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ARTICULATED CORK IN *CALOTROPIS PROCERA* (ASCLEPIADACEAE)

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ABSTRACT

The cork of the small tree, *Calotropis procera,* which grows in a very hot district of Israel, is remarkable for its thickness and brittleness. The cork of the stems and large branches is composed of longitudinal ridges that extend over several internodes. The cork ridges have deep fissures around the circumference at almost every node. I propose that these nodal fissures in the cork serve as joints for two functions: (1) to prevent breakage of the fragile cork layer when branches bend under wind stress, and (2) to allow thermal expansion while avoiding tissue cracking on extremely hot days, similar to the joints left between steel rails in railroads and between concrete beams in bridges.

Key words: Bark, *Calotropis procera,* cork, periderm, thermal expansion.

INTRODUCTION

Periderm is the secondary protective tissue, which replaces the epidermis in woody plants. It and the other parts of the bark play an important role in insulating the live underlying tissues from the environment (Fahn and Cutler 1992). Insulation is important as protection from the sun, and interestingly, cork formation is stimulated in sun-exposed tissues (Borger 1973; Lev-Yadun and Aloni 1990).

Calotropis procera (Aiton) Aiton fil. (apple of Sodom) (taxonomy according to Feinbrun-Dothan 1978), is a small, poisonous (poisonous latex is found in all parts of the plant) tree or shrub of the Asclepiadaceae, of African origin, growing naturally in very hot habitats in Israel, its northern limit of distribution (Feinbrun-Dothan 1978). It is also found in hot regions of the Sahara and Sudan, in India, and in Central and South America (Pereira 1988). In Israel, major populations grow around the Dead Sea, at ca. 350–400 m below sea level but also in the lower Jordan Valley up to about sea level (Karschon 1970). This region is very hot and sunny and for several months every year, and the day-time temperature in the shade usually ranges from 35C to 42C. The mean annual temperature is ca. 25C. The mean temperature (day and night) of the hottest month (August) is ca. 33C and that of the coldest month (January) is ca. 15–16C. The mean annual number of days with maximum temperature of 35C or more is ca. 115 (Atlas of Israel 1970). The plants are exposed to much higher temperatures than those measured by the meteorological service and are also exposed to strong winds that blow along the rift valley.

The cork of *C. procera* has deep cracks and longitudinal fissures. It is cream colored, very light and soft, and yet quite brittle and inelastic. Fahn (1990) described the mature cork as rhytidome. Cells in the cork are roughly polygonal or rounded, are partially disconnected, and form radial rows. The cork cells of *C. procera* are much larger (ten times in volume) than those of *Quercus suber* L. (cork oak), although their cell walls are of the same thickness. The cork of *C. procera* is much less elastic than that of *Q. suber* and this difference has been explained by both the different chemical composition and the structure of the tissue (Pereira 1988). Periderm formation in *C. procera* is inhibited just below leaf bases or below and around suppressed buds. The enhanced cork formation on the sunny side of shoots eliminates the gaps in the cork found below leaf bases or below and around suppressed buds in shaded sides (Lev-Yadun and Aloni 1990).

The objective of this study was to examine the morphology of the remarkable cork in *C. procera* and propose a hypothesis to explain the function of the deep fissures.

MATERIALS AND METHODS

The cork was examined morphologically in the years 1995–1998 in several scores of mature plants of *C. procera* growing in three populations in the Dead Sea region in Israel (En-Gedi, Massada and En Boqek) ca. 350–390 m below sea level. The common formation of deep fissures around the circumference in almost every node was obvious in all plants. The great fragility of the cork of *C. procera* (Pereira 1988) was examined in many plants and was easily confirmed even under a gentle touch.

RESULTS AND DISCUSSION

The ridges of mature cork in *C. procera* are formed in an ordered pattern. In large mature individuals, in

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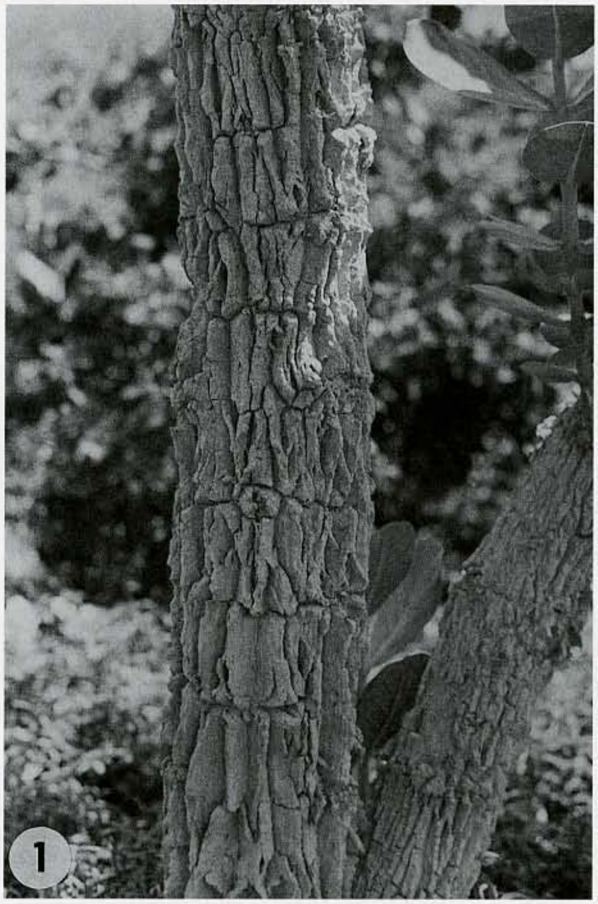

Fig. 1. A trunk of *Calotropis procera* about 15 cm in diameter from En Boqek growing about 380 m below sea level, about 100 m west of the Dead Sea coast, showing longitudinal ridges that extend over several internodes and the deep fissures around the circumference at every node.

the cork-covered stems and branches, the orientation of cork ridges is axial. In most of the nodal regions there are deep fissures encircling the trunk (Fig. 1).

The cork of *C. procera* serves in defense, probably from sun irradiation, desication, and abrasion by sand carried with the strong winds. Its thickness indicates the considerable importance of protection and insulation of the inner live tissues. Gaps that occur regularly in this strong defense should have a function. There are three types of gaps in the cork of *C. procera:* (1) longitudinal deep axial cracks and fissures which characterize the cork of many trees, (2) a zone lacking periderm just below leaf bases or below and around suppressed buds (Lev-Yadun and Aloni 1990), and (3) the deep fissures in the cork cover that appear around the circumference at almost every node shown here. Cork-free and cork-poor regions in *Melia azedarach* L. appear below or around suppressed buds and serve as openings for future bud sprouting following damage to the tree (Lev-Yadun and Aloni 1993), and they probably serve the same purpose in *C. procera.* I propose that since the cork of *C. procera* is very brittle (Pereira 1988), the deep fissures that occur both longitudinally in every internode and around the circumference at almost every node serve as joints and prevent breakage: (1) when branches bend under wind stress, and (2) during thermal expansion and constriction on extremely hot days, similar to the joints left between steel rails in railroads and between concrete beams in bridges. The longitudinal axial fissures in *C. procera* and in the bark of many other tree species probably also serve as joints during the shrinkage of stems in times of strong transpiration. Kozlowski et al. (1991) and Mattheck (1998) described the process and mechanical consequences of thermal expansion, when barks shrink and expand while exposed to large temperature changes. When a tissue confined by solid walls at both ends elongates because of thermal expansion, or where temperature gradients exist in the heated component, it suffers from the accumulation of stresses. In *C. procera* such large differences in temperature occur (1) when parts of stems are exposed to the sun and others are shaded, (2) between day and night, and (3) during interseasonal differences.

The bark considerably contributes to the bending resistance in young stems, but this contribution becomes marginal when the secondary wood becomes thicker and harder with age (Niklas 1999). In *C. procera,* in young parts of shoots, all parts of the bark have no cracks, and may contribute to the bending resistance. Only in older shoots does the cork develop deep fissures that lower the contribution of the outer bark to bending resistance. However, at this mature stage, the wood is thick and strong enough, and the bending resistance of the outer bark is of less importance.

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