Spatial Aluminium Sensitivity of Root Apices of Common Bean (*Phaseolus vulgaris* L.)

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Introduction

About 40% of the common bean (*Phaseolus vulgaris* L.)-growing area in Latin America and 30 to 50% of Central, Eastern, and Southern Africa are affected by Al toxicity resulting in yield reduction from 30 to 60 % (CIAT, 1992). Common bean needs significant improvement in Al resistance to reduce farmer's dependence on lime and fertilizer. Reduction of root growth is the most widely recognized symptom of Al toxicity. In plants, growth is confined to distinct zones along which diverse spatial patterns of growth exist. Hence, detailed quantitative description of spatial growth profiles help to understand the effect of stress conditions in the regulation of growth (Peters and Bernstein, 1997). Research work by Sivaguru and Horst (1998) and Kollmeier et al (2000) presented evidence that the distal transition zone (DTZ) is the most Al-sensitive zone of the root apex in maize. Spatial Al sensitivity studies has not been conducted in common bean so far. Therefore, the aim of the present study was to understand the spatial effect of Al on root growth in order to develop quick screening techniques for Al resistance in common bean.

Materials and Methods

Three-days old seedlings of an Al-sensitive cultivar (VAX-1) and an Al-resistant cultivar (Quimbaya) were grown in nutrient solution containing 5 mM $CaCl_2$, 0.5 mM KCl and 8 µM H_3BO_3 under controlled environmental conditions. After pH adjustment to 4.5 ± 0.1, plants were exposed to 0 or 20 µM Al for up to 24 h. Local Al treatment was performed in low gelling-temperature agarose (1% w/v) dissolved in nutrient solution containing 0 or 200 µM Al (Sivaguru and Horst, 1998). Aluminium was applied to specific 1 mm apical root zones using a polyvinylchloride (PVC) block (Fig. 1) or to 20 mm apical root zones using a plastic-cylinder block system (Fig. 2), in this case the apical root in consideration was located outside the Al-treated zone. Root elongation rates were calculated from measurements of root length after 4 h of Al treatment. Spatial growth patterns of individual root sections where obtain from root tips previously marked at 1 mm intervals. The distances between the dots were measured after 4 h, and then the elongation rates of each specific zone were calculated and plotted as a continuous curve against the distance from the root apex.

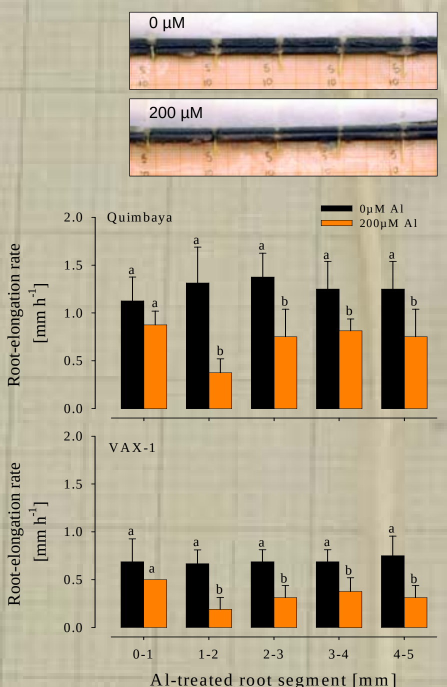

Fig 1. Aluminium inhibited root elongation when applied to all segments except the apical segment. Aluminium was particularly toxic when applied to the 1-2 mm zone, a zone that corresponded with the distal transition zone (DTZ).

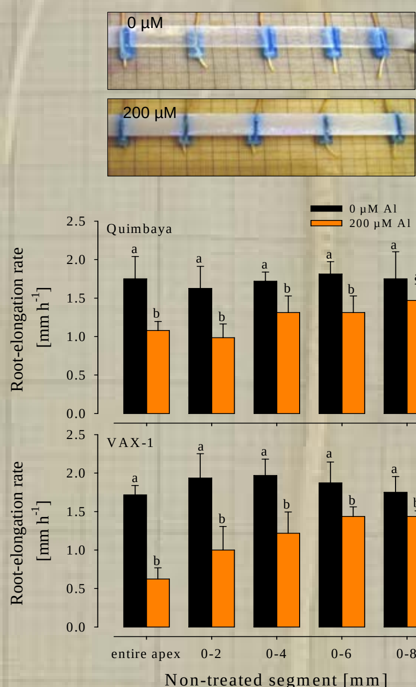

Fig 2. Aluminium treatment significantly inhibited root elongation even if Al was not applied to the 0-8 mm zone. Aluminium applied to the 0-2 mm segment was more toxic, although basal root segments also contributed to the inhibition of the overall root elongation.

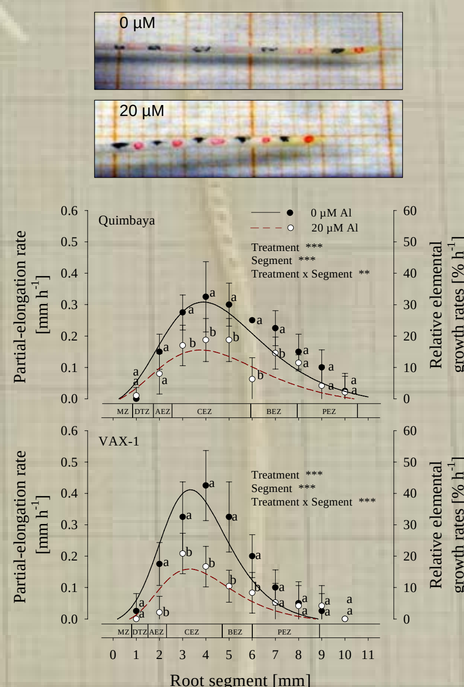

Fig 3. Root growth inhibition induced by Al treatment resulted from a general inhibition along the entire elongation zone (EZ). The inhibition was greater in the central elongation zone (CEZ). VAX-1 was more severely inhibited (60%) than Quimbaya (40%) in the entire EZ.

Conclusions

The results presented confirm that in both species the DTZ is the most Al-sensitive root zone. However, in common bean Al inhibits root elongation also when applied exclusively to the EZ. Aluminium resistance in common bean thus requires the protection of the entire EZ from Al injury. Genotypes differing in Al resistance in medium and long-term studies do not differ in their short-term sensitivity to Al. Therefore, Aluminium resistance in common bean is building up during medium-term exposure, supporting the idea of a mechanism of Al resistance based on exclusion.

References

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