The relationship between growth and Al accumulation in *Melastoma malabathricum* L., an Al accumulator growing in tropical acid soils

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ABSTRACT

Aluminum (Al) accumulators are widely distributed in tropical acid soils with severe Al stress. These plants are considered to develop physiological mechanisms to resist high concentrations of Al in their aboveground tissues. In previous studies, we elucidated beneficial effects of Al on growth and nutrient uptakes, and the mechanisms of the accumulation and transport of Al in *Melastoma malabathricum* L., which is an Al accumulator growing in tropical acid soils. In the present study, we carried out a split-root experiment in order to know whether Al has any specific role in the plant tissue of this species.

INTRODUCTION

Al ions in soil solutions often inhibit nutrient uptake of plants through the blockage of channels (e.g. calcium (Ca)), formation of an insoluble precipitation (e.g. phosphorus (P)), or inhibition of root growth and root activity (lower uptake of most nutrients). In some plants growing in acid soils, however, nutrient uptake, especially P uptake is enhanced in the presence of Al. *Melastoma malabathricum* L. is a woody Al accumulator growing in tropical acid soils, whose growth, root morphology and P uptake are improved by Al application (Osaki et al., 1997). However, it has not been clearly shown yet whether Al in the plant tissue directly stimulates the growth and nutrient uptake in *M. malabathricum*. Therefore, in the present study, we carried out a split-root experiment to elucidate these subjects.

MATERIALS AND METHODS

Treatment

Preparation of *Melastoma malabathricum* seedlings was carried out as described in a previous paper (Watanabe et al., 1998a). Seedlings were transferred to the individual split-root pots with three replicates in a greenhouse. The experimental design is shown in Fig. 1. One side of the pot (A) contained a standard nutrient solution (Watanabe et al., 1998a, P=2mg L^{-1}) with or without 0.5 mM $AlCl_3$ and the other side (B) contained a 0.2 mM Ca solution with or without 0.5 mM $AlCl_3$, at pH4.0. Roots in pot A and pot B were defined as root (A) and root (B), respectively. The pH of the solutions was daily adjusted to 4.0 with NaOH or HCl, and the solutions were renewed every 5 days.

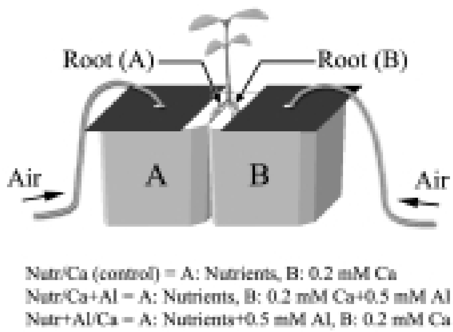

Fig. 1. Experimental design of the split-root experiments. Solution in each pot (2 L) aerated continuously.

Sampling and analysis

The seedlings were sampled 18 days after the treatment started. Mineral and organic acid concentrations in the plant samples were determined as described by Watanabe and Osaki (2001). Results were analyzed with ANOVA, and Fisher's LSD when significant (P<0.05) treatment effects were found.

RESULTS AND DISCUSSION

As mechanisms of positive Al effect on the growth of Al accumulators, several possibilities are suggested, including stimulation of P uptake and direct (physiological) effect of Al in plants (Watanabe and Osaki, 2002a; Jansen et al., 2003). However, it is difficult to remove nutrients from the Al treatment solution in long-term experiments in order to evaluate the direct role of Al in the growth of Al accumulators. Therefore, in this experiment, we adopted the split-root experiment. The growth and P accumulation in shoots of *Melastoma malabathricum* were significantly enhanced with the Nutr+Al/Ca treatment compared with the Nutr/Ca treatment (control), whereas those in the Nutr/Ca+Al treatment were not (Fig. 2 and Table 1). Al accumulation in leaves with the Nutr/Ca+Al treatment showed almost the same level as in the control treatment, although the Nutr+Al/Ca treatment showed a very high Al concentration (Table 1). Since no significant Al accumulation in shoots with the Nutr/Ca+Al treatment was found, we could not evaluate the direct role of Al in the plant (especially in shoot tissue). In the absence of nutrients, beneficial effects of Al on root morphology (development of white and fine roots) were not observed (Fig. 3), indicating that the relationship between Al and some nutrients takes part in this phenomenon.

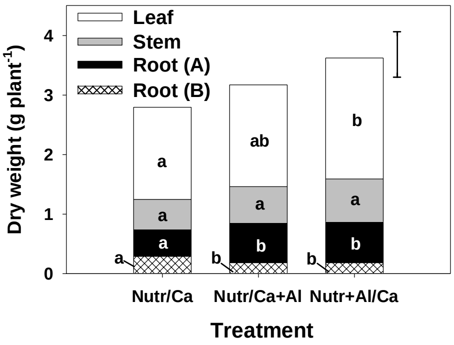

Fig. 2. Dry weight of *Melastoma malabathricum* after the treatment. Different letters in each organ indicate significant differences at $P<0.05$. Bar indicates LSD for total dry weight.

Table 1. Al, P, oxalate and citrate concentrations in each organ after the treatment. Different letters in each organ indicate significant differences at $P<0.05$.

		Leaf	Root (A)	Root (B)
Al (mg kg^{-1})	Nutr/Ca	102 a	283 a	408 a
	Nutr/Ca+Al	185 a	366 a	4099 b
	Nutr+Al/Ca	3552 b	14653 b	1042 c
P (mg g^{-1})	Nutr/Ca	2.90 a	10.12 a	3.77 a
	Nutr/Ca+Al	2.97 ab	8.60 a	3.38 a
	Nutr+Al/Ca	3.28 b	12.15 b	3.21 a
Oxalate (μmol g^{-1})	Nutr/Ca	178.9 a	77.6 a	124.1 a
	Nutr/Ca+Al	177.9 a	116.4 a	232.5 b
	Nutr+Al/Ca	280.6 b	176.4 b	148.1 a
Citrate (μmol g^{-1})	Nutr/Ca	1.82 a	0.00 a	2.46 a
	Nutr/Ca+Al	3.73 a	1.20 a	18.05 b
	Nutr+Al/Ca	13.42 b	77.97 b	9.12 c

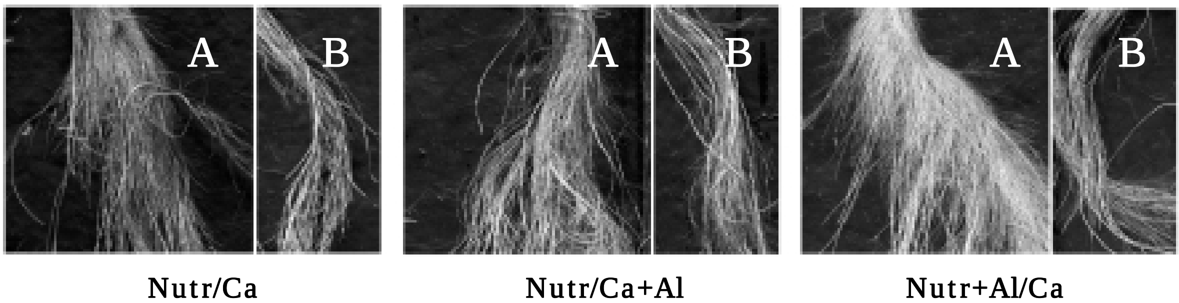

Fig. 3. Photograph of roots after the treatment. A and B indicate the side of pot.

It is noteworthy that no significant Al accumulation was found in the Nutr/Ca+Al treatment. There are several possibilities to explain this result. One possibility is the existence of a specific counter anion for Al absorption in *M. malabathricum*, because no anion except for Cl^- (and OH^-) was applied in the Ca+Al treatment solution. Pi, NO_3^-, or SO_4^{2-} may be considered as a counter anion. However, applications of Pi (Watanabe and Osaki, 2002b), NO_3^- (Watanabe et al., 1998a) and SO_4^{2-} (unpublished data) did not affect Al uptake in *M. malabathricum* at all. Therefore, this hypothesis was denied.

Another possibility is that the nutrient condition in the medium affects Al uptake. Previously, we elucidated that the Al-form for translocation from roots to shoots in *M. malabathricum* is an Al-citrate complex (Watanabe and Osaki 2001). Under nutrient deficient conditions, *M. malabathricum* may not be able to transport Al from roots to shoots, because of insufficient synthesis of citrate in roots (Table 1). In addition, a relatively high concentration of oxalate, which is a ligand of Al for its accumulation (Watanabe et al., 1998b), may fix Al in root cells, while a low level of citrate is formed (Table 1).

Unfortunately, we could not find out whether Al has any specific role in the plant tissue of *M. malabathricum* using the split-root experiment. Other techniques, such as foliar spray of Al, may solve this problem.

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