Ecological Study of Xerophytes of Ahmad Abad, District Karak, Khyber Pakhtunkhwa, Pakistan

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Abstract: The ecological (Taxonomical, morphological and anatomical) study of 11 xerophytes belonging to 10 families was conducted to understand the elasticity of the plants to adopt in high temperature and scarcity of water. The selected plants also reflected the ecological importance as indicators of the area. The species are *Acacia nilotica* (L.) Willd. ex Delile, *Alhagi maurorum* Medik, *Aloe vera* L., *Calotropis procera* (Ait.). f., *Capparis deciduas* (Forssk.) Edgew., *Fagonia cretica* L., *Opuntia ficus-indica* (L.) Mill., *Prosopis spicigera* L., *Saccharum spontaneum* L., *Tamarix aphylla* (L.) Karst and *Ziziphus jujuba* Mill. Among the plants species, *Alhagi maurorum* (pappilionaceae), *Acacia nilotica* and *Prosopis spicigera* (Mimosaceae) are well equipped with elaborate vascular bundles both in root and stem. Internal structure of *Capparis deciduas* showed numerous water strong tissues along with highly developed vascular bundles. *Opuntia ficus-indica* having modified stem as phylloclades which are succulent and thus may retain water for a long time. The leaves are modified as spines on phylloclades to reduce the loss of water through transpiration to put up with the critical environment. The *Saccharum spontaneum* from family Poaceae is a perennial grass spreading by stout rhizomes which helps in controlling erosion in sandy areas. Its transverse section of root represents numerous metaxyylems which show high capacity of water storage and conduction. Its histology of stem and that of root reflect that the plant has developed a strong vascular system for its survival as xerophyte. *Tamarix aphylla* (L.) Karst can adopt in saline areas and having the characteristic of excluding ions of salts and thus minimizing the concentration of the salts of the habitat.

Key words: Xerophytes • Ecology • Morphology • Anatomy • Ahmad abad • Karak • Pakistan

INTRODUCTION

Karak is the district of the Khyber Pakhtunkhwa, Pakistan, at an altitude of 70.40°-70.30°N and the longitude of 32.48°-33.23°E. It is situated at 340m above the sea level. Climate of the Karak is very hot. During the summer, temperature remains between 45-50°C with sand storms which are common. Average annual humidity is 60% and the rain fall ratio is 300 millimeters [1]. Xerophytes may have adapted shapes and forms (morphology) or internal functions (physiology) that reduce their water loss or store water during long periods of dryness [2]. Plants with such morphological adaptations are called xeromorph [3]. Xerophytes have been under the constant vigilance of the ecologist, for analyzing its adaptation in order to have comprehensive information on various groups and anatomical characteristic controlling their range of distribution under the different environment region throughout the world. It’s a never ending process and ecologist continue their effort constantly to achieve their objectives by knowing the global changes and adaptation of different plant species The Karak district is dry and rainfed therefore its vegetation is mostly xerophytes. So there was a need to investigate the morphological and anatomical adaptation of these plants species to the harsh and dry environment. The objectives of the present study were to explore the ecological, morphological and anatomical adaptation of some important xerophytes of Ahmad Abad Karak.
MATERIALS AND METHODS

During the survey of the study area all the important plants species were collected by folding them in news papers and then put into plastic bags. The poisoning of the plants species were properly carried out by spraying them with mercuric chloride, CuSO₄ and spirit to protect them from the attack of fungi and other germs. After drying and poisoning, each xerophyte was mounted on standard herbarium sheet.

Taxonomical Studies: The proper identification the plant species was carried out with the help of available literature [4]. It was confirmed and authenticated by Mr. Abd- ur-Rehman, Professor of Botany, Govt Post Graduate College Bannu.

Morphological Studies: Morphological parameters including habit, root, stem, leaves and flowers were investigated through general observation [5]. After taking the photograph of each plant species, fresh samples of the plants species were collected for further studies.

Anatomical Studies: or the investigation of the anatomical study, transfer sections (T.S) of stem and roots were examined under high power microscope. With the help of digital camera the colored photographs of the prepared sections were prepared.

RESULTS

Opuntia ficus-indica (L.) Mill.
Morphological Description: It is a massive trunk-forming segmented cactus having evergreen phylloclade and spines. Flowers, yellow or orange cup-shaped along edge of pads; bloom in spring or early summer. Fruit are edible, roundish, 3.5in long in length, ripening to attractive purple color.

Anatomical Description: Transfer sections (T.S) of root and stem of Opuntia ficus-indica show the following descriptions.

Root: The epidermis encloses by cuticle layer which prevent the water from transpiration. The cortex comprises of compactly arranged parenchymatous cells. Vascular bundles are radially arranged. Large parenchymatous pith is present which retain moisture to compensate the xerophytic character of the plant.

Stem: A cuticle layer is found around the epidermis. Beneath the epidermis is parenchymatous cortex. Endodermis also found. Pericycle is separating the cortex from the vascular region and pith.

Saccharum spontaneum L.
Morphological Description: Perennial grass, spreading by stout rhizomes. Erect, 2-4 m in height. Leaf sheath glabrous with overlapping margins, 3-4 mm long with a rounded apex fringed with scattered hairs. Inflorescence a plumose panicle 25-60 cm long with numerous smaller racemes, rachis and pedicels hirsute, rachis falling off in units comprising a pair of spikelets and the rachis below them.

Anatomical Description: Anatomical study of root and stem of Saccharum spontaneum is described as under.
**Root:** Epidermis is present around the cortex. Small cortical zone is present. Metaxylems are arranged in a circle around the pith which shows high capacity of water conduction. Pith is present which is composed of ground tissues.

**Stem:** Epidermis is present. Thick parenchymatous ground tissues are found in the centre. Vascular bundles are present along the periphery. Whole of the histology of stem and that of root reflect that the plant had developed a strong vascular system for its survival as xerophyte. It is also known as sand binder and is frequently found in sandy area.

**Tamarix aphylla** (L.) Karst.

**Morphological Description:** It is a fast growing moderate sized evergreen tree up to 18 m high with erect tapering trunk having many stout spreading purplish brown and smooth branches. Twigs drooping, wiry or needle-like, up to 1.5 mm diameter, jointed, older twigs greenish-brown, hairless, mostly shedding. Bark light grey-brown or reddish-brown, rough, becoming thick and deeply furrowed into long narrow hard ridges. A deep and extensive root system, about 10 m vertically and 34 m horizontally. Leaves bluish-green, alternate, reduced to tiny scales ensheathing wiry twigs and ending in points, hairless, often with epidermal salt glands each forming a joint along the twig. Flowers many, nearly stalkless, tiny, whitish-pink, in racemes. Fruit a small capsule, many, narrow, pointed, 5 mm long, splitting into 3 parts. Seeds are brown each with tuft of whitish hairs.

**Anatomical Description:** Transverse sections (T.S) of root and stem of *Tamarix aphylla* is shown as under.

**Root:** Epidermal layer is present which consist of closely elongated cells. Thick parenchymatous cortex is present which has the capacity to store profound amount of water that helps the plant in the adaptation of xerophytic situation. Vascular bundles are arranged radially in such a way that protoxylem towards the centre while metaxylem towards the cortex. Pith is not present.

**Stem:** There is not present countable differences in root and stem anatomy. Stem is also covered by thick epidermal layer. Cortex is thick and also composed of parenchymatous cells. Vascular bundles are radially arranged from centre towards the periphery. Pith is absent.

**Ziziphus jujuba** Mill.

**Morphological Description:** A small deciduous tree or shrub reaching a height of 5-10 m, usually with thorny branches. The leaves are shiny-green, ovate-acute, 2-7-cm wide and 1-3 cm broad, with three conspicuous veins at the base and a finely toothed margin. The flowers are small with five inconspicuous yellowish-green petals. The fruit is an edible oval drupe 1.5-3 cm deep, when immature it is smooth-green, maturing dark red to purplish-black and eventually wrinkled, looking like a small date.

**Anatomical Description:** Transverse sections of root and stem of *Ziziphus jujuba* show the following features.

**Root:** Epidermis is encloses the cortex. The thick parenchymatous cortex retain large amount of water. Vascular bundles are radially arranged in several circles from pith towards the periphery. Whole of the root section is covered by vascular bundles.

**Stem:** The epidermal layer covering the cortex. The parenchymatous cortex is present which has the ability to store large amount of water that helps the plant to survive in severe climate. Vascular bundles are polyarch and radially arranged. Pith is large and because of presence of parenchymatous cells it can retain maximum water within to sustain its life within critical period.

**Acacia nilotica** (L.) Willd. ex Delile

**Morphological Description:** A tree usually 2.5-15 m high. Bark or trunk rough, black to blackish grey or brown, never powdery or peeling. Young branchlets almost glabrous to subtomentose. Spines paired, mostly 1-8 cm long, straight and often deflexed. Petiole having glands. Pinnae 3-9 pairs, with glands on the rachis at the junction of at least the topmost pairs. Leaflets mostly in 12-27 pairs per pinna, glabrous to pubescent, 1-5-7 mm long and 0.5-1.5 mm wide. Flowers bright or golden yellow, sweetly scented, in round fluffy heads 6-15 mm in diameter, on axillary peduncles 1.2-4.5 cm long. Pods very variable, indehiscent, dark brown to grey, straight or curved, glabrous to velvety and compressed but rather thick. Seeds 6.16 per pod, lying transversely to long axis of pod.

**Anatomical Description:** The prepared transverse sections of root and stem show the following anatomical features.
Root: The epidermis surrounded the small cortex. The vascular bundles are found in scattered form. The protoxylem is present in the centre while metaxylems are arranged towards the cortex. Xylem vessels are many in numbers which show the xerophytic characters of the plant.

Stem: Epidermis encloses the cortex. Cortex is composed of collenchymatous cells. Beneath the cortex endodermis is present. Next to the pericycle radially arranged parenchymatous tissues are present having the capacity to retain large amount of moisture. Numerous vascular bundles are present in the centre and also some in scattered form.

**Alhagi maurorum Medik.***

**Morphological Description:** Noxious green shrub 1- 2 m tall, with simple leaves, many thorny branches and an extensive root system. Plants spread rapidly by clonal vegetative reproduction from vigorous rhizomes. Seedlings lack thorns. Seedling shoots grow slowly compared to its roots. Stem glabrous, greenish, longitudinally ridged and highly branched. Leaves alternate, sparse, simple, thick, leathery, elliptic or obovate and 7-20 mm long and petiolate. Upper leaf surfaces glabrous and covered with minute red dots, while the lower leaf surfaces are sparsely covered with hairs. Extensive rhizomes present. Woody root system can grow to a distance of 8-12 m or more in all directions. Flowering; June-July. 2-6 short-stalked pink flowers are produced alternately along each thorn branchlet axis. Sepals persistent, fused and cup-like, with small unequal teeth. Stamens 10, with bases of 9 filaments fused into a tube around the style and 1 separate. Flower production is high under hot, dry conditions. Fruits and seeds are produced in July-August. Pods (loment) reddish-brown at maturity, slender, often curved. Pods do not split open to release seeds but can break apart between seeds. Seeds are oval, yellowish or greenish-brown with dark mottling or solid dark brown, smooth-textured, about 3 mm long and 2.5 mm wide. Soft and hard-coated seeds are produced.

**Anatomical Description:** Transverse sections of root and stem of Alhagi camelorum show the following features.

**Root:** The root consists of thick epidermis which enclosed the cortex. Large collenchymatous cortex is present. Vascular bundles are more in numbers. The vascular bundles are radially arranged. Protoxylem and metaxylem are well developed. Parenchymatous Pith is found in the centre which retains moisture to help the xerophytic condition.

**Stem:** Epidermis layer covering the small cortical region. Vascular bundles are large in number which is helpful in conduction of sufficient amount of water from the roots and are arranged radially from pith towards the cortex.

**Aloe vera L.***

**Morphological Description:** Aloe Vera is a succulent plant. It has a rosette of large, thick, fleshy leaves. The leaves are often lance-shaped with a sharp apex and a spiny margin. Flowers are tubular, frequently yellow, pink or red and are borne on densely clustered, simple or branched leafless stems.

**Anatomical Description:** Transverse section of root and stem of Aloe vera show the following features.

**Root:** Epidermal layer composed of compact cells is present around the cortex. Cortex is extra thick and is composed of loosely arranged rounded parenchymatous cells which have the ability to store large amount of water to compensate xerophytic condition. Endodermis and pericycle is clearly developed. Vascular bundles are present at the periphery of the small pith.

**Stem:** Cuticle layer is present around the epidermis. Next to the epidermis a large parenchymatous cortex is present. Large number of scattered vascular bundles is present in the central zone which shows the monocotyledonous character of the plant.

**Calotropis procera (Ait.) f.***

**Morphological Description:** Spreading shrub or small tree to 4 m, exuding copious milky sap when cut or broken. Leaves opposite, grey-green, large up to 15 cm long and 10 cm broad, with a pointed tip. Flowers waxy white, petals 5, purple-tipped inside and with a central purplish crown, carried in stalked clusters at the ends of the branches. Fruit grey-green, inflated, 8 to 12 cm long, containing numerous seeds.

**Anatomical Description:** Transverse section of root and stem of Calotropis procera show the following features.
Root: The epidermis consists of elongated cells. The cortex is massive and composed of polygonal parenchymatous cells. Uniseriate endodermis is found beneath the cortex. Heavy development of xylem vessels is present. Protoxylem vessels are lying towards the periphery while the metaxylems are present in the centre.

Stem: The epidermis consists of single layer of compact cells having no intercellular spaces. The cortex consists of collenchymatous cells and endodermis is separating the vascular region from the cortex. The vascular bundles are arranged radially in the pattern that the protoxylem is lying towards outer periphery while the metaxylem are arranged towards the pith, which is thick and is composed of parenchymatous cells.

**Capparis decidua (Forssk.) Edgew.**

**Morphological Description:** *Capparis decidua* is commonly known as karir, kair, kirir, karril. It is either a small tree with many branches or a shrub of a common desert in hot and dry regions in southern Asia. It rarely grows above a height of 5 meters (15 feet). It has a lot of thin, leafless branches, the small leaves being found only on young shoots. The berries can be eaten.

**Anatomical Description:** Transverse sections of root and stem show the following features.

**Root:** The cortex of *Capparis decidua* root is large and composed of thick parenchymatous cells surrounded by epidermal layer. Vascular bundles are clear and covered whole of the central region which helps in conducting of water molecules from the soil. Numerous large wood vessels are seen which reflect its efficiency regarding rapid absorption to compensate the rapid loss of water through transpiration and evaporation.

**Stem:** Thick cuticle layer is present above the epidermis. The cortical region is composed of palisade parenchyma. Endodermis separates the cortex from the vascular region. Vascular bundles are arranged along the medullary rays from pith towards the cortex. Large parenchymatous pith is present in the centre composed of polygonal parenchymatous cells.

**Fagonia cretica L.**

**Morphological Description:** Semi-shrub. Stem is hard, rough, glabrous and spiny. Leaves; Leaves opposite, compound, trifoliolate, smooth, spinescense stipules. Flowers are pink, solitary, 5 free, mucronate. Sepals 5 free, clawed imbricate. 10 free stamens inserted on a disc, filaments filiform, without appendages, 5-celled sessile ovary, 2 ovules at the base of each cell; 5-angled style persistent. Septicidal capsule fruit, pentagonous, deeply 5-lobed, splitting along the axis into 5 carpals. Seeds ovate or ovate-oblong, compressed, with mucilaginous coat.

**Anatomical Description:** Anatomical description of transverse sections of root and stem of *Fagonia cretica* is described as under.

**Root:** The T.S of root shows thick epidermal layer that enclosed the cortex. Cortex is large. To the inner side of cortex, a clearly shown endodermis is present. The vascular bundles are radially arranged in circles. Most of the root is covered by vascular bundles.

**Stem:** The T.S of root shows that epiblema encircles the collenchymatous cortex. The big glands are also apparent within the thick cortex. To the inner side of cortex, a clearly shown endodermis is present. The vascular bundles are radially arranged in circles. More than half of the stem is covered by vascular bundles. A vast number of glands are also seen in the slide within the thick cortex.

### Table 1: Taxonomic classification of the plants

<table>
<thead>
<tr>
<th>Family</th>
<th>Genus</th>
<th>Species</th>
<th>Botanical name</th>
<th>Local name</th>
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<tbody>
<tr>
<td>Cactaceae</td>
<td>Opuntia Mill</td>
<td>O. ficus-indica (L.) Mill</td>
<td>Opuntia ficus-indica (L.)</td>
<td>Balo Sapera</td>
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<td>Mimosaceae</td>
<td>Prosopis L.</td>
<td>P. spicigera L.</td>
<td>Prosopis spicigera L.</td>
<td>Sangara</td>
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<tr>
<td>Poaceae</td>
<td>Saccharum L.</td>
<td>Saccharum spontaneum L.</td>
<td>Saccharum spontaneum L.</td>
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<td>Tamaricaceae</td>
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<td>T. aphylla</td>
<td>Tamarix aphylla (L.)</td>
<td>Ghaz</td>
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<td>Ziziphus</td>
<td>Z. jujuba</td>
<td>Ziziphus jujuba Mill.</td>
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<td>A. nilotica (L.)</td>
<td>Acacia nilotica (L.) Wild.</td>
<td>Kikar</td>
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<td>Pappilionaceae</td>
<td>Alhagi</td>
<td>A. maurorum Medik.</td>
<td>Alhagi maurorum Medik.</td>
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<td>Zargya</td>
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<td>Spalmaka</td>
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<td>Capparidaceae</td>
<td>Capparis</td>
<td>C. decidua</td>
<td>Capparis decidua (Forssk.) Edgew</td>
<td>Krera</td>
</tr>
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</table>
Morphological Figures:

Fig. 1: *Opuntia ficus-indica* L.

Fig. 2: *Prosopis spicigera* L.

Fig. 3: *Saccharum spontaneum* L.

Fig. 4: *Tamarix aphylla* (L.) Karst

Fig. 5: *Ziziphus jujuba* Mill.

Fig. 6: *Acacia nilotica* (L.)

Fig. 7: *Alhagi maurorum* Medik.

Fig. 8: *Aloe vera* L.

Fig. 9: *Calotropis procera* Ait. f.

Fig. 10: *Capparis aphylla*

Fig. 11: *Fagonia cretica* L.

Fig. 1: Transfer section(T.S) of root of *Opuntia ficus-indica*
Fig. 2: Transfer section of stem of Opuntia ficus-indica

Fig. 3: Transfer section of root of Prosopis spicigera

Fig. 4: Transfer section of stem of Prosopis spicigera

Fig. 5: Transfer section of root of Saccharum spontaneum

Fig. 6: Transfer section of stem of Saccharum spontaneum

Fig. 7: Transfer section of root of Tamarix aphylla

Fig. 8: Transfer section of stem of Tamarix aphylla

Fig. 9: Transfer section of root of Ziziphus jujuba

Fig. 10: Transfer section of stem of Ziziphus jujuba

Fig. 11: Transfer section of root of Acacia nilotica
Fig. 12: Transfer section of stem of *Acacia nilotica*

Fig. 13: Transfer section of stem of *Alhagi camelorum*

Fig. 14: Transfer section of stem of *Alhagi camelorum*

Fig. 15: Transfer section of root of *Aloe vera*

Fig. 16: Transfer section of stem of *Aloe vera*

Fig. 17: Transfer section of root of *Calotropis procera*

Fig. 18: Transfer section of stem of *Calotropis procera*

Fig. 19: Transfer section of root of *Capparis decidua*

Fig. 20: Transfer section of stem of *Capparis decidua*

Fig. 21: Transfer section of root of *Fagonia cretica*

Fig. 22: Transfer section of stem of *Fagonia cretica*
DISCUSSION

The present study showed that the area of Ahmad Abad is rich in wild flora. In order to investigate the ecology, morphology and anatomy of the plants species, some xerophytes were selected. Most of these plants are being used by the local inhabitants for medicinal, as well as other purposes. *Acacia nilotica* tree is usually 2.5-15 m in height having rough, black to blackish grey or brown bark. The transverse section of root shows that xylem vessels are many in number which represents the xerophytic characters of the plant. The transverse section of stem depicts collenchymatous cortex. Numerous vascular bundles are present in the centre and also some are radially arranged. The ground tissues are parenchymatous, having the capacity to store large amount of water. *Prosopis spicigera* has compound leaves and tap root extended more than 3 m long. The present study are in agreement with those reported by [6] in the morphological characterization. The transverse section of root shows the composition of dense parenchymatous cortex. The cortical parenchyma accumulates large quantity of water. Metaxylems are well developed. The transverse section of stem represents that cuticle layer is found around the epidermis to prevent the water during transpiration. Parenchymatous pith is present which retains moisture. It has also reported that in *Prosopis*, xylem is diffuse-porous with indistinct growth rings. *Alhagi maurorum* (Pappilionaceae) xerophytic thorny weed which usually invade agriculture field at large scale [7]. Woody root system grows to a distance of 8-12 m or more in all directions. Anatomically the plant is also equipped with large number of wood vessel to compensate the rapid loss of water along with conservation. This plant is also found in waste places where there is no proper cultivation and irrigation, thus conforming their hardening within the prescribed severe climate. It was also stated the same morphological and anatomical study about *Alhagi maurorum* [8]. [9] reported the morphology of *Alhagi maurorum*. *Aloe vera* of family Liliaceae is a flowering succulent plant. It has a rosette of large, thick and fleshy leaves. The leaves have sharp apex and spiny margin. In root and stem the cortex is extra thick and is composed of loosely arranged rounded parenchymatous cells which have the ability to store large amount of viscous fluid to tolerate critical condition. Numerous vascular bundles are present to conduct large amount of water. *Calotropis procera* plant species of family Asclepiadaceae is covered by white powder to reduce the insulation of sun light. It is also laticiferous having viscous latex to retain the water molecules within its body along with all parts. The cortex is massive and composed of parenchymatous cells. The stem has numerous vascular bundles to conduct large amount of water. The same study was also reported by [10] which showed that the primary root is diarch in the plant. [11] reported that tufts of long silky hairs are present at the surfaces of the leaves. It is a tall herb with sessile, obovate, glaucous leaves less than 2 times longer than broad, bud globular and flowers umbellate [12]. *Fagonia cretica* is an interesting medicinal xerophyte from family Zygophyllaceae having hard, rough, glabrous and spiny stem. The vascular bundles are radially arranged in circles. Most of the root is covered by vascular bundles which help in conduction and storage of water to survive in severe condition. The stem also has the ability to retain large amount of water. Large glands are also present in the cortex of stem. *Capparis decidua* is small tree of family Capparidaceae with many branches bearing deciduous leaves for a short, while or a shrub of a common desert in hot and dry regions. Because of tolerance against high concentration of calcium oxalate crystals, it can absorb and retain calcium within its tissues. Transverse sections of both root and stem depict large parenchymatous cortex which is enough to keep hold of maximum water to perennate drought environment. In root the metaxylem and protoxylem are well developed which help in conduction of water. *Opuntia ficus-indica* is a massive trunk-forming segmented cactus bearing evergreen plant. The stem is modified as phylloclades which are succulent and thus having the water storing capacity. The leaves are modified as spines on phylloclades to reduce the excess loss of water through transpiration. The root cortex comprises of compactly arranged parenchymatous cells. Pith is also well developed. *Saccharum spontaneum* (Poaceae) is a perennial grass, spreading by stout rhizomes. It is also known as sand binder and may be useful in controlling erosion in sandy areas by speedy blowing winds. It is erect 2-4 m or more in height. Transverse section of root represents numerous metaxylems which show high capacity of water conduction. The stem cross section shows that thick parenchymatous ground tissues are found in the centre. Whole of the histology of stem and that of root reflects that the plant has developed a strong vascular system for its survival as xerophyte. [13] has also
reported the same morphology. *Tamarix aphylla* (Tamaricaceae) is a fast growing, moderate sized evergreen tree, up to 18 m height with erect tapering trunk, with many stout spreading purplish brown and smooth branches. The plant can adopt saline area and having the characteristic of excluding ions of salts and thus minimizing the concentration of the salts of the habitat. In both the root and stem thick parenchymatous cortex are present having the capacity to store profound amount of water that helps the plant in the adaptation of xerophytic situation. [14] reported the same anatomy of secondary xylems. *Ziziphus jujuba* is a small deciduous tree or shrub reaching a height of 5-10 m. Modified leaves as thorns are enough to minimize the transpiration. The root and stem anatomy along with paranchymatous cortex enable the plant to store large amount of water that helps the plant to survive in severe climate. Numerous vascular bundles are present to conduct large amount of water.

The study explains that the reported plants species are of great importance for the poor local community of the area, but proper management is needed.

REFERENCES