MANAGING SUBSOIL ACIDITY (GRDC DAN00206)

# Genetic potential for yield improvements on acid soils in Australia's major grain crops

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http://www.dpi.nsw.gov.au/agriculture/soils/acidity

A scoping study provides an overview of current knowledge of acid soil tolerance in the major winter crops species (wheat, barley, canola and pulses).The review listed known mechanisms and genes controlling Al and Mn tolerance and proposed strategies for improving tolerance in certain species.

## Project background

Crop yields begin to be limited when soil pH falls below 5.0 in $CaCl_2$. Australia's major grain crops (wheat, barley, canola and pulses) continue to be affected by acid soils (Figure 1) and total losses to agriculture are estimated to be $900 to $1,585 million per annum (Hajkowicz 2005).

Acid soils present many stresses to plants but chief among them is aluminium ($Al^{3+}$) toxicity which inhibits root growth (Figure 2). Although acid soils can develop naturally, certain agricultural practices increase the rate of acidification. If left unmanaged acidification will degrade agricultural land and cause larger yield losses in the future.

The most effective management practice for slowing and even reversing acidification is the application of lime (calcium carbonate) but it can take years for the lime to correct pH in the subsoil below 10 cm. This is particularly true in minimum tillage production systems. Crops and cultivars with a greater tolerance to acid soils are important resources for farmers because they maintain production and income while amelioration efforts continue.

It is unlikely that the genetic yield potential of Australia's major crops on acid soils has been fully realised. Further increases in production could be achieved through standard breeding strategies, from wider crosses to related species and from genetic engineering (Ryan *et al*. 2011).

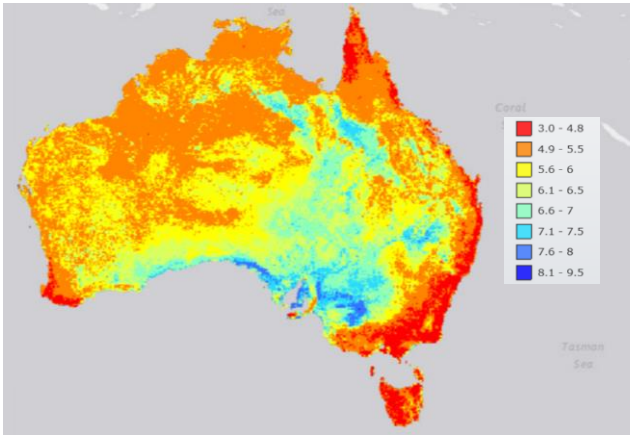


**Figure 1. Distribution of acid soil in Australia. Data show the estimated value for soil pH at 5-15 cm depth. Source is the Soil and Landscape Grid of Australia (http://www.asris.csiro.au/viewer/TERN/).**

## Potential for improvement

- **Bread wheat** is Australia's largest crop so even small yield increases on acid soils can significantly impact production. Most cultivars are already reasonably tolerant to low pH because they possess the major gene for tolerance that controls the $Al^{3+}$-activated malate release from root tips. Further improvements might be possible by pyramiding other known QTL and by introducing genes from highly-tolerant cereals such as rye or triticale.
- **Barley** is Australia's second largest grain crop, more sensitive to acid soils than wheat. Nevertheless there is some genotypic variation and breeders have exploited this variation to develop a commercial cultivar "Litmus". Litmus yielded significantly better than other elite barley cultivars on acid soils in Western Australia. More advanced material is currently being generated and this could expand the total area of barley cultivation.

- **Durum wheat** is among the most sensitive cereal species to acid soils. It shows very little genotypic variation in tolerance so cultivation is restricted to non-acid regions of South Australia, Victoria and northern NSW. Although production is small compared to bread wheat durum it is a lucrative crop with strong market potential. Recent programs at CSIRO have successfully increased the acid tolerance of durum by introducing genes from hexaploid wheat (Han *et al*. 2016). These lines could raise production significantly by increasing yields and expanding the area under cultivation.
- **Canola** is Australia's third major grain crop and also more sensitive to acid soils than bread wheat. Genotypic variation for acid soil tolerance appears to be small and so breeding strategies to improve adaptation to acid soils may have limited success. However since canola is one of two genetically-modified crops currently grown in Australia biotechnology could be used to increase production on acid soils.
- **Pulses** have become popular choices for crop rotations. Substantial benefits would result from improving the acid soil-tolerance of pulses because, apart from the lupin species, most are sensitive or very sensitive to acid soils. Any improvement in the tolerance of chickpea, lentils, faba bean or field pea would be welcomed by farmers across Australia. Significant genotypic variation for acid soil-tolerance has been reported in most of these pulse species. Whether the cultivars grown in Australia have reached their genetic yield potential on acid soils is unknown and should be a priority for breeders.

## References


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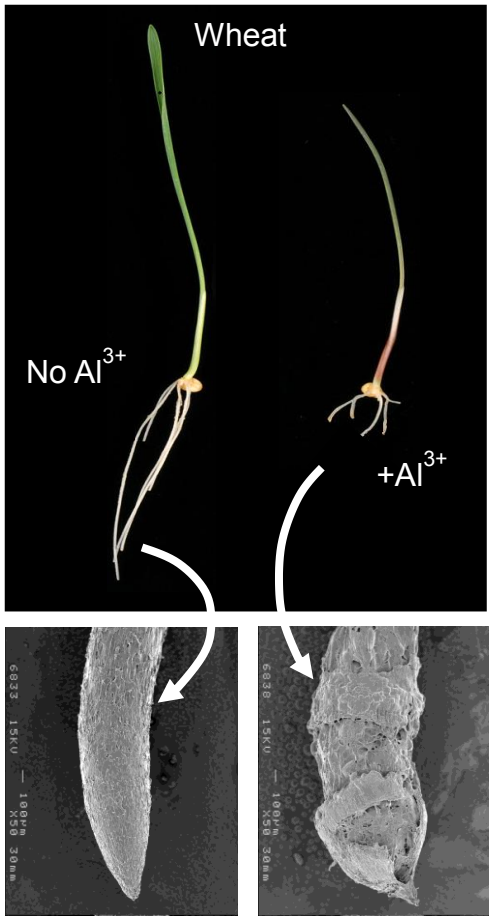


**Figure 2. The Al3+ ions prevalent in acid soils inhibit root growth by damaging the root tips where cell division and elongation occurs (Micrographs by E. Delhaize).**

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