Variable Aluminium Toxicity and Root Distribution in Acidic Soil Profiles

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Subsoil acidity currently affects two thirds of the arable soils in the WA wheatbelt. At acidic soil pH, aluminium (Al) is solubilised from the solid phase into soil solution, creating a direct and localised toxicity to plant roots. Aluminium toxicity to plant roots constrains crop productivity by reducing root proliferation through soil, and inhibiting the capacity of roots to tolerate other constraints, such as compaction. Ongoing acidification of the subsoil is a direct artefact of the productive farming systems that are required to feed our world's growing appetite for grain and livestock products. Soil acidification under cropping systems is primarily attributed to product removal (disturbances in the carbon cycle) and interruption of the nitrogen cycle. Currently, the incorporation of agricultural lime into acidic soil is the only widely applicable strategy for the amelioration of soil acidity in a broad-acre cropping scenario. However, due to the slow movement of alkalinity in soil, the effects of lime application on soil acidity and Al toxicity are largely localised to the soil volume through which lime had been incorporated. Technical and economic constraints limit the capacity to incorporate lime through the acidic subsoil horizon, and current strategies result in a heterogeneous distribution of lime in the soil profile. As part of Soils West, a collaboration between The University of WA (UWA) and the Department of Primary Industries and Regional Development (DPIRD), a series of glasshouse and field experiments have characterised the response of wheat root growth and distribution to heterogeneous distribution of lime in acidic, Al-toxic soil. The effects of lime amendment on root proliferation are highly localised within lime-amended sections of soil, and do not extend beyond. Root length density can be many times greater in lime-amended, compared to adjacent acidic subsoil. Lime amendment of acidic subsoil increased cation uptake by plants in both field and glasshouse experiments, which is attributable to the increased root length within lime-amended soil sections. Similarly, lime amendment of acidic topsoil increases the uptake of phosphorus by wheat plants, which is associated with increased root length within the lime-amended topsoil layer. Where lime slotting treatments were imposed on 80-cm-deep constructed soil profiles in large plastic crates, wheat root proliferation in lime-amended slots, and subsequent plant growth response, was dependent on the distance of the crop rows from the lime amended slots. Wheat root proliferation within the lime-amended slots did not increase the capacity of plants to acquire water from the acidic subsoil horizon; however, it did allow roots to access water in deeper soil layers where slots of lime-amended soil traverse an acidic subsoil layer. Understanding crop response to the variability of pH in the soil profile following lime incorporation will enable better evaluation of existing (and facilitate development of new) lime incorporation strategies