DOCTORAL THESIS

The accumulation of aluminium and it's effect on the uptake and distribution of Ca, Mg, K, Mn, Fe, Cu and Zn in Camellia sinesis (L.)

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The Accumulation of Aluminium and it's Effect on the Uptake and Distribution of Ca, Mg, K, Mn, Fe, Cu and Zn in *Camellia sinensis* (L.)

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ABSTRACT

Camellia sinensis preferentially grows on acid soils which are rich in solubilised aluminium (Al) and deficient in nutrients. Despite the predominantly rhizotoxic nature of Al, it is accumulated in excessive levels in the leaves of *C. sinensis*. It is generally assumed that Al accumulation and tolerance are concomitant with reduced uptake / demand for nutrients such as Ca, Mg, K, and Fe. This study was undertaken to determine the nature of Al accumulation in *C. sinensis*, and also to gain a better understanding the relationships between Al and other nutrients (Ca, Mg, K, Fe, Mn, Cu, and Zn).

In the first part of the study, a 50-year old disused tea plantation colonised by natural vegetation was selected for this study and Al accumulation in *C. sinensis* and 14 selected woody dicotyledens were comparatively assessed. The soil had an acidic pH (4.1 – 4.9) and soil exchangeable Al of the surface soils varied between 146 – 523 mg kg^{-1}. The soil Ca/Al ratios were very low (0.082 – 2.685). Based on the criteria of 0.1% Al in leaf tissue, *C. sinensis* and two other plants (*Melastoma affine* and *Ficus hirta*) were identified as Al accumulators. The highest Al levels were recorded in the mature leaves of *C. sinensis* which had a maximum of 22,000 μg g^{-1}. This was followed by *Melastoma affine* which had 11,601 μg g^{-1}Al. The levels of Al in the older leaves of other tested species, ranged from 10.7 - 624 μg g^{-1}Al. In general the concentrations of calcium (Ca), magnesium (Mg), and potassium (K) did not vary greatly between the 15 plants, but iron (Fe), manganese (Mn), copper (Cu) and zinc (Zn) were found to be low in several species. The concentrations of certain nutrient elements (Ca, Mg, Mn, Fe) and Al were correlated.

The relative effects of age (comparing monoclonal bushes of 10, 25, 30 and 50 years), soil available Al (comparison between different varieties of *C. sinensis* growing at two different sites), and genetic differences (four intraspecific varieties of *C. sinensis*) on the levels of Al accumulated by tea bushes were investigated. It was found that there was no definitive trend between the amount of Al accumulated and the age of tea bushes. The soil available Al influenced the levels of Al in *C. sinensis* to a certain extent, but it was evident that the ability of different varieties of *C. sinensis* to accumulate Al was variable. *C. sinensis*, accumulated Al in all stages of growth. Young seedlings had lower contents of Al and also Ca, Mg, K, Mn and Zn. The mobility of Al within the tea bush was high. In a manner typical of hyperaccumulators, Al is not retained in the roots, but consistently transported to the shoots. Aluminium in the tea bush was distributed between the different organs in the following order: mature leaves > roots > branches > young leaves. Aluminium levels in the young leaves of *C. sinensis* were consistently correlated with Ca ($p < 0.01$) and Mg ($p < 0.01$), and in the mature leaves with Ca ($p < 0.05$).

The effect of various doses of Al (0, 0.25, 0.5, 1.0, 5.0, 10.0 mM Al) on the growth and nutrient of *C. sinensis* was studied. In the absence of Al, growth of *C. sinensis* was retarded. Test doses over 1 mM Al were toxic to *C. sinensis*. At concentrations of 0.25 mM or 0.5 mM, distinct rhizostimulation was noted, within a short period (2 weeks) the biomass of these seedlings increased by

44% and 35% respectively compared to 0% and 14% increase in control and 1 mM Al treated seedlings respectively. In general, at beneficial doses (0.25, 0.5), Al stimulated the uptake of Ca, Mg K and Mn, whereas the uptake of Fe, Cu and Zn was retarded. In seedlings, fine roots had the highest levels of Al, compared to leaves, branches and main roots. It was found that in the root tips, most of the Al was present in the soluble fractions of the apoplasm and symplasm and very low levels of Al was bound to the cell walls, which was in good agreement with the observed mobility of Al in *C. sinensis*.

The distribution of Al, Ca, Mg and K was quantitatively estimated in frozen hydrated tissues of *C. sinensis* young and mature leaves using SEM EDXMA. Aluminium was preferentially localised in the upper wall of the upper epidermis. The distribution of Mg was similar to that of Al. Although high levels of Ca were detected in the epidermal cell walls, Ca was also present as Ca oxalate crystals in the spongy mesophyll. Potassium was found to be distributed more evenly over various tissues of the leaves of *C. sinensis*.

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