SHORT AND MEDIUM-TERM ROOT-GROWTH RESPONSES TO ALUMINIUM IN COMMON BEAN (*Phaseolus vulgaris* L.)

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Introduction

Aluminium toxicity in acid soils in the tropics is a serious problem and amending soils with lime is difficult and prohibitively expensive for small farmers. Common bean needs significant improvement in Al resistance to reduce farmer's dependence on lime and fertilizer. Field screening of 5000 germplasm accessions and breeding lines in Al-toxic soils with and without lime (65% Al saturation) indicated significant genotypic variation in seed yield (Rao, 2001). Likewise, significant genotypic differences for Al resistance have been found in nutrient-solution based screenings using inhibition of root elongation after 36 h (medium-term) at 20 µM Al supply as parameter for Al injury (Rangel et al., 2004). An approach to further accelerate and facilitate the screening for Al resistance after short-term Al treatment (< 4 h) was not successful (Rangel et al., 2004). The present work aimed at understanding the kinetics of Al-induced inhibition of root elongation and Al accumulation in an effort to identify plant traits allowing to develop efficient screening procedures for genetic enhancement of the adaptation of common bean to acid soils.

Materials and Methods

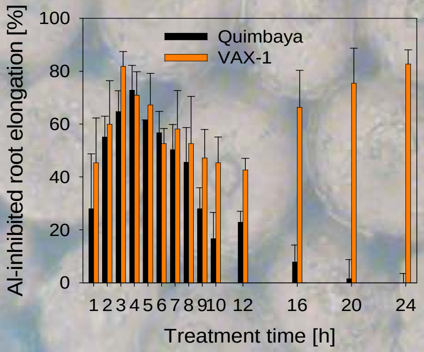
Three-days old seedlings of an Al-sensitive cultivar (VAX-1) and an Al-resistant cultivar (Quimbaya) were grown in nutrient solution containing 5 mM $CaCl_2$, 0.5 mM KCl and 8 µM H_3BO_3 under controlled environmental conditions. After pH adjustment to 4.5 ± 0.1, plants were exposed to 0 or 20 µM Al for up to 24 h. Root length was measured through marking of the main root 3 cm behind the root tip at the beginning of the treatment. Root Al content was determined by GFASS (Analytical Technologies Inc., Cambridge, UK) after wet digestion (Eticha et al., 2005). For the collection of citrate exuded from root apices, we employed the method described by Kollmeier et al. (2001). Briefly, 10 intact 5-days-old seedlings were bundled and the tips (maximum 2 cm) were incubated for 2 h in 10 ml of treatment solution with or without 40 µM Al. Citrate was analyzed by isocratic HPLC (Kroma System 3000; Kontron Instruments, Munich).

Set-up to study phenotypic differences among common bean cultivars in root growth and development under Al stress.

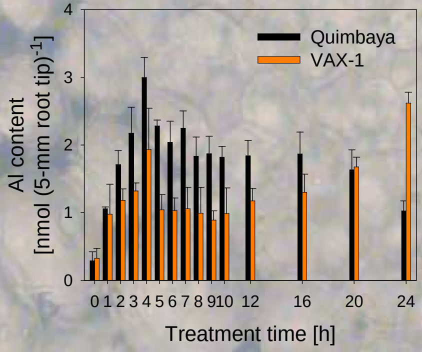
Root development of an Al-resistant (Quimbaya) and an Al-sensitive (VAX-1) common bean cultivars grown in nutrient solution for 24 h at 0 and 20 µM Al, pH 4.5.

Set-up to study organic-acid anion (i.e Citrate) exudation from root apices.

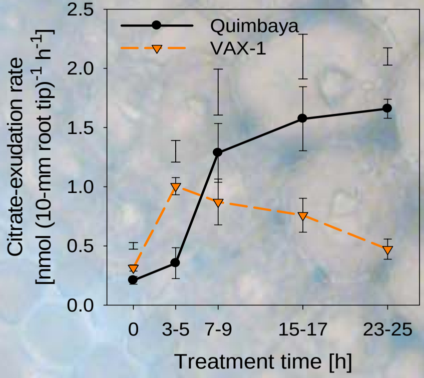
Results



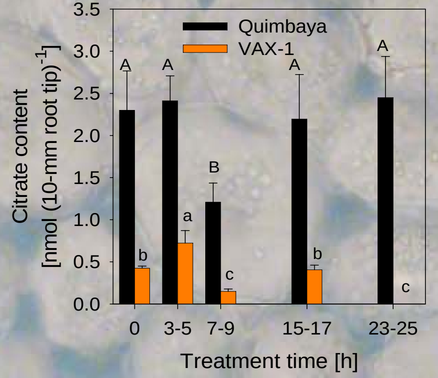
Root growth of both cultivars was severely inhibited during the first 3 to 4 h of Al treatment. After a short recovery period in both cultivars, Quimbaya kept steadily recovering while VAX-1 was increasingly inhibited.



Enhanced inhibition during up to 4 h Al treatment was related to high root -tip Al contents in both cultivars. They were even higher in cv Quimbaya than in cv VAX-1. Recovery from Al stress was reflected by decreasing Al contents. After 24 h Al treatment, the genotypic differences between the cultivars observed in root growth were clearly reflected by much higher Al contents in cv VAX-1 compared to cv Quimbaya.



Al induced citrate exudation with a lag phase of 3 h (cv VAX-1) to 4 h (cv Quimbaya). Thereafter, citrate exudation increased to a higher rate and remained at that high level in cv Quimbaya, whereas it gradually declined in cv VAX-1.



Citrate contents in both cultivars were slightly increased during the first 3 to 5 h of Al treatment. After a severe (ca. 50%) decrease in both cultivars, Quimbaya gradually recovered until it reached the level of the controls, while VAX-1 steadily declined, until it was practically not detected in the HPLC.

Conclusions

The results shown here demonstrate that genotypic differences in Al resistance in common bean are not constitutive, but build up during exposure of the roots to Al. For this acquisition of Al resistance the release of organic acid anions, particularly citrate, and the maintenance of high root citrate-contents appear to be decisive.

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