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Urban Development Threatening Wild Plants in Doha City-Qatar: Ecophysiology is a Prerequisite for Ecological Restoration

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ABSTRACT

Rapid disappearing of many coastal and inland habitats in the State of Qatar, due to the enormous activities of constructions, would put wildlife at real risk; urging scientists for environment conservation. This study was aimed to document the morphological features and the ecophysiological aspects of four wild plant species, *Aeluropus lagopoides*, *Sporobolus spicatus*, *Ochradenus baccatus* and *Tetraena qatarense*. Analyses included physical and chemical properties of soils and organic and inorganic contents of these plants were carried out. Although these plants are considered as xerophytes as the data of soil water content have shown; they might have well adapted to saline environments, since they live in soils of high salinity levels. *A. lagopoides, S. spicatus* and *T. qatarense* were living in soils of ECe ranged between 45 to 50 dS m^{-1}, between 107 to 128 dS m^{-1} and between 12 to 187 dS m^{-1} respectively. *O. baccatus*, on the other hand, proved to be a typical xerophyte plant since it was never found in saline soils and survived water deficit as low as 4-12% field capacity. Considerable variations were found in all parameters studied especially in the electrical conductivity of the saturated soil extracts (ECe). Also, these species showed great variation in the organic components especially proline, soluble sugars and nitrogen, photosynthetic pigments and major elements. The data of trace elements, however, did not indicate clear differences. Such efforts can be considered as a prerequisite for successful ecological restoration, encouraging the decision makers to implement plans for restoration of vegetation.

Key words: Chemical composition, ecological restoration, ecophysiology, halophytes, soil properties, xerophytes

INTRODUCTION

The State of Qatar has become an important international center for various activities, political, sports, social, etc which requires tremendous expansion in the infrastructure of various aspects of the civil life (Richer, 2008). Recent reports have shown that the wildlife, environment, ecosystem services and biodiversity in the State of Qatar are under real threat. This is because of the industrial development and expansions in the activities of oil and gas industry which are accompanied with enormous urban constructions in various areas especially in Doha city (Yasseen and Al-Thani, 2007; Yasseen and Abu-Al-Basal, 2008, 2010). Scientific solutions to minimize the impact of the new developments on the environment were strongly suggested and urgently needed. Thus, efforts should start with the recording and documenting the existing wildlife and plants and their ecophysiology under their natural habitats. Such efforts can be considered as a prerequisite for successful ecological restoration (Al-Ansi *et al.*, 2004; Abdel-Bari *et al.*, 2007; Yasseen and Abu-Al-Basal, 2010). Moreover, it would be very useful to improve the awareness and comprehend the importance of wild plants under their natural habitats. One most important reason for studying sites around Doha, their plant cover and the life they support, is the fast rate at which many habitats are disappearing specifically in Doha and also in a number of other areas in the State of Qatar. Some practical measures were suggested for the local authorities to maintain the environment and to solve the problems and difficulties facing such efforts (Al-Ansi *et al*., 2004; Flowers, 2004; Abdel-Bari *et al*., 2007; Richer, 2008; Yasseen and Abu-Al-Basal, 2010). Moreover, many wild plants living in the State of Qatar have been considered as economic and medicinal plants (Shabana *et al*., 1990; Rizk and El-Ghazaly, 1995; Al-Easa *et al*., 2003), as well as addressing very important topics in biology (Sage, 2002; Lara *et al*., 2006; Boyd *et al*., 2007; Mohsenzadeh *et al*., 2006). Some halophytes can be exploited in saline and sodic soils to achieve ecological recovery (Guan *et al*., 2010). These plants can be considered as good sources of salt and drought resistant traits from which genes can be manipulated (Flowers, 2004; Yasseen and Al-Thani, 2007) and of which some anatomical, physiological and biochemical features are consistently associated with the resistance to stress conditions (Yasseen *et al*., 2010). The Arabian Gulf States with their comparatively superior financial status may be leaders in the technological research in salinity and drought stresses (Abdel-Bari *et al*., 2007; Yasseen and Abu-Al-Basal, 2010). Therefore, the present work focuses on four wild xerophytic species belonging to three families; two species *Aeluropus lagopoides* and *Sporobolus spicatus*, belong to Gramineae and *Ochradenus baccatus* from Resedaceae and *Tetraena qatarense* from Zygophyllaceae. Therefore, this study was carried out to document the morphological features and the ecophysiological aspects of these plants and the soil properties in various parts of Doha.

MATERIALS AND METHODS

The study location: The main study location as shown in the Fig. 1 was around Doha city. Samples of the plants and soils were collected from various areas in that location for different types of analyses required. The field surveys were started in September 2001 and continued throughout 2002 till 2004. The details of these trips were described by Yasseen and Abu-Al-Basal (2010). The morphological characteristics of the plant species covered in this study were determined.

Analysis of soils and plants: Methods of analysis of plants and soils were described and followed by many authors (Abdel-Bari *et al*., 2007; Yasseen and Al-Thani, 2007; Yasseen and Abu-Al- Basal, 2008). Soil samples were collected from the root zone of the plants studied and transported to the laboratory. The physical and chemical properties of soil including water content, soil texture, pH of soil extract, ECe, mineral content and the field capacity (FC) were studied. The concentration of major elements (potassium, K^+; calcium, Ca^{2+} and magnesium, Mg^{2+}) and, sodium, Na^+ and chloride, Cl^- in the water soil extracts were determined according to the method described by Chapman and Pratt (1961). Also, trace elements namely, Fe, Cu, Zn, Co, Ni, Cr and Cd were determined in the water soil extracts and plants using an Atomic Absorption Spectrophotometer (Model Analyst 700, Perkin Elmer) (Yasseen and Abu-Al-Basal, 2010). Measurements of the chemical composition were done on the shoots of plants. The measurements of ionic composition were done according to the methods of Chapman and Pratt (1961). Proline was determined according to the method described previously (Bates *et al*., 1973). Total Soluble Sugar (TSS) and Total Soluble Nitrogen (TSN) were determined according to the method described by

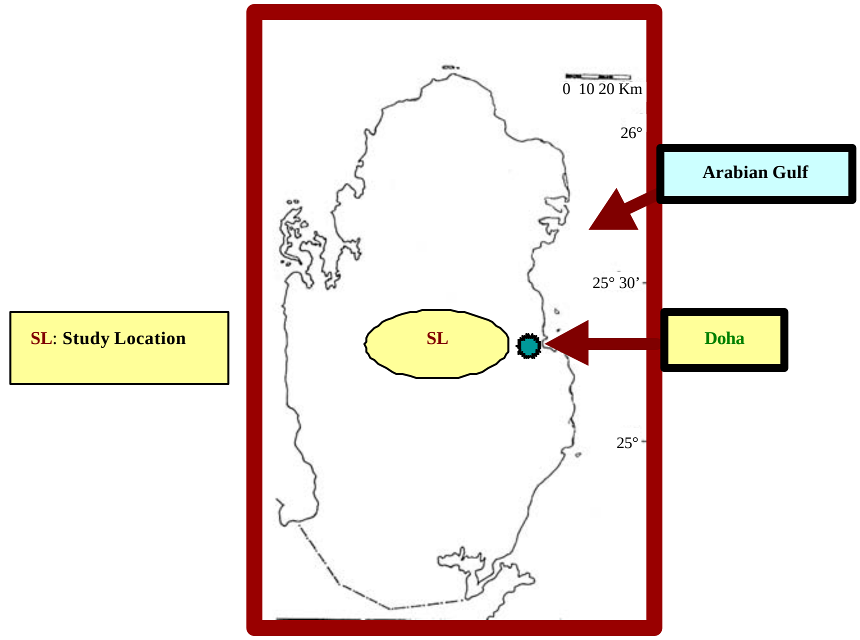

Fig. 1: A map of Qatar showing the study location (It was provided by the Environmental Studies Centre, Qatar University)

Alhadi *et al*. (1999). Photosynthetic pigments (chlorophylls a and b as well as carotenoids) were determined according to the procedure described and used by many authors (Metzner *et al*., 1965; Abdel-Bari *et al*., 2007).

Climatic data: An overall climatic data were extracted from Doha airport for the last 17 years (Abulfatih *et al*., 2001).

RESULTS

Description of plants: These plants are found at the coastline from 0 to 500 m from the sea water front to landward and extend to a few kilometers beyond especially for *Ochradenus baccatus*. *Aeluropus lagopoides* (L.) Trin. ex Thw., Enum. Pl. Zeyl: 374 (1864) Syn. *Dactylis lagopoides* L., Mant. 1:33 (1767). Shirraib/Iqrish/Ikrish (Ar.).

This plant is prostrate trailing perennial rigid grass giving off upright short culms up to 15 cm high terminating in inflorescences. Leaves linear; lanceolate 4×0.2 cm, small blades ending in sharp rigid points. Ligules hairy,. Inflorescences 1-3 cm long with small congested and overlapping spikelets. short spicate-sub-capitate broadly pyramidal-sub-orbicular. Caryopsis minute.

The genus *Sporobolus* is represented by two species in the flora of Qatar. However, only one species is found in our survey; *Sporobolus spicatus* (Vahl) Kunth, Rev. Gram.1:67 (1829). Syn. *Agrostis spicatus* Vahl, Symb. Bot. 1 : 9 (1790). Sukham (Ar.).

This plant is very common grass and pale yellow-green short tufted perennial stoloniferous grass. Basal growth arising from the branched stolons is leafy rigid spiky and pungent leaf-blades. Inflorescence narrow spike, 6 cm longx 0.3 cm. Spikelets awnless, 1-flowered. Glumes unequal. Caryopsis ellipsoidal. Flowers throughout the year where moisture is available in cultivated and arable lands, in sewage disposal localities, near residential areas, etc.

Ochradenus baccatus Delile, Descr. Egypte, Hist. Nat. 63 (1814). Kardi (Ar.). It is densely branched bush appearing dome-shaped with long green±leafless branches; crown not exceeding two m spread and up to 1-1.5 m high. Plant dioecious, very rarely monoecious. Inflorescences simple spikes (rarely pedicellated) of small yellow flowers; male flowers yellow, at anthesis producing large amount of pollen attracting flies, bees and various other insects feeding on the pollen; female flowers producing white oval berries about 1 cm long with black seeds on±sweetish pulp always eaten by birds. It is common in Doha in disturbed areas. Widespread on University of Qatar grounds, rare in rodats and usually occurs under *Acacia* trees on fine to stony-sandy soils., It has been reported (Wolfe and Shmida, 1995, 1997) that the male plants representing 35% of this species, whereas 65% were inconsistent males bearing staminate and pistillate flowers on the same plant (i.e. unisexual, monoecious) (Abdul-Bari *et al*., 2007).

Tetraena qatarense (Hadidi) Beier and Thulin. Pl. syst. Evol. 240 (1-4): 36 (2003), (previously known as *Zygophyllum qatarense*): Hadidi in Boul. Webb. 32. 2:394 (1978) (http://www.theplantlist.org/tpl/record/kew-2469698), Shrublet, perennial, fleshy, 40-60 cm high, Branches ascending, purple when young, then changing into woody, pubscent. Leaves succulent, usually simple, rarely bifoliate (where moisture is available), petiolate; petioles terete, fleshy.

It is found on rocky and sandy grounds and is widespread in all disturbed areas including the coastline and can be found in many locations around the country (Abdel-Bari *et al*., 2007). Inflorescences solitary on short peduncles. Flowers slender, pale yellow. Fruit elongated pale berries and splitting longitudinally. It flowers during March - April.

Climate and soil characteristics: The climatic data of Doha city that have been obtained from Doha airport for the last 17 years have given clear evidence that the environment of Qatar is an arid one (Abulfatih *et al*., 2001). For example, the average annual rainfall is 81 mm, average maximum temperature is 31°C, average minimum temperature is 22°C, absolute maximum temperature is 47°C, absolute minimum temperature is 1°C, average morning relative humidity is 71% and average afternoon relative humidity is 43%. Moreover, the outcomes of the analysis of soil samples collected from different areas around Doha city confirmed the nature of the harsh environment of soil. In fact, considerable variations have been found in all parameters studied including: soil texture, water content, pH of the soil extracts and EC_e; EC of the saturated soil extracts (Table 1). However, such variations in those parameters were more obvious in EC_e; which accompanied with the variation in Na^+ and Cl^- ions content in those soils. In fact, the data have shown that the main elements that could cause salt stress in such soils are Na^+ and Cl^- in

Table 1: Physical and chemical properties of the soil samples collected from the study location

Parameters	Properties[a]
Soil texture	Sandy-Sandy clay loam
Absolute water content (%)	2.2-25.7
Soil water content (% FC[b])	7.9-65.9
pH (soil extract)	6.6-8.4
ECe (dS m^{-1})	4.2-195.0[c]
Na^+ (mg L^{-1}) of soil extract	186-726
K^+ (mg L^{-1}) of soil extract	60-108
Ca^{2+} (mg L^{-1}) of soil extract	63-113
Mg^{2+} (mg L^{-1}) of soil extract	34-82
Cl^- (g L^{-1}) of soil extract	2-344

[a]The number of observations for the soil properties ranged between 6 to 9. [b]Field Capacity. [c]ECe in allover the soils around Doha

Table 2: The concentrations of soluble trace elements ($\mu g\ L^{-1}$ of soil extract) in the soil samples collected from root zones of the plants studied

Elements	Range of concentrations
Fe[a]	2.1-9.8[b]
Cu	13.9-54.3
Zn	18.0-59.1
Co	1.8-26.7
Ni	37.0-61.0
Cr	1.8-16.4
Cd	0.25-2.35

[a]mg L^{-1} of soil extract, [b]The number of observations ranged between 6 to 9

Table 3: Shoot chemical composition of the shoot system of the studied plants

Parameters	*A. lagopoides*	*S. spicatus*	*O. baccatus*	*T. qatarense*
ECe of soil (dS m^{-1})	45-50[a]	107-128	7-8	12-187
Soil water content (% FC)	40-66	32-44	4-12	10-46
Plant water content (%)	70-72	58-66	68-71	81-87
Proline ($\mu g\ g^{-1}$ fresh wt.)	241-253	40-147	1277-1347	419-1136
TSS (mg g^{-1} dry wt.)	1.5-1.7	3.3-3.4	2.9-3.5	2.9-4.3
TSN ($\mu g\ g^{-1}$ dry wt.)	84-126	195-236	92-109	85-190
Na^+ (mg g^{-1} dry wt.)	34-70	76-88	25-32	50-225
K^+ (mg g^{-1} dry wt.)	6.9-12.9	9.4-13.2	4.5-5.2	2.6-7.4
Ca^{2+} (mg g^{-1} dry wt.)	22-54	27-39	48-51	14-47
Mg^{2+} (mg g^{-1} dry wt.)	0.53-1.91	0.72-1.25	0.42-0.48	0.27-1.13
Cl^- (mg g^{-1} dry wt.)	19-65	32-79	9.0-10.0	14.0-94.0
Chlorophyll a ($\mu g\ g^{-1}$ fresh wt.)	733 (621-798)	455 (386-521)	639 (425-853)	84 (64-104)
Chlorophyll b ($\mu g\ g^{-1}$ fresh wt.)	301 (245-368)	208 (175-230)	314 (268-360)	38 (24-52)
Carotenoids ($\mu g\ g^{-1}$ fresh wt.)	133 (118-158)	151 (132-173)	139 (124-154)	33 (20- 46)
Total Photosynthetic pigments ($\mu g\ g^{-1}$ fresh wt.)	1167 (984-1324)	814 (693-924)	1092 (817-1367)	155 (108-202)

[a]The number of observations was 6

addition to other cations like Ca^{2+}, Mg^{2+} and K^+. Trace elements were measured in water soil extracts; Fe was found in higher concentrations followed by Ni, Zn, Cu, Co, Cr and Cd (Table 2).

Plants chemical contents: The chemical constituents (organic and inorganic) of the shoot system of the plant species are shown in Table 3. These plants differ in their organic contents under their natural habitats; *O. baccatus* accumulated much proline, followed by *T. qatarense, A. lagopoides* and the least was found in *S. spicatus*. *T. qatarense,* contained much soluble sugars followed by *O. baccatus* and *S. spicatus* and the least was found in *A. lagopoides*. Although, little soluble nitrogen was found in these plants as compared to other plants such as fenugreek (Alhadi *et al*., 1999), high concentrations were found in *S. spicatus* followed by *T. qatarense, A. lagopoides* and *O. baccatus*. On the other hand, high content of Total Photosynthetic Pigments (TPP) was found in *A. lagopoides* followed by *O. baccatus* and *S. spicatus*, while *T. qatarense* had the lowest concentration among the species studied. However, chlorophyll a had the main contribution in the order of TPP contents in these plants. Moreover, the lower concentrations of TPP in *T. qatarense* could be a result of the impact of saline soil on plants living at the coastline, or it could be an artifact of expressing the concentrations of TPP on fresh weight basis, keeping in mind that this plant has succulent leaves.

Table 4: Shoot trace elements content (μg g^{-1} dry wt.) of the studied plants

Parameters	*A. lagopoides*	*S. spicatus*	*O. baccatus*	*T. qatarense*
Fe	7.58-33.74[a]	16.53-20.93	23.67-31.94	16.53-20.93
Cu	0.965-7.607	0.32-4.28	0.34-0.66	0.32-4.28
Zn	0.660-1.601	0.72-0.97	0.77-0.99	0.72-0.97
Co	0.018-0.109	0.039-0.042	0.04-0.22	0.039-0.042
Ni	1.353-8.249	6.35-13.43	1.86-4.88	6.35-13.43
Cr	0.990-4.821	2.14-2.95	2.14-6.92	2.14-2.95
Cd	<0.0350	<0.004	<0.0160	<0.004

[a]The number of observations was 6

The mineral contents including Na^+, Cl^-, K^+, Ca^{2+} and Mg^{2+} were measured in these plants. The data in Table 3 showed little variation between these plants; however, *T. qatarense* and *S. spicatus* accumulated much Na^+ and Cl^- than did *A. lagopoides* and *O. baccatus* while these plants had similar content of the major elements. Trace elements were measured in the plants studied and the order of contents was almost as similar as to that in the soil; Fe was found in higher concentrations followed by Ni, Zn, Cu, Co, Cr and Cd (Table 4).

DISCUSSION

The data of study revealed that wild plants in Doha city-Qatar are exposed to a number of extreme environmental stresses including drought and salinity as well as high temperatures during most days of the year. Such conditions could be a reason behind the great deficit in the soil water content. Also, high levels of salinity found in such soils could have come from the intrusion of seawater into the underground waters accompanied with the great evaporation; such conditions might lead to the emergence of salts on the soil surface. However, great variation in the EC_e values was detected even within the same confined area of the location studied which can be explained by climatic aridity, rain scarcity coupled with high evaporation (Abdel-Bari *et al.*, 2007). These climatic and ecological conditions have put plants under a state of multifaceted stress. The results of soil analysis have shown that the main elements that could cause salt stress in such soils are Na^+ and Cl^- in addition to Ca^{2+}, Mg^{2+} and K^+ (Shonubi and Okusanya, 2007). Although, the plants under investigation are considered as xerophytes as can be drawn from the data of soil water content; they might have also well adapted to saline environments, since they were living in soils of high salinities. ECe of 45 to 50 dS m^{-1} was found in soils of *A. lagopoides*, *S. spicatus* was living in a soil salinity ranged between 107 to 128 dS m^{-1} while *T. qatarense* was living in a wide range salinities from 12 to 187 dS m^{-1}. However, *O. baccatus* proved to be typical xerophyte, since it was never found in saline soils and survived soil water deficit as low as 4-12 % field capacity. The contents of trace elements in the water soil extracts and in the plant shoots indicated clearly that Fe was the main trace element found in the plant tissues. The ranges of concentrations were acceptable and comparable to those recommended by many authors for normal plant growth (Chapman and Pratt, 1961). Thus, the trace elements found in the soils of Doha area might not be involved to any extent to the harsh characteristics of these soils (Milner and Kochian, 2008).

The chemical contents of the plants revealed that *O. baccatus* and *T. qatarense* showed xerophytic characteristics, not only because of the morphological characteristics and the harsh environment they live in but also they accumulated substantial amounts of proline to cope with soil of a severe water shortage (Aziz *et al.*, 2011). Also, the data suggested exchanged roles between proline and soluble sugars and/or nitrogen in many physiological and biochemical roles under osmotic stress conditions (Yasseen *et al*., 2006; Abdel-Bari *et al*., 2007). This means that in many plant systems, osmoregulation inside plant cells can be achieved mainly either by proline and/or soluble sugars and in such systems the origin of proline is from the carbohydrate degradation especially when nitrogen sources are limited (Kavi Kishor *et al*., 2005). Other organic solutes might be involved in the processes of osmoregulation in wild plants when exposed to osmotic stress (salinity and/or drought) (Rhodes and Hanson, 1993; Youssef *et al*., 2003). It was hypothesized that organic solutes such as glycinebetaine could cause a minimum amount of perturbation of the macromolecular stability and therefore function, accumulate in the cytoplasm in order to adapt to low osmotic potential. Thus, glycinebetaine might play the same role the proline does in achieving osmoregulation and protecting the protein and membrane systems, in *S. spicatus* and *A. lagopoides*, at least under the conditions of the present experiments (Khan *et al*., 1998). This needs further investigation for all wild plants to see what kind of mechanisms these plants might have to cope with stress conditions (Abdel-Bari *et al*., 2007; Yasseen and Al-Thani, 2007; Yasseen and Abu-Al-Basal, 2010). On the other hand, much soluble nitrogen was found in the shoots of *S. spicatus* as compared to the other plants. Low proline found in this species might cause imbalance in the process of osmoregulation; such role might be filled with soluble nitrogen components to achieve the osmoregulation inside the plant tissues (Khan *et al*., 1998). Also, the inconsistency in the photosynthetic pigments content found in these plants can be explained as the great variations in the salinity levels in the soils of, *S. spicatus* (EC_e: 107-128 dS m^{-1}), *A. lagopoides* of (EC_e: 45-50 dS m^{-1}) of *T. qatarense* (EC_e12-187) and *O. baccatus* (EC_e 7-8 dS m^{-1}). Moreover, high salt stress of the soils could have great impact on the photosynthetic pigments in the leaves of these plants (Levitt, 1980; Yasseen, 2001) while carotenoids biosynthesis might have promoted under high salt stress (Gomez *et al*., 2003). Considerable variations also found in the mineral contents of the plants studied; however, it seems that *T. qatarense* accumulated much Na^+ and Cl^- than did the others, as this plant survived high soil salinity level of 187 dS m^{-1}. However, it appeared that these plants are living under extreme stress conditions of both salinity and/or aridity (Abdel-Bari *et al*., 2007). Thus, further studies are needed to investigate the possible mechanisms of resistance to those conditions, since such plants might have epidermal bladder cells or hairs as a possible avoidance mechanism to facilitate the excretion process of extra toxic ions such as Na^+ and Cl^{-1} (Pollack and Waisel, 1970; Yasseen and Abu-Al-Basal, 2008).

THREATS, SOLUTIONS AND CONCLUSIONS

Perhaps the importance of such studies could come from the fact that many habitats are disappearing from many locations in the Gulf region, with the completion of constructions and urban development's due to the great expansion caused by the establishment of infrastructure of the extraction and industry of oil and gas (Richer, 2008; Yasseen and Abu-Al-Basal, 2008). Such studies were trying to address the threats of those activities on wild plants and, also urging the decision makers to document endangered wild plants (Gorsi and Shahzad, 2002; Al-Rawahy *et al*., 2003) and to implement plans for restoration of vegetation (Al-Ansi *et al*., 2004); to maintain the gene bank stored in them (Yasseen and Al-Thani, 2007). In fact, urban development and construction activities that are being established in Qatar could greatly affect the wildlife (Fig. 2). Ecological restoration as a conservation strategy is urgently required since the world became conscious of the extent of degradation in landscape and resources due to human activities. Therefore, such efforts would be possible (Al-Ansi *et al*., 2004) for these plants after the determination of physical and chemical properties of their soils and the ecophysiological characteristics (Table 1, 3).

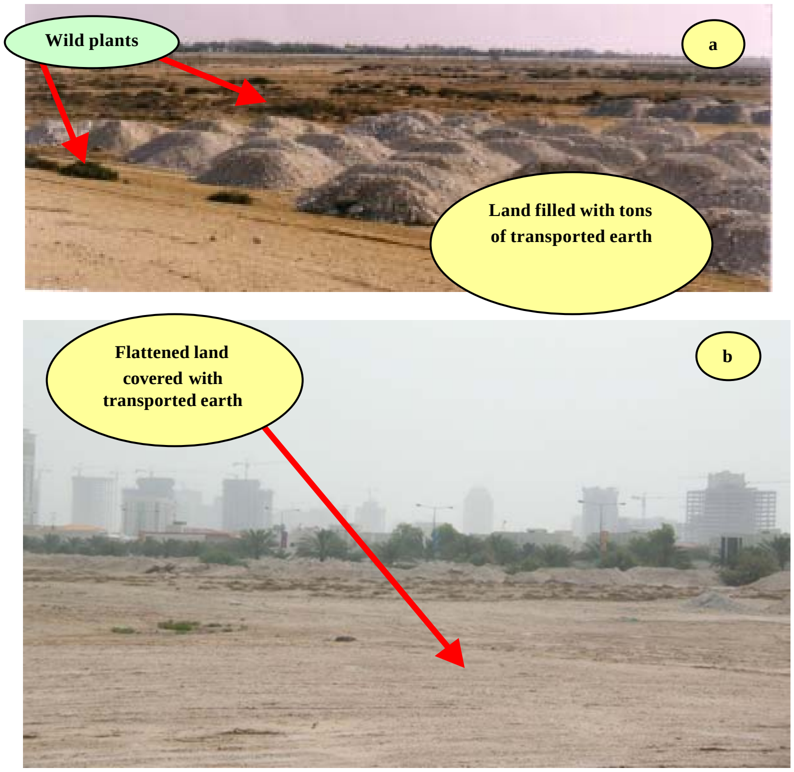

Fig. 2: Changes on the ground as a result of the establishment of towers and buildings which affected the wildlife in Doha: (a) near Qatar university, (b) inside Doha city

It is worth emphasizing that some ideas have been suggested that might help the decision makers in such efforts; in addition to the implementation of restoration and conservation plans; other measures can be taken including: imposing laws, creating natural reserves, activate the scientific research (Anish *et al*., 2008; Siddique and Bari, 2010; Zaman *et al*., 2011) and offering the educational materials to improve the awareness of people to the conservation of natural habitats (Yasseen and Al-Thani, 2007; Yasseen and Abu-Al-Basal, 2008, 2010). In fact, biologists might have no clear ideas about the real importance of wild plants in spite of the significant technical progress in molecular biology, genetic engineering and biotechnology tools. Moreover, people are not aware of what these plants might hide of unique genes that could provide experimental materials for modern molecular studies. Thus, mankind is clinging to what exist on the Earth surface to survive the current challenges in solving the problems of food crisis or those that might facing them in the coming years when the population is doubled with limited water and natural resources.

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