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Localization of aluminium in the leaves of some aluminium-accumulating species

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Summary Transverse sections of leaves of some aluminium-accumulating and nonaccumulating species of the cerrado vegetation of central Brazil were coloured using aluminon to identify the tissues where aluminium occurs or is deposited. None of the tissues of the nonaccumulating species showed evidence of high concentrations of Al. All of the aluminium accumulating species showed high concentrations of Al in all of the elements of the phloem of the midrib and the secondary veins and total absence of it in the vessel members, xylem fibres and the palisade parenchyma. Walls and contents of the collenchyma of the midrib, epidermal cells, guard cells of the stomata and spongy parenchyma showed evidence of high concentrations of Al in the accumulating species.

Introduction

Recent publications[3,7] reported that many species of the cerrado vegetation of central Brazil accumulate aluminium in large quantities in their leaves and that accumulation of Al does not interfere in the absorption of other cations like K, Ca and Mg in these cerrado species. However, there is no information in the literature on the role of Al in the metabolism of these plants or on the sites of Al accumulation in different organs. Matsumoto *et al.*[6] reported that Al occurs in large quantities in the epidermis of tea leaves. Very little is known about the retranslocation of aluminium from leaves. High concentrations of Al in the seeds of some accumulating species is indirect evidence of phloem transport and of some probable metabolic function of Al in these plants[5]. The presence of Al in the phloem of aerial parts has not been previously reported in the literature though there has been evidence of it in root phloem[4]. In this paper we present evidence of Al in the leaf phloem of some Al-accumulating species of the cerrado vegetation of central Brazil. Our objective was to identify the tissues where Al occurs or is deposited in these plants.

Materials and methods

Leaves of Al-accumulating and non-accumulating species listed in an earlier publication[3], as well as that of two new accumulating species (*Miconia albicans* (Sw.) Triana and *Vochysia rufa* (Spr.) Mart.) were collected from plants growing in a native cerrado (*sensu stricto*) vegetation on a dystrophic latosol in Brasília. The vegetation and soil were similar to the ones described in earlier publications[2,3,7].

In the first set of samples, free-hand sections of the midrib region and margin of fresh leaves were made and stained with aluminon following the method described by Aimi and Murakami[1]. The sections were first floated in water for 5 min and then in a 0.1% aluminon solution containing 3.2 *N* ammonium acetate for an hour. The sections were then floated in water, 3.2 *N* ammonium carbonate, and again in water for 5 min each and mounted on glass slides for

Table 1. Localization of Al in the leaves of Al-accumulating species

Family	Species	Sites showing positive response to aluminon test for Al
Melastomataceae	*Miconia albicans* (Sw.) Triana	Walls and contents of the internal and external phloem of the midrib and phloem of secondary veins, walls and contents of midrib collencyma, walls and contents of abaxial and adaxial epidermis, walls of the spongy parenchyma and xylem parenchyma
	Miconia ferruginata (DC) Cogn.	Walls and contents of the phloem of the midrib and secondary veins, walls and contents of the midrib collenchyma, walls and contents of the abaxial and adaxial epidermis, walls of the spongy parenchyma.
	Miconia pohliana Cogn.	Walls and contents of the phloem of the midrib and secondary veins, walls and contents of the midrib collenchyma, walls of the abaxial and adaxial epidermis and spongy parenchyma.
Rubiaceae	*Palicourea rigida* H. B. K.	Walls and contents of the phloem of the midrib and veins, walls of the xylem parenchyma, walls and contents of the abaxial and adaxial epidermis and hypodermis, contents of leaf hairs.
Vochysiaceae	*Qualea grandiflora* Mart.	Walls and contents of the phloem of the midrib and secondary veins, walls and contents of the midrib collenchyma, walls and contents of the abaxial and adaxial epidermis, contents of the guard cells of the stomata.
	Qualea parviflora Mart.	Walls and contens of the phloem of the midrib and secondary veins, walls and contents of the abaxial and adaxial epidermis, hypodermis and phloem of vascular bundles.
	Qualea multiflora Mart.	Walls and contents of the phloem of the midrib and secondary veins, walls and contents of the abaxial and adaxial epidermis, hypodermis, spongy parenchyma and phloem of vascular bundles, contents of the guard cells of the stomata.
	Vochysia elliptica (Spr.) Mart.	Walls and contents of the phloem of the midrib and secondary veins, walls and contents of the midrib collenchyma, walls of the xylem parenchyma, walls of the abaxial and adaxial epidermis.
	Vochysia thyrsoidea Pohl	Walls and contents of the phloem of the midrib and secondary veins, walls and contents of the abaxial and adaxial epidermis, spongy parenchyma, phloem of the vascular bundles and midrib collenchyma.
	Vochysia rufa (Spr.) Mart.	Walls and contents of the phloem of the midrib and secondary veins, walls and contents of the abaxial and adaxial epidermis, spongy parenchyma and phloem of the vascular bundles.

observation under a light microscope. In the second set of samples, portions of fully mature leaves from the mid rib region were fixed in a fixative containing 45% alcohol, 5% formaline, 5% acetic acid and 45% waer (FAA) and free-hand sections of the fixed material were stained using aluminon.

Results and discussion

None of the tissues of the nonaccumulating species listed in the earlier publication[3] showed any colour typical of the reaction of Al with aluminon. The leaves as a whole of these plants contain very little Al (less than 700 mg/kg dry matter) and a positive colour reaction to aluminon was not expected. On the other hand, all of the accumulating species showed positive response with the aluminon staining technique, with the intensity and the sites of colouring varying from species to species. There were no differences between the section of fresh leaves and that of material fixed in FAA in the colour reaction. The results are summarized in Table 1.

As a rule, the most common was a positive reaction of all the elements of the phloem of the midrib and the secondary veins and total absence of colour in the vessel members, xylem fibres and the palisade parenchyma. In most cases the collenchyma cells of the midrib on the abaxial side were intensely coloured. Both the cell walls and the contents showed evidence of high concentrations of Al. The intensity of colour of the cell walls of the epidermal layers varied from species to species. In *Palicourea rigida,* the contents of the leaf hairs were coloured but not the cell wall; in *Miconia ferruginata,* neither the walls nor the contents of the leaf hairs were coloured. In a few guard cells observed, the contens were intensely coloured. In many cases, cell walls of the spongy parenchyma were coloured dark red; in others the colour varied from none to slight pink.

The intense colouring of all the elements of the phloem in all accumulating species is evidence of phloem translocation of Al in these species. Indirect evidence of phloem translocation of Al in these species exists because seeds of these plants contain upto 4% Al (of dry weight). Aluminium present in the cell walls is probably deposited and not very active metabolically. In the cell contents it may be associated with ergastic substances. It should be interesting to investigate (1) the nature of compounds or complexes associated with Al transport in these species, (2) the nature of accompanying anions or cations, (3) the nature of absorption of aluminium, and (4) the influence of external concentration of Al on the uptake of Al and that of other elements to better understand the role of Al in the metabolism of these species. The possibility that Al may have some metabolic function such as regulation of osmotic pressure in these species should also merit further studies.

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