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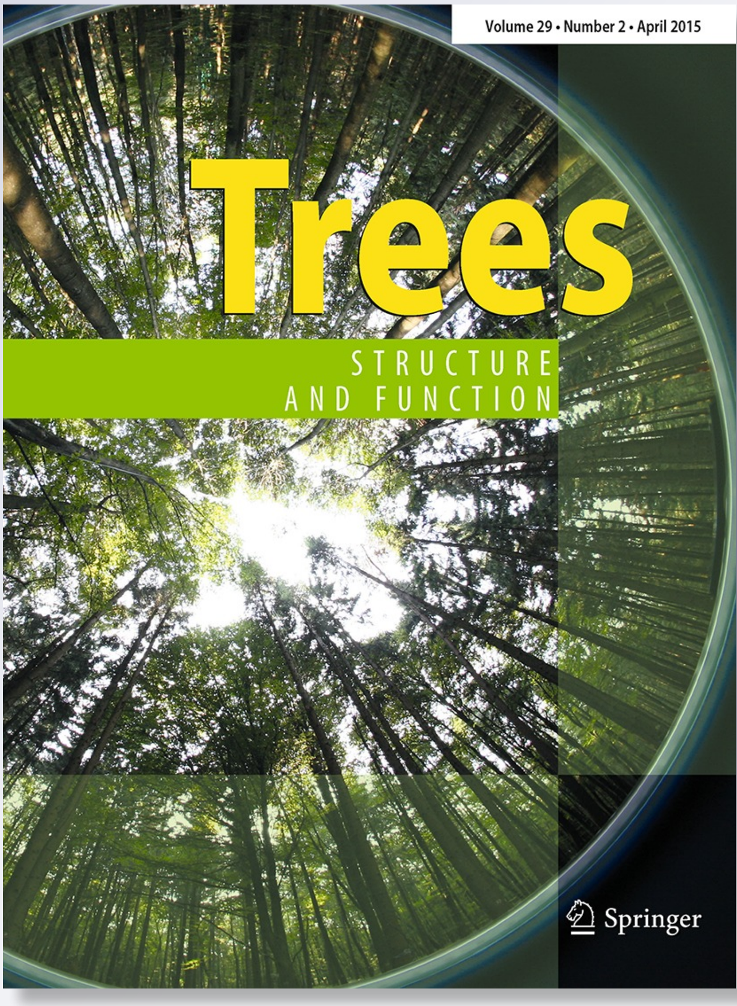

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REVIEW

The biology of *Calotropis procera* (Aiton) W.T.

Loutfy M. Hassan · Tarek M. Galal · Emad A. Farahat · Maha M. El-Midany

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Abstract

Key message **This review article contributes in more understanding of most aspects of *Calotropis procera* biology and extend our knowledge about its behavior.**

Abstract *Calotropis procera* (Aiton) W.T (Asclepiadaceae) (Giant milkweed) is a xerophytic perennial shrub or small tree. It is native to tropical and subtropical Africa, Asia and common in the Middle East. It grows on a variety of soils, from fine to coarse texture, with varying degrees of salinity. The importance of *C. procera* in the functioning of ecosystems is reflected in its hosting of butterflies, while it also acts as a food plant for arthropods. In addition, it is used for medicinal purposes in many arid countries. Potential new uses of this species in semi-arid regions include the phytoremediation of soils contaminated with trace elements and the use of biomass as a source of renewable energy.

Keywords *Calotropis procera* · Macromorphology · Anatomy · Reproduction · Phytochemistry · Phytoremediation

Introduction

The present review describes the available literature on the biology of *Calotropis procera*. It covers the geographical distribution, plant macromorphology, anatomy, pollen and economic uses. We examine the reproduction of this species, its propagation and dispersal in addition to its interactions with other biota. We review its phytochemistry, control measures and toxicity, and its possible utilization in the emerging technologies of phytoremediation of contaminated soils and energy.

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Geographical distribution and ecology

Calotropis procera (Aiton) W.T (Asclepiadaceae) is a xerophytic perennial shrub or shallow tree that grows in many arid and semi-arid countries. It is native to tropical and subtropical Africa and Asia, common in the Middle East (Parsons and Cuthbertson 2001; Lottermoser 2011) and in Latin America, where the species has high socioeconomic value (Fig. 1) (Abbas et al. 1992). It often grows in saline or slightly saline soils with low soil moisture, forming mono-specific stands (El-Midany 2014).

Calotropis from the Greek words meaning 'beautiful' and 'keel of a boat' and refers to the scales in the flowers. Procera is from the Latin words 'in favor of' and 'wax' referring to the waxy appearance of the plant. On the other hand, the scientific name of the family is derived from Asklepios, the Greek god of medicine (Parsons and Cuthbertson 2001). The most common synonym for the species is *Asclepias procera* Aiton (Boulos 2000). The common names of *C. procera* are Giant milkweed, Madar, Sodom apple, Calotrope cabbage tree and Rubber tree (Liogier 1995; Parrotta 2001). Besides, it is known in Arabic as "Ushar" or "Oshar" (Akhtar et al. 1992 and Orwa et al. 2009). It has two subspecies, which differ only in fruit characteristics: *C. procera* subsp. *procera*, C. *procera* subsp. *hamiltonii* (Ali and Ali 1988).

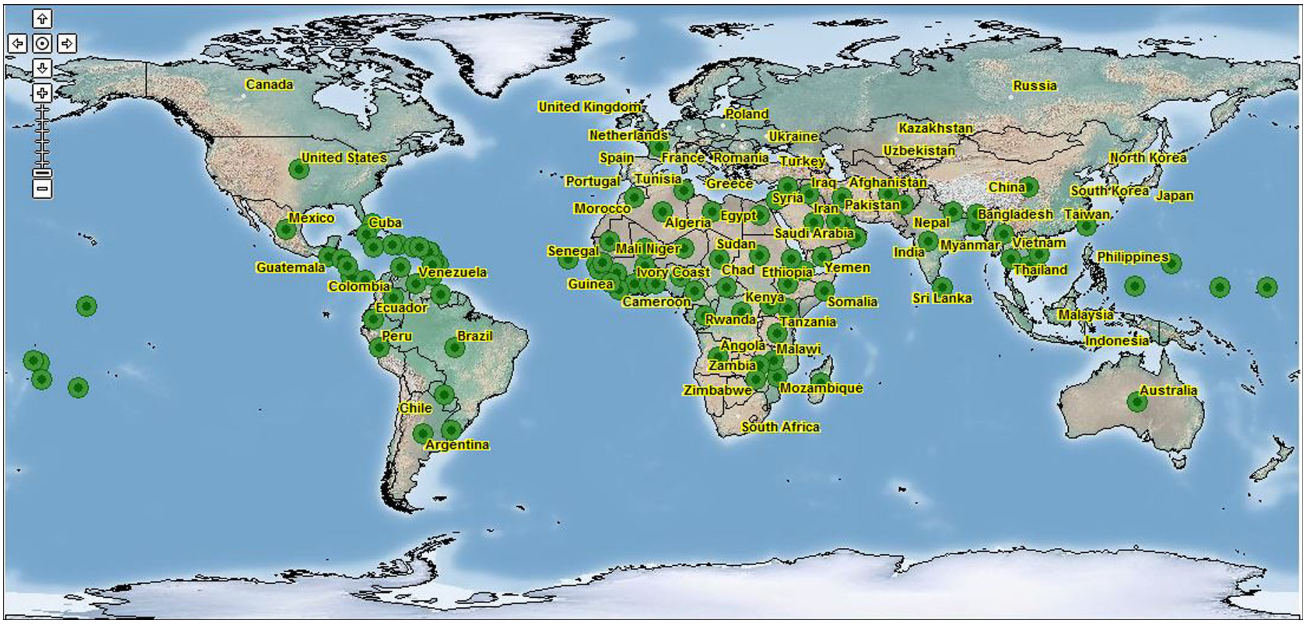

Fig. 1 Global distribution of *C. procera*, compiled by the Plantwise knowledge bank based on published reports in the scientific literature. Reproduced by kind permission of CABI. © CABI (2014). www.plantwise.org/KnowledgeBank

Calotropis procera is a drought-resistant and salt-tolerant species that is capable of surviving in a range of soil types including alkaline and saline soil, and prefers free-draining sandy soils. It grows abundantly in arid and semi-arid regions without irrigation, chemical fertilizers, pesticides or other agronomic practices (Sharma et al. 2012). Akhtar et al. (1992) reported its growth as secondary vegetation after the eradication of *Acacia* trees for fuel purposes. It produces deep roots and root suckers, and rarely grows in shallow soils over unfractured rock (D'Souzaa et al. 2010). It grows in open habitats and is particularly common in overgrazed pastures and poor soils, where there is little competition with grasses. It is also found along roadsides, watercourses, river flats and coastal dunes, and is often prevalent in disturbed areas (Parsons and Cuthbertson 2001; Francis 2003; Orwa et al. 2009). *C. procera* favors the habitats that receive 150–1,000 mm annual rainfall. Mean annual monthly temperatures for the species' range are from 20 to 30 °C, and it is not frost tolerant (CABI 2005).

Macromorphology

Stems

The stem of *C. procera* occurs as single- or many-stemmed soft-wooded shrubs that reach a height of 2–6 m, with stem diameters of 25 cm (Little et al. 1974; Orwa et al. 2009) and a crown diameter of 6.9 m (Brandes 2005). Young stems are grayish-green in color, smooth in texture, and have a covering of whitish colored hairs (i.e., they are hoary). Mature stems have a deeply fissured, cork-like bark that is light brown in color (Parsons and Cuthbertson 2001; Boulos 2000) (Fig. 2a).

Roots

Calotropis procera has a taproot 3–4 m deep, and a secondary root system with woody lateral roots, which may rapidly regenerate adventitious shoots when plants injured (Orwa et al. 2009). The taproots of *C. procera* have prominent tops with rounded head, with the rest of the portion spirally curved; they form large tubers (Grace 2006). These hard roots are grayish-white in color and exhibit sap exudations if the bark has been cut. The upper cork portion is spongy and rough, while the inner portion of the bark is smooth and mucilaginous. The dried bark has a bitter taste (Alikhan and Khanum 2005).

Leaves

The leaves are simple, sub-sessile, opposite decussate, slightly thick or fleshy, oblong, obovate to nearly orbicular, short-pointed to blunt at the apex and have a clasping heart-shaped base. The leaf blades are light to dark green with nearly white veins, slightly leathery, and have a fine coat of soft hairs that rub-off. Leaves are pubescent when young and glabrous on both sides on maturity. They have a waxy appearance and contain a white milky sap (Murti et al.

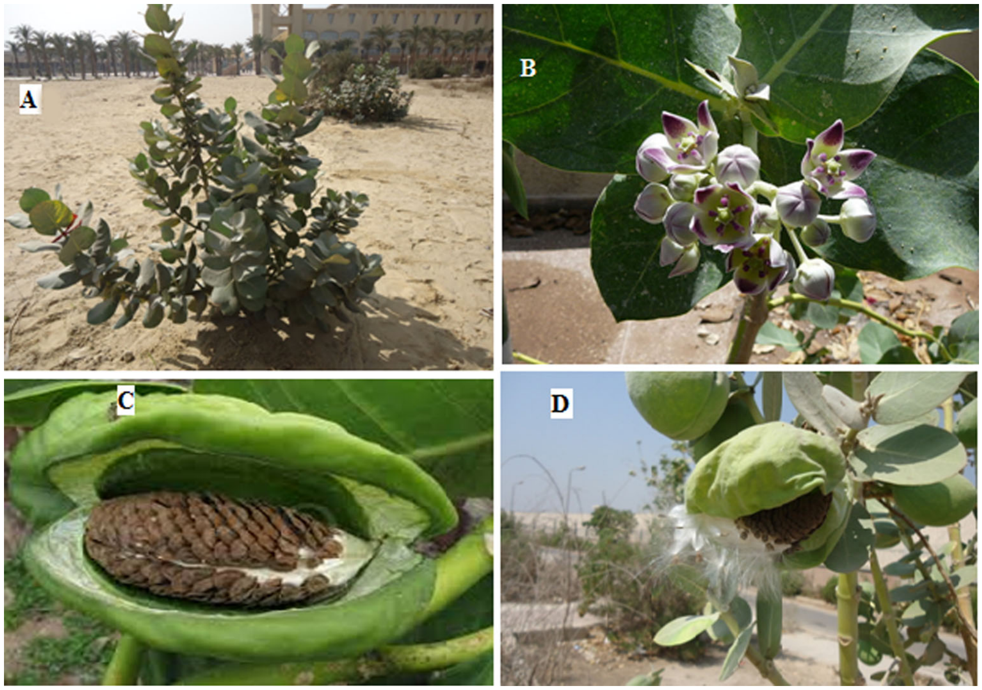

Fig. 2 **a** *Calotropis procera* grows in monospecific stand, **b** open flowers, **c** dehiscent fruit showing *dark brown* seeds and **d** dispersal of seeds with *white silky* pappus

2010; Sharma et al. 2012). Leaves are large up to 15 cm long and 10 cm broad, with no leaf stalk (Fig. 2b) (Kleinschmidt and Johnson 1977).

Flowers

Flowering takes place throughout the year (Little et al. 1974). The flowers are regular, bisexual and have a faint odor (Figs. 2b–d, 3). They are borne in clusters of ovoid flower buds in the forks of the uppermost leaves (i.e., in axillary inflorescences); each cluster contains 3–15 flowers. The clusters are surrounded by involucres of several small oblong, pointed scaly caduceus bracts. The main stalk of these flower clusters (i.e., peduncle) is 20–55 mm long, and each flower has a stalk (i.e., pedicel) about 15–25 mm long. Calyx and corolla are 5-lobed; sepals 7–8 mm long; ovate acute, hairy outside; while petals 2–3 cm wide, white with purple tips internally; fruit ovoid, inflated, 8–12 cm long (Parsons and Cuthbertson 2001). Flowers have crown-like center (corona) (Kleinschmidt and Johnson 1977; Boulos 2000).

The androecium is formed of five stamens, inserted at the base of the corolla. The five androecial members are adnate, united with the gynoecium (forming a gynostegium). Filaments unite to form a large staminal column with five conspicuous radiating coronal appendages that are completely adnate to, but slightly shorter than, the column. Anthers are short, broad and somewhat horny, with broadly triangular membranous anther tips that are inflexed over the sides of the stigmatic hood. Each flower produces significant quantities of nectar (Sharma et al. 2011).

The gynoecium of *C. procera* consists of two free carpels, which are united at the apex of the style. The "stigma" is broad, pentagonal and the true stigmatic surfaces are enclosed below the stigmatic lobes within stigmatic chambers between adjacent anthers. The corona is made up of five fleshy, purple, laterally compressed lobes radiating from the gynostegium. Each lobe consists of a recurved vesicle at the base and a bifid apex with a cleft outside (Ali and Ali 1988; Boulos 2000).

Pollen

The pollen of *C. procera* is green and somewhat sticky, with brown translator and enclosed in pollinia (a coherent mass of pollen grains). The pollinia are the product of only one anther and attached to an adhesive glandular disc at the stigmatic angle as a single unit. The pollinial wall is acetolysis resistant (Namboodiri and Sreedevi 1980). The pollinarium of *C. procera* is composed of two pollinia, each of which contains all of the microspores of a single anther locule embedded in a hard matrix and a translator apparatus, which develops from a stigmatic secretion (Swarupanandan et al. 1996).

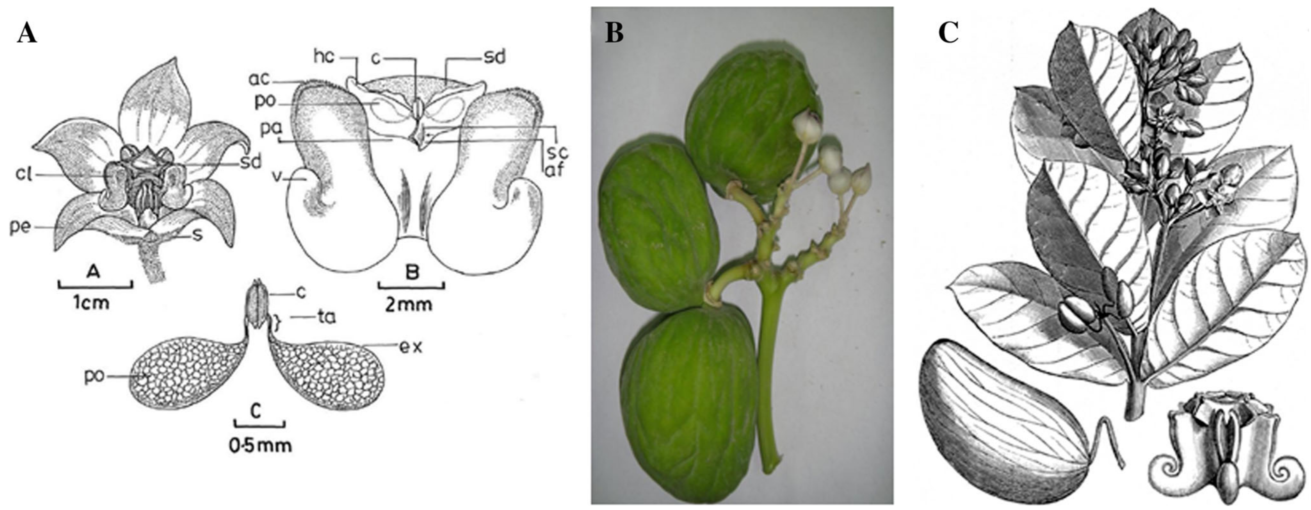

Fig. 3 Diagrammatic sketch for *C. procera* showing **a** Flower, side view of the gynostegium and two corona lobes, and pollinarium (cited from Ali and Ali 1988), **b** and **c** flowering and fruiting branch (**b** is after El-Midany (2014) and **c** and **d** are cited from the following URCL: http://www.plantsystematics.org/imgs/sv22/r/Apocynaceae_Calotropis_procera_17832.html. A. Engler (1910). Vegetation der Erde. IX. Band 1. Figure 16). *ac* apex of corona lobe, *af* anther flap, *c* corpusculum, *cl* corona lobe, *ex* exo-lateral surface, *hc* hyaline outgrowth of connective that covers the stigmatic disc at the periphery, *pa* pad, *pe* petal, *po* pollinium, *s* sepal, *sc* stigmatic chamber, *sd* stigmatic disc, *ta* translator arm, *v* vesicle (cited from Ali and Ali 1988)

Fruit and seed

The fruits are follicle (8–14 × 6–9 cm), sub-globose to obliquely ovoid. Its apex is rounded, green, spongy, and smooth—that split and invert when mature to release seeds (Howards 1989; Sharma et al. 2012) (Fig. 3b, c). Seeds are numerous (350–500 per fruit), flat, obovate, 6 × 5 mm, with silky white pappus of 3 cm or longer (Orwa et al. 2009). Fruiting takes place throughout the year (Little et al. 1974).

Seedling

The cotyledons are broadly elliptic, (16–25 × 13–15 mm) with a rounded apex, attenuate base, and exude milky sap. The first pair of leaves is stipulated; stipules are small, linear and 1 mm long. At the tenth leaf stage: leaves are obovate, both the upper and lower surfaces are densely clothed in a spider-web-like hairy material that is easily rubbed off with a fingernail. Usually two brown hair-like structures (glands), 1 mm long, are on the upper surface of the leaf blade; one gland on each side of the midrib. Terminal bud and stem are woolly white. Seedlings often grow in large numbers after rainy periods, but only a few survive the first season. The plant's large taproot enables it to re-sprout year after year if burned or cut (Francis 2003).

Anatomy

Stem

The epidermis is characterized by uniseriate cells with a thick cuticle (Table 1; Fig. 4a) and multi-cellular hairs. Cells are barrel to rectangular in shape and compactly arranged (Sharma et al. 2011). Cork arises superficially, usually in the epidermis or sub-epidermis (Metcalfe and Chalk 1950a). The cortex forms a few layers below the epidermis, which are collenchymatous with thickened corners and a few chloroplasts, while the rest of the cortical cells are parenchyma. Intercellular spaces are numerous and a few crystal druses are observed in the cortex (Schweingruber et al. 2011; Sharma et al. 2011; El-Midany 2014). The endodermis consists of a uniseriate row of cells that form a wavy ring around the vascular tissue and separate cortex from underlying tissues. It contains starch grains, which is defined as starch sheath. The pericycle is in the form of small patches of sclerenchymatous fibers. A few parenchymatous cells of the original pericycle are present between these groups (Sharma et al. 2011).

In the vascular tissue system, secondary growth is prominent. It shows groups of primary and secondary phloem, cambium, secondary and primary xylem, and intraxylary phloem. These groups are accompanied internally by fibers that appear as dark patches in cross section. There are several conjoint, open, bicollateral and endarch vascular bundles. Primary phloem is completely obliterated, while patches of secondary phloem occur above and close to the cambium. The cambium is unistratose but its derivatives on either side, which are alike, give an appearance of a broad zone of cambium (approximately 86.4 µm) (El-Midany 2014). A few groups of phloem are situated just below the primary xylem in the region of pith and are the groups of intraxylary or internal phloem (Sharma et al. 2011).

Table 1 Anatomical characteristic (Mean ± SD, $n = 6$) of stem and root of *C. procera*

Anatomical character	Stem	Root
Thickness (μm)		
Cuticle	6.0 ± 2.0	Nd
Epidermis/periderm	36.0 ± 17.0	960.0 ± 84.9
Cortex	1,408.0 ± 200.0	Nd
Lactiferous glands		Nd
Length	264.8 ± 56.9	
Width	92.0 ± 11.0	
Outer phloem	148.8.0 ± 36.2	85.3 ± 9.2
Inner phloem	82.4 ± 17.3	
Outer cambium	86.4 ± 16.6	84.8 ± 20.9
Inner cambium	68.0 ± 11.0	
Thickness of xylem layer	333.3 ± 57.7	1,744.0 ± 87.6
Xylem vessels diameter	42.3 ± 29.6	54.4 ± 18.2
Total thickness	3,800.0 ± 951.0	5,384.0 ± 1,678.2
Presence of distinct annual rings	No	Yes
Rays (mean number of rows between vessels)	3.6 ± 1.1	2.4 ± 0.5

Nd not detected

Phloem and xylem are usually in the form of continuous cylinders, transverse by <3 rows of ray parenchyma (Metcalfe and Chalk 1950b; Sharma et al. 2011; El-Midany 2014). Groups of sclereids, some few crystal druses and laticifers are observed in the phloem (Kokate et al. 2005; Schweingruber et al. 2011) and in the cortex, which appears rectangular in shape (El-Midany 2014). Secondary xylem forms a broad and extensive region, and comprises vessels and tracheids. The annual rings are feeble; where xylem rings are distinct, semi-ring porous, with numerous vessels that are medium-sized to small. The vessels are multiples of 4 or more cells in radial multiples, and the diameter of the vessel is larger than 100.0 μm in adult plants. Simple perforations, thin-walled fibers, fiber cell wall are slightly thicker in the late wood than in the early wood. Rays are typically narrow with 1–3 cells and 5–10 marginal rows of upright cells with laticifers. Small groups of collapsed sieve cells are present at the beginning of the secondary xylem (Metcalfe and Chalk 1950a, b; Kokate et al. 2005; Schweingruber et al. 2011). Primary xylem occurs near the pith and is endarch. Pith is occupied by thin-walled parenchyma and also many latex vessels (Sharma et al. 2011).

Root

Periderm is a well-developed outermost layer in root system of the plant with a thickness of 960.0 μm (Table 1; Fig. 4b). Xylem vessels and tracheids are also well developed and separated by narrow rows of ray parenchyma. Annual rings are more distinct in the root system and devoid from large vessels. Root vessels are scattered in the cross section (i.e., diffusive) with diameters around 42 μm (El-Midany 2014). The thickness of the xylem and tracheids layer is more than one-third of the total thickness of the cross section in 2-year-old roots (El-Midany 2014).

Leaf

Transverse section through the midrib shows an upper and lower, single-layered epidermis that is covered with a thick, striated cuticle (about 1 μm in thickness). The epidermal layers consist of few epidermal cells, on both lower and upper surfaces, and parenchymatous cells that are thin walled and iso-diametric to circular (Table 2; Fig. 4c). Intercellular spaces are present in ground tissue and the stele is crescent-shaped and composes of open bi-collateral vascular bundles. The xylem consists mostly of vessels and tracheids, and a strip of the cambium is present between the xylem and phloem tissues (Sharma et al. 2011). The lamina, which is dorsi-ventral with the mesophyll, is differentiated into a palisade and spongy tissue. Three to five rows of elongated, closely arranged, palisade parenchyma were below the upper epidermis with thickness 232.0 μm. The lower palisade parenchyma is armed and consists of three compact rows (thickness 218.7 μm). Spongy parenchyma tissues are almost radial and elongated with intracellular spaces. The parenchyma is >30 % of the total cross section of the leaf (El-Midany 2014). Central cells are irregular in shape, with some scattered laticifers and vascular bundles (Murti et al. 2010). Lactiferous canals are present in the leaf and stem (Metcalfe and Chalk 1950b).

Stomatal characteristics

Stomata are paracytic with stomatal length and width equal to 24.0 μm and 18.1 μm, respectively (Metcalfe and Chalk

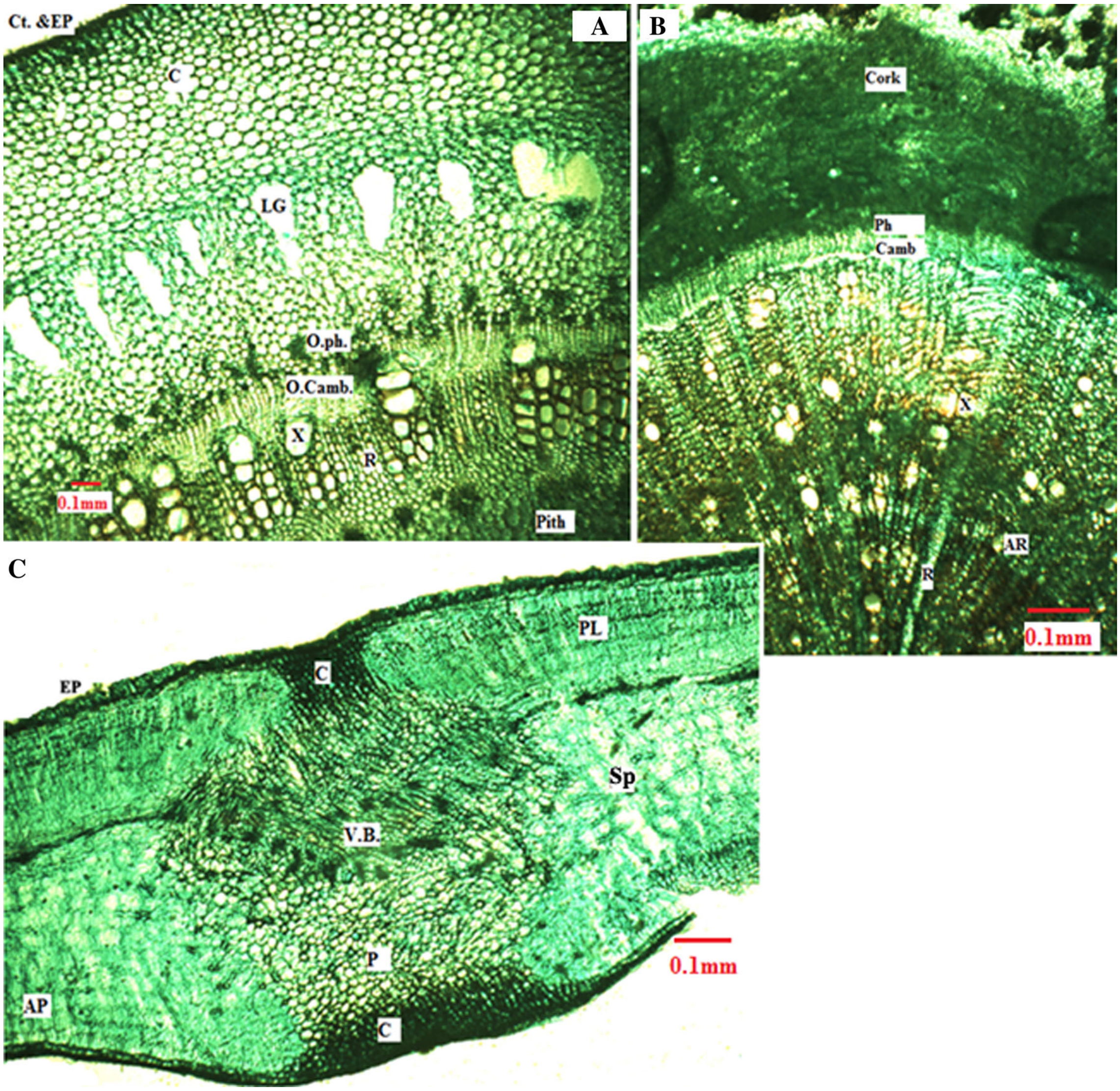

Fig. 4 Cross sections of *C. procera* showing the anatomical structure of **a** stem, **b** root, and **c** leaf. *AP* armed parenchyma, *AR* annual ring, *C* cortex, *Ct* cuticle, *EP* epidermis, *LG* lactiferous glands, *O.Camb.* outer cambium, *O.ph.* outer phloem, *P* parenchyma, *Pl* palisade parenchyma, *R* rays, *Sp* spongy parenchyma, *V.B.* vascular bundle, *X* xylem

1950a; El-Midany 2014) (Table 3; Fig. 5). Stomatal pore surface is 22.0 μm^2, with a pore length of 10.0 µm and width of 2.7 µm, while stomatal density is 105.0 mm^{-2}, in the typical range of xerophytic plants (El-Midany 2014).

Reproduction

Pollinators and their behavior

Cross-pollination occurs by insects, particularly by species such as the monarch butterfly (*Danaus plexippus*), which uses *C. procera* as a host plant for various stages of its life cycle (Orwa et al. 2009). In Egypt, *Xylocopa leucothorax* males (exclusively) are the main pollinators and a Scoliid wasp is a facultative one (Schremmer 1972).

Reproduction, propagation and dispersal

Calotropis procera is a perennial shrub that primarily reproduces by seeds (Lottermoser 2011) and also by vegetative propagation through half stumps, as each plant gives rise to two half stumps. Vegetative propagation is also through stem, root suckers and root cuttings (Morcelle et al. 2004). Most seeds fall close to the parent plants; they have a silky pappus that enables wind dispersal over several hundred meters (Francis 2003). *Calotropis* seeds are spread by wind, animal, and may be transported on long

Table 2 Anatomical characteristic (Mean ± SD, *n* = 6) of *C. procera* leaves

Leaf characteristics	Mean ± SD
Thickness (μm)	
Cuticle	
Upper	1.0 ± 0.4
Lower	1.0 ± 0.4
Upper epidermis	24.0 ± 6.5
Palisade parenchyma	
Upper	232.0 ± 21.2
Lower	218.7 ± 32.3
Spongy parenchyma	232.0 ± 13.9
Lower epidermis	28.3 ± 4.6
Total	738.7 ± 60.6

Table 3 Stomata size and density (Mean ± SD, *n* = 6) of *C. procera* leaves

Stomatal characteristic (*n* = 6)	Mean ± SD
Stomatal length (μm)	24.0 ± 3.3
Stomatal width (μm)	18.5 ± 1.9
Pore length (μm)	10.0 ± 2.0
Pore width (μm)	2.7 ± 1.2
Stomatal pore surface (μm^2)	22.0 ± 13.7
Density (stomata mm^{-2})	105.0 ± 18

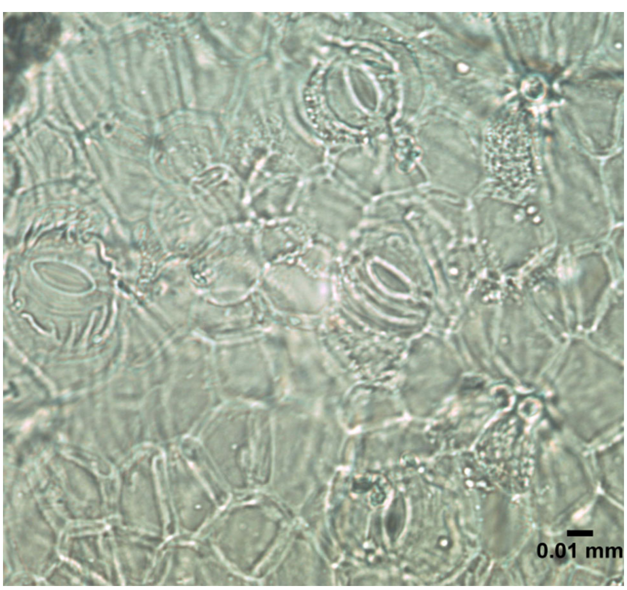

Fig. 5 Leaf abaxial epidermal cells of *C. procera* showing its stomata

distances in flood waters (Parsons and Cuthbertson 2001). The continuous flowering and fruiting for 2–6 months of the species observed in the invaded habitats, in contrast to native habitats, may facilitate its invasion (Sobrinho et al. 2013).

Control methods

In places where the number of *Calotropis* individuals is small, it is recommended to remove the tree mechanically with its deep tap root and lateral roots to prevent suckering. Light competition with tall weeds, brushes and especially grass may be an efficient way to weaken *Calotropis* and to prevent seed germination (Parsons and Cuthbertson 2001). Chemical control is advisable for larger *Calotropis* colonies (Parsons and Cuthbertson 2001). Repeated spraying with picloram plus 2, 4-D amine when seedling and small trees are actively growing provides good control (Declared plant in Western Australia 2012).

Phytoremediation

Calotropis procera has good phytoextraction potential as shown by the accumulation ratios under natural conditions. It is well adapted and proliferates freely through seeds and root suckers even in adverse conditions. It is a safe choice to be used as an instrument of phytoremediation. *C. procera* showed higher Pb and Cd accumulation in leaves compared to roots (D'Souzaa et al. 2010). The order of heavy metal accumulation by the plant was Cd > As > Zn > Cu > Pb. Cd and As were found to be particularly mobile in the soil–plant systems. Zn, Cu and Pb were slightly mobile (Al-Farraj and Al-Wabel 2007). The plant is a useful bio-indicator for monitoring pollution in urban and suburban areas (Waleed 2006).

Allelopathic effect of *C. procera*

Calotropis procera have allelopathic properties including germination inhibition, plumule and radicle growth reduction. Dry leaf-water extract (5, 10, 20, 40 and 60 %) has an allelopathic effect on the seed germination of barley (*Hordeum vulgare* L.), wheat (*Triticum aestivum* L.), cucumber (*Cucumis sativus* L.), fenugreek (*Trigonella foenum-graecum* L.), alssana (*Senna occidentalis* L.), tomato (*Lycopersicon esculentum* Mill.), and eggplant (*Solanum melongena* L.). The final germination percentage decreased with increasing leaf extract concentration (Al-Zahrani and Al-Robai 2007; Ghasemi et al. 2012). In addition, the delay in seed germination and the reduction in germination index may reflect the presence of water-soluble inhibitors in *C. procera* extract (Yasin et al. 2012). Allelochemicals present in leaves and stems of *C. procera* strongly inhibited the germination, seedling growth, fresh and dry biomass of *Pennisetum americanum* (L.) Leeke and *Setaria italica* (L.) P. Beauv. Moreover, this plant has strong allelopathic potential and might be a candidate for biological control of weeds and insects (Samreen et al. 2009). It has widespread and persistent occurrence near barley, oat, rice, sorghum, maize, cotton, sugarcane and especially wheat crop fields, which suggests some adverse effects on these crops through allelopathic interactions. Therefore, there is always a threat that it may become a major weed of cropping systems (Yasin et al. 2012).

Phytochemistry and traditional use

The phytochemical studies on the aerial parts of the plant showed the presence of alkaloids, cardiac glycosides, tannins, flavonoids, sterols and/or triterpenes (Mossa et al. 1991). The leaves contain mainly the amyrin, amyrin acetate, ß-sitosterol, ursolic acid, cardenolides, calotropin and calotropagenin (Sharma et al. 2011). Pentacyclic triterpenes, phytosterols and triterpenoids saponins have been isolated from the roots of *C. procera* (Ansari and Ali 1999). Chemical investigations of the seeds indicate the occurrence of coroglaucigenin, frugoside and corotoxigenin (Rajagopalan et al. 1955). In addition, flowers contain terpenes, multiflorenol, and cyclisadol (Al-Yahya et al. 1990). Moreover, the latex contains caoutchouc, calotoxin 0.15 %, calactin 0.15 %, uscharin 0.45 %, trypsin, voruscharin, uzarigenin, syriogenin and proceroside (Ansari and Ali 1999).

Calotropis procera was known to the ancient Egyptians as a medicinal plant, and excavations at the Helwan site in Egypt showed that the plant was in use in the Neolithic period in Egypt (Greiss 1955). *C. procera* have antioxidant, antimicrobial and cytostatic properties (Kumar and Arya 2006). The leaf, stem and root are utilized in traditional medicine for treatment of wounds, sores and skin diseases, diarrhea, sinus and fistula (Moronkola et al. 2011). In the past, it has been reported that the silky hairs of seeds were used to stuff pillows (Little et al. 1974). The floss of the seeds is used as a substitute for cotton wool in surgical operations in the Sahelian zone of Western and Central Africa (von Maydell 1986). Compounds such as asclepsin and mudarin reportedly isolated from this plant have emeto-cathartic, digitalic, bactericidal and vermicidal properties in Pakistan (Taylor 2004).

Calotropis procera releases irritating volatiles to repel desert grazers in addition to toxins (Russell et al. 2011). Its tissues, especially the root bark, are used to treat a variety of illnesses, including leprosy, fever, malaria, and snakebite in India (Parrotta 2001), and dermatitis, dysentery, and elephantiasis in the Sahelian zone of Western and Central Africa (von Maydell 1986). It is also used in tanning, brewing, and for curdling milk (Leeuwenberg 1987). Traditionally, the dried root is powdered and is effectively used to cure bronchitis, asthma, hepatic and spleen enlargement in India (Vohra 2004).

Leaves of *C. procera* are used as an antidote for rheumatism, mumps and burn injuries in India (Murti et al. 2010). Leaves also are used for fertilizer (Akhtar et al. 1992). The latex is used as a source of an indicator of soil-exhaustion in tropical West Africa (Leeuwenberg 1987). The latex is processed and used for treating hair fall, tooth aches, intermittent fevers, rheumatoid/joints swellings and paralysis in India (Vohra 2004). The Flower is used as a digestive, tonic for asthma and catarrh in the Sahelian zone of Western and Central Africa (von Maydell 1986).

Calotropis procera is useful for bioenergy and biofuel production in semi-arid regions (Rathore and Menna 2010). The plant yields valuable hydrocarbons, which could be converted into diesel substitutes (Choudhury and Singh 1993, 2007). Different parts of the plant (latex, stem, leaves and pods) have been evaluated as sources of hydrocarbons (Behera et al. 2000). The biodiesel derived from *C. procera* produces emissions with low NO_x, SO_2 and particulate matter, and has a high cetane value (Kumar and Vijay 2004; Padmaja et al. 2009). *C. procera* is recommended as a host plant for butterflies (Mikula 2001).

Author contribution statement All authors contributed to this work. Maha El-Midany collected the preliminary literature and worked with Emad Farahat preparing anatomical cross sections for all organs of the plant. Emad Farahat prepared the manuscript and navigated the peer-review process. T. Galal, and L. Hassan helped in reviewing the manuscript. All the authors approved the submission of this manuscript to Trees Journal.

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Conflict of interest The authors declare that they have no conflict of interest.

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