Tuberous Roots in *Ravenea xerophila*

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1. Greg Ksenzakovic holding sections of the tuberous root of *Ravenea xerophila*.

Tuberous, water-storing roots in *Ravenea xerophila* are described and illustrated. They are the first such roots ever recorded for a palm. Tuberous roots are probably an adaptation to the xeric habitat in which this palm grows in southern Madagascar.

It is a sobering thought that when we look at a palm, we are seeing only a fraction of it. The above-ground parts are plainly obvious, but the underground parts, namely the roots, are subterranean "dark matter" – we know they must be there, but we rarely see them. Roots comprise ca. 30–50% of a palm's total biomass (Goodman et al. 2013), and yet they remain poorly known. On the few occasions botanists have critically examined palm roots, they have found variation in anatomy that has taxonomic value at the generic (Seubert 1996a & b, 1997, 1998a & b) and species (Martel 2012) levels, diversity in structure and function (Tomlinson 1990, Jourdan & Rey 1997) and adaptations to anaerobic environments (De Granville 1974). Botanists have even discovered that, at the microscopic level, the cellulose orientation in the cell walls of palm roots is unique, unlike that of any other flowering plant (Kerstens & Verbelen 2002).

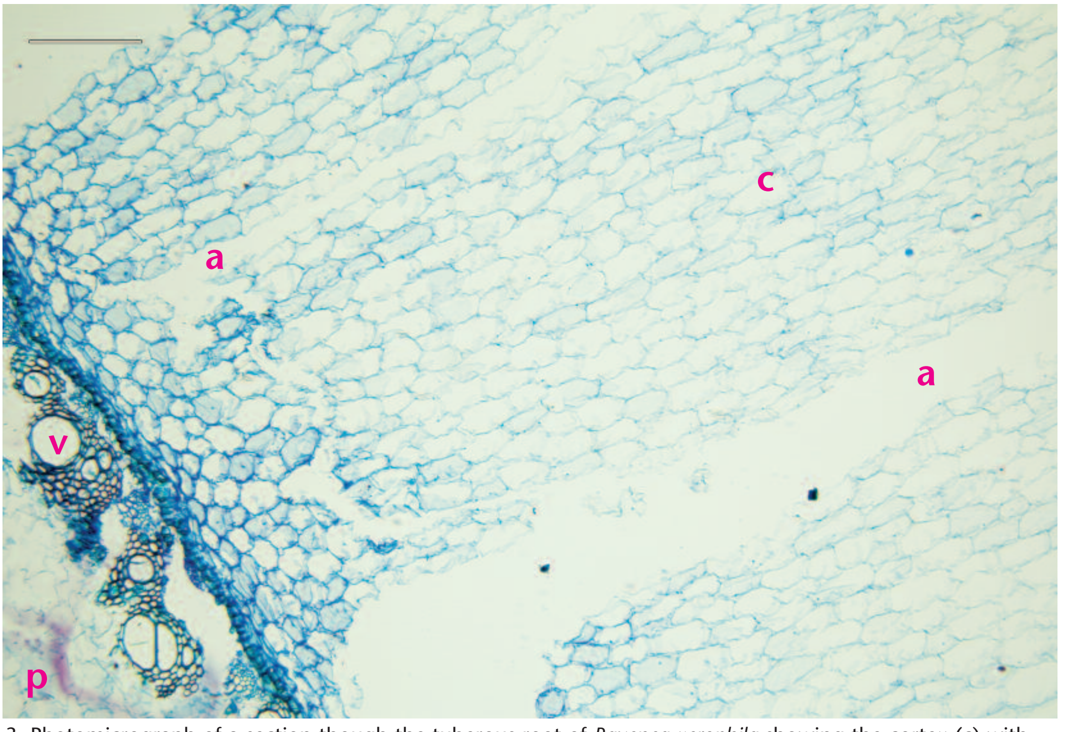
Even in the light of these remarkable findings, palm roots are too often ignored and assumed to be of little interest. So it was when we met Greg Ksenzakovic in the garden of Mike Harris of Cooper City, Florida. Greg casually mentioned his observation of thickened roots in *Ravenea xerophila*, a seldom-cultivated species restricted to a small area of dry and spiny forest in southern Madagascar (Dransfield & Beentje 1995). We were immediately intrigued, as no such roots had ever been noted for this or any other species of palm. Greg grabbed a shovel and satisfied our curiosity by excavating around a young *R. xerophila* and producing the section of the root seen in Fig. 1. The root was sliced by the shovel during excavation, but the general shape and size of the thickened region can be clearly seen.

The root bearing the tuberous portion was growing laterally in soil at about 30–40 cm depth. Greg noted that tubers can occur up to 2 m away from the palm. The enlarged area that makes up the tuberous portion occurs within the length of the non-thickened root and is tapered at both ends. In the specimen we examined, the largest diameter of the thickened region is 3.5 cm, compared with 0.5 cm in the non-thickened root (Fig. 2). We estimate the length (from the two pieces) at ca. 30 cm. Fine roots, 0.1 cm in diameter, emerge from both the thickened region and the non-thickened root. The enlarged region shows no signs, externally or internally, of damage, so we conclude that it is not a pathogenic condition.

Anatomical investigation revealed that both the thick and thin roots are generally differentiated into a surface layer, cortex and stele (terminology of Tomlinson et al. 2011). In both kinds of roots, the surface layer forms a tough cylinder (0.2 mm thick) of thick-walled, tanniniferous cells, making sectioning the root very difficult. In the tuberous root (Fig. 3), the cortex, comprising thin-walled parenchyma, is much larger than in the thin roots (ca. 10 mm vs. 0.5 mm thick). The cells of the cortex are radially elongated, ca. 162.2 µm long and 66.4 µm diameter and function in water storage. A few scattered raphide-containing cells were observed but no fibers or secretory canals. No starch granules were visible. Radial air-canals (lacunae) are present (Tomlinson 1990). The stele (vascular cylinder) of the tuberous root is also larger than that of the small roots (11.6 mm vs. 2.5 mm in diameter). The xylem and phloem, along with thin-walled fibers, form a thin cylinder (0.2–0.3 mm thick) around the thin-walled parenchyma of the pith, which lacks any distinguishing anatomical features.

2. Cross-sections of the tuberous root (right) and the non-thickened root (left) to which it was attached. Air-canals are visible as radial splits in the cortex. Scale divisions are millimeters.

As its epithet suggests, *Ravenea xerophila* grows in dry (xeric) habitats. Its stiff, waxy leaves are probably evolutionary adaptations to the dry, sunny conditions in which it grows. It really should come as no surprise that water-conserving adaptations extend to the root system as well. Water storage systems are clearly beneficial to species that are regularly subjected to drought stress. Such systems can be seen in succulent plants of all kinds. A dispersed storage system, scattered under-



3. Photomicrograph of a section though the tuberous root of *Ravenea xerophila* showing the cortex (c) with air-canal (a), vascular cylinder (v) and pith (p). Scale bar = 0.2 mm. Photo by Jack Wahl.

ground among the larger roots, would have obvious benefits in both redundancy and secrecy. Large, visible, water-storing stems or leaves might be more susceptible to attack by thirsty predators than the numerous, hidden storage roots of *R. xerophila*. The water-storing capacity of these roots is considerable. In a simple cylinder, volume increases with the square of the radius, so a 1-cm length of the non-swollen root has a volume of less than 0.2 cm^3 whereas the 1-cm length of the tuberous portion has a volume of more than 9.6 cm^3 – a 48-fold increase!

It is not known whether the morphology of these tuberous roots was affected by cultivation, under which the plants received irrigation during droughts. The fact that this palm produced tuberous roots even under irrigation, when water-storing structures are not "needed," suggests that the structures are under strong genetic control. Our observations were made on a single, cultivated individual. Clearly it would be highly desirable to examine the roots of wild *R. xerophila* growing in its natural habitat, as well as palms cultivated elsewhere, and compare them with the roots from the Harris garden.

The tuberous roots reported here drive home two important points. Firstly, we still know very little about palm roots. They represent a largely unknown area for palm research, and we cannot help but wonder what other interesting features of palm roots await discovery. Secondly, the observations of palm growers, who live and work with palms on a daily basis, are of tremendous value. The science of botany is advanced incrementally, and everyone can contribute useful data.

Acknowledgments

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ANNOUNCEMENT

World Palm Symposium 2015
Cocora Valley, Quindío, Colombia, June 22–26, 2015
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The World Palm Symposium 2015 will be held in the Cocora Valley, Colombia, home of the famous Quindío wax palm (*Ceroxylon quindiuense*), the world's tallest palm. For the first time, this event will take place in a tropical country, in fact, one of the world's most palm-rich countries.

The Symposium will be developed in collaboration between the National University of Colombia, the University of Aarhus, the Quindío Botanical Garden and the IRD and CIRAD institutes in France. There will be two field trips: a one-day visit to the huge stands of *Ceroxylon quindiuense*, where hundreds of thousands palms are to be found, and two trips to the Serranía del Baudó, in the Panama-Colombia border, home of the recently discovered *Sabinaria magnifica*. For further information, please contact Yisela Figueroa (yfigueroac@unal.edu.co).