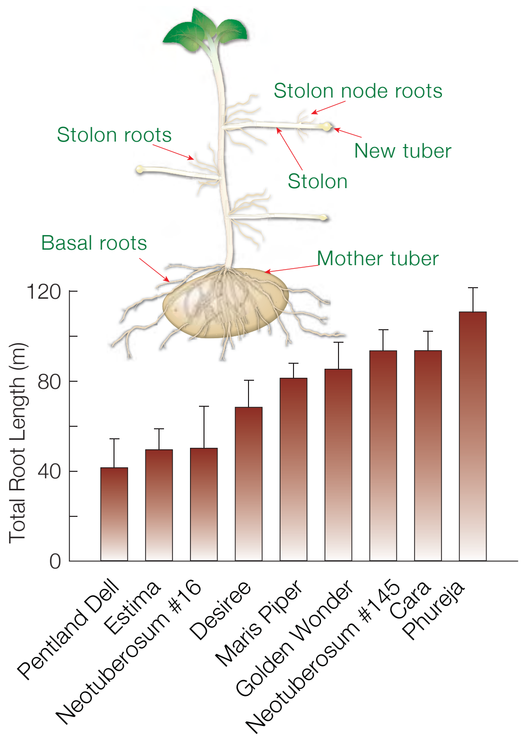

Figure 2 Total root length (m) of field grown potato plants excavated at tuberisation in the 2007 growing season. Potato varieties screened included European tetraploid potato (***Solanum tuberosum*** Group *Tuberosum*), a diploid Phureja potato (*Solanum tuberosum* Group *Phureja*) and some neotuberosum germplasm. Plants were grown at an 80 cm spacing. Data are the means of four replicates with standard error presented as a bar. Inset: Representation of potato rooting system.

varieties. In future research, this trait might be exploited in breeding programs for improved P acquisition. In addition, we are studying the ability of plants to mobilise sparingly-soluble soil P. In collaboration with Dr Alan Richardson (CSIRO, Australia) we have expressed extracellular phytase genes in plants, in an attempt to improve P acquisition from organic compounds in the soil. Recent experiments compared plants grown in soils that had been amended with manures from monogastric animals, which is thought to contain high concentrations of phytate (the substrate of phytase), with those grown in soils amended with low-phytate

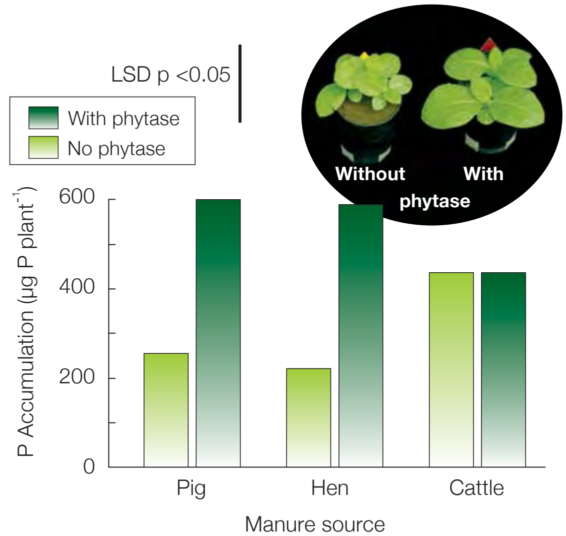

Figure 3 Accumulation of P by plants expressing extracellular phytase genes compared to controls without phytase, when grown in soils amended with manure from monogastric animals (Pig, Hen) and that from ruminants (Cattle). Data are the mean of five replicates and LSD ($p<0.05$) is shown as a bar. Inset: Growth of tobacco plants with and without the expression of phytase.

manure from ruminants (Figure 3). Plants expressing extracellular phytases had greater P-uptake than untransformed controls when grown in soils amended with high-phytate manures, but had no advantage in soils amended with low-phytate manures. These results suggest that it may be possible to enhance P-acquisition by potatoes by increasing rhizosphere phytase activity. This might be achieved by expressing phytase genes in commercial germplasm or by fostering phytase exuding microorganisms in the rhizosphere.

The research being performed by the EPI Resource Capture Group is enhancing our physiological understanding of traits affecting potato P nutrition and their genetic control. This will allow us to select potato varieties requiring less fertiliser P, fulfilling our objective of reducing P-fertiliser inputs to potatoes, thereby increasing the economic and environmental sustainability of this enterprise.