The aluminium trees of Sulawesi

Trees of the genus *Symplocos* in the Indonesian mountain rainforest store so much aluminium in their leaves that it can be used for dyeing textiles. A research project at the University of Ulm aims to preserve the traditional dyeing methods of Indonesian weavers, protect these rare trees and increase our knowledge of aluminium-accumulating plants.

Mosses and ferns grow on the trees in the mountain rainforest on the Indonesian island of Sulawesi. Pitcher plants and orchids flourish and are very popular with wild honeybees. In between all these plants, trees of the genus *Symplocos* can be found. Georg Eberhard Rumpf was the first to describe the *Arbor aluminosa*, the aluminium tree, in the Indonesian rainforests in the 17th century, which was later identified as a species of *Symplocos*. The trees are eight to fifteen metres tall and are relatively inconspicuous. The genus *Symplocos* includes around 250 species that are native to the tropical zones. Indonesia is experiencing a huge reduction in the number of *Symplocos*, amongst other things because the tree’s leaves have traditionally been used by the locals as a mordant for dyeing textiles. The mordant ensures that the dye adheres more strongly to the cotton threads and gives them a more intensive colour. The traditional harvesting method for *Symplocos* involves collecting leaves and bark from trees, which for a long time involved the felling of entire trees.

In 2013, Marco Schmidt, a biologist and chemist from the Institute for Systematic Botany and Ecology at the University of Ulm, spent four months in Indonesia collecting samples from three *Symplocos* species and bringing them back to Ulm for further analysis. Getting to the aluminium trees in Central Sulawesi involves a somewhat arduous journey. The Lore Lindu National Park where Schmidt knew there were *Symplocos* trees from colleagues from Göttingen is around 100 km from the provincial capital, Palu. The terrain there rises to a height of 1,500 to 3,000 metres above sea level. Local road conditions are very poor, so it can easily take a whole day to cover a distance of 100 km. The national park cannot be reached by car and the final kilometres have to be covered by foot, which takes around five hours.

On their trip to the Lore Lindu National Park, the researchers from Ulm were accompanied by local porters, the botanist Firdaus Daeng Mattata from Tadulako University in Palu and a chef who prepared food and also helped collect soil samples. The team stayed overnight in tents that were protected above and below against rain and damp with tarpaulins. “At first we were not sure how we were going to reach the leaves in the treetops, but Firdaus showed us how to do it by tying a saw blade to a rope, then throwing the rope into the tree and cutting a branch from the crown of the tree,” says Schmidt describing the logistical challenges the team experienced on their sample collection tour.
Scientists led by Marco Schmitt (second row, centre) and his former master’s student Sven Boras (back row) were the first University of Ulm scientists to carry out research in Indonesia. During their field trips for collecting aluminium tree leaves, the Ulm researchers were assisted by locals, including Indonesian botanist Firdaus Daeng Mattata (front row, centre).

In their jungle camp, Marco Schmitt and Sven Boras managed to collect more than 1,000 samples from three species of Symplocos and three other jungle trees that were then analysed in the laboratory. On average, the aluminium tree leaves contained between 7,000 and 24,000 mg/kg aluminium; a sample of fallen leaves from the species Symplocos odoratissima even contained 49,100 mg/kg. Bark and wood contained much less aluminium than the leaves.

In their scientific investigations, the researchers were able to confirm two hypotheses. First, the Symplocos species actually store huge amounts of aluminium in their tissue, and second, the highest aluminium concentrations were contained in old, fallen leaves. This is the best argument for not felling trees. According
to information from the Indonesian organisation Yayasan Pecinta Budaya Bebali (YPBB), which helps the 13,000 or so weavers to sell their products at a fair price, sustainable harvesting has since become the rule.

The aluminium strategy of plants

Aluminium occurs everywhere in soil, as does iron, magnesium and potassium, which are all important trace elements. Aluminium is also the most abundant metal in the Earth’s crust. “Aluminium is ubiquitous and can bind to virtually everything. This is probably why hardly any living organism can metabolise the metal,” says Schmitt highlighting the chemical peculiarities of aluminium. Aluminium is readily available in the acidic environment of rainforest soil as the low pH transforms aluminium from a crystalline structure into a soluble, plant-available form. A high aluminium concentration in the soil is toxic for many plants – most grains, rice and vegetables cannot tolerate high aluminium levels, the main symptom of aluminium toxicity being the inhibition of root growth. In general, aluminium toxicity is one of the major constraints for crop production on acidic soils worldwide, especially in tropical countries (source: Al-ex Institut).

However, a number of plant species are able to tolerate high aluminium levels in soils and have evolved two different response mechanisms to toxic aluminium concentrations, namely exclusion and accumulation. “Aluminium excluders do what is the most obvious and prevent aluminium ions from entering the plants through the roots. Aluminium accumulators such as the Symplocos species transport the metal from the root and plant juices into the bark and leaves where it is deposited in the cell walls and thus rendered harmless. Plants are therefore divided into two camps with respect to the way they deal with aluminium concentrations in soil. Aluminium accumulators are typically those plants that have aluminium levels in above-ground tissue of over 1,000 mg/kg dry mass. Aluminium excluders have aluminium levels in above-ground tissue that are around 200 mg/kg.

Although these days aluminium has a very bad reputation because it is suspected of causing Alzheimer’s and other neurological diseases, it is not toxic per se. For example, tea plants grow better in soil with elevated aluminium concentrations. This is most likely due to the improved ability to take up phosphorus (Jansen et al. 2004). In general, a great deal of research is still needed to understand in detail the accumulation of aluminium by plants, as the researchers from Ulm and Japan conclude in a paper recently published in the science journal PLOS ONE (Schmitt et al. 2016).

Benefit for agriculture

Besides the protection of trees and the preservation of local artisanal dyeing techniques, research into aluminium trees also has a benefit for agriculture. “Important agricultural crops such as rice and many grain species are aluminium-excluding plants. A greater understanding of the physiology of aluminium-accumulating plants would help us make these crops more resistant to the toxic aluminium levels in soil,” says Professor Steven Jansen, head of the research project in Ulm, which is funded by the Baden-Württemberg Ministry of Science, Research and the Arts. The aluminium trees from Sulawesi therefore have the potential to make a contribution to increasing food yields in the tropics.

References:

Aluminium Institute from Aluminium Research (Al-ex Institut zur Wissensvermittlung im Umgang mit Aluminium)
