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Studies on some anatomical features of selected plant species grown in sand dune areas of North Sinai, Egypt

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ABSTRACT

The present investigation aims at studying some anatomical features of some selected native plant species in arid environments of sand dunes at North Sinai, Egypt. Plant samples were collected from three localities; Coastal sand dunes of Balouza (*Zygophyllum album*, Zygophyllaceae; root, stem and leaf); sand sheets of El-Arish city (stems of *Anabasis articulata*, Amaranthaceae and *Salsola tetrandra*, Chenopodiaceae) and El-Owga interdune areas (*Fagonia indica*, Zygophyllaceae; stem and root, *Zygophyllum album*, stem). Anatomical adaptations in leaves of *Zygophyllum album* include the presence of palisade layers on the adaxial and abaxial surfaces, thick cuticle layer cover the epidermis, spongy mesophyll and the presence of water storage cells. Stem anatomical adaptations in different plant species as general observations were the presence of thick cuticle, multiepidermal layers, palisade shape chlorenchyma, patches of sclerenchymatous fiber in the cortex and the precipitation of raphid and druse crystals of different sizes in plant tissues. Root adaptations in *Zygophyllum album* and *Fagonia indica* include the presence of periderm layers composed of compacted and elongated cells of different origins and increase the number of small xylem vessels which can guarantee the continuity of water uptake from soil in the case of xylem embolism.

1. Introduction

Native plants to arid environments in sand dune areas are very important for sand dune stabilization and reducing wind and water erosion resulting from severe floods. Such plants have different anatomical and physiological adaptations to maintain survive under adverse conditions of limited water resources and active sand encroachment. Hence plants can exhibit a quick growth development to overcome being buried by sand accumulation. Substantial leaf loss and more developed vascular are also noticeable and the presence of water storage tissues in mesophyll cells to withstand drought, this is consider as a prevalent character of xeromorphic leaves [31,33]. Plants in such circumstances tend to reduce it by transpiring surface area by means of substantial leaf loss. Therefore, plants with small leaves are more common in dry habitats [8,22–24]. A very common characteristic of xeromorphic leaves is a lower surface area to volume ratio, thick cuticle and sunken stomata, thus reducing water loss [19,20,30]. The presence of a palisade layer on both leaf surface, together with a mesophyll composed of smaller cells and reduced intracellular spaces is reported to be a characteristic of xerophytic species [9,25]. The increase of mesophyll thickness enhances the photosynthetic capacity if it is accompanied by an increase in the number of chloroplasts exposed near the surface area facing the intercellular spacing [21].

The presence of additional layers of palisade parenchyma at the expense of spongy tissue is also considered a way to increase the path of water through intercellular spaces to reach stomata; this would be a strategy to increase water use efficiency (ratio of carbon dioxide fixed to water lost) [17]. Many plants in desert environments produce different shapes and volumes of crystals in plant tissues. Calcium (Ca) oxalates are among the most abundant crystals present in different plant tissues, it is found as crystalline deposits [2,7,12,32]. The formation of calcium (Ca) oxalate crystal is considered to be a high capacity mechanism for regulating Ca in many plants. Needle shaped raphides and multifaceted druse crystals are the two common types of crystals formed in the plant tissues. [18]. In a study on four genera of the tribe Salsoleae, Chenopodiaceae, crystals of calcium (Ca) oxalate are formed in *Anabasis articulata*, they precipitated in epidermis, palisade shape chlorenchyma, cortex and in the vascular cylinder and also they found fibers in the cortex and in the vascular bundles [10].

Fibers are found in many plant tissues and in various organs of the plant and vary in position, they are sclerenchymatous (thick-walled) cells that form the bulk of mechanical or supporting tissue in the plants, [29]. The chief function of the fibers to the plant is to give it mechanical strength and save the plant from the various stresses and strains of the environmental factors e.g., strong winds. Their presence in the leaf gives

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it rigidity and prevents it from collapsing. Their presence on the surface of seeds and fruits may help in dispersal by wind.

Another kind of a protective tissue called periderm, is highly developed in perennial roots [11]. Generally, it is not produced in the leaves and in most of the monocot stems and roots, but it develops in majority of woody dicots, gymnosperms and some herbaceous dicots called periderm which is developed by the activity of a secondary lateral meristem and replaces the epidermis which is ruptured and destroyed by the pressure of the increasing secondary vascular tissue and form phelloderm or cork layers. Phelloderm may arise from the permanent living cells of the epidermis, hypoderms, cortex and the phloem cells (including the phloem ray cells). Its activity adds to the diameter of the stem and root because cells divide in a tangential plane cutting of cells towards its inner as well as outer face consists of compactly arranged thin or thick-walled cells, [29]. The present study aims at studying some anatomical features of some selected native plant species, which are promising in sand dune stabilization at three different geomorphological areas (Balouza, El Arish and El-Owga) at North Sinai, Egypt.

2. Materials and methods

Plant samples for the anatomical study were collected in October 2010 from three localities; Coastal sand dunes of Balouza (*Zygophyllum album*, Zygophyllaceae; root, stem and leaf), sand sheets of El-Arish city (stems of *Anabasis articulata*, Amaranthaceae and *Salsola tetrandra*; Chenopodiaceae), and El-Owga interdune areas (*Fagonia indica*, Zygophyllaceae; stem and root; *Zygophyllum album*, stem).

2.1. Study area

Sinai peninsula is located in the far northeast of Egypt. It represents about 6% of Egypt's area (61,000 Km^2). It is characterized by the distribution of active sand dunes in the north coastal and the middle areas, they elongated and directed from NNW to SSE with migration rate ranged from 1.6 to 8.4 m/year [5,6]. Natural vegetation of different plant species has an important role in stabilizing dune sand. Their survival and distribution depend upon their ability to withstand the harsh environments through morphological, physiological and anatomical traits of these plant species and the amount of rainfall. Rainfall and floods are the only sources of renewable water resources in Sinai Peninsula. Mediterranean climate is prevail in the northern parts of Sinai to be close to the desert and semi desert climate to the south. Temperature is hot in the northern areas or very hot with a higher temperature degrees inland. During May/June to September/ October, the mean daily maximum temperature is 28 °C to 37 °C in the north, 31 °C to 42 °C near the south coast and 35 °C to 41 °C inland. Minimum temperature degrees average between 20 °C to 25 °C in the summer. The amount of rainfall in Sinai decreases from the northeast towards the southwest. Highest amount was 304 mm at Rafah. The annual rainfall average is about 120 mm/year along the Mediterranean Coast, it decreases in the uplands to the south to about 32 mm/ year, [4].

Three localities were selected for the study area, two of them their natural plant species are subjected to severe wind erosion and sand drift processes in Balouza (31° 1′ 49.70″ N, 32° 35′ 27.81″ E) and El Arish sand sheets (31° 4′ 30.77″ N, 33° 50′ 21.86″ E) and the third location at El-Owga (30° 58′ 01.05″ N, 33° 56′ 25.09″ E) in the path of floods especially the severe flash flood of January 18, 2010, natural plants here are subjected to severe water erosion.

2.2. Microtechniques

Johansen [16] method was used to prepare permanent slides. Plant samples were immediately immersed in FAA and transferred to the histology laboratory of Desert Research Center (DRC), samples were dehydrated in a graded ethanol series, infiltrated, embedded in paraffin wax and microtome sectioned, and stained with safranin and light green then slides were mounted in Canada balsam and were examined under light microscope then photographs were taken with camera fixed (MC 80) in the microscope (Zeiss, Germany, Standard 20).

3. Results

The examination of the native perennials anatomy yielded more interesting results about stem, leaf and roots of these plant species.

3.1. Stem anatomy

3.1.1. Anabasis articulata, Amaranthaceae

It is clear that the multilayered epidermis is covered by thin cuticle layer then hypodermis is found and palisade shape chlorenchyma ended by short cell chlorenchyma layer. It is obvious that there are many small druse crystals in the epidermal cells, hypodermis and in palisade shape chlorenchyma. However, bigger druse crystals and tannin cells are found in the cortex cells, (Fig. 1A–B). Cortical and vascular fibers are also presented, (Fig. 1C–D).

3.1.2. Zygophyllum album, Zygophyllaceae

It is a common xerophyte belonging to family Zygophyllaceae, a transverse section of the stem (Fig. 1E–F) reveals the following structures; epidermis, it made up of a single layer of compactly arranged cells. The cells are radially elongated and are covered with a thick cuticle.

Cortical parenchyma shrunk lead to irregular epidermis surface obtain ridges and furrows (Fig. 1E), which may be an anatomical adaptation to aridity and adverse conditions prevailed in the interdune of El-Owga region, this anatomical adaptation is not found in Balouza coastal sand dunes may be due to high rainfall in the Coastal area.

Cortex is 15–20 layers thick. Cortical and phloem fibers are found. In Balouza sand dunes, the same structures are found in the transverse section of the stem, except that the regular epidermal surface without shrunk of Cortical parenchyma and the cortex is 8–10 layers thick (Fig. 1F).

3.1.3. Fagonia indica, Zygophyllaceae

It is clear that cross section of stem of Fagonia showed that the epidermis is covered with cuticle, and then cortex is 8–10 layer thick. Separated longitudinal patches of fibers are found as a ring around the vascular cylinder. Modularly rays are long and enclosed small vessels. Pith occupies the center of the stem and consists of thin walled oval or rounded cells with small intracellular spaces. Raphid crystals are found in the cortex, (Fig. 1G–H).

3.1.4. Salsola tetrandra, Chenopodiaceae

A transverse section of stem reveals the following structures; epidermis is consists of single layers of cells and is covered with thin cuticle layer. Cortex is distinguished to collenchymatous cells 5–8 layer thick and chlorenchymatous cells of 4–8 thick layer. Sclerenchymatous patches of fibers are spread in the cortex. Complete rings of external and intraxylary phloem or internal phloem are present and the modularly xylem is found in-between (Fig. 1I–J).

3.2. Root anatomy

In *Zygophyllum album*, it is clear that a phelloderm (periderm) layers comprised of are 10–21 thick layers of compacted and elongated cells arise from sub-epidermal cells, then the cortex parenchyma occupied large area and is composed of large elongated cells contains many starch grains (Fig. 2A). Fibers and raphid crystals are found in the cortex and phloem (Fig. 2A). Many xylem vessels in different diameters are observed (Fig. 2C–E). In *Fagonia indica*, It is obvious that the phelloderm layers originate from bast fibers obtained from the phloem. Successive layers of suberized periderm of compacted cells are recognizable outside the stele (Fig. 2E–F). Different xylem vessels are also observed with tendency to more narrow vessels.