Fundación Miguel Lillo
Tucumán
Argentina

The Secret of Baobab's (*Adansonia* spp., Malvaceae) Longevity

El secreto de la longevidad del baobab (*Adansonia* spp., Malvaceae)

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Abstract

The Baobab (*Adansonia* spp.) is known as the "tree of life", renowned for its longevity, with individuals that can survive for thousands of years. This article reviews various baobab adaptations supporting their survival and longevity, encompassing morphological and physiological mechanisms in the seedling phase, water storage in stems, and resistance to extreme environmental conditions. Baobabs also exhibit special adaptive mechanisms, such as stomatal regulation, UV resistance, and antibacterial properties. In addition, the heat-resistant morphology of the baobab fruit and the hard skin play an important role in preserving seeds from forest fires and dispersing them through various means. This study emphasizes that baobab's unique adaptations not only support their sustainability but also provide significant potential for the conservation and study of plant survival under extreme environmental conditions.

Keywords: *Adansonia*; adaptation; plant conservation.

Resumen

El baobab (*Adansonia* spp.), conocido como el "árbol de la vida", es famoso por su longevidad, que puede alcanzar los miles de años. Este artículo repasa diversas adaptaciones de los baobabs que favorecen su

➤ Ref. bibliográfica: Nashrullah, S.; Rosida, W.; Salsabila, D. A.; Su'udi, M. 2025. The Secret of Baobab's (*Adansonia* spp., Malvaceae) longevity. *Lilloa* 62 (1): 311-321. doi: https://doi.org/10.30550/j.lil/2124
➤ Recibido: 6 de febrero 2025 – Aceptado: 19 de mayo 2025 – Publicado: 7 de junio 2025.
➤ URL de la revista: http://lilloa.lillo.org.ar

supervivencia y longevidad, como los mecanismos morfológicos y fisiológicos en la fase de plántula, el almacenamiento de agua en los tallos y la resistencia a condiciones ambientales extremas. Los baobabs también poseen mecanismos especiales de adaptación, como la regulación estomática, la resistencia a los rayos UV y propiedades antibacterianas. Además, la morfología del fruto del baobab, resistente al calor, y la dura corteza del fruto desempeñan un papel importante a la hora de preservar las semillas de los incendios forestales y esparcirlas por diversos medios. El estudio subraya que las singulares adaptaciones del baobab no sólo favorecen su sostenibilidad, sino que también ofrecen un importante potencial para la conservación y el estudio de la supervivencia de las plantas en condiciones ambientales extremas.

Palabras clave: *Adansonia*; adaptación; conservación de plantas.

INTRODUCTION

Baobab is a tree that belongs to the angiosperm group (Patrut *et al.*, 2018). Baobab refers to eight species of the genus *Adansonia* sp. which is native to Africa with one endemic species, Madagascar with six endemic species, and Australia with one endemic species (Baum, 2015; Wan *et al.*, 2024). Baobab has a very long lifespan of 2,500 years based on radiocarbon studies conducted on samples of dead trees in 2011 in Zimbabwe (Patrut *et al.*, 2018), while for the surviving samples, the age ranges from hundreds of years to the oldest reaching 1,800 years (Patrut *et al.*, 2010; Patrut *et al.*, 2015; Patrut *et al.*, 2018), hence the baobab tree is nicknamed as '*Tree of Life*' (Kitony *et al.*, 2024).

The longevity of baobab cannot be separated from its extraordinary adaptation role, when it has just reached the stage of seedling morphological and physiological mechanisms are used to survive drought stress such as leaf shedding, allocation of biomass to roots, water storage in roots and stems, as well as strict stomata control (De Smedt *et al.*, 2012; Van den Bilcke *et al.*, 2013). The typical large stem of baobab also has an important function that supports its longevity, the large stem has a special morphology, namely as a store of water and nutrient reserves when environmental stress occurs (Chapotin *et al.*, 2006a,b,c).

Flowers and fruits have played an important role in the reproductive cycle of baobab for thousands of years, where the cycle is always stable in each season and different environmental conditions (Venter & Witkowski, 2019; Abere *et al.*, 2023) even the fruits and seeds can still germinate after forest fires (Kempe *et al.*, 2018). Baobab maximizes photosynthesis in the rainy season by leaf propagation to store enough energy reserves during the dormancy phase in the dry season (Venter & Witkowski, 2019). Another adaptation mechanism that baobab has to support his lifespan is the recent discovery of the UV light resistance gene (UVR8) (Kitony *et al.*, 2024) and antibacterial compounds that make it possible to avoid pathogens such as well as many other plants (Aulia *et al*., 2023; El Yahyaoui *et al*., 2023). The uniqueness of adaptations that support the longevity of baobab is very different from other plants, therefore the purpose of this study is to examine the various unique adaptations that support the longevity of baobab.

Adaptation in the Seedling Phase

Morphological and physiological mechanisms are used in the baobab seedling phase to survive drought stress, the mechanisms include leaf shedding, allocation of biomass to the root system, water storage in roots and stems, and strict stomata conductance regulation (Patrut *et al*., 2018). There are differences in response to drought between baobab originating from West Africa (Mali) and Southeast Africa (Malawi). Baobab from Mali tends to shed more leaves and allocate more biomass to the roots (De Smedt *et al*., 2012). Baobab in the seedling phase adapts to reduce the conductance of stomata when hit by drought to conserve water. Baobab was able to reduce the conductance of stomata up to 85% after two weeks of drought, when compared to *Parkia biglobosa* (Jacq.) R.Br. ex G.Don, which is only able to reduce stomata conductance by 50% with the same drought stress exposure time. The reduction of stomata conductance aims to reduce the rate of transpiration in leaves through stomata so that water availability is maintained during drought stress. This mechanism allows baobab to reduce the transpiration rate by up to 90%, when compared to *Ziziphus mauritiana* Lam., which is only able to reduce the transpiration rate by 25% (Chapotin *et al*., 2006c). Baobab in the seedling phase is also able to maintain the potential pressure of leaf water remains high > 1 MPa to avoid cavitation of xylem. The leaves of the baobab gradually fall off during drought, but grow back after sufficient water availability (Van den Bilcke *et al*., 2013).

Allocation of biomass on leaves during the seedling phase in drought stress is severely restricted. Biomass allocation is preferential towards the roots because the root organs (*taproot*) in baobab during the seedling phase since that organ can store large amounts of water while reaching water sources in the ground. Baobab has a large amount of water stored in the roots up to 90% at the stage seedling of the total water reserves in the whole organ but will gradually move towards the stem as it mature (Van den Bilcke *et al*., 2013). The use of water stored in the stems and roots during the seedling phase only occurs on a limited basis, where only a small amount of water is taken from the reserve to cover the daily water deficit. Morphological studies show the presence of a large amount of mucus and water-storing tissue on the roots. Strict stomata regulation strategies, proper allocation of biomass, and the ability to store large amounts of water in the roots help baobab seeds to survive during drought (De Smedt *et al*., 2012).

Adaptation of baobab in the seedling phase is very helpful in its survival, but anthropogenic factors are one of the major obstacles. Obstacles in the regeneration of baobab trees (*Adansonia* spp.) in some parts of Africa, especially in Quara and Kafta Humera, Ethiopia. The lack of seedlings and shoots of baobab is caused by encroachment and trampling of livestock, as well as land clearing for moving farms. These factors interfere with the natural growth of baobab trees in this region. In addition, natural and human activities, such as the presence of elephants in Zimbabwe that damage buds, also have an impact on the regeneration of baobabs. However, in Tselemt, which is a watershed, baobab regeneration is better. This is supported by high soil moisture that facilitates seed germination and seedling growth, as well as locations around rivers that are difficult for livestock to reach, so that seedlings are more protected from damage due to animal activities. Although baobabs have a natural ability to produce seedlings, environmental factors and human activities often hinder these seedlings from growing to adulthood, especially in agricultural lands and forests that are disturbed by human activities (Abere *et al.*, 2023).

Morphology and Adaptation of Baobab Stems

The baobab tree has the characteristic of being multi-stemmed. Some rods form a circle or elliptical in the ground with a space in the middle or what is commonly called a ring-shaped structure (RSS). Older baobab trees have large cavities, especially in the middle part of the trunk (Fig. 1). Large normal cavities are formed due to the loss of wood caused by fungal decay, fire, and other damage (Patrut *et al.*, 2018). *Adansonia* sp. is a succulent plant and a global tree that can store water in its trunk and does not form a terraced wood and can store water in its internal cavity. The new growth layer of the baobab tree sample segment is a differentiation of the xylem part after severe wood damage in the cavity. The wood on the baobab stem is mostly composed of parenchymal tissue, which mostly remains alive for long periods and at significant depths within the stem. Baobab wood contains more parenchyma cells in its trunk (69–88% by volume) than any other tree species (Patrut *et al*., 2010). The abundance of parenchyma is a special characteristic of *Adandsonia* sp., which has the main function of storing water and carbohydrates. The results of ecophysiology studies show that the use of stored water is limited to baobab trees for physiological processes such as leaf flushing and daily water deficit buffering, even during the dry season. The abundant parenchyma also provides mechanical support for the baobab stem (Kotina *et al*., 2017).

Baobab trees are known to have shallow roots and can grow new leaves before the rainy season. Baobab has a sizable stem water content and does not change significantly during the dry months. The dry season affects the adaptation of the baobab tree. During the dry season period, the baobab leaves fall and the sap flow rate at the bottom of the trunk is low, which indicates little or no water entering from the roots and soil to the trunk during the dry season. The rate of water used in the branches and the top of the stem increases as leaf shedding progresses, then gradually decreases as the leaves expand. After the rainy season arrives, along with the increase in the availability of groundwater, the rate of sap flow at all points of the tree reaches higher values. The baobab's adaptation during the dry season is to limit the use of water to flow the leaves rather than opening the stomata, the baobab tree is able to maintain the leaf turgor until the rainy season arrives, and produce new leaves for the following year (Chapotin *et al*., 2006b).

Morphology and Adaptation of Baobab Fruit

Boabab fruit is an important part that is often used by the community. The flesh of the baobab contains a source of vitamin C. Variations in the shape of the baobab fruit can occur due to regional differences. The most found fruit is ellipsoid-shaped. Baobab fruits are adapted to the climate. Baobabs that are in a climate with high temperatures and prolonged water stress tend to preserve the substrate so that the size of the fruit is larger and heavier compared to other plants (Murage *et al*., 2022). *Adansonia* sp. produces large ovoid fruits with woody pericarp. The baobab fruit has a special structure commonly called amphisarcum, and is a simple fruit whose outer part is differentiated into a dry crust and inside into one or more layers of flesh (Fig. 2). It is a drought-resistant fruit with a bark that adapts well to withstand drought (Kempe *et al*., 2018).

The hard shell of the fruit in *Adansonia* not only plays a role in protecting the seeds from fruit-eating animals (zoochory) or allowing the seeds to spread through water (hydrochory). Fruit shell also play a role in protecting the seeds from the heat generated by wildfire. Through heat tests carried out, it was found that the shell *of Adansonia digitata* L., and *Adansonia gregorii* F. Muell., can withstand an increase in temperature inside the fruit for 5-10 minutes even though the temperature outside the shell has reached 300 °C. This suggests that the shell of the fruit can protect the seeds from heat during forest fires that usually last less than 10 minutes. The temperature inside the fruit tends to be higher in fruits with thinner shell. Nevertheless, most fruits can still withstand temperatures below 90 °C which is a fatal temperature for the seeds. Germination tests showed that seeds exposed to heat of more than 100 °C tended to have better germination power than controls. This suggests that heat can break dormancy in *Adansonia* seeds (Kempe *et al*., 2018).

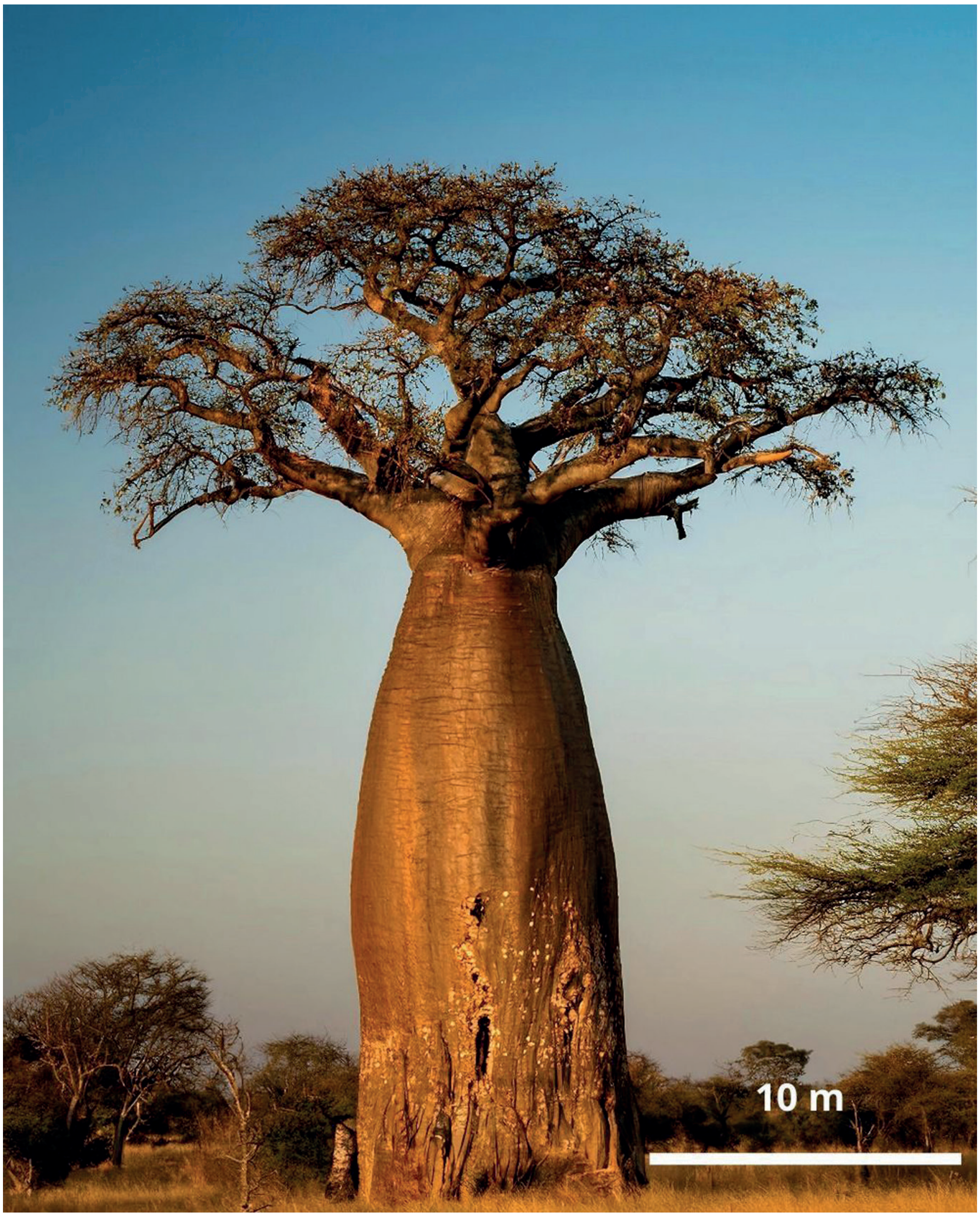


Fig. 1. Baobab tree.
Fig. 1. Árbol de baobab.

Flowering on the Baobab Tree

The baobab tree consists of a single flower located in the axils of the leaves near the ends of the branches. The flowers are white, large, hanging, solitary, or paired in the axils of the leaves. Flowering is usually initiated when the first leaves appear or before the first rainy season. The flowers emit a scent that can attract pollinators, especially bats (Rahul *et al*., 2015). Baobab flowers have the uniqueness of the flower size, color and position of the flower facing down. Flowering or pollination usually occurs at night (Rashford, 2015).

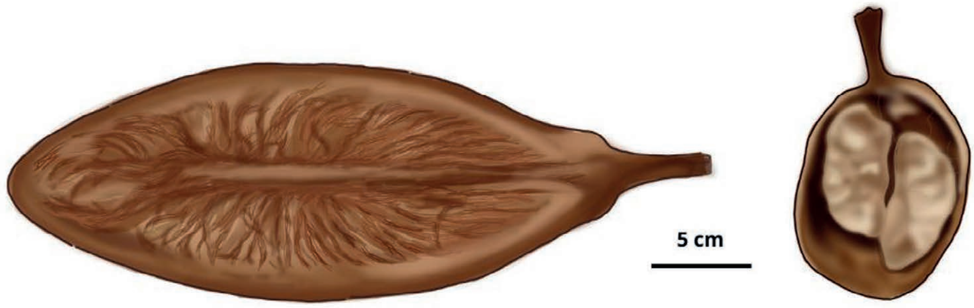
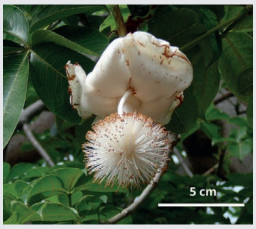


Fig. 2. Halved fruit of *Adansonia* sp.
Fig. 2. Fruto seccionado de *Adansonia* sp.

Baobab trees have leafy and flowering phases that coincide with each other in summer. The leaves wilt and continue until the second week of September starting from mid-August. The initiation of flowering begins from mid-August (from the third week of August to mid-September). Full bloom starts from the third week of September to the middle of October. The baobab tree species take two months and 60 days to reach full bloom. (Abere *et al*., 2023). Leaf growth and fall are affected by rainfall rather than daily temperature. Leaf fall occurs later during the rainy season while the beginning of flowering can vary from year to year. The flowering of the baobab tree shows a stable pattern. The peak of flowering occurs at almost the same time every year, it suggests that flowering is determined by the length of the day or temperature rather than by rainfall. Baobab trees bloom profusely during late summer in response to rainfall. Flowering begins before the rain falls and is then supported by the stem water reserve. Good stem water storage and stored energy or nutrient reserves can be advantageous and allow the tree to produce more flowers and thus produce more fruit (Venter & Witkowski, 2019).

The composition of the floral aroma of the baobab species affects its pollination. The main function of flower scent compounds is to encourage cross-pollination by influencing pollinator flower visit behavior and patterns. Different groups of pollinators are known to be attracted by different floral scent compounds (Table 1). Bat-pollinated flowers are dominated by sulfur compounds while moth-pollinated plants (especially those visited by hawk moths) secrete volatile substances consisting of oxygenated terpenes and nitrogen-containing compounds (Razanamaro *et al*., 2015). Flowering is determined by the length of the day or temperature in a condition and can be affected by the conditions of the previous season. Variation in fruit production between the years is a consequence of reduced flower production. An increase in flowers can occur with the size and age of the tree (Venter & Witkowski, 2019).

Table 1. Floral characteristics of *Adansonia* sp. based on the pollinator.
Tabla 1. Características de las flores de *Adansonia* sp. basadas en el polinizador.

Species	Characteristic	Morphology	Pollinators	Reference
Adansonia digitata L.	The flowers are white, large, revolved, solitary or paired in the axils of the leaves, having many stamens. The bloom time only lasts 1 night.		Bat	(Rashford, 2015)
Adansonia madagascariensis Baill.	The flowers are delicate and elongated, the petals are brightly colored ranging from orange to red. Has a long staminal tube (6-10 cm), the number of stamens 90-100.		Hawk moth	(Razanamaro *et al.*, 2015; Steentoft, 2015)
Adansonia rubrostipa Jum. & H. Perrier	Delicate flowers elongate brightly colored petals from bright yellow to orange. Have a long staminal tube (6-10 cm) and stamens count of 100-150.		Hawk moth	(Razanamaro *et al.*, 2015; Steentoft, 2015)
Adansonia za Baill.	The petals are predominantly yellow orange with red stripes. The length of the flower buds varies between 15-24 cm.		Lemurs, Eagle moths and butterflies	(Steentoft, 2015)

CONCLUSIONS

Baobab is a unique tree with various adaptations that support its longevity and resistance to harsh environmental conditions. These adaptations include a mechanism to deal with drought in the seedling phase, a water storage mechanism on the stem with a unique morphology, stomata regulation, a unique flowering mechanism, and seed protection against extreme heat. This study shows that understanding the mechanisms of baobab adaptation can provide important insights in the fields of botany, ecology, and conservation, as well as serve as a model in research on plant resilience to climate change.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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