Pak. J. Bot., 45(2): 525-534, 2013.

DISTRIBUTION AND ABUNDANCE OF *ASTRAGALUS* L. IN SOME OF THE PERIPHERAL POPULATIONS IN THE CENTRAL REGION OF SAUDI ARABIA

JACOB THOMAS[1*], M.A. EL-SHEIKH[1,2], A.A. ALATAR[1], A.H. ALFARHAN[1] AND M. SIVADASAN[1]

[1]*Department of Botany & Microbiology, College of Science, King Saud University, Riyadh, Saudi Arabia*
[2]*Permanent address: Botany Department, Faculty of Science, Damanhour University, Damanhour, Egypt*
[*]*Corresponding author's e-mail: jathomas@ksu.edu.sa*

Abstract

Peripheral populations have significant conservation values due to their evolutionary potential and regional ecological implications. *Astragalus*, the largest genus in the flora of Saudi Arabia, has an extensive distribution range in West Asia. However, the distribution of *Astragalus* species in Arabian Peninsula is restricted. The present study analyzes the floristic diversity and ecology of some of the peripheral populations of *Astragalus* species occurring on the edge of their distribution range in central Saudi Arabia and highlights its common associations through TWINSPAN, DCA and CCA approach. Five 'Raudhas' (meadows) in the central region have been selected to quantify the density and abundance of *Astragalus* species. Although these populations in no way dominate the selected habitats as a whole, at least a few species exert a local dominance in some stands. 180 species were recorded from 150 stands, including 14 species of *Astragalus* and 15 very common associated species. 12 plant communities were recognized after application of TWINSPAN and DCA programmes. Based on the data obtained from 150 species-rich stands, we also assessed the relationships between edaphic-gradients and plant relationships using CCA. The results show that the pattern of distribution and existence of *Astragalus* species are highly influenced by both edaphic factors such as soil texture, pH, organic matter, etc. and competition among *Astragalus* species and associated species. As the peripheral populations of *Astragalus* in all ecologically divergent habitats of the central and eastern regions are potentially significant for future speciation events, protection of such populations have impending importance in the evolutionary process.

Introduction

Peripheral populations are seen along the edges of a species distribution range and are often regarded as isolated or disjunct (Jones *et al*., 2001). Populations seen on the periphery of a species' distribution range are ecologically divergent than central populations and are crucial to a species' past, present and future existence. Although the evolutionary importance of peripheral populations has been widely recognized, conservationists pay little attention for their preservation (Leppig & White, 2006). However, scientists have different opinions about the conservation importance of peripheral populations or habitats that hold disjunct or rare species. According to Gärdenfors (2001), extra attention is being given to common species that are considered rare in a jurisdiction because they are peripheral, or at the edge of their geographic range.

Astragalus L., apparently the largest genus in Angiosperms, consists of about 2500-3000 species, most of which are reported from the Irano-Turanian phytogeographical region (Podlech, 1986, Lock & Simpson, 1991, Mabberley, 1997, Maassoumi, 1998). A significant number of species is also reported from the Great Basin and Colorado Plateau of western North America (Polhill, 1981, Podlech, 1986; 1998). *Astragalus* is known to occur in a wide range of habitats in West Asia at altitudes varying from 600 to approximately 2800 m; of which majority are found in the Central Asian-Irano-Turanian region. Its occurrence gradually decreases and finally disappears towards south of this region. Arabian Peninsula is one such area where one can expect such decrease in concentration. This possibility underlines the importance of this species to the plant diversity of Saudi Arabia.

The presence of *Astragalus* species in other phytogeographical regions south of Saharo-Arabian zone is also less significant. Unlike the Saharo Arabian zone which includes the entire North Africa, where the genus has more than 33 species (Boulos, 1995), the diversity of *Astragalus* species is poor in Somalia-Masai phytogeographical region which includes both Northeast Africa and southwestern Arabian Peninsula. Several countries in the region such as Somalia, Eritrea, Sudan, Djibouti and southern Arabian Peninsula, the genus is represented by not more than 4 species each. Among these, *A. atropilosulus* is a polymorphic species containing about 7 varieties, and is widely distributed in the highlands of Somalia, Ethiopia and southwestern parts of Arabian Peninsula. So far only one work has been published on the occurrence of *Astragalus* species in the Arabian Peninsula (Hedge & Podlech, 1987) and it was based on an earlier account on the species present in the region.

Over the years, a large number of publications have been brought out on the genus, both on regional and global basis (Podlech, 1984, 1986, 1990, 1993, 1999, 2001; Wenninger, 1991). These publications have added several significant changes in the circumscription, nomenclature and distribution of many species of West Asian *Astragalus*. Migahid (1978) reported 19 species from Saudi Arabia, while Chaudhary (2001) and Collenette (1999) reported 24 and 25 species respectively. Recent estimates on the size of this genus in Saudi Arabia show that, species are classified under 15 sections; among these, sections *Chronopus*, *Harpilobus* and *Oxyglottis* are the largest with 4 species each. Distribution of species belonging to the Sections *Ammodendro*n, *Stenonychium* and *Xiphidium* is highly restricted, some of which are reported from a single locality with populations comprising not more than 100 plants.

Although the *Astragalus* account in the region is well below the *Astragalus* species in the Irano-Turanian region, the diversity of the genus in Saudi Arabia is very high, compared to the species' diversity present in other countries in Arabian Peninsula. Despite the wide occurrence of *Astragalus* species in other parts of West Asia, the genus occurs in marginal populations in some of the 'Raudhas' (meadows) of the Najd area of Saudi Arabia (an area which includes provinces such as Riyadh, Qassim and parts of eastern province), where it is given partial protection from over-grazing and off-road trafficking (Fig. 1). Apart from the morphological and phytogeographical analysis, no attempt has been made to study the ecology of the peripheral populations of *Astragalus* species. The main objective of this work is, therefore, (1) to evaluate the floristic and quantitative analysis of *Astragalus* populations and their associated species found on the edge of their distribution range in central region of Saudi Arabia and (2), to analyses the importance of conserving the vegetation of raudhas, using the populations of *Astragalus* and associated plants as a focal point.

Material and Methods

Study area: Raudhas are one of the characteristic features of the central region (Najd) of Saudi Arabia. These are large depressions against sand dunes, such as in the case of Raudhat Khuraim and Raudhat As Sabalah (Fig. 1), collecting propagules and rain water from watercourses during November to February. The soil water retention capacity of these depressions is, therefore, very high compared to the surrounding regions. Five meadows have been selected from the central region to study the abundance and frequency of *Astragalus* species, namely Raudhat Kafs (25° 26' 41.09" N- 46° 29' 01.00" E – Alt.-1919 ft.); Raudhat Noura (25° 42' 09.23" N 46° 13' 28.89" E– Alt.-1865 ft.), Raudhat Khasham (25° 55' 48.69" N 45° 46' 43.68" E– Alt.-2127 ft.), Raudhat Khuraim (25° 24' 43.2" N – 47° 15' 22.75" E Alt.- 1827 ft.) and Raudhat As Sabalah (26° 20' 46.25" N 44° 58' 01.14" E – Alt.-2169 ft.). All these habitats (A-E, Table 2), with areas ranging from 1000 to 3000 hectares, are partially protected from grazing and fully protected from wood cutting and off-road driving (Fig. 1).

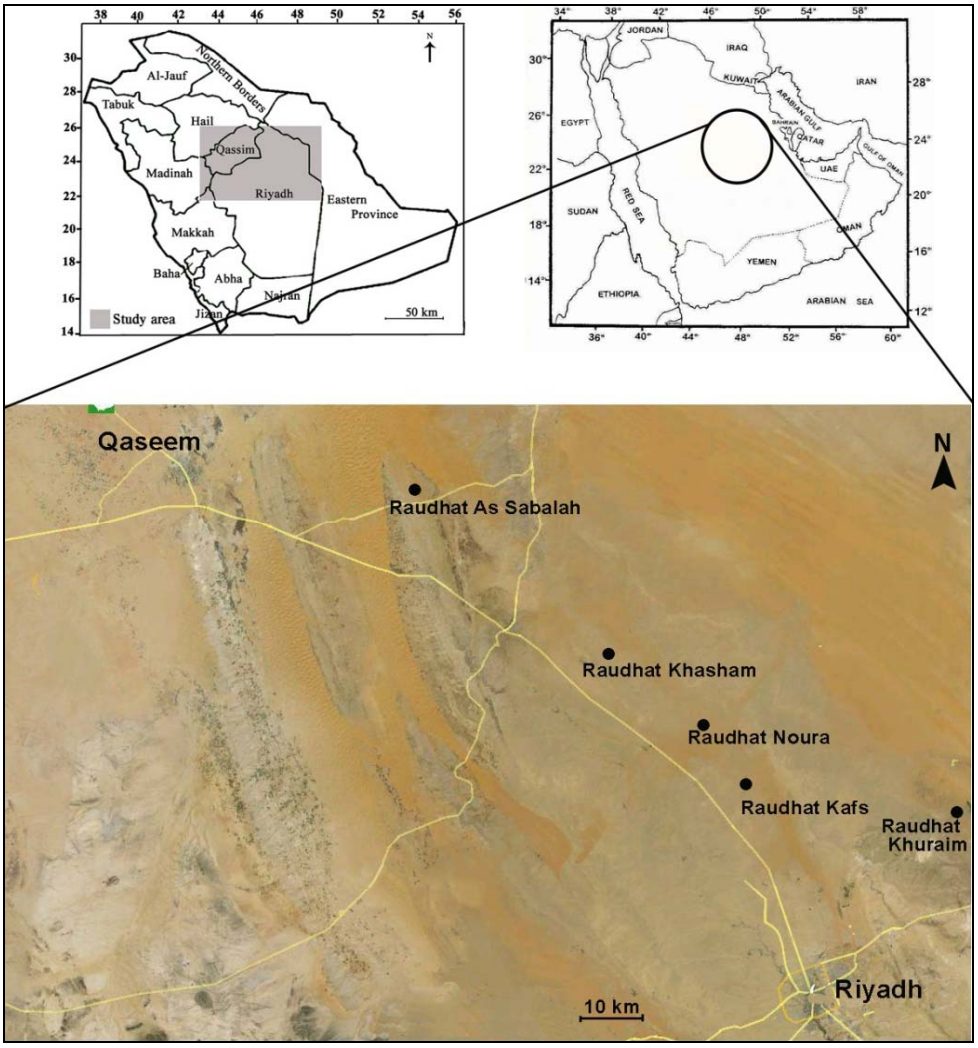


Fig. 1. Map showing various provinces and study area in Saudi Arabia.

Climate: Climate of the study areas is mild during winter and hot during summer. The mean maximum and minimum temperature, relative humidity and mean rainfall recorded at the three meteorological stations of the central region located at Riyadh, Qassim and Khurais are shown in Table 1. The data about *Astragalus*, in general, are based on documentation, accumulated and collated over many years of research. Rain plays an important role in shaping the diversity and abundance of the flora of Saudi Arabia, particularly in areas around the central region. Hence the qualitative studies were carried out mainly on certain years, where the amount of rainfall was above the average level. In general terms, the ecological conditions of the central region in Saudi Arabia are harsh. Rainfall is low to the extent that it only supports simple/impoverished vegetation gradients and, therefore, guarantees low establishment rates. However, meadows in the central region are rich in vegetation during spring season, most of which contain a variety of species of all types of life forms.

Sites: The data for this study was collected during a 10 year old field study to evaluate the floristics of all provinces in Saudi Arabia, including the ecology of the Raudhas of Najd region (Farraj *et al*., 1997, Al-Yemeni *et al*., 2000). Three transect lines were laid across the meadows in such a way that the lines pass through the areas with maximum vegetation or the areas containing maximum number of *Astragalus* spp. Ten stands, each measuring 50 m^2 were selected from each of these transects. Thus a total of 150 stands (10 stands x 3 transects x 5 localities/habitats) which approximates the minimum average area of the prevailing plant communities were selected so as to study the variations (Table 2). From each stand, species were recorded and the vegetation was analyzed qualitatively to determine the density value following the plot method described by Daubenmire (1968). Voucher specimens of plant species are kept in the Herbarium (KSU) of King Saud University and their identifications were carried out with the help of Chaudhary (1989, 1999, 2000, 2001), Collenette (1999) and Mandaville (1990). Three soil samples were taken along the depth of 0-50 cm from each stand. These soil samples were mixed together forming one composite sample for each stand and later air dried, sieved through 2 mm mesh and packed in cloth bags for physical and chemical analysis as outlined by Jackson (1960).

Results

Multivariate analysis: The data matrices of species density data were created: (1) matrix of 150 stands x 29 species density value of 15 *Astragalus* spp. and 14 very common associated species in the study area, (2) matrix of 150 stands x 29 species density values and soil variables. The first matrix was subjected to a numerical classification using Two-way indicator species analysis "TWINSPAN" (Hill, 1979a). TWINSPAN produces a hierarchical classification of vegetation groups (i.e. plant communities). Plant communities were named after their dominant species. The Detrended Correspondence Analysis "DCA" (Hill, 1979b) was applied to the same first matrix data sets in order to obtain an efficient graphical representation of ecological structure of the vegetation groups identified using TWINSPAN. In order to detect correlations of the derived vegetation associations with environmental data, Canonical Correspondence Analysis "CCA" according to (Ter Braak & Smilauer, 2002) was conducted with species density, stands and soil variables, "second matrix". Relationships between the ordination axes on one hand, and clusters group and soil variables, on the other hand were tested using Pearson's simple linear correlation coefficient (r).

Table 1. Annual range and mean of important climatic factors.

Climate factors	Riyadh		Qassim		Khurais	
	Range	Mean	Range	Mean	Range	Mean
Max. Temp. (°C)	20 - 43.9	31.95	19.7 - 46.3	33	19.2-42.9	34.6
Min. Temp. (°C)	7.5 - 25.7	16.6	6.4-26.6	16.5	6.4-26.6	16.4
Max. Rel. Hum. (%)	30.4 - 98	64.2	28.8-97	62.9	31.7-99	65.35
Min. Rel. Hum. (%)	4.0 - 14.4	9.2	5.6-15.1	10.35	7.1-16.2	11.65
Evaporation rate(mm)	105.4-432.6	269	102-408.6	255.3	68.3-607.3	337.8
Rainfall (mm)	0-24.6	12.3	0-38.6	19.3	0-49.7	24.85

Table 2. Stands (sites) code list. I, II and III are Transects of habitats A-E.

Raudhat Kafs (A)			Raudhat Noura (B)			Raudhat Khasham (C)			Raudhat Khuraim (D)			Raudhat As Sabalah (E)		
I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Stands 1-10	Stands 11-20	Stands 21-30	Stands 31-40	Stands 41-50	Stands 51-60	Stands 61-70	Stands 71-80	Stands 81-90	Stands 91-100	Stands 101-110	Stands 111-120	Stands 121-130	Stands 131-140	Stands 141-150

Table 3. ***Astragalus*** **species with sections and their representation in various provinces of Saudi Arabia.**

Names of sections, species and abbreviations of species names	Provinces in Saudi Arabia												
	Riyadh (a)	**Eastern Pro. (b)**	**Qassim (c)**	**Hail (d)**	**Tabuk (e)**	**Northern Pro. (f)**	**Jauf (g)**	**Madina (h)**	**Makkah (i)**	**Baha (j)**	**Abha (k)**	**Jizan (l)**	**Najran (m)**
Section- Haematodes	+	+	+	+		+	+						
A. annularis (A.ann.)													
A. arpilobus (A. arp.)					+								
Section- Oxyglottis													
A. asterias (A. ast.)			+		+								
A. schimperi (A. sch.)	+	+	+	+	+	+	+						
A. sinaicus (A. sin.)	+												
A. tribuloides (A. tri.)	+	+	+	+	+	+	+						
Section- Chlorostachys													
A. atropilosulus ssp. *abyssinicus (A. atr.)*				+					+	+	+	+	
Section- Platyglottis													
A. bombycinus (A. bom.)	+	+		+	+	+	+						
Section- Caprini													
A. caprinus (A. cap.)					+								
Section Ammodendron													
A. collenettiae (A. col.)				+	+		+						
Section- Harpilobus													
A. corrugatus (A. cor.)	+	+	+		+		+						
A. hauarensis (A. hau.)		+	+			+							
A. intercedens (A. int.)					+		+						
A. mareoticus (A. mar.)							+	+					
Section- Chronopus													
A. dactylocarpus (A. dac.)					+		+				+		
A. fruticosus (A. fru.)					+								
A. seiberi (A. sie.)	+	+	+	+	+	+							
A. sparsus (A. spa.)								+			+		
Section- Stenonychium													
A. echinus ssp. *arabicus (A. ech.)*					+								
Section- Falcinellus													
A. eremophilus (A. ere.)	+	+											
Section- Poterion													
A. fasciculifolius (A. fas.)		+											
A. spinosus (A. spi.)	+	+	+	+	+		+						
Section- Buceras													
A. hamosus (A. ham.)				+									
Section- Eremophysa													
A. kahiricus (A. kah.)		+	+	+		+	+						
***Section*- Xiphidium**													
A. trachoniticus (A. tra.)							+						
Section- Herpocaulos													
A. vogelii ssp. *fatmensis (A. vog.)*	+				+		+					+	+
(γ)Gama diversity	10	11	9	10	15	6	12	2	1	1	3	2	1

Floristic analysis: The northern half of Saudi Arabia contains more *Astragalus* than the southern half (Al-Hassan, 1427 H). The number of species occurring in different regions of Saudi Arabia is depicted in Table 3. The number of species falls dramatically towards south with only 2-4 species occurring in northwest, south and southwest. *Astragalus atropilosulus* is the only species found in the southwestern mountains with an East African affinity and a distribution range extending from Ethiopia to Yemen. Southwestern and northwestern mountains are remarkable in terms of speciation and density and contain a significant number of plant diversity hotspots, such as Jabal Dabbagh, Jabal Lauz, Asir Mountains, etc. These areas serve as an ideal niche for several endemic species of Arabian flora including a few *Astragalus* species. *A. echinus* ssp. *arabicus* and *A. collenettiae* are endemic to the region with restricted distribution and population sizes of fewer than 500 plants each, particularly in Saudi Arabia. Among the endemics, *A. fruticosus* Forssk., is an endangered Mediterranean plant represented by less than 50 plants housed in Jabal Lawz (2700 m), a mountain situated in the extreme northwestern part of Saudi Arabia. The analysis show that the highest diversity is in the Northern Provinces (15 spp.), where the genus accounts for at least 58% followed by the Najd region (14 spp.). However, as far as the abundance and density are concerned (over 30 individuals of a particular species were recorded from some of the stands), the Najd region, which comprised of some of the areas of the central and eastern provinces, predominate all other regions, primarily due to the presence of all major raudhas/meadows. Meadows or areas filled with silt are the main habitat of majority of *Astragalus* species of the central and eastern regions exccept *A. spinosus* which often found outside meadows, especially in wadis (Valleys).

Viewed against the overall ecological conditions of areas south of Iraq and Jordan, it seems logical to speculate that aridity, which is the most prominent selection pressure in Saudi Arabia, is responsible for the non-occurrence of some of the widely distributed *Astragalus* taxa of Iraq and Iran. *A. corrugatus* and *A. tribuloides* of sectons *Harpilobus* and *Oxyglottis* respectively are the most highly derived infra-generic taxa within *Astragalus*. Both occur almost throughout the geographic range of the northern, central and eastern regions, being absent only from the sandy deserts. *A. vogelii* ssp. *fatmensis,* the only annual under the section *Herpocaulos* in West Asia, has a wide distribution within Saudi Arabia, while *A. atropilosulus* ssp. *abyssinicus* (section *Chlorostachys*) is frequently seen in the southwestern mountains (Wood, 1997). *A. vogelii*, however, has a disjunct distribution, as it is also reported from South Asia. Both species are abundant in North East Africa, particularly in Somalia, Ethiopia, Sudan, Eritrea, with smaller centers of abundance in North African region, particularly in Egypt. The center of origin of these 2 species is, therefore, appears to be the Somali-Masai phytogeographical zone which includes both northeast Africa and southwestern Arabia.

Among the regions studied, the highest similarity of occurrence is between Tabuk Province and Al-Jouf Province (34.62%) followed by Riyadh Province and Eastern Province and between Qassim Province and Eastern Province (30.77% each). Northern provinces such as Tabuk and Al-Jouf are close to Irano-Turanian phytogeographic region and therefore contain more *Astragalus* taxa. Species such as *A. arpilobus, A. asterias, A. echinus* ssp. *arabicus* have restricted their distributions in the above provinces, some 900 km north of Riyadh. About 42.31% of the taxa occur in hard sand/silt habitats, 19.24% and 11.53% in Rocky/gravel and high altitude areas respectively, while the remaining 26.92% inhabit edges of meadows, sandy and rocky deserts. Most of the other taxa had restricted ranges or occurred in relatively small disjunct patches over their ranges (Table 4).

Table 4. Matrix of similarity indices showing species occurrence (%) between different regions/provinces.

Region/ province	a	b	c	d	e	f	g	h	i	j	k	l	m
a	-	30.77	23.08	26.09	19.23	15.38	23.08	0	3.84	3.84	7.69	0	7.69
b		-	30.77	26.92	23.07	26.92	26.92	0	0	3.84	3.84	0	0
c			-	23.07	23.07	23.07	23.07	0	0	3.84	3.84	0	0
d				-	23.07	23.07	26.92	0	3.84	3.84	0	3.84	0
e					-	15.38	34.62	0	0	0	3.85	3.85	3.85
f						-	19.23	0	0	0	0	0	0
g							-	3.85	0	0	7.69	3.85	3.85
h								-	0	0	3.85	0	0
i									-	7.69	7.69	7.69	0
j										-	7.69	7.69	0
k											-	3.85	0
l												-	0
m													-

a- Riyadh, b- Eastern Province, c- Qassim, d- Hail, e- Tabuk, f- Northern region, g- Jauf, h- Madina, i- Makkah, j- Baha, k- Abha, l- Jizan, m- Najran.

Community structure: The density estimates data of 180 species from 150 stands, 29 species of them are filtered which include 14 *Astragalus* species and 15 very common associated species in 150 stands (i.e. the first matrix was 29 species x 150 stands). 151 species of the total species 180 are excluded to avoid disturbances in analysis as most of them are constantly sparse and geographically restricted in specific stands with lower densities. Therefore, application of TWINSPAN on the density estimates matrix of 29 filtered species x 150 stands, led to the recognition of 12 vegetation groups at the 6th level of classification (Fig. 2a). The application of DECORANA (DCA) on the same set of data indicated a reasonable segregation between many of these groups along the ordination plane of axes 2 and 3 and the mean values of these 12 groups were drawing along these axes (Fig. 2b). The characteristic species of these groups are identified according to the dominant species (Table 5). These are the most common *Astragalus* species, associated with other common species in the study area. The *A. tribuloides-A. annularis* VG no. 9, characteristic of the Riyadh region (63 stands = 42 %), has the highest representation and contains most of the *Astragalus* spp., followed by *A. spinosa,* VG no 8 (23 stands = 15.3 %) which inhabits in the Eastern and Riyadh Provinces. *A. corrugates* VG no. 7, on the other hand, (19 stands = 12.7 %) inhabit the Eastern Province-Qassim Region (Table 5 and Fig. 2a & b). In almost all stands the common annuals associating with the populations of *Astragalus* spp. are *Calendula arvensis, Spergula fallax, Tripleurospermum auriculatum, Trigonella anguina, Phalaris minor* and *Matricaria aurea.* However, the perennial components vary from stand to stand. In Raudhat Khuraim and Raudhat Khafs, the dominant species are *Acacia gerrardii, Rhazya stricta* and *Lycium shawii* while in others *Pulicaria undulata, Calotropis procera* and *Lycium shawii* predominate.

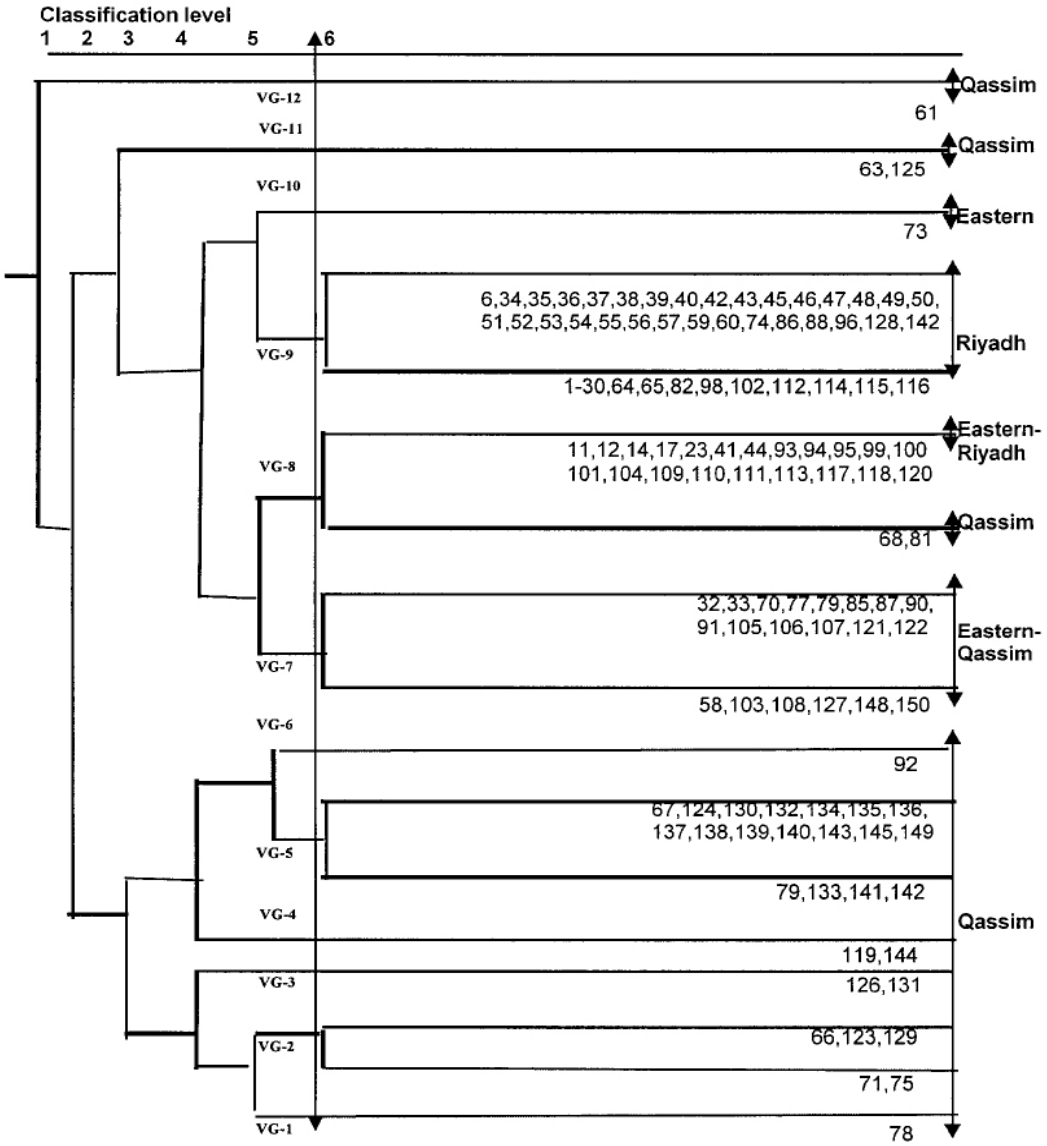
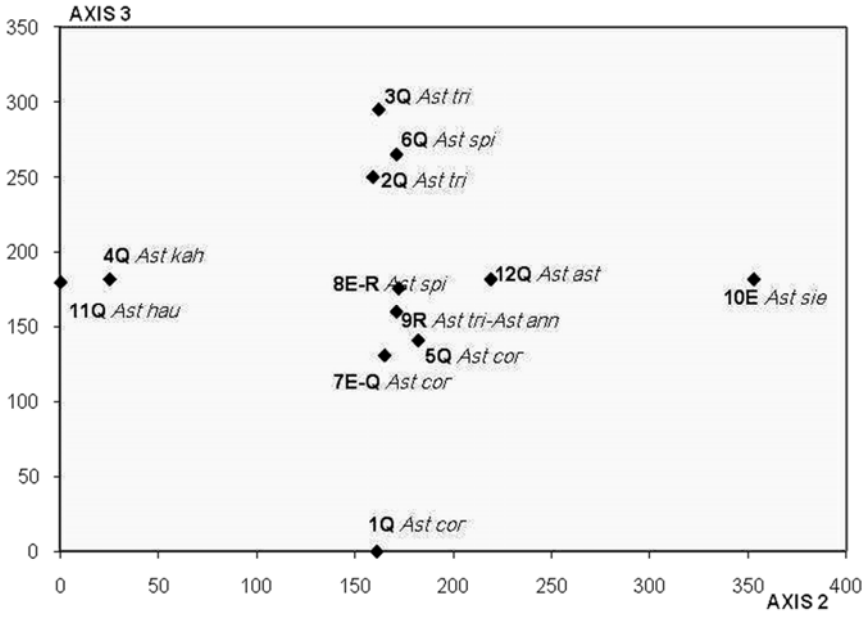


Fig. 2a. TWINISPAN and DCA of classification and ordination of the 12 vegetation group identified after TWINSPAN applied on the density values of *Astragalus* spp. and their associated species in 150 stands.



2b. DCA. E- Eastern Province, Q- Qassim, R-Riyadh.

Table 5. The characteristic species of 12 vegetation groups and their localities.

Veg. group	Characteristic species	No. of stands	Locality	Average relative density of the characteristic species
1	*Astraglus corrugatus.*	1	Qassim	32
2	*A. tribuloides*	5	Qassim	31
3	*A. tribuloides*	2	Qassim	8
4	*A. kahiricus*	2	Qassim	1
5	*A. corrugatus*	18	Qassim	2
6	*A. spinosus*	1	Qassim	3
7	*A. corrugatus*	19	Eastern-Qassim	13
8	*A. spinosus*	23	Eastern-Riyadh	1
9	*A. tribuloides- A. annnularis*	63	Riyadh	2
10	*A. sieberi*	1	Eastern Province	33
11	*A. haurensis*	2	Qassim	34
12	*A. asterias*	1	Qassim	11

Edaphic variables and plant communities: The values of correlation coefficients between the soil variables and the axes for CCA ordination (Table 6) suggest that the separation of the *Astragalus corrugates, A. bombicynus, A. annularis, A. sieberi*, *A. tribuloides* and *A. haurensis* are strongly influenced by positive values of sand (r = 0.40) and organic matter (r = 0.2) and *A. sinaicus, A. fasiculifolius* and *A. kahiricus* are strongly influenced by the negative values of silt (-0.31) and clay (-0.30) along the first axes. On the other hand, *A. spinosa, A. schimperi, A. vogelii* and *A. eremophilus* are negatively correlated with pH (r = 0.30) along the second axis of CCA (Table 6). The CCA diagram (Fig. 3) shows that sand, organic matter, pH, silt and clay are the most important factors relating to the distribution of *Astragalus* and associated species in the study area.

Table 6. The correlation values between soil variables and CCA axes.

Variables	Axis 1	Axis 2	Axis 3	Axis 4
pH	-0.2423*	0.2911*	-0.0846	0.0476
EC	0.0086	-0.1203	0.2594*	-0.0554
Organic matter	0.2000*	-0.0673	-0.1444	-0.0299
Sand	0.3388**	0.1318	0.1253	0.1572
Silt	-0.3066*	-0.1021	-0.1203	-0.1878
Clay	-0.2399*	-0.2390*	-0.0686	0.1597

*= p≤0.05 and ** =p≤0.01

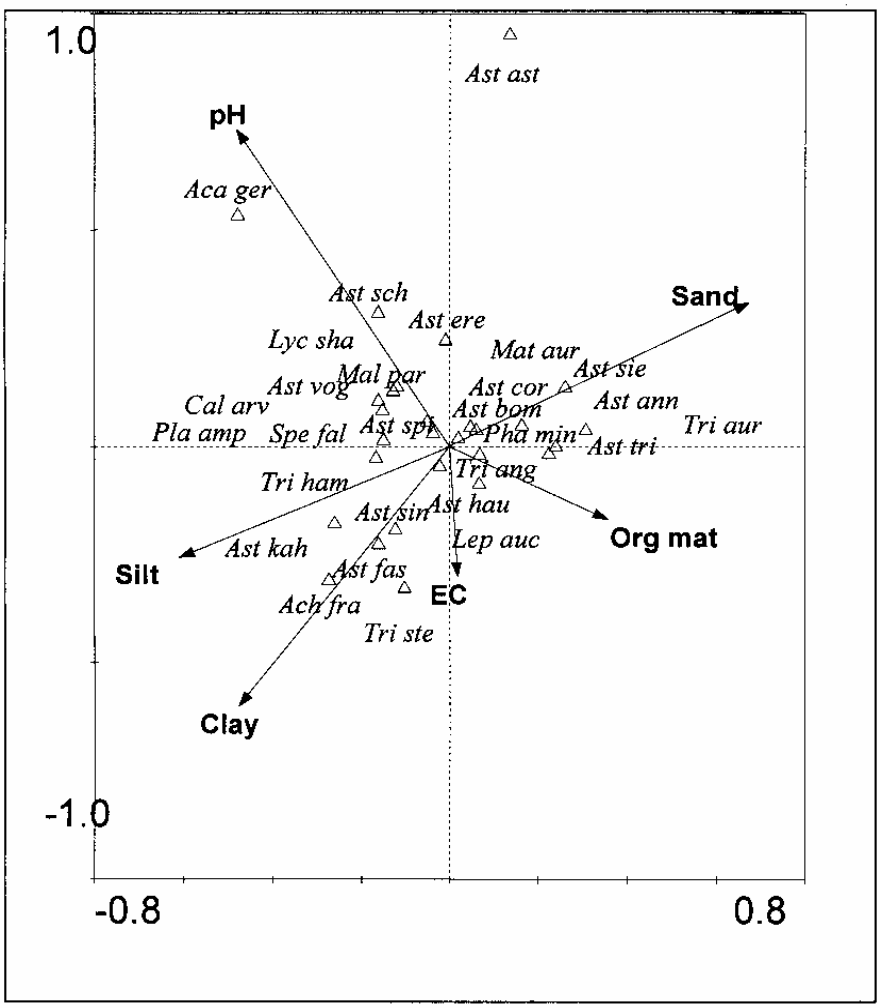


Fig. 3. CCA. Species and environment biplot with arrows and points indicating the environmental factors and the species respectively. Aca. ger. (*Acacia gerrardii*), Mal. par.(*Malva parviflora*), Lyc sha (*Lycium shawii*), Cal. arv (*Calendula arvensis*), Pla amp (*Plantago amplexicaulis*), Spe fal (*Spergula fallax*), Ach fra (*Achillea fragrantissima*), Lep auc (*Lepidium aucheri*), Tri ang (*Trigonella anguina*), Pha min (*Phalaris minor*), Mat aur (*Matricaria aurea*), Tri aur(*Tripleurospermum auriculatum*), Tri ste(*Trigonella stellata*), Tri ham (*Trigonella hamosa*)

Discussion

Peripheral populations are more likely to be vulnerable than central populations as they have several characteristics such as their occurrence in variable densities, ecologically distinctiveness, restricted level of gene flow, low level of genetic variation and greater extinction risk (Jones *et al*., 2001). Majority of peripheral populations, in general, tend to exhibit in variable densities and are more fragmented than central populations. Species such as *A.asterias,A. haurensis* and *A. fasciculifolius* are represented in Saudi Arabia by a small populations represented by not more than 100 individuals. Although the evolutionary significance of peripheral populations has long been documented, their characteristics and conservation value generally received little attention. Peripheral populations can also have enhanced ecological and evolutionary significance. It can be both a cause and a consequence of their isolation and small size, and therefore correlated with reduced viability and increased extinction risk (Leppig & White, 2006).

It is widely accepted that species conservation depends on safeguarding the genetic variability present throughout the range of a species. However, one of the main reasons for the extinction of rare or highly fragmented species at regional/local level is the negligence of peripheral but distinctive populations. Existing evidences support that peripheral populations are often genetically and morphologically divergent from central populations. This is true in the case of *A. haurensis* and *A. fasiculifolius* because both species are almost disappeared from Raudhat Khuraim and Noura due to some anthropogenic activities like setting up of some enclosures and excessive grazing. Leppig & White (2006) proposed three categories of criteria for evaluating the conservation significance of a peripheral population: 1) geographic isolation, 2) environmental distinctiveness, and 3) intrinsic human values. Small scale pattern of *Astragalus* communities is one of the remarkable sources of diversity in species-poor arid regions (El-Sheikh & Yousaf, 1981; Schultz & Whitney, 1986)). Many of these species have shown highly restricted distribution,

apparently related to the prevailing soil types in the central region and possibly due to short range dispersal methods, such as hydrochory. Species richness and density of *Astragalus* observed in this study were relatively higher than similar studies conducted in at least one of the prominent raudhas in the Eastern Province (Shaltout & Mady, 1996; Al-Yemeni *et al*., 2000).

The *Astragalus* floras of northwestern and southwestern regions are highly distinctive; it shows a greater degree of similarity to Mediterranean and northeast African *Astragalus* species respectively. However, the density and speciation of *Astragalus* in these regions, particularly in East Africa is significantly low. The genus shows two 'centres of species richness', one in the northern region and a second one in the Eastern Province. Only two sections, *Harpilobus* and *Oxyglottis*, are somewhat widespread, occurring in all parts of the distributional range within the highly dominated areas except in high altitude areas and in deep sands. All other sections have fairly restricted distributions, being more or less confined to raudhas or to open plains of central region. There are a few widespread species in *Astragalus*. The most important of which, occurring naturally in all parts of the central, eastern and northern regions, except in sand dunes, is *A. spinosa* followed by *A. corrugatus*.

Other notable features of the distribution patterns in *Astragalus* include low levels of regional endemism. Species belonging to the floras of Arabian Peninsula thus tend to be less distinctive and are dominated by members of only a few of the sections recognized within the genus. The highest degree of similarity between any 2 regions occurs between the Najd area and the regions covering flora of Northern regions. The degree of similarities/ dissimilarities between these regions, however, is relatively insignificant.

Twelve plant communities of *Astraglus* are created after application of TWINSPAN to the estimates of 29 (14 *Astragalus* species and 15 associated species) species in 150 stands. The application of DCA to the same set of data also supports the difference between the 12 vegetation units coinciding with ecological variations. Although majority of *Astragalus* spp. in no way demonstrated any dominance in their respective stands, the genus has some indicator value in the stands from where the species has been recorded. This is evident from the abundance value of each *Astragalus* species in various vegetation groups obtained from two way indicator species analysis. Riyadh plant community (VG-9) has the highest number of stands supporting the *A. tribuloides-A. annularis* group while *A. corrugatus* is characterized for VG-1, 5 and 7. *A. spinosa*, a dominant component of the desert ecosystem in the Riyadh and Qassim Provinces is characteristic of the VG-6. The members of each pair of groups are in most cases linked together by having one of the indicator species in common. The relationships between soil and vegetation units are more significant when DCA and CCA are applied to correlate the species to various soil characteristics. The demarcation of VG along different axis implies that various intricate factors control the distribution pattern of vegetation in the studied raudhas of the central region. Extrapolation of the arrow back through the origin gives indication that species such as *A. sieberi, A. corrugatus, A. fasiculifolius, A. eremophilus*, etc. prefer silt while *A. annularis, A. spinosa, A. schimperi, A. bombycinus*, etc. prefer soil with less moisture content. It is apparent from the field study that the latter set of species usually found in habitats away from the raudha, are often found in less deep sandy areas close to raudhas. From the study it can be concluded that ordination of vegetation groups are generally separated from each other and sometimes often interrelated. The segregation of these groups along both axis of biplot implies that soil characters seem to play an important role in the distribution pattern of *Astragalus* species in the studied Raudhas (Shaltout & Mady, 1996).

A number of factors are correlated with the existence of peripheral populations in a fragile environment such as the arid habitats prevailing in the central parts of Saudi Arabia. Favorable soil composition and water are essential for plants for a number of reasons (Ghazanfar & Osborne, 2010, Shaukat *et al*., 2012, Altay *et al*., 2012). Soil water affects plant growth directly through its controlling effect on plant-water status and indirectly through its effect on temperature, nutrient transport and aeration uptake and transformation (Bouma *et al*., 1982). Evidently, extreme dryness/aridity as found in some localities in northern, central and eastern Saudi Arabia is detrimental to *Astragalus* diversity (Mandaville, 1990; Shaltout & Mady, 1996). As shown from the analysis here, species richness peaks around two Provinces of northern region. These can be seen as 'islands' of *Astragalus* diversity in Saudi Arabia that have in common a high diversity of terrain and habitats that jointly support varied life forms and can be considered as high priority areas for the conservation of the genus.

Conclusion

One foreseeable result of ignoring peripheral populations without efficient and critical assessment of their state is the loss of habitats where these populations are housed. The conservation of peripheral plant populations is inconsistent. Populations occurring on the edge of a species' range tend to be smaller, more isolated, and more genetically and ecologically different than central populations. The diversity and abundance of *Astragalus* in the northern half of Saudi Arabia is somewhat significant. However, most of the *Astragalus* populations restricted to the Northern provinces (Tabuk and Al-Jouf) are thin and highly fragmented. The abundance and frequency of these populations are mainly controlled by local environmental factors such as topography, sediment type and local moisture conditions. Analysis of vegetation carried out in a few important raudhas in the central region of Saudi Arabia shows that the vegetation of these depressions carries low species diversity than the diversity of vegetation elsewhere. The extra arid climate due to low precipitation and soil instability are some of the reasons for low species diversity, particularly the perennial components. However, the presence of annuals in areas with low rainfall is relatively high. About 46-55 % of the total native flora of Northern, Eastern and Central Provinces are annuals, majority of which are found in depressions, along the banks of seasonal streams and crevices of slopes. Better soil moisture and fertility in raudhas are the basic reasons for the active growth of raudha-vegetation. This explains why most of the *Astragalus* species are found in the raudhas and their density and speciation decreases towards south of Riyadh where aridity increases. As the habitats of peripheral populations are potentially important for future speciation events, the long-term

conservation of the genetically depend peripheral populations of *Astragalus* species is expected to depend on total protection. At present, the raudhas are managed by either the local governments such as in the case of Raudhat Khuraim by the Municipality of Rumah or by the Ministry of Agriculture itself. All these raudhas are partially protected and grazing is controlled or deferred until the seed setting of annuals. The significant and most effective conservation measures for *Astragalus* spp. in these raudhas and the central region in general would be to maintain the populations at the existing stands by protecting them fully and attempting to expand the populations by increasing their size and the habitats they cover.

Acknowledgements

Authors are thankful to the National Plan for Science and Technology, (NPST) program, King Saud University, Riyadh, Saudi Arabia for providing funds through Project No. 10-ENV1295-02.

References

Al-Hassan, H.O. 1427 H. *Wild plants of the Northern Region of the Kingdom of Saudi Arabia*. Camel and Range Research Center, Al-Jouf.

Altay, V., I.I. İözyiğit and C. Yarci. 2012. Plant communities in urban habitats of Istanbul-Turkey. *Pak. J. Bot*., 44(SI): 177-186.

Al-Yemeni, M.N., M.M. Al-Farraj and A.H. Alfarhan. 2000. Ecological studies on Rawdhat system in Saudi Arabia - II. Soil seed bank of Rawdhat Khorim, *Pak. J. Bot*., 32(2): 273-282.

Boulos, L. 1995. *Flora of the Egypt, Checklist*. Al Hadara Publishing, Cairo, Egypt.

Bouma, J., R.B. Brown and P.S.C. Rao. 1982. Basics of Soil-Water Relationships - Part I. Soil as a Porous Medium. *Soil Science Fact Sheet SL-37*. Florida Cooperative Extension Service, IFAS, Gainesville, FL.

Chaudhary, S. 1989. *Grasses of Saudi Arabia*. Ministry of Agri. & Water, Riyadh.

Chaudhary, S. 1999. *Flora of the Kingdom of Saudi Arabia. Vol. 1*. Ministry of Agri. & Water, Riyadh.

Chaudhary, S. 2000. *Flora of the Kingdom of Saudi Arabia. Vol. 2 (part 2)*. Ministry of Agri. & Water, Riyadh.

Chaudhary, S. 2001. *Flora of the Kingdom of Saudi Arabia. Vol. 2 (part 1)*. Ministry of Agri. & Water, Riyadh.

Collenette, S. 1999. *Wild flowers of Saudi Arabia*, National Commission for Wildlife Conservation and Development, Riyadh.

Daubenmire, R. 1968. *Plant communities: a textbook of plant synecology*. Harper and Row, New York.

El-Sheikh, A.M. and M.M. Yousaf. 1981. Halophytic and xerophytic vegetation near Al-Kharj springs. *J. Coll. Sci.*., University of Riyadh, 12: 5-21.

Farraj, M.M., M.N. Yemeni, A.H. Alfarhan. 1997. Ecological studies on raudhat system in Saudi Arabia. 1- Raudhat Khorim. *Pak. J. Bot*., 29(1): 75-88.

Gärdenfors, U. 2001. The application of IUCN Red List criteria at regional levels. *Conserv. Biol*., 15: 1206-1212.

Ghazanfar, S.A. and J. Osborne. 2010. Conservation through restoration: study of a degraded gravel plain in south-eastern Arabia. *Pak. J. Bot*., 42(SI): 193-204.

Hedge, I.C. and D. Podlech. 1987. A first survey of *Astracantha* and *Astragalus* in the Arabian Peninsula. *Botanische Jahrbücher für Systematik*. 108: 259-270.

Hill, M.O. 1979a. *DECORANA- A FORTRAN Program for Detrended Correspondence Analysis and Reciprocal Averaging*. Cornell University, Ithaca, NY.

Hill, M.O. 1979b. *TWINSPAN- A FORTRAN Program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes*. Cornell University, Ithaca, NY.

Jackson, M.L. 1960. *Soil Chemical Analysis*. Prentice-Hall, Englewood Cliffs, New York.

Jones, B., C. Gliddon and J.E.G. Good. 2001. The conservation of variation in geographically peripheral populations: *Lloydia serotina* (Liliaceae) in Britain. *Biological Conservation* 101: 147-156.

Leppig, G. and J.W. White. 2006. Conservation of peripheral plant populations in California. *Madrono* 53(3): 264-274.

Lock, J.M. and K. Simpson. 1991. *Legumes of West Asia, a check-list*. Royal Botanic Gardens, Kew.

Mandaville, J.P. 1990. *Flora of Eastern Saudi Arabia*. Kegan Paul International, London jointly with the National Commission for Wildlife Conservation and Development, Riyadh.

Maassoumi, A.A. 1998. Old world checklist of *Astragalus*. Research Institute for Forests and Rangelands, Tehran.

Mabberley, D.J. 1997. *The Plant Book*. Cambridge University Press, Cambridge.

Migahid, A.M. 1978. Flora of Saudi Arabia. Vol. 1. Riyadh University Publications, Riyadh.

Podlech, D. 1984. Revision von *Astragalus* L. sect. *Herpocaulos* Bunge. *Mitt. Bot. Staatss. Munchen*, 20: 441-449.

Podlech, D. 1986. Taxonomic and phytogeographical problems in *Astragalus* of old world and south – west Asia. *Proc. Roy. Soc. Edinburgh*, 89: 37-43.

Podlech, D. 1990. Revision von Astragalus L. sect. Platyglottis Bunge (Leguminosae). *Mitt. Bot. Staatss. Munchen*, 29: 541-572.

Podlech, D. 1993. Revision von *Astragalus* L. sektion *Erymophysa* Bunge unde *Erymophysopsis* Gontsch. (Leguminosae). *Sendtnera*, 1: 45-64.

Podlech, D. 1998. Typification of Astragalus species II. Species mainly of the herbaria of Paris (P) und Geneva (G). *Sendtnera*, 5: 247-263.

Podlech, D. 1999. Papilionaceae III. Astragalus. In: *Flora Iranica*, (Ed.): K.H. Rechinger, No. 174. Akademische Druck und Verlagsansta, Graz, Austria. pp. 1-350.

Podlech, D. 2001. Contribution to the knowledge of the genus *Astragalus* L. (Leguminosae) VII – X. *Sendtnera*, **7**: 163-201.

Polhill, R.M. 1981. Tribe Galegeae. In: *Advances in Legume Systematics*, (Eds.): R.M. Polhill and P.H. Raven. Royal Botanic Gardens, Kew, England. 1: 357-363.

Schultz, E. and J.W. Whitney. 1986. Vegetation in north-central Saudi Arabia. *J, of Arid Environments*, 10: 175-186.

Shaltout, K.H. and M.A. Maday. 1996. Analysis of Raudhas vegetation in Central Saudi Arabia, *J. of Arid Environments*, 34: 441-454.

Shaukat, S.S., S. Aziz, W. Ahmed and A. Shahzad. 2012. Population structure, spatial pattern and reproductive capacity of two semi-desert unfershrubs Senna holosericea and Fagonia indica in southern Sindh, Pakistan, *Pak. J. Bot*., 44(1): 1-9.

Ter Braak, C.J.F. and P. Šmilauer. 2002. CANOCO *Reference Manual and CanoDraw for Windows User's Guide: Software for Canonical Community Ordination (version 4.5). Microcomputer Power*, Ithaca, NY, USA.

Wenninger, J. 1991. Revision von *Astragalus* L. sect. *Chlorostachys* Bunge, sect. *Phyllolobium* Bunge und sect. *Skythropos* Simpson (Leguminosae). *Mitt. Bot. Staatss. München* 30: 1-196.

Wood, J.R.I. 1997. *A handbook of the Yemen Flora*. Royal Botanic Gardens, Kew.

(Received for publication 9 January 2012)