FOLIAR ANATOMY OF CHENOPODIACEAE FAMILY AND XEROPHYTES ADAPTATION

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Foliar anatomy of three species of *Chenopodiaceae* family including *Chenopodium album*, *Kochia prostrata* and *Noaea mucronata* are studied. Various anatomical characters such as stomatal densities, guard cell length for the adaxial and abaxial epidermis, type of stomata, and density of trichome on surface, cuticle thickness, mesophyll type and variety of crystal are compared. Photosynthesis pathway is C4 in *Kochia prostrata* and *Noaea mucronata*. Foliar internal structure of species studied typically is characterized by xerophytes plants accompany by extensive central water-storage tissue which explaines *Chenopodiaceae* adaptation to arid and semi-arid area.

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Key words. Foliar anatomy, *Chenopodiaceae*, Kranz anatomy, xerophytes plants

ساختمان تشریحی برگ گونه‌هایی از خانواده اسفناج و بررسی ویژگیهای سازگاری خشکی پسند گونه‌ها

فاطمه زرین‌کمر

در طی این تحقیق آناتومی برگ در گونه‌های *Kochia prostrata, Chenopodium album* و *Noaea mucronata* ازخانواده اسفناج مورد مطالعه قرار گرفت . تراکم روزنه درواحد سطح، و اندازه و نوع روزنه، تراکم کرک ونوع آنها مقایسه گردید. مشخصات برگ در برش عرضی بیانگر آناتومی کرانزدر دو گونه میباشد.تغییرات ساختمانی برگ از جمله بافت ذخیره کننده آب بیانگر سازش این نوع گیاهان در زیستگاههای خشک است

Introduction

Approximately about 100 genera and 1300 species of *Chenopodiaceae* occur in the world, with near to 30 genera in Iran is found from annual herbs to trees (Dimmitt 2000). Majority are herbs, some shrubs and few trees, mainly find in arid areas, deserts, and coastal and saline habitats. Some species are more or less is 'cactoid' (e.g. *Salicornia*). They are annual, biennial, or perennial (often glaucous) with a basal aggregation of leaves, or with neither basal nor terminal aggregation of leaves. Usually self supporting but rarely climbing. Leaves well developed, or much reduced, or absent, alternate, or opposite when alternate, spiral, or distichous (rarely); succulent, or non-succulent nearly all halophytic. Leaves minute to large, herbaceous, or fleshy, or membranous, petiolate to sessile;. lamina dissected, or entire with one-veined (Watson & Dallwitz1998; Assadi 2001).

Many species of *Chenopodiaceous* are adapted to arid or semi-arid environments of the world.

Many species have C4 **Photosynthesis** pathway. Many of the earlier studies recognized the distinction between what is now generally called the Kranz or C4 anatomy and the C3 anatomy. Moser (1934) examined the distribution of Kranz anatomy in *Atriplex* quite thoroughly, and studies like those of Hauri (1912) and Rosengart-Famel (1937) all provide good quality data on the anatomy and distribution of the Kranz syndrome in other genera. Metcalfe and Chalk (1950), Napp-Zinn (1973), Voznesenskaya and her coworkers (2001-2002) have reported that species in the *Chenopodiaceae* have unusual chlorenchyma and Kranz anatomy.

Materials and Methods

The studied materials were fixed in FAA and were sectioned with a sliding microtome. Sections were cleared with sodium hypochlorite, dehydrated and colored with methyl green and carmine-vest and mounted in gelatin. In order to study stomata density, the diafanization technique (Stritmater 1973) was employed. Observation were carried out with light microscope.

The list of species under study in this paper is as follows and the herbarium specimens are preserved in TARI.

Chenopodium album L. -Arasbaran, Heidarkanlou, 450 m, SE, slope 40%, Hamzehee & Asri.

Kochia prostrata (L.) Schrad. - Arasbaran, Heidarkhanlou, 400 m, N-W, slope 55%, Hamzehee. & Asri. 81399.

Noaea mucronata (Forssk.) Asch. & Schweinf- Arasbaran, Babaylou, 400 m, S, slope 10%, Hamzehee. & Asri. 81400.

Observation (table 1)

Chenopodium album L.

Surface view (Fig. 1, F-H)

Both leaf surfaces are pubescent**. trichome** with thin wall and swollen base is observed on both leaf surfaces. Anticlinal **epidermal** cells have sinuous thin walls. **Stoma** is anomocytic. The leaves had an average stomatal density of 93 and 123 per mm^2 for upper and lower surfaces. Abundant sandy **crystals** are present in basal cells of trichome especially on adaxial surface.

Transversal section

Cuticle is smooth, with about 2µ thick on both leaf surfaces and coated with wax**. Epidermis** includes relatively small cells in different size. **Stoma** is superficial. Dorsiventeral **mesophyll** consists of 2-3 layers of palisade cells with thin wall adaxially and 5-6 layers of lobed spongy cells with large intercellular space. **Vascular bundle** is collateral and **midrib** formed by 4-6 small veins enclosed by a parenchymatous bundle sheath with thin wall which extend to both epidermises. Internal structure of leaf specially bundle sheath and arrangement of mesophyll which enclose vein indicates that photosynthesis pathway is not Kranz.

Table 1. Anatomical characters of studied species.

Species	Density of stom.adx (mm^2)	Density of stom.abx (mm^2)	Length of stom.adx (m)	Length of stom.abx (m)	Type of stomata	Density of trich.adx (mm^2)	Density of trich.abx (mm^2)	Type of trichome	Cuticule: adaxial (m)	Cuticule: abaxial (m)	Type of mesophylle	Crystal	Canal
Chenopodium album	93.2	123.33	28.58	28.4	anomo>aniso	>10%	>10%	simple	2	2	dorsiventral	sandy	-
Kochia prostrata	92.73	78.23	28.591	29.109	brachyparacitic	dense	dense	simple	5	5	isobilatheral	druse	-
Noaea mucronata	132.38	150.73	27.112	24.305	brachyparacitic	>10%	>10%	simple, glandular	9	8	centeric	druse	-

Kochia prostrata (L.) Schrad.

Surface view (Fig. 1, D, E)

Both leaf surfaces are densely pubescent. Simple, unicellular **trichome** with swollen base, rigid and often calcified sometimes with curvature, is observed on both leaf surfaces (Fig. 4, A-B). **Epidermis** includes small rectangular cells with smooth thin wall. **Stoma** is brachyparacytic some anomocytic present too. The leaves had an average stomatal density of 93 and 78 per mm^2 for upper and lower surfaces.

Transversal section (Fig. 4, A-D)

Cuticle is about 5µ thick on both leaf surfaces. **Epidermis** includes different size of cell. **Stoma** is superficial tending to be sunken. Partial **hypoderm** is present. **Mesophyll** is isobilateral, the outer layer consists of palisade cells but the inner layer formed of large water-storage tissue with thin wall. **Vascular bundle** is collateral and surrounded by partial bundle sheath which is generally containing more chloroplasts and thick walls. A large sclereids cell is observed in water-storage tissue. Numerous large **crystals** (druses) are present in hypoderm and mesophyll tissue. Kranz anatomy and C_4 photosynthesis pathway is notable in cross section of leaf.

Noaea mucronata (Forssk.) Asch. & Schweinf.

Surface view (Fig. 1, A-C)

Various unicellular, simple **trichomes**, extremely short sometimes similar to papillae accompany by glandular trichomes are present on both leaf surfaces (Fig. 2; Fig. 3, E). **Epidermis** includes small polygonal cells with thick smooth wall. **Stoma** is brachyparacytic some anomocytic present too. The leaves had an average stomatal density of 132 and 151 per mm^2 for upper and lower surfaces. Numerous large **crystals** (druses) are observed at leaf margin.

Transversal section (Fig. 2; 3, A-F)
Cuticle is thick about 8-9 µ and coated with wax. **Epidermis** includes quadrangular cells with thick outer wall. **Stoma** is superficial. **Mesophyll** is centric usually includes one long layer of palisade cells encircle central water-storage tissue which formed by large parenchymatous cells. **Vascular bundle** is collateral and includes small veins arranged in one circle and single large vein in the middle. Veins and water-storage tissue surrounded by bundle sheaths which is generally contain thicker walls and more chloroplasts. Internal structure indicated Kranz anatomy. Several large **crystals** (druses) are present in mesophyll and water-storage tissue.

Discussion

One of the most exquisite examples of the correlation of internal structure and function in plant biology is the necessity of Kranz anatomy for C_4 photosynthesis. The family with the largest number of C_4 species is *Chenopodiaceae*. The leaves of *Kochia prostrata* and *Noaea mucronata* typically are characterized by an orderly arrangement of mesophyll cells around a layer of large bundle sheath cells, so that the two together form concentric layers around the vascular bundle. This wreath-like, two-layered arrangement of the chlorenchyma is termed Kranz anatomy (Kranz is the German word for `wreath'). The bundle sheath cells of *Noaea mucronata* and *Kochia prostrata* generally contain thicker walls, more chloroplasts and other organelles, and smaller central vacuoles than do mesophyll cells. The function of the mesophyll cells in C_4 plants is to fix CO_2 into oxaloacetate by means of phosphoenolpyruvate (PEP) carboxylase. In the most common C_4 scheme, this oxaloacetate is quickly converted to malate, which is then rapidly transferred to the bundle sheath cells, where it is decarboxylated. The released CO_2 is rapidly fixed by Rubisco in the bundle sheath cells. Thus, the spatial separation of PEP carboxylase in the mesophyll from Rubisco in the bundle sheath greatly improves the efficiency of photosynthesis under many environmental conditions. Because of the close correspondence we can find between Kranz anatomy and C_4 photosynthesis and xerophytes conditions.

Kochia prostrata includes isobilateral mesophyll with peripheral bundle sheath. *K. prostrata* and *N. mucronata* species, including in cross section exhibited one to two peripheral rings as layers of palisade parenchyma. Although their vascular bundles were surrounded by green bundle sheath cells, their organelle numbers were comparable to those in mesophyll cells. In both species Photosynthesis path way is C_4 type (Carolin et al. 1975). In species studied the Kranz cells form arcs along the xylem of peripheral bundles. There is a main bundle and several peripheral bundles with the Kranz cells forming a partial thickness. On the main bundle this partial thickness is on the adaxial side but often is not present towards the base of the leaf. The Kranz cell walls are thicker than those of the mesophyll. The Kranz-cell has well developed starch grains. There is usually only one layer of mesophyll cells and in transection most of these appear to be in contact with a Kranz cell.

The species studied have extensive central water-storage tissue. In some cases (e.g., the *Noaea mucronata*) the leaf may be very stem-like occupied by water-storage tissue in the middle of leaf. The terms used are a standard term which is used to describe large, often highly vacuolated parenchymatous cells with visible plastids or other organelles; such cells may contain large crystalline inclusions. In *Kochia prostrata* the central water-storage tissue is reduced and the lateral bundles opposite each other are pressed together and the Kranz cells form a partial interrupted laterally. Succulent leaves are drought tolerant plants (Fahn 1992). They store in their tissue

considerable amounts of water, which during drought can be mobilized and used to maintain essential life processes. Survival success in arid environment depend of several internal structure factors such as presentation of stomata more abaxially, vesicular trichomes, photosynthesis pathway, water-storage tissue and abundant and extremely large crystal (Zarinkamar, 1993).

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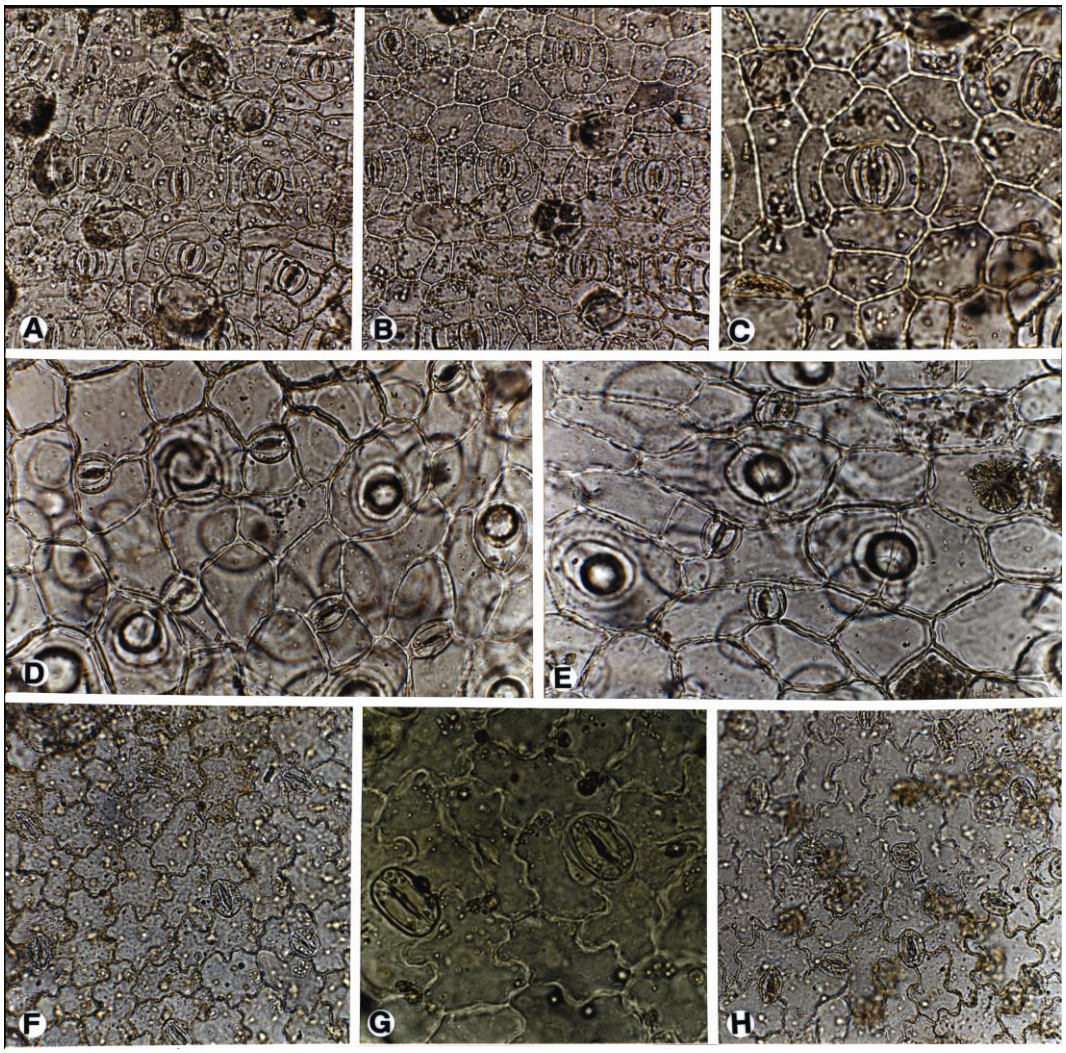

Fig. 1. A-H, epidermis surface view of the *Chenopodiaceae*; A-C, *Noaea mucronata*; A, adx; B, C, abx; D, E, *Kochia prostrata*; D, adx; E, abx; F-H, *Chenopodium album*; F, G, adx; H, abx; A, B, D-F, H, (x 150); C, G, (x 300).

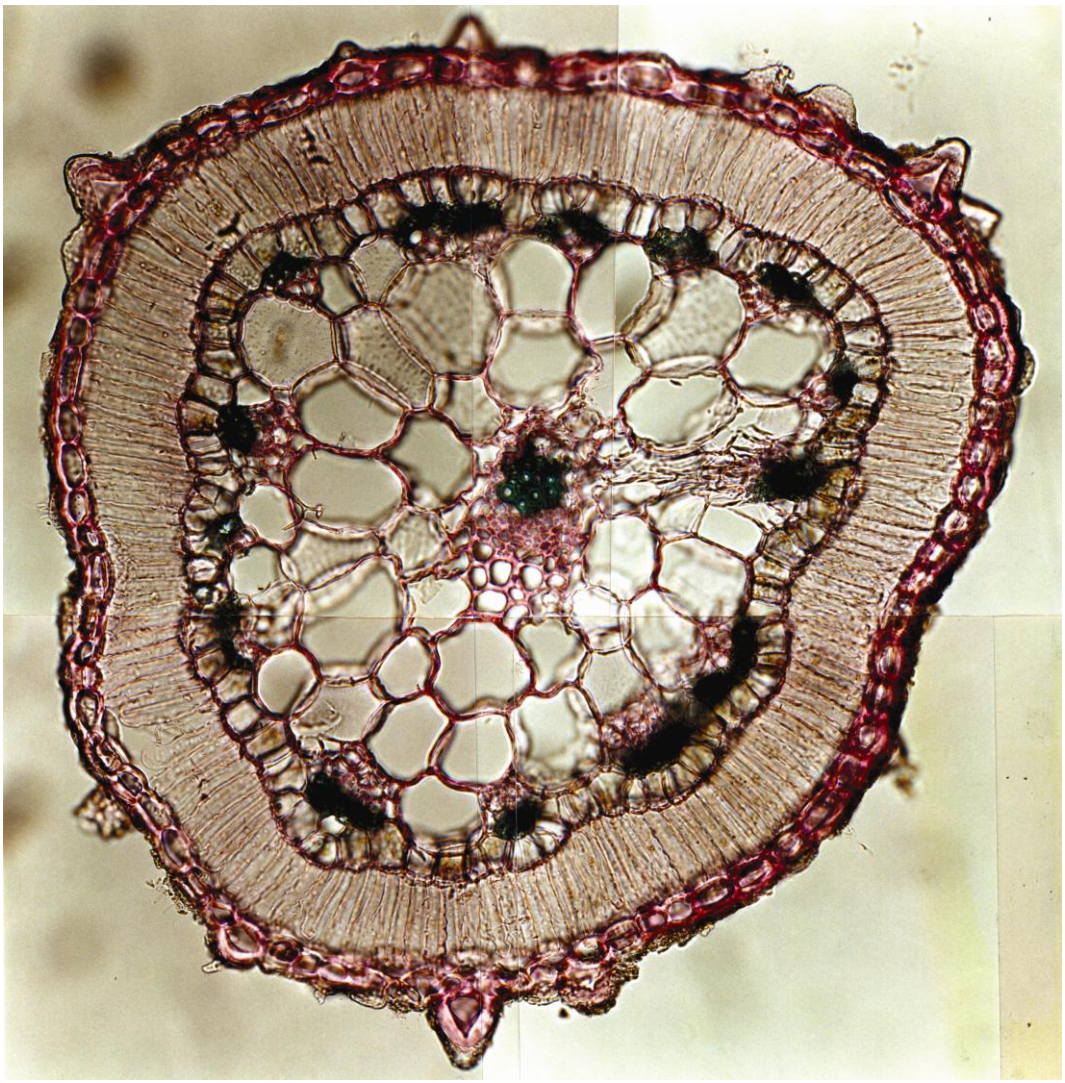

Fig. 2. *Noaea mucronata* (x 180).

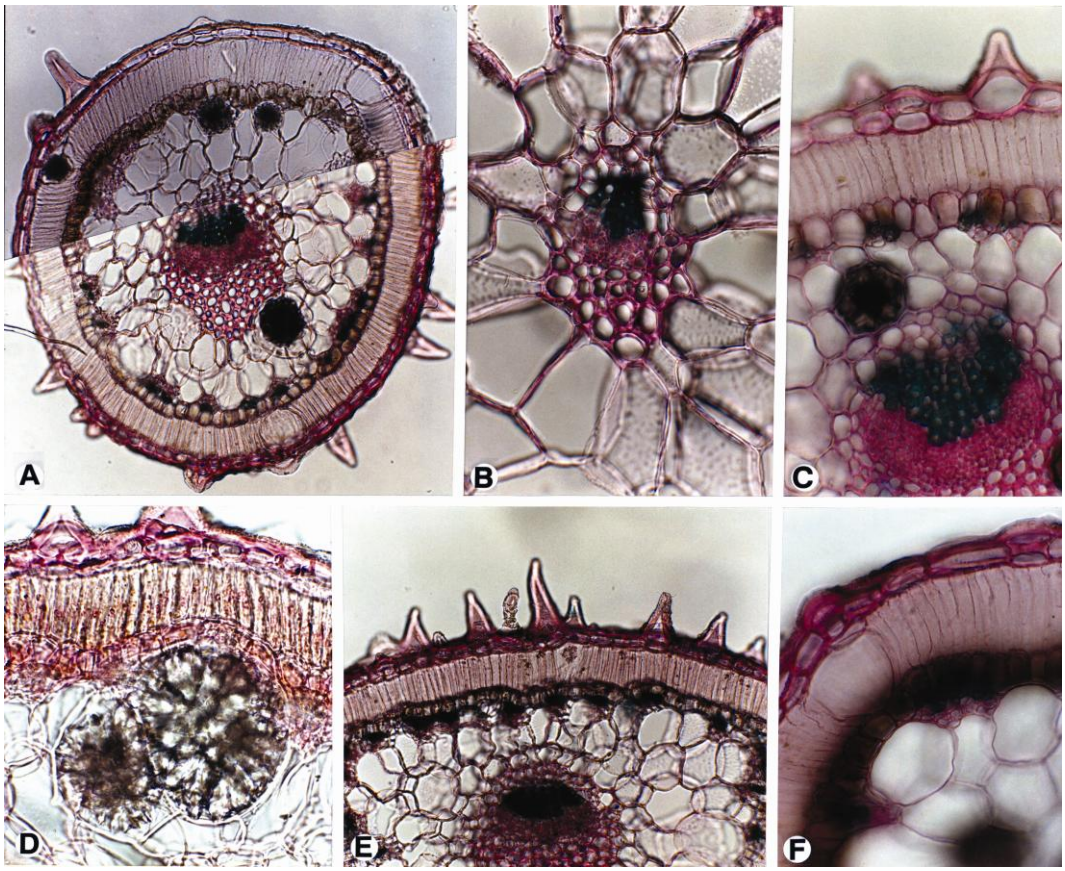

Fig. 3. A-F, leaf of *Noaea mucronata* in Ts; A, general aspect; B, central vein; C, D, crystal (druses) in the water-storage tissue; E, F, observating the aboundance of tannin; A, E (x 75); B-D, F, (x 150).

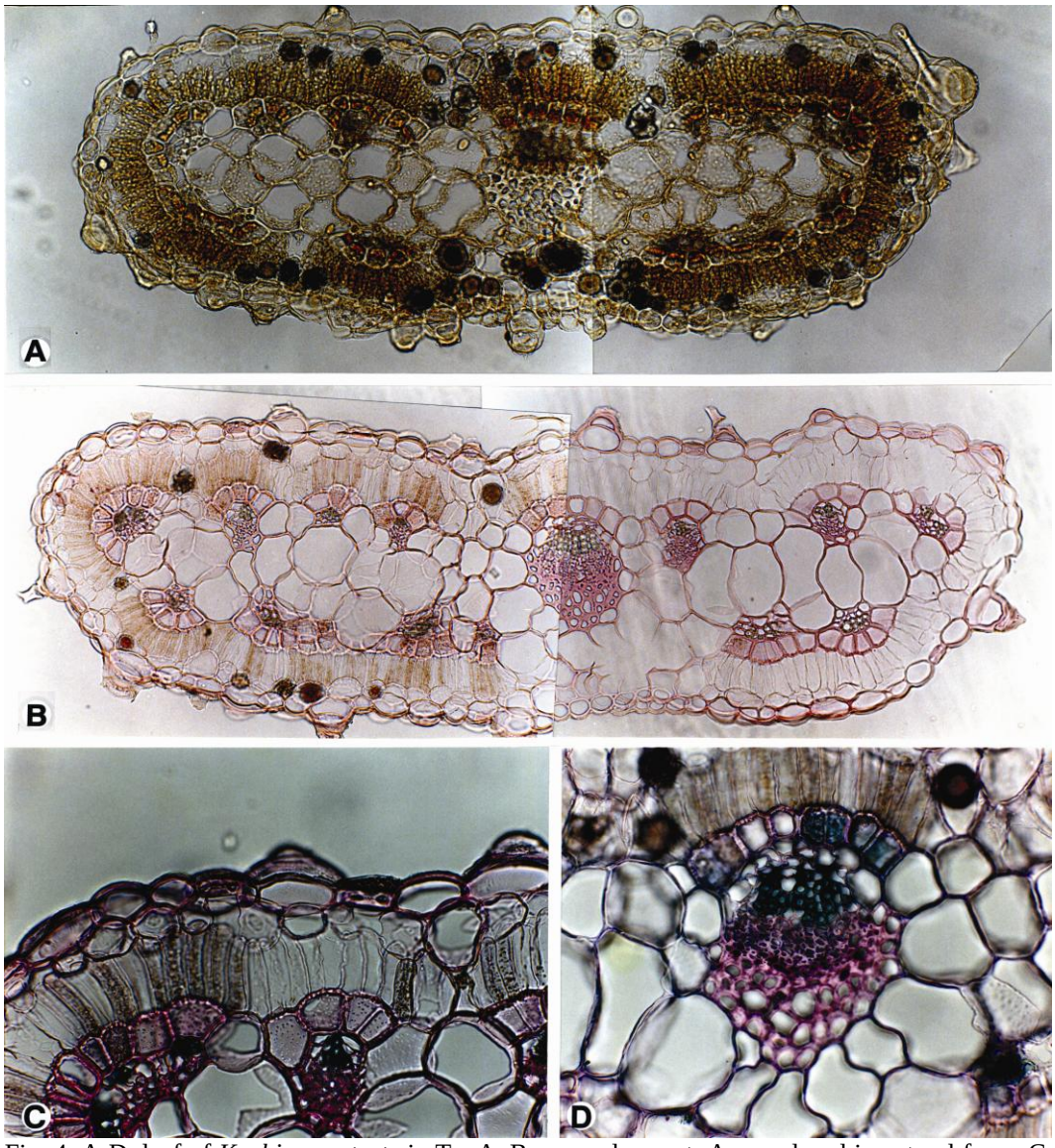

Fig. 4. A-D, leaf of *Kochia prostrata* in Ts; A, B, general aspect; A, uncolored in natural form; C, detail of mesophyll; D, central vein; A, B, (x 75); C, D (x 150).