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Effects of abscisic acid on alleviation of aluminum toxicity in alfalfa

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Introduction

On a global scale, acidic soils cover an estimated 37.8 million km^2 of the earth's surface, and up to 50% of the world's potentially arable soils are acidic. Aluminum (Al) is highly abundant in acid soil conditions. At low (<5.5) pH, a toxic form of aluminum, Al^{3+}, is solubilized from aluminosilicate clay minerals into soil solutions. High concentrations of Al^{3+} in soil solutions caused seriously damage to plants by inhibiting cell elongation and division in roots, leading to swollen root apices with poor or no root-hair development, and decreasing plant growth (Kochian *et al*., 2005). Al toxicity represents one of the most important constraints for agricultural production in areas with acidic soils. Plant hormones are involved in plant adaptation to environmental stresses (Zhu *et al*., 2013). However, limited information is available for hormones effects on plant tolerance to Al^{3+} toxicity. Alfalfa (*Medicago sativa* L.) is an important legume used as a forage crop worldwide. Al toxicity is a major factor limiting alfalfa production in soils with low pH. The purpose of this study was to investigate Al^{3+}-induced abscisic acid (IAA) transport, distribution and their relation to Al^{3+}-inhibition of root growth in alfalfa by exogenous foliar application of IAA on plants with or without apical buds.

Materials and Methods

Alfalfa seedlings with or without apical buds were grown in pH 4.5 nutrient solution containing Al at 0 (-Al) or 100 μM L^{-1} $AlCl_3 \cdot 6H_2O$ (Al), and were foliar sprayed with water or IAA during 10-d treatment. The measurements of root length, root weight, above-ground biomass, root viability reflected by triphenyltetrazolium chloride (TTC) reduction, leaf membrane lipid peroxidation reflected by malondialdehyde (MDA) content, callose content, IAA concentration and expression of three genes related to IAA transport were taken.

Results and Discussion

Aluminum stress caused a significant reduction in plant growth, and significant increases in leaf membrane lipid peroxidation and callose production in root tips; Aluminum stress also induced a significant increase of IAA concentrations in root base, but a significant reduction in apical buds, root tips and shoot base, with most pronounced reduction in root tips when apical bud was removed. The variation of IAA distribution in Al^{3+}-stressed plants would influence its function on regulating plant development and growth, while the decreased IAA concentrations in apical buds and root tips may directly restrict the growth of shoots and roots, and disturb physiological process in Al^{3+}-stressed alfalfa. Exogenous application of IAA markedly alleviated the Al^{3+}-induced inhibition of plant growth by increasing IAA concentrations in root tips, whereas the increased degree of IAA accumulations was significantly lower in the treatments with Al^{3+} than that without Al^{3+} and in plants with or without apical buds. In addition, Al^{3+} stress up-regulated *AUX1* and *PIN2*, but had no significant effects on *PIN1* gene. These results indicate that Al^{3+}-induced reduction of plant growth could be associated with the inhibition of IAA synthesis in apical buds and IAA transport from shoot to root.
Data are means ±SE of three replicates. Bars with different letters indicate significant difference at $P < 0.05$ (Least significant difference test).

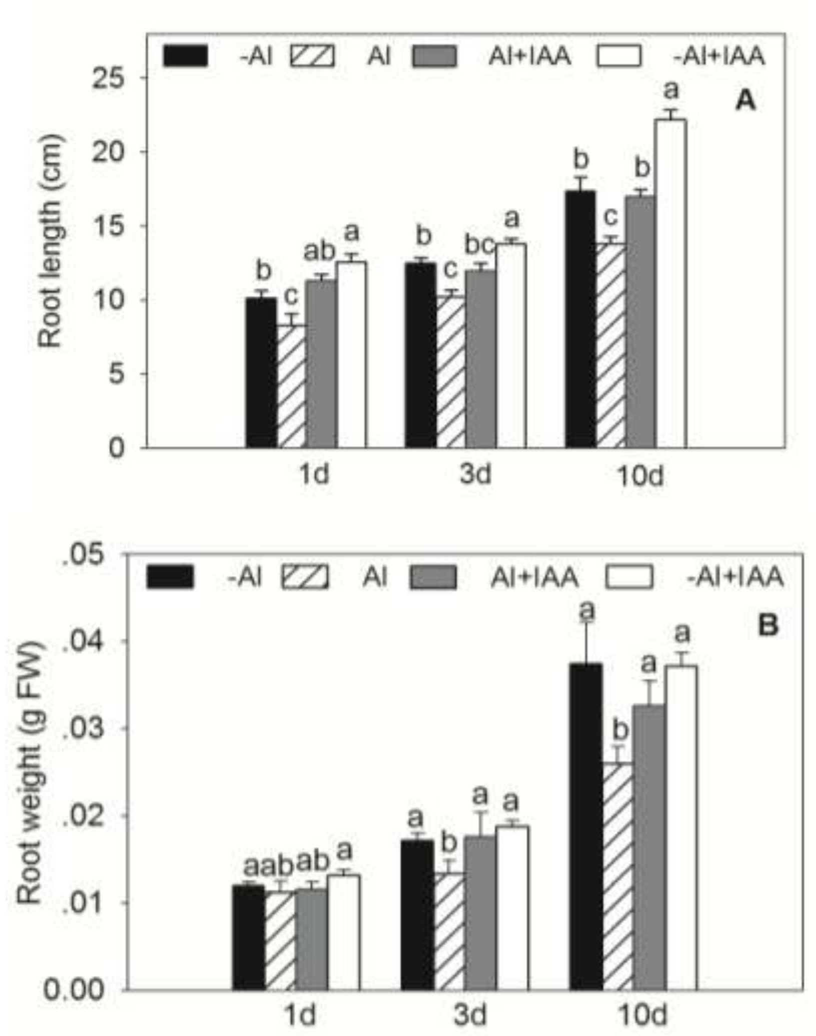

Fig. 1: Root length (A) and root fresh weight (FW) (B) of alfalfa seedlings grown for 1, 3 and 10 days on ½-strength Hoagland's medium (pH 4.5) with treatments of without aluminum (-Al), aluminum stress (Al) (100 µM AlCl3), aluminum with additional IAA (Al+IAA) (100 µM AlCl3+IAA) and -Al with additional IAA (-Al+IAA).

Conclusion

Our results demonstrated that IAA played an important role in alfalfa responses to Al^{3+} stress. IAA synthesis and transport in alfalfa was sensitive to Al^{3+} stress, as manifested by quick changes in the distribution of IAA in apical buds, shoot base, root base and root tip of alfalfa in response to Al^{3+} stress. The significant reduction of IAA concentrations in apical buds and root tips could be the fundamental factor attributing to restricted plant growth by Al^{3+} stress. The reduction in IAA concentration in root tips was partly due to disturbance of the auxin signal transduction pathways by inhibiting IAA transport from shoots to roots, and promoting IAA transport from root tip to root base. IAA transport from shoots to roots could play key roles in plant tolerance to high Al^{3+} stress.

References

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