Overexpression of *SbMATE* gene improves aluminum tolerance in maize

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Aluminum (Al) toxicity is a limiting factor for crop production on acid soils. Citrate efflux from root apices is a mechanism of Al^{3+} tolerance in many plant species, which is facilitated by membrane transporters encoded by MATE (Multidrug and toxic compound exudation) genes, such as *SbMATE*, the major Al^{3+} tolerance gene in sorghum. The aim of this study was investigating whether the overexpression of *SbMATE* gene can improve Al^{3+} tolerance in maize. A single-copy event constitutively overexpressing *SbMATE* was introgressed into a maize breeding line using marker-assisted backcrossing. Transgenic lines and the isogenic non-transgenic line were analyzed for the transgene expression, citrate efflux, Al^{3+} tolerance in hydroponic solution, and root morphology in acid soils. The transgenic lines showed high levels of *SbMATE* expression in the root, which was induced up to three times in root apices after 24 hours of Al treatment. The overexpression of *SbMATE* increased the citrate efflux in the maize transgenic lines in comparison to the non-transgenic line. Furthermore, the transgenic lines improved significantly the Al tolerance in nutrient solution, showing up to 77% of relative net root growth in contrast to the non-transgenic line, which presented 37%. Finally, these transgenic lines showed a superior root development in the sub-superficial soil layer with 15% of Al saturation. Thus, our current results indicate that transgenic technology using *SbMATE* can be used to improve Al tolerance in maize and other crops, opening new avenues to guarantee yield stability on acid soils.

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