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ORIGINAL ARTICLE

Development of the successive cambia in *Sesuvium verrucosum* Raf (Aizoaceae)

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Abstract The structure and development of successive cambia and its products were studied in the stems of the halophyte *Sesuvium verrucosum* Raf. The young stem has several collateral vascular bundles arranged in a circle and separated by interfascicular zones. The secondary thickening begins with the differentiation of fascicular and interfascicular cambia which give rise to secondary xylem, phloem and lignified cells. This normal cambium ceases to divide after a limited period of activity. A new segment of anomalous cambium was developed from the phloem parenchyma cells outside the normal previous cambium. These cells are served as a site for the origin of the anomalous cambium and subjected to repeated periclinal divisions. This cambium has fusiform cells with semi-storied appearance. The activity of this anomalous cambium produces secondary xylem, phloem, fibers and soft parenchyma as conjunctive tissues. The formation of subsequent cambia followed a similar pattern of development and causes vascular increments in the old stem. So, the old stem of *S. verrucosum* is constructed of concentric fibrovascular bands separated from each other by cylinders of conjunctive parenchyma tissue. This internal structure has a great adaptive potential to the halophyte *S. verrucosum*. This can be detected by the following points: (1) Production of large number of vessels and sieve tubes elements increases the conductive activity; (2) Occurrence of fibers alongside the vessels increases the mechanical strength that helps and protects water columns from embolism and ensures this water to store and transport in the succulent leaves; and (3) Thin walled parenchyma conjunctive tissue offers flexibility to the plant stem which forms a mat like and able to bend toward the ground without harm. Perhaps these features matched well with the *S. verrucosum* plant habitat.

Introduction

The formation of Successive cambia was early recorded in different plants (Schenck, 1893; Pfeiffer, 1926). Recently, many authors studied the initiation and activity of these cambia, Fahn and Zimmermann (1982) in *Atriplex halimus*, Carlquist (2003, 2007a,b), Rajput et al. (2008) in some plants of

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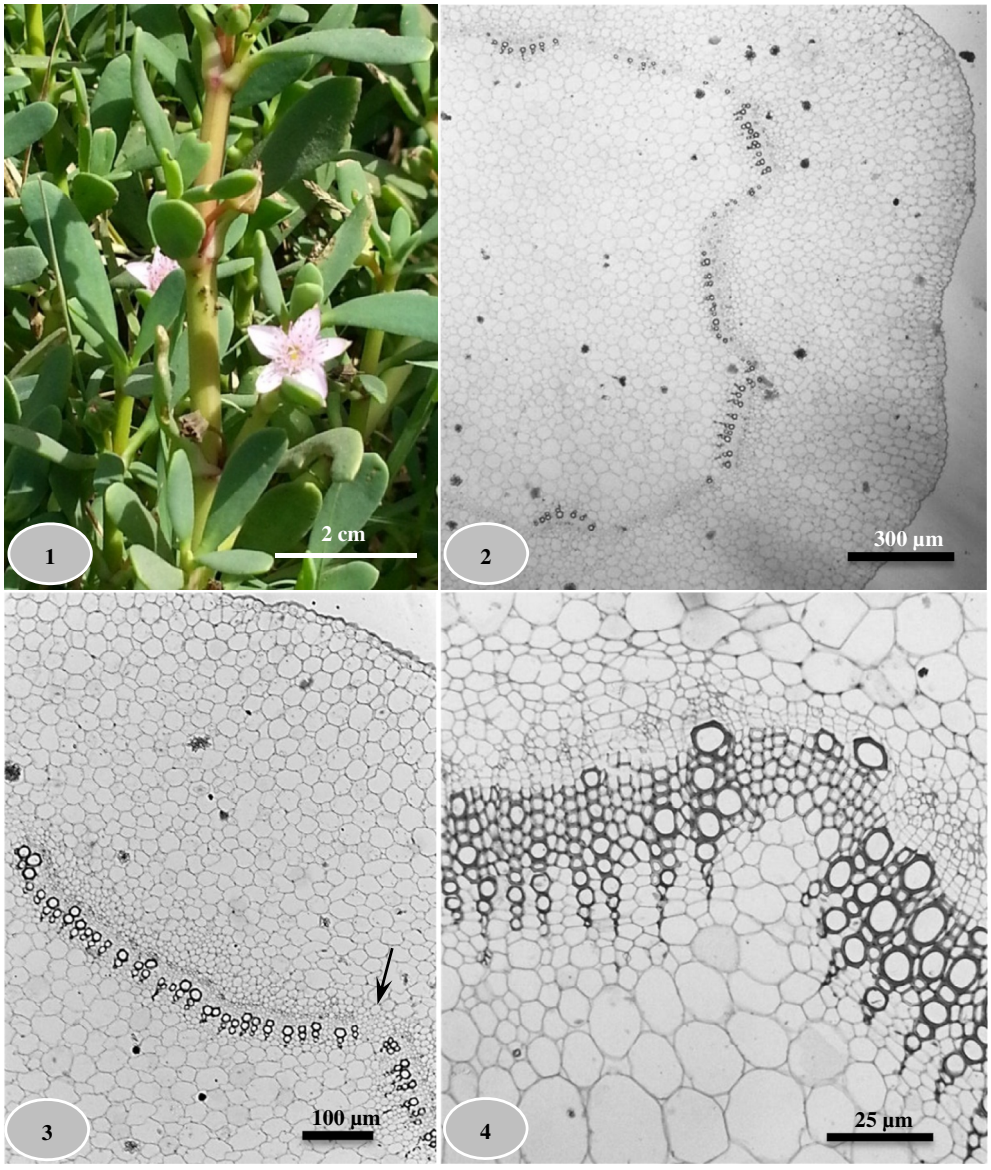

Figs. 1–4 Fig. 1: Morphology of *Sesuvium verrucosum* plant. Fig. 2: Transection in a young stem reveals its structure. Note the distribution of the vascular tissues, wide parenchymatous cortex and pith. Fig. 3: An enlarged view of Fig. 2 showing the primary vascular tissues. A narrow interfascicular region separating each two vascular bundles (arrow). Fig. 4: Development and activity of the fascicular cambium. Note some lignified cells produced from the interfascicular cambium.

Aizoaceae. This phenomenon was considered a characteristic feature of some families as Aizoaceae (Pax and Hoffman, 1934; Rao and Rajput, 1998; Carlquist, 2007a,b). It has been considered that, during the course of evolution, different groups of plants have undergone various modifications, which may be biochemical, morphological or structural. These modifications helped the plants to adapt to particular climatic or ecological conditions. Among these structural modifications the patterns of secondary thickening include formation of successive cambia, rayless xylem and paedomorphosis, and the formation of included phloem or of internal phloem Rajput et al. (2008). Stems and roots with successive cambia have great adaptive potential. The relative amounts of parenchyma, fibers, vessels, and sieve tubes can easily be reallocated by this ontogenetic system so as to provide more mechanical strength, more flexibility, or more storage capacity. Aizoaceae have a wide range of diversity in this respect (Carlquist, 2007a). Therefore, studying successive cambia in Aizoaceae could potentially offer important information on this phenomenon. The present study aims to follow the initiation and the products of the different successive cambia in *Sesuvium verrucosum* and to explain the correlation between the pattern of secondary growth and habit of the plant as well as to elucidate its xylem structure.

Material and methods

Stems of various ages were collected from an identified population of *S. verrucosum* Raf growing in a greenhouse of Department of Agricultural Botany, Faculty of Agriculture,