Review Article

Ecology and establishment of fiber producing taxa naturally growing in the Egyptian deserts

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ABSTRACT

The natural plant life of The Egyptian deserts is formed mainly of xerophytes and halophytes rich with fiber taxa that could be considered renewable resources for various fiber industries. Fourteen of these species were described ecologically. The fiber contents of seven species, namely, Thymelaea hirsuta, Cyperus papyrus, Desmostachya bipinnata, Typha domingensis, Typha elephantina, Juncus rigidus and Juncus acutus were measured. The long fibers (1200–6100 μm) represent about 60% of the fiber contents of the first five species; the reverse was true in the two Juncus species. Juncus spp. are halophytes proved experimentally to produce good quality paper. Successful field experiment to establish Juncus spp. in saline soil of Egypt's desert was conducted. Irrigation of the experiment was carried out using the non-fresh water of Manzala Lake.

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1. Introduction

Egypt, being part of the arid region, is an almost rainless country (mean annual rainfall = 10 mm). Egypt's deserts (Western, Eastern and Sinai) occupy more than 95% of its total area (1,019,600 km²) [1]. Vast areas of these deserts are practically barren, however, natural vegetation usually occurs in the narrow northern Mediterranean coastal desert which enjoys, relatively, considerable amounts of rainfall (mean annual = 60–250 mm). Also, desert vegetation is a characteristic feature of the oases and depressions in the inland part of the Eastern Desert where the ground water is shallow or even exposed. In the Eastern and Sinai Deserts, the natural vegetation occurs in the main stream and deltas of the wadis as well as on the slopes of the mountains that receive orographic rainfall with mean annual up to 60 mm [2,3]. On the other hand, the narrow areas of the fertile lands of the River Nile Region (Nile Valley and Nile Delta), through occupy less than 5% of Egypt's area, yet they represent the backbone of the cultivation of the traditional crops that are fully utilizing the freshwater of the River Nile. Thus, there is no surplus of Nile water that could be used for any agro-industrial and social activities in Egypt's deserts which should depend mainly upon

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their own natural resources of water to grow and establish non-conventional crops having low water requirements to be selected from the desert plants.

Ecologists are claiming that the green areas of the world are getting smaller as a result of uncontrolled felling of forest trees associated with ill advised land and water management. This may indicate that the pulp importing countries, mostly in arid regions, could face some difficulties. The pulp exporting countries may reduce and/or stop cutting their woods to maintain environmental equilibrium [4]. Thus, Egypt and other pulp importing countries should search for sufficient amounts of local raw materials for their paper and other fiber industries.

The present paper is an attempt to brief the environmental factors and main groups of the desert vegetation as well as to throw light on representative most well-known fiber producing plants naturally growing in Egypt’s deserts. Their ecological characteristics are described. In addition; establishment of two of these species under desert conditions is discussed.

2. Desert vegetation in Egypt

2.1. Physical environment

The land of Egypt occupies the north eastern corner of The African continent (lat. 23°N–22°N) with total area of 1,019,600 km² including the Sinai Peninsula (the Asian part of Egypt) [1]. Being an arid country, apart from the fertile land of the River Nile region (Nile valley and Nile Delta), which occupies less than 5% of its total area, Egypt is ecologically, hot and dry desert. The country forms part of the great desert belt that stretches from the Atlantic Ocean across the whole North Africa through Arabia.

The Egyptian deserts are: Western Desert (west of the Nile, about 681,000 km²), Eastern Desert (east of the Nile, about 223,000 km²) and Sinai Desert (about 610,000 km²). The western Desert is characterized by oases and depressions and one mountain (Gebel Uweinat) in its south-western corner whereas both Eastern and Sinai Deserts are characterized by several wadis and chains of mountains [3].

Egypt is characterized by a hot and almost rainless climate. The average annual rainfall over the whole country is only about 10 mm. Even along the narrow northern strip of the Mediterranean coastal land where most of the rain occurs, the average annual rainfall is usually less than 200 mm and the amount decreases very rapidly inland (southwards). The scanty rainfall accounts for the fact that the greater part of Egypt (>95%) is barren and desolate desert with very low population density. The reverse is true in the River Nile Region where almost all Egyptians (up to 90 million on 2013) are living. Egypt’s fertile land is intensively used for agriculture as well as for establishments of houses, schools, hospitals etc. Unfortunately, the areas of the fertile land are decreasing quickly by increasing population. Thus, Egyptians should move to their deserts to overcome such acute problem.

2.2. Vegetation groups

The permanent framework of the desert vegetation is formed mainly of perennial plants that could be classified under five groups: xerophytes, halophytes, psammophytes, helophytes and mangroves. The xerophytes are, by far, the most important and characteristic type of the natural plant life of Egypt’s desert. Being drought resistant, the members of this group covers vast area of the deserts, mostly shrubs and under shrubs e.g. species of Calotropis, Anabasis, Hammad, Leptadenia, Lycium and Zilla, robust grasses e.g. species of Panicum and Pennisetum and few trees e.g. species of Acacia and Balanites. The halophytes (salt marsh plants) are the second most important type of vegetation, occurring in the extensive salt –affected lands along the coastal belts but also in the inland oases and depressions. Halophytes are either succulents, e.g. species of Arthrocnemum, Halocnemum, Suada, Salicornia, Salsola etc., excretives e.g. species of Aeluropus, Limoniastrum, Sporobolus and Tamrix and cumulatives e.g. Juncus rigidus and Juncus acutus.

The psammophytes (sand dune vegetation) include species of Ammophila, Euphorbia, Silene, Thymeleae, Halopyrum, Aristidae, Stipagrostis and Popula, limited number of species are helophytes (reed swamp vegetation) e.g. species of Phragmites, Typha and Cypruss. Mangrove vegetation, being tropical formation, occurs only south of Lat. 28°N in the shorelines of the Red Sea coast from Hurghada (Lat. 27°14’ N) southwards to Mersa Halaib (Lat. 22°N) as well as in the swamps of Ras Mohammed cap (Lat. 27° 45’ N) and southern section of the Gulf of Aqaba of Sinai Peninsula. It is represented by two species namely: Avicennia marina and Rhizophora mucronata.

Although the mountains of the Red Sea coast and Sinai Peninsula are in extremely dry deserts, rainfall is relatively high (up to 60 mm/year, mainly orographic) forming relatively favorable climate for plants than in the other parts of Egypt's deserts. The flora includes species of Caralluma, Coccus, Dodonaea, Draecaena, Moringa and Rhus. In the high mountains of Sinai Peninsula (up to 2641 m a.s.l), air temperature are lower than elsewhere in Egypt, being usually below freezing point in winter; some plants of cold regions of the world occur here, e.g. species Juniperus, Crataegus etc. [3].

Apart from the perennial flora in Egypt’s desert, the short-lived plants (therophytes) comprise the greatest number of herbaceous plants that appear only during the short winter rainy season changing the yellow desert into green carpets. These plants (ephemerals, annuals and biennials) get dry with the arrival of the long summer rainless period [5].

3. Ecology of representative fiber producing plants

Many plant species that supply 90% of world’s food, fodder, fibers, drugs etc. were domesticated from wild plants in the tropics [6]. Thus the existing wild desert plants, mostly still unclassified and unevaluated, remain interesting to plant ecologists, agronomists etc. to introduce them as non-conventional crops to be cultivated under desert environmental conditions.

Field studies and personal communications with the local Bedouins of the Egyptian deserts enables the authors to determine that, the flora of Egypt’s deserts is rich with fiber producing taxa. Out of these 14 most well-known species had been selected for the present study. The followings are short notes on these representative species.
1. *Calotropis procera* (family Asclepiadaceae)

*C. procera* (Oshar) family is a xerophytic shrub or small tree (3.5 m high) with spongy bark that is often cut for fuel. The leaves are ovate-fleshy, flowers outside green, inside pink in terminal and axillary clusters. Fruits are smooth, swollen and spongy-apple like and the seeds bear long hairs used by the local inhabitants for making cushions [17].

In Egypt, being tropical plant, *C. procera* is totally absent from the whole stretch of the Mediterranean coastal desert as well as from the northern sections (north of Lat. 30° N) of the Western, Eastern and Sinai Deserts. Its domination or as an associated species are obvious in the remaining southern sections of these deserts.

2. *Leptadenia pyrotechnica* (family Asclepiadaceae)

*L. pyrotechnica* (markh) is a xerophytic, erect leafless shrub or tree (up to 5 m high). It belongs geographically to the Old World Tropics [7]. It has numerous long virgate spinescent branches hard to cut by land. Flowers yellow–green, fruit, peduncles thick recurved, carrying a very long, narrow linear fruit. For their strong fiber contents, the branches are used by the local inhabitants for making robes, the fruits and twigs are eaten as food.

The distribution of *L. pyrotechnica* in Egypt's deserts is of ecological interest. The growth and domination of this xerophyte is confined to the deltas of many wadis of the Red Sea Coastal desert as well as in those of the inland part of the Eastern Desert south of Lat. 28° N. In Sinai Desert, *L. pyrotechnica* has been recorded in the wadis of the southern section of the coastal desert of the Gulf of Aqaba as well as in the coastal hills of the Gulf of Suez and those of the Red Sea proper [8]. On the other hand, *L. pyrotechnica* is absent from the floristic elements of both Mediterranean coastal desert and the Oases and depressions of the Western Desert [7].

3. *Thymelaea hirsuta* (family Thymelaeaceae)

*T. hirsuta* (mitnan) is a drought resistant shrub up to 2 m high that may be considered one of the psammophytes. Stems are rigid, fibrous and much branched [9]. Branches are white-woolly, leaves (2–5 × 1–2 mm) imbricate, sessile, leathery and ovate-triangular. Geographically, it belongs to the Old World but specially the Mediterranean region [7].

In Egypt, *T. hirsuta* is one of the widely spread species in the three sections of the relatively rainy Mediterranean coastal desert: western (Mariut) section, middle (Deltaic) section and eastern (Sinai) section. The gradual decrease in the annual rainfall and increase in air temperature landward in the Western Desert are associated with the gradual disappearance of *T. hirsuta* plants which are absent after 90 km south of the coast. The climatic conditions in the other parts of the coastal and inland deserts of Egypt are not suitable for the growth of this xerophyte [10].

4–6 *Palm trees* (family Palmae)

*Phoenix dactylifera* (date palm) is a dioecious tree up to 25 m high, trunk unbranched, 30–60 cm diameter covered with old-leaf bases, crown of 25 leaves or more, leaves up to 4.5 m pinnate, stiff, leaflets about 80 on each side of rachis. *P. dactylifera* belongs geographically to the Old World Tropics and Sub-Tropics [5].

In Egypt, *P. dactylifera* has wide ecological range. It grows naturally in all coastal and inland parts of the deserts, it is also cultivated in the Nile Region and Oases. Apart from the dates, practically all parts of the plant being rich fiber materials are used as building materials, making baskets, mats, cages, ropes, chairs, tables, beds etc. Recently El-Hadidi [11] succeeded to use the chemically treated palm leaves instead of the iron bars in the roofs of the houses.

*Hyphaene thebaica* (Dom palm) and *Medemia argun* (argun palm) are palms with fan shaped leaves naturally growing in Egypt's deserts. Dom palm has dichotomously branched stem that occurs in the southern sections of the deserts whereas argun palm has been recorded only in two of the most southern Oases of the Western Desert [12]. In consistence of palm trees, all parts of dom and argun palms (fruits, leaves, stems etc.) have similar uses.

7. *Desmostachya bipinnata* (family Poaceae, Gramineae)

*D. bipinnata* (halfa grass) is a robust — harsh tussock — forming rhizomatous perennial grass up to 1.5 m high. Geographically it belongs to the old world tropics [5]. It has rosetted very long leaves surrounded by glossy yellow sheath and elongated compound spike like panicle of many flowered spikelets.

In Egypt, apart from its common presence and dense cover along almost all canal banks of the River Nile Region, *D. bipinnata* predominates in the wet and sandy habitats of the oases and depression, of the Western Desert, absent from the coastal deserts of Egypt. Though considering one of the most serious weeds difficult to control *D. bipinnata* has economic potentialities as fiber plant. It is used for thatching, dry straw for making roof, forage, erosion control, paper making and bedding materials for livestock [13].

8–9 *J. rigidus* and *J. acutus* (family Juncaceae, rushes)

*J. rigidus* and *J. acutus* (samar mur) are closely related euhalophytes of the cumulative type [14]. They accumulate excess salts in the upper parts of their green culms, an advantage that characterizes these two *Juncus* species. Boyko [15] stated that each harvest (of the green culms) is diminishing the salt content of the soil and/or ground water, i.e. phyto-desalination of the soil.

*J. rigidus* is a densely tufted rush with slender pungent nodeless culms more than 1 m high. It has sympodial creeping rhizomes developing leafy shoots (culms) every year. These rhizomes extend horizontally exploiting wide areas and may produce a dense plant growth within a few years. It has been recorded in southern Anatolia, Cyprus, North Africa, Sinai, Palestine, Syria, Arabia, Iraq, Iran, Afghanistan, Pakistan and South Africa [5].

The biogeography of *J. rigidus* in Egypt shows that the plant is not only salt tolerant but it also tolerates a wide range of climatic conditions. It occurs in the salt marshes of the coastal as well as inland parts of Egypt's deserts [16].


J. acutus has the same morphological aspects as J. rigidus, but its rhizomes grow in a special way giving rise to a great member of green culms that form circular patches of variable sizes. It is recorded in the coasts of Western Europe, Mediterranean region, SW Asia, Black Sea and South Caspian region [5]. In Egypt J. acutus is widespread in the salt marshes of Mediterranean coast, Wadi El-Natrun and El-Fayoum but it is almost absent from the littoral salt marshes of the Red Sea and extreme arid parts of Egypt’s deserts.

Tackholm and Drar [17] reported that both Juncus species are frequently used for making mats which is described by Abu Hanifa (895 A.D.) and Ibn El-Beitar (1248). Boyko [15] and Zahran et al. [16] referred to the use of Juncus culms as raw materials for paper industry.

10–11 Typha domingensis and Typha elephantina (family Typhaceae)

Typha species (cattails, reed swamp plants) are monocoeous herbaceous perennials with creeping rhizomes, upper parts of stems emerging above water (emersed hydrophytes) Leaves alternate with long open sheath, lower leaves with shorter blades than the upper ones. They usually inhabit the slow moving shallow fresh and brackish water bodies (ponds, lakes, swamps etc.) as well as canal banks and borders of the dams. T. domingensis is best considered Pantropical- Cosmopolitan as it occurs in almost all contents except the very cold regions. T. elephantina, however, is native in North Africa, India, Nepal, Pakistan and Iran [5,18]. Zahran [19] recorded T. elephantina in the downstream part of Wadi Giza, Saudi Arabia.

In Egypt T. domingensis is widespread in all Egypt’s deserts and river Nile region as well whereas the giant cattail (up to 4 m high), T. elephantina is localized in the brackish swamps of Wadi El-Natrun depression, Western Desert but absent elsewhere. Morton [20] confirmed that Typha plants have potential sources of raw materials for paper pulp and other fiber industries.

12. Cyperus papyrus (family Cyperaceae)

C. papyrus is a robust, tufted, glabrous perennial reed sedge with numerous roots and rootlets, rhizomes are short, thick, creeping, woody, densely covered by black scales, culms 2–3 m high, 1.5 cm diameter, native to Tropical Africa, Madagascar, Mascarene Island [5].

C. papyrus was used by ancient Egyptians in paper making is almost extinct from Egypt, only few individuals are still growing in Umm Risha Lake of Wadi El-Natrun Depression, Western Desert as well as in the wetlands associated with the Damietta Branch of the River Nile [21]. However, establishment of papyrus plants is being conducted along the River Nile bank in Cairo to produce from its culms paper sheets in the same way like the ancient Egyptians for tourists [21].

13. Arundo donax (family Poaceae)

The giant reed (A. donax) is a tall perennial grass with culms up to 4–6 m tall from creeping woody rhizomes, leaves 30–60 cm × 2.5–5 cm, the blades are linear-lanceolate rounded or cordate at the base. In Egypt A. donax inhabits in the swammy areas of the deserts as well as in the River Nile region. It grows both subspontaneously and by cultivation along water courses, rarely occurring as native [5]. Verweris et al. [22] determined that A. donax is suitable for paper industry as it contains satisfactory amounts of a-cellulose (close to 40%) and relatively low amount of lignin (<30%) and ash (4–5%).

14. Phragmites australis (family Poaceae)

P. australis is a perennial robust reed arising from creeping woody rhizoms, leaf-blade 20–60 cm & 0.8–2.2 cm glabrous, smooth beneath, culms up to 6 high and 4 cm diameter often wood and bamboo like. It belongs to temperate region of both hemispheres of the world [5]. Holm et al. [23] started that P. australis is a cosmopolitan angiosperm believed to be one of the most widely species in the world. In Egypt, P. australis is the major component of the reed swamps both in the deserts and Nile region. Eid et al. [24] found that the above ground biomass production of the reed was 3.5 times higher than the below ground biomass. Wiedermann [25] stated that P. australis is a fiber non-wood pulping grass.

4. Fiber measurements of selected species

To determine their potentialities as raw materials for various fiber industries, the fiber lengths of the above ground parts of seven species were measured. These species are: T. hirsuta, T. domingensis, C. papyrus, D. bipinnata, T. elephantina, J. rigidus and J. acutus [9,13,18,26]. All of the selected species are commonly used for the production of local products commonly used by local people. The fiber lengths of these plants are shown in Table 1.

The branches of T. hirsuta include 2 types of fibers: a) short fibers (from <400 μm up to 1200 μm length) and b) long fibers (from 1201 μm up to 6100 μm length). The number of short fibers constitute about 40% of the total fibers of the plants, mostly (>50%) with length of 400 μm and the least number (8%) have lengths ranging between 800 and 1200 μm. on the other

| Species                       | Short fibers Length | Long fibers Length | Means |
|------------------------------|---------------------|--------------------|-------|
| Thymelaea hirsuta            | 400 μm              | 6100 μm            | 4318 μm |
| Cyperus papyrus              | 410 μm              | 930 μm             | 630 μm |
| Typha domingensis            | 520 μm              | 1560 μm            | 960 μm |
| Typha elephantina            | 480 μm              | 2300 μm            | 1390 μm|
| Desmostachya bipinnata       | 250 μm              | 1500 μm            | 875 μm |
| Juncus rigidus               | 467 μm              | 2421 μm            | 1484 μm|
| Juncus acutus                | 467 μm              | 2421 μm            | 1484 μm|

LSD 68.10 116.29 54.83
hand, the long fibers constitute about 60% of the total fiber of the plant, mostly of lengths ranging between 3000 and 6000 μm with average length of 4318 μm.

The fiber lengths of the culms of C. papyrus range between 410 and 930 μm (mean = 630 μm) whereas those of T. dominantis and T. elephantina range between 520 and 1560 μm (mean = 960 μm) and between 480 and 2300 μm (mean = 1390 μm) respectively. In the culms of D. bipinnata, according to Eisa et al. [13], the percentages of the long fibers (up to 1500 μm) was relatively higher (60%) than those of the short fibers (<250 μm, <40%).

In the culms of J. rigidus, fiber lengths range between 467 μm and 2421 μm with average of 1484 μm. The percentages of fibers having lengths >1500 μm constitute about 40% of the total fibers. Almost comparable results were obtained for the fiber lengths of J. acutus culms [16].

5. Juncus plants and paper industry in Egypt

5.1. General remarks

Ecologists claim that the green areas are getting smaller as a result of the uncontrolled felling of forest trees and ill-advised land and water management. This may indicate that the pulp importing countries could face some future difficulties. The pulp exporting countries may stop cutting their woods to improve the strength of paper produced from locally available raw materials. The amount of wood pulp imported is increasing considerably. Consequently, the search for local material for the paper industry is necessary [26].

Those plants which are salt tolerant and fiber producing, e.g. Juncus spp., if successfully managed to produce good quality paper, would provide a non-conventional crops to be cultivated on salt affected soils of Egypt. Three advantages can be obtained. These are: (a) cultivation of the saline soils which are usually left barren or covered with unwanted wild halophytic vegetation; (b) production of local raw material for paper industry; and (c) saving the hard currency used to purchase paper and paper pulps from abroad.

In the following pages the authors present and discuss the possible industrial potential of J. rigidus as non-conventional crop to be cultivated in salt affected lands of Egypt as a part of the arid region and making use of its vegetative yields as raw materials in paper industry.

5.2. Production of paper pulp

In Egypt, both in old and recent times, Juncus plants are used for making good quality mats [17]. However, the most important industrial use of these plants is that their culms showed to high potentialities as raw material for the paper industry. Zahran et al. [26] stated that the chemical analyses and pilot plant experiment (carried out at the National Company for Paper Industry, Alexandria, Egypt) proved that J. rigidus culms contain low ash content (6.5%), low percentage of lignin (13.3%), high percentage of a-cellulose (39.8%) and high yield of unbleached pulp (36.8%). The strength properties of

| Strength properties | Juncus rigidus | Rice straw | Bagasse | Kraft |
|---------------------|---------------|------------|---------|-------|
| Tensile strength (kg) | 6.3 | 6.7 | 3.0 | 6.3 | 9.0 |
| Breaking length (m) | 7000 | 9667 | 3333 | 7000 | 10000 |
| % of Breaking length to that of Kraft pulp | 70 | 96.7 | 33.3 | 70 | 100 |
| Bursting strength (lb/m²) | 47 | 62 | 15 | 43 | 58 |
| Bursting index | 55 | 73 | 18 | 50 | 80 |
| % of Bursting index to that of Kraft pulp | 68.6 | 91.2 | 22.5 | 62.5 | 100 |
| Tear strength (g) | 26 | 48 | 28 | 28 | 60 |
| Tear index | 43 | 80 | 47 | 47 | 100 |
| % of Tear index to that of Kraft pulp | 39 | 72.7 | 42.7 | 42.7 | 100 |
| Folding (no. of double folds) | 300 | 1570 | 20 | 500 | 3000 |
| % of Folding to that of Kraft pulp | 10 | 52.7 | 0.7 | 16.7 | 100 |
| Grad index | 40 | 73 | 24 | 42 | 100 |

Table 2 – Comparison between the strength properties of the pulps of J. rigidus, rice straw, bagasse and Kraft.

| Initial freeness (OSR) | Brightness (photo volt) (%) | Ash content (%) | Time of beating (min) | Freeness (SR) | Tensile strength (kg) | Bursting strength (lb/m²) | Tear strength (g) | Folding (no. of double folds) |
|------------------------|-----------------------------|-----------------|----------------------|---------------|----------------------|-------------------------|-------------------|-------------------------------|
| 40 | 76 | 0.85 | 0 | 40 | 52 | 41 | 44 | 235 |
| 16 | 49 | 40 | 16 | 49 | 40 | 50 | 40 | 540 |
| 20 | 75 | 6.8 | 20 | 75 | 6.8 | 45 | 32 | 690 |
| 30 | 61 | 6.5 | 30 | 61 | 6.5 | 42 | 28 | 52 |
the depithed unbleached Juncus pulp are much higher (73%) than those of rice straw (24%) and bagasse (42%) compared to the imported soft-wood long fiber unbleached depith Kraft pulp (grad index = 100%) (Table 2).

5.3. Biomass production

The vegetative yield (biomass) of Juncus plants was estimated by the difference in fresh and oven dry (at 60 °C) weights of culms of J. rigidus covering measured areas (1 m² each) of the salt affected lands of Wadi El-Natrun Depression, Western Desert, Egypt. It was found that one feddan (4200 m²) may produce 4–4.5 tons of fresh culms (i.e. 95–107 tons/ha). Regarding the paper pulp production, the pilot experiment carried out in the National Paper mill at Alexandria, Egypt [26] revealed that 1 ton of oven dry J. rigidus culms may produce 375–400 kg pulp. This means that one feddan dominated by J. rigidus (plant cover = 100%) may produce about 6–6.4 tons paper pulp each year (+14.2–15.3 tons/ha).

6. Establishment of Juncus spp.

Field experiment was conducted to study the salt tolerance of Juncus plants on saline soil. The site of experiment was selected in the part of poorly drained soil under the influence of El-Manzala Lake. The underground water table (brackish) was shallow (about 10–150 cm in summer and 50–70 cm in winter below soil surface). The soil of the site was usually saturated with water. Analyses of the representative soil samples collected, at random, from the experimental site before transplanting Juncus showed that the soil was clayey in texture, black in color, alkaline in reaction (pH = 7.8–8.4), and with high organic carbon content (0.9–1.2%), calcium carbonate content (3.85–4.4%) and total soluble salts (0.89–1.85%) in the surface layers and (0.28–0.65%) in the subsurface layers.

An area of 4032 m² was prepared and divided into 96 plots (7 × 6 m each) for the experiments of both Juncus species. Rhizomes of the two Juncus spp. were collected from natural domination in Mariut salt marshes (Mediterranean coast, near Alexandria). Equally sized pieces of rhizomes were transplanted at equal distances, about 5–10 cm deep in each plot. Irrigation was carried out at every 5 days in summer, and 7 days during winter using Manzala Lake’s water with EC ranging between 750 and 448 μhos/cm. After one year of growth, aerial green culms were harvested and the following parameters were studied: (1) number of Juncus rhizomes succeeded to produce new tussocks; (2) mean fresh and oven dry weights of Juncus culms per plot; (3) mean height of Juncus culms.

The results of this experiment (Table 3) show that both Juncus spp. may be cultivated on poorly drained saline soil. The growth of J. rigidus seems to be better than that of J. acutus. Mean numbers of rhizomes that produced new tussocks was higher for J. rigidus (80%) than for J. acutus (74%). Similarly, mean height of J. rigidus culms was more (162 cm) than that of J. acutus (85 cm). Mean fresh weight of J. rigidus culm (4.96 kg plot⁻¹) was higher than that of J. acutus (2.81 kg plot⁻¹). Though the mean water content of J. rigidus culms was slightly higher (63.50%) than that of J. acutus (60.23%), yet the mean oven dry weight of the former (1.95 kg plot⁻¹) was higher than that of the latter (1.11 kg plot⁻¹).

7. Concluding remarks

The preceding pages reveal the following remarks:

1. Egypt, though part of the arid lands, its deserts are rich with their natural vegetation types the framework of which are formed of drought resistant (xerophytes) and salt tolerant (halophytes) plants.
2. Most of the desert flora have valuable economic values as wood, fodder, fiber, drug etc. producers that could play the main role in the sustainable development of these deserts.
3. The fiber producing plants are commonly used by bedouins for various local productions.
4. The various agro-industrial potentialities of the two halophytic rushes: J. rigidus, J. acutus are discussed. These rushes can be cultivated successfully on saline non-productive soils. Their growth rates were so fast that enlarged vegetational cover of cultivated saline lands with non-conventional and economic crop may be expected. Consequently, it is possible that Juncus halophytes and other fiber producing taxa could play an effective role for human welfare in Egypt as a promising means for the sustainable development of its deserts.

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