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Population Ecology of *Rhazya stricta* Decne. in Western Saudi Arabia

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ABSTRACT

The present study aims at analyzing the phytosociological behavior and size structure of *Rhazya stricta* Decne. This plant is distributed in many parts of Saudi Arabia except the high mountains. It is known worldwide as a medicinal plant with economic potentialities. The study area comprises three locations (1) Wadi Fatma which was crossed by the motor road for a distance about 28 km, (2) Makkah-Al-Sharaya road, 30 km from Makkah, (3) Al-Sharaya-Al-Taif road along Makkah-Al-Taif road, that extends for about 70 km. The application of multivariate techniques such as TWINSPAN, DCA and CCA lead to identify five vegetation groups associated with the distribution of *Rhazya stricta*, namely *Acacia trotilis-Capparis deciduas* and *Senna italica-Citrullus colocynthis* (group A), *Acacia hamulosa- Acacia ehrenbergiana* (group B), *Aerva javanica-Blepharis ciliaris* (group C), *Lycium shawii-Acacia tortilis* subsp. *raddiana* (group D) and *Fagonia acerosa- Euphorbia granulata* (group E). Apart from *Rhazya stricta*, *Acacia ehrenbergiana* and *Aerva javanica* were the most common recorded species. The highest species richness was found in group (D) that in the meantime characterized by the highest share of annuals. From the intraset correlations of the environmental variables, CCA axis 1 was negatively correlated with silt, clay and pH, while axis 2 was positively correlated with sand. Size differences in plant population revealed that the highest values of size index per individual were in Wadi-Fatma (183.75± 89.23). The height/diameter ratio for *Rhazya stricta* populations was less than 0.5 which indicates that the individuals of this species tend to expand horizontally rather than vertically.

Key Words: Demography; Species diversity; Multivariate analysis; Vegetation-environment relations; Saudi Arabia

INTRODUCTION

Extensive studies on the desert vegetation in Saudi Arabia has been described in terms of the climax dominants, amongst others, Vesey-Fitzgerald, 1955; 1957a, b; Mandaville, 1965; 1986; Migahid & El-Sheikh, 1977; Organgi, 1982; Batanouny & Baeshin, 1983; Zayed & Fayed, 1987; Abd El-Ghani, 1993; 1996). This desert vegetation was by far the most important and characteristic type of natural plant life, it is mainly formed of xerophytic shubs and sub-shrubs. Monod (1954) recognized two types of desert vegetation, namely contracted and diffuse. Both types refer to permanent vegetation that can be accompanied by ephemeral (or annual) plant growth depending on the amount of precipitation in a given year. Kassas (1966 & 1971) added a third type termed "accidental vegetation", where precipitation is so low and falls so irregularly that no permanent vegetation exists. As arid zones are usually characterized by minimal precipitation and frequent droughts (Mabbutt, 1977), thus availability of water is one of the primary factors controlling the distribution of species (Noy-Meir, 1973; Yair & Danin, 1980). Correlation of soils and vegetation are important for most investigations of plant habitats. In the arid regions of the Middle East, Hillel and Tadmor (1962), Kassas and Girgis (1965), Olsvig-Whittaker *et al*. (1983), Bairele *et al.* (1985) Stahr *et al*. (1985) and Abd El-Ghani (1997, 2000b) worked in this direction. These investigations include large areas and therefore, they reported striking gradients referring to soil conditions and vegetation.

The study area was selected according to extensive spread of *Rhazya stricta* Decne. that located at the middle parts of the western coastal plain around Makkah. This plant is one of the perennial shrubs, belonging to the family Apocynaceae, which includes about 1300 herbs, shrubs and trees belonging to about 300 genera mostly tropical and subtropical regions (Täckholm, 1974; Boulos, 1995). Plants of this family are of medicinal and economic value.

The present study provides an analysis of the phytosociological behavior and size structure of *Rhazya stricta* shrub in its natural habitats along three locations, Wadi-Fatma, Makkah-Al-Sharaya road and Al-Sharaya-Al-Taif road. Vegetation composition in relation to the prevailing environmental gradients was also described.

To the author's best knowledge, nothing was published until the present concerning the population ecology of the Saudi Arabian plants. This encourages the author to conduct this study.

MATERIALS AND METHODS

Twenty-eight stands each of 10x10 m were sampled.

Twelve stands were located at Wadi-fatma along Makkah-Jeddah Road, four stands in Makkah-Al-Sharaya Road and twelve stands at Al-Sharaya-Al-Taif Road (Fig. 1). The environmental variations that associated with the distribution range of *Rhazya stricta* were represented. In each stand, a reasonable degree of homogeneity was ensured. Within each stand, species present were recorded, also the number of *Rhazya stricta* individuals was counted, their heights (H) and mean crown diameter (D) were measured (based on 2-4 diameter measurements/ind.). The size index of each individual was calculated as the average of its height and diameter [(H+D)/2]. Plant identifications were according to Migahid (1989) and Boulos (1995) for updated nomenclature.

For each sampled stand, three soil samples were collected at profiles 0-50 cm and then mixed in a single sample. Soil-water extracts (1:5) were prepared for estimation of electric conductivity (EC) using electric conductivity meter, soil reaction using pH meter. Soil nutrients (Na^{+1}, K^{+1}, Ca^{+2} and Mg^{+2}) were determined using atomic absorption (Allen *et al*., 1989). Chlorides, bicarbonates, organic carbon and sulphates were determined according to procedures outlined by Jackson (1962).

Two Way Indicator Species Analysis (TWINSPAN), as a classification technique, and Detrended Correspondence Analysis (DCA), as an ordination one, were applied to presence-absence data matrix of 45 species in 28 stands according to the computer programs of Hill (1979). Canonical Correspondence Analysis (CCA), or direct gradient analysis (Jongman *et al*., 1987), and a Monte Carlo permutation test for the significance of the first canonical axis (value at 0.01- significance level), was used to ordinate vegetation with the environmental variables. The computer program CANOCO ver. 4.1 for windows (Ter Braak & Smilauer, 1998) was used for all ordinations.

The variation of floristic composition and soil variables in relation to vegetation groups were assessed using One-Way Analysis of Variance (ANOVA). Species richness as a measure of species diversity was calculated as the average number of species recorded in each vegetation group that yielded from TWINSPAN. Relationships between the community and soil variables were tested using simple linear correlation coefficient (*r*). The statistical package SPSS version 10.0 for windows was used for different statistical analysis.

The Study Area. It comprises three locations: (1) The Wadi Fatma System is crossed by the motor road for a distance of about 28 km. This part of the Wadi is can be differentiated into various habitats: (a). Wadi bed; which is represented by the channel of the wadi and is subjected to floods, so that it is swept bare of plant life; (b). Terraces; which are slightly elevated embankments along the wadi bed. Their width varies according to the meandering of the wadi, and the exposure and steepness of the adjacent slopes. The thickness and texture of the soil deposits vary widely in different parts of the wadi. The depth of alluvial deposits varies from a thin mantle to a depth of several meters. In some parts, the surface is covered with gravels; (c). Sand dunes; a sector of the wadi system crossed by the road is characterized by a series of sand dunes which are usually barren except of some *Leptadenia pyrotechnica* and *Panicum turgidum* plants (Batanouny, 1979); and (d) Cultivated land; agriculture is practiced in widely spaced parts of the wadi depending on the supply of ground water, (2) The Makkah-Al-Sharaya road (30 km from Makkah); it occupies gentle slopes and sandy plains; the habitat supporting the community is characterized by the presence of stones, pebbles and gravels on the ground surface. The plant cover ranges between 15 to 25%. *Acacia hamulosa*, *Acacia tortilis* subsp. *raddiana* and *Acacia ehrenbergiana* form the tree layer (Fayed & Zayed, 1989). This part of the study area crosses the Asir Mountains, a range formed of crystalline and Metamorphic basement materials and volcanic rocks (Brown, 1960), and (3) Al-Sharaya-Al-Taif road, along Makkah-Al-Taif road that extends for about 70 km. The western part of the road lies at the level of 277 m above sea level at Makkah, and then rises sharply to reach 1540 m at Al-Taif city (Fig. 1). Three main sectors may be distinguished in this area according to the soil type, topography and climatological conditions. The landscape of this part is characterized by its mean dense, steep ridges crossed by numerous runnels and narrow wadies. Generally, the habitat is rocky and subjected to severe erosion. The soil is coarse textured and shallow except in some sites where fine sediments were found (Fayed & Zayed, 1989).

Climate. Available climatological data showed wide differences among stands of the study area. As in most arid regions, rainfall was characterized by scantiness, irregularity and variability, both in time and location. The mean annual rainfall at the nearest stations to the study area was about 71.3, 86.6, 127.9 and 208.4 mm at Jeddah, Makkah, Al Sail Al Kabir and Al-Taif, respectively. The air temperature was high particularly in summer. The mean maximum temperature at Jeddah was 41.6°C in July, while the minimum in January was 14.5°C. Eastwards from Makkah to Al-Taif, air temperature decreased. The mean maximum air temperature during July was normally higher than 40°C in Makkah, 38.1°C in Al Sail Al Kabir and 24.9°C in Al-Taif. On the other hand, the mean minimum air temperature during January was 17.7, 8.2 and 9.0°C in the above mentioned localities, respectively (Zahran, 1983; Abd El-Ghani, 1997).

RESULTS

Forty five species from 22 families were recorded. Annuals constitute about 24.4% of the recorded species, while the woody perennials (trees and shrubs) were highly dominated (75.6%). The largest family was Leguminosae (7 species).

Vegetation types. Classification of the presence-absence data set of 45 species recorded in 28 stands using the

TWINSPAN analysis yielded five vegetation groups at level 4 of the hierarchical classification (Fig. 2). Apart from *Rhazya stricta*, *Acacia ehrenbergiana* and *Aerva javanica* were the most common species recorded in all the recognized vegetation groups. Important but less common species include, amongst others, *Acacia tortilis* subsp. *tortilis*, *Citrullus colocynthis*, *Panicum turgidum*, *Indigofera spinosa*, *Senna alexandrina* and *Dipterygium glaucum* (Table I). The five vegetation groups were named after their characteristic species, which were *Acacia trotilis* susp. *tortilis-Capparis decidua* and *Senna italica- Citrullus colocynthis* (group A), *Acacia hamulosa- Acacia ehrenbergiana* (group B), *Aerva javanica- Blepharis ciliaris* (group C), *Lycium shawii-Acacia tortilis* subsp. *raddiana* (group D) and *Fagonia acerosa- Euphorbia granulata* (group E). Some species demonstrated certain degree of consistency i.e. they occur in a certain group and do not penetrate in another e.g. *Salsola imbricata*, *Cleome brachycarpa* (group B); *Pergularia tomentosa* (group C); *Datura innoxia*, *Pulicaria crispa*, *Asteriscus hierochunticus*, *Heliotropium arbainense*, *Ochradenus baccatus* and *Lavandula pubescens* (group D).

One Way ANOVA test showed significant differences (F-ratio = 3.106; p =0.04) between species richness of the five vegetation groups (Table II). The highest total number of species (35) was found in group D, while the lowest total number of species was found in group E (Table I). The highest species richness of 16.33± 4.5 was found in group D that was also characterized by the highest share of annuals (28.57%) of which *Datura stramonium*, *D. innoxia*, *Filago desertorum*, *Malva parviflora*, *Zygophyllum simplex* were recorded. Group B had the lowest share of annuals (4.55). DCA ordination plot of stands on the first and second axes (eigenvalues 0.530 and 0.368, respectively) was displayed in Fig. 3 with TWINSPAN vegetation groups superimposed. Group (A) occupied the negative end of axis 1, while group (E) occupied the positive end.

Vegetation-environment relationships. The variation in the soil and vegetation variables in relation to the five vegetation groups (Table II) indicated that the soil of group (D) had the highest content of silt (25.75± 6.54) and clay (15.77± 9.31), but it had the lowest content of Ca^{+2} (0.35± 0.12), K^{+1} (0.04± 0.006) and SO_4^{-2} (0.09± 00.07). The calculation of correlation coefficient (r) between different environmental variables (Table III) indicated that clay, Ca^{+2}, Mg^{+2}, $Na^{+1}$and SO_4^{-2} had the highest number of correlations with high significant positive correlations between each other, and with electric conductivity (EC).

The successive decrease of the eigen values of the first three CCA axes (Table IV) suggesting a well-structured dataset. From the intra-set correlations of the environmental variables at the first three axes of CCA shown in Table IV, it can be inferred that CCA axis 1 was negatively correlated with silt, clay and pH, while CCA axis 2 was positively correlated with sand. Therefore, CCA axis 1 was defined as sand-clay gradient, while CCA axis 2 was defined as sand-chlorides gradient.

Table I. Presence value (%) of the characteristic species in five vegetation groups (A-E) derived after application of TWINSPAN (●= above 50%, ○= less than 50%, - = absent)

	A	B	C	D	E
Number of stands	3	12	5	3	5
Total number of species	15	22	19	35	10
% of perennial species	100	95.45	89.47	71.43	9.00
% of annual species	-	4.55	10.53	28.57	10.00
Rhazya stricta Decne.	●	●	●	●	●
Acacia tortilis (Forssk.) Hayne *subsp. tortilis*	●	○	○	○	-
Capparis decidua (Forssk.) Edgew.	●	○	-	-	-
Senna italica Mill.	●	○	-	-	-
Citrullus colocynthis (L.) Schrad.	●	-	○	●	○
Suaeda monoica Forssk. ex. J. F. Gmel.	●	○	-	-	-
Acacia hamulosa Benth.	-	●	○	●	-
Acacia ehrenbergiana Hayne	○	●	●	●	●
Senna alexandrina Mill..	○	●	○	○	-
Cenchrus ciliaris L.	○	●	○	-	-
Panicum turgidum Forssk.	-	●	○	○	●
Aerva javanica (Burm. f.) Juss. ex. Schult.	○	○	●	○	○
Blepharis ciliaris (L.) B. L. Burtt	-	○	●	○	-
Calotropis procera (Aiton) W. T. Aiton	-	○	●	○	-
Indigofera spinosa Forssk.	○	-	●	●	○
Acacia tortilis (Forssk.) Hayne subsp. *raddiana* (Savi.) Brenan	-	-	-	●	-
Datura stramonium L.	-	-	-	●	-
Filago desertorum Pomel	-	-	-	●	-
Lycium shawii Roem. and Schult.	-	-	-	●	-
Malva parviflora L.	-	-	-	●	-
Solanum carense Dunal	-	-	-	●	-
Stipagrostis plumosa (L.) Munro ex T. Anderson	-	-	-	●	-
Zygophyllum simplex L.	-	-	-	●	-
Dipterygium glaucum Decne.	○	○	○	○	-
Haloxylon salicornicum (Moq.) Bunge ex. Boiss	○	○	-	-	-
Maerua crassifolia Forssk.	○	○	-	○	-
Abutilon pannosum (G. Forst.) Schltdl.	○	-	○	○	○
Pulicaria crispa (Forssk.) Oliv.	-	-	-	○	-
Fagonia acerosa Boiss.	-	-	○	○	●
Euphorbia granulata Forssk.	-	-	○	○	●
Farsetia longisiliqua Decne.	-	○	●	●	-
Leptadenia pyrotechnica (Forssk.) Decne	-	○	-	-	-
Cressa cretica L.	-	○	-	-	-
Fagonia indica Burm. f.	-	○	-	○	-
Salsola imbricata Forssk.	-	○	-	-	-
Cleome brachycarpa DC.	-	○	-	-	-
Argemone mexicana L.	-	-	○	●	-
Pergularia tomentosa L.	-	-	○	-	-
Forsskaolea tenacissima L.	-	-	-	○	○
Datura innoxia Mill.	-	-	-	○	-
Asteriscus hierochunticus (Michon) Wiklund	-	-	-	○	-
Heliotropium arbainense Fresen.	-	-	-	○	-
Ochradenus baccatus Delile	-	-	-	○	-
Lavandula pubescens Decne.	-	-	-	○	-

Five species groupings were evident in Fig. 4. Group B was highly associated with electric conductivity, Mg^{+2},

Fig. 1. Location map of the study area

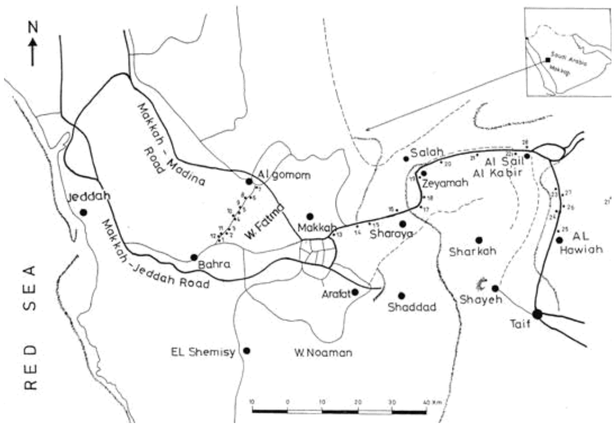
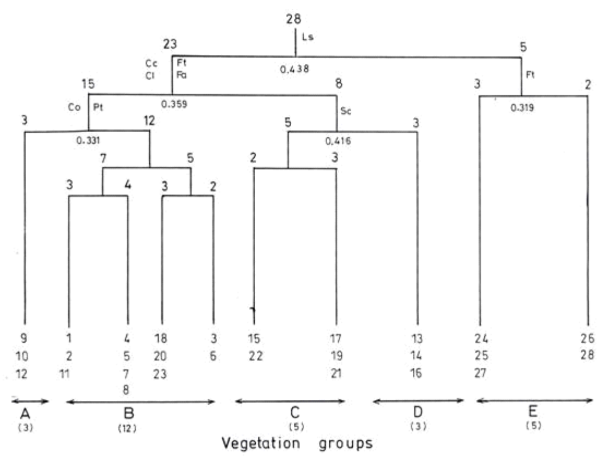


Fig. 2. Dendrogram of the five vegetation groups (A-E) after the application of TWINSPAN classification technique. Cc=*Cenchrus ciliaris*, Ci= *Cassia italica*, Co= *Citrullus colocynthis*, Fa= *Fagonia acerosa*, Ft= *Farsetia longisiliqua*, Ls= *Lycium shawii*, Pt= *Panicum turgidum*, Sc= *Solanum carense*.



Ca^{+2} and Na^{+1} and included species such as *Acacia hamulosa*, *Acacia ehrenbergiana*, *Senna alexandrina*, *Cenchrus ciliaris*, *Panicum turgidum*, *Aerva javanica*, *Blepharis ciliaris* and *Maerua crassifolia*. Group (D) showed significant correlation with clay, while group E was associated with sand and pH. These data indicated that Na^{+1}, K^{+1}, Ca^{+2}, Mg^{+2} and SO_4^{-2} were the important factors controlling the distribution of the vegetation in the study area.

The ranges, means and standard deviations of the individual dimensions of *Rhazya stricta* populations indicated the wide dispersions of these variables around their means in the three locations (Table V). The highest range of size index (75.8-343.5) was recorded in Wadi Fatma with the mean of 183.75± 89.23. This location comprises vegetation groups A and B that had low species richness and sparse vegetation. On the other hand, at Al-Sharaya area the lowest range of size index (97.1- 141.1) was recorded. Thus, the development of local populations of *Rhazya stricta* varies greatly among habitats. The height/diameter ratio was less than 0.5, which give an idea about the growth habit of the plant populations.

DISCUSSION

Plant growth in this area comprises units that are recognizable on the bases of composition, structure and ecological relationships. Results of this study demonstrated that the distribution of the various plant communities and their composition over a small geographic area in desert ecosystems is related to heterogeneous topography and landform pattern (Kassas & Batanouny, 1984; Abd El-Ghani & Amer, 2003). The heterogeneity of local topography, edapohic factors, microclimatic conditions lead to variation of the distributional behavior of the plant

Fig. 3. DCA ordination of the 28 stands on DCA axes 1 and 2 as classified by TWINSPAN

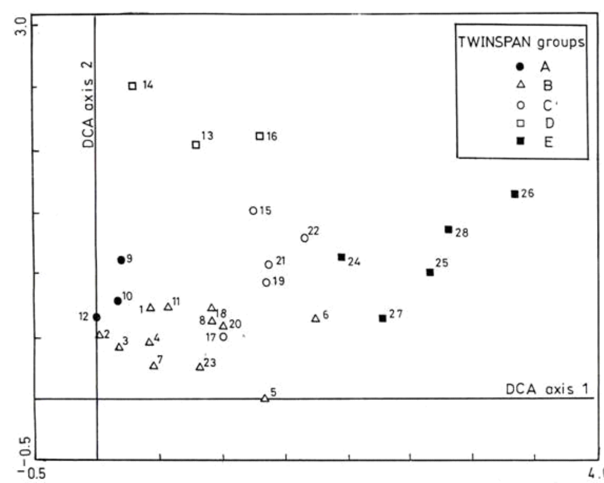


Fig. 4. CCA ordination biplot of the first two axes showing the distribution of the stands with their TWINSPAN groups and soil variables.

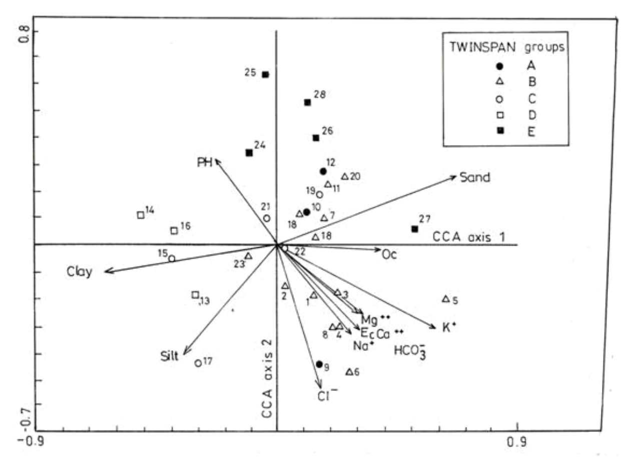


Table II. Means of soil characteristics (±S.D) of the stands supporting the five vegetation groups derived from TWINSPAN analysis (**, significant at $P \leq 0.05$; EC, electric conductivity; SR, species richness; OC, organic carbon)

Soil variables		Vegetation groups A	B	C	D	E	Total	F-ratio	P
Sand		72.31±10.41	74.68±9.55	65.75±28.48	51.82±19.48	74.51±5.54	70.35±15.87	1.569	0.22
Silt		17.74±5.60	18.80±7.89	15.10±6.85	25.75±6.54	16.99±4.43	18.45±7.02	1.199	0.34
Clay		9.95±4.93	6.52±2.97	11.14±11.05	15.77±9.31	8.49±4.70	9.06±6.48	1.529	0.23
OC (%)		0.71±0.03	0.7±0.07	0.61±0.15	0.58±0.04	0.56±0.32	0.65±0.16	1.149	0.36
pH		8.29±0.46	8.27±0.30	8.25±0.06	8.41±0.05	8.32±0.20	8.29±0.25	0.218	0.93
EC		0.11±0.03	0.17±0.20	0.06±0.05	0.07±0.006	0.06±0.02	0.11±0.14	0.958	0.45
Meq/L	Ca^{+2}	0.57±0.13	0.71±0.51	0.36±0.09	0.35±0.12	0.38±0.09	0.53±0.37	1.418	0.26
	Mg^{+2}	0.33±0.19	0.69±0.99	0.22±0.09	0.23±0.12	0.24±0.11	0.44±0.68	0.734	0.58
	$Na^{+}1$	0.21±0.08	0.27±0.40	0.04±0.007	0.09±0.05	0.04±0.02	0.16±0.28	0.974	0.44
	$K^{+}1$	0.10±0.02	0.08±0.04	0.06±0.01	0.04±0.006	0.06±0.02	0.07±0.03	3.115	0.04**
	Cl^{-1}	0.38±0.20	0.41±0.08	0.38±0.0	0.38±0.0	0.30±0.10	0.38±0.09	1.305	0.30
	HCO_3^{-1}	0.37±0.06	0.33±0.16	0.20±0.0	0.23±0.12	0.24±0.05	0.29±0.13	1.772	0.17
	SO_4^{-2}	0.46±0.21	1.02±1.72	0.10±0.07	0.09±0.07	0.17±0.14	0.55±1.19	0.882	0.49
SR		9.0±2.65	8.33±4.21	9.20±1.92	10.33±4.5	7.80±3.63	9.32±4.25	3.106	0.04**

Table III. Pearson's-product moment correlation coefficient (*r*) between the measured soil variables. For variables abbreviations and units, see Table II

Sand													
Silt	-0.68**												
Clay	-0.91**	0.40*											
OC	0.26	-0.18	-0.13										
pH	-0.12	0.19	0.05	0.19									
EC	0.03	0.01	0.05	0.24	-0.47*								
Ca^{+2}	-0.07	0.16	0.10	0.28	-0.39*	0.93**							
Mg^{+2}	0.06	0.05	-0.05	0.18	-0.51**	0.90**	0.80**						
Na^{+1}	0.02	0.01	0.08	0.23	-0.42*	0.98**	0.91**	0.83**					
$K^{+}1$	0.14	-0.05	-0.04	0.38*	-0.22	0.66**	0.72**	0.42*	0.71**				
Cl^{-1}	-0.05	0.12	-0.01	0.25	-0.18	0.09	0.09	0.06	0.07	0.15			
HCO_3^{-1}	0.07	0.28	-0.15	0.13	-0.02	0.62**	0.65**	0.60**	0.65**	0.61**	-0.13		
SO_4^{-2}	0.02	0.04	0.04	0.22	-0.49**	0.98**	0.92**	0.96**	0.94**	0.58**	0.02	0.62**	
SR	-0.29	0.16	0.31	-0.03	0.02	-0.08	-0.20	-0.13	-0.06	-0.28	0.37	-0.36	-0.14
	Sand	Silt	Clay	OC	pH	EC	Ca^{+2}	Mg^{+2}	Na^{+1}	K^{+1}	Cl^{-1}	HCO_3^{-1}	SO_4^{-2}

Values with ** are significant at $P \leq 0.01$.

associations of the study area.

The application of TWINSPAN, DCA and CCA techniques (Hill, 1979) on the vegetation data of the present study yielded five vegetation groups associated with the distribution of *Rhazya stricta*. In terms of classification, the vegetation that characterizes the study area can be divided five vegetation groups named after characteristic species, which were *Acacia tortilis* subsp. *tortilis-Capparis decidua* and *Senna italica-Citrullus colocynthis* (group A), *Acacia hamulosa-Acacia ehrenbergiana* (group B), *Aerva javanica-Blepharis ciliaris* (group C), *Lycium shawii-Acacia tortilis* subsp. *raddiana* (group D) and *Fagonia acerosa-Euphorbia granulata* (group E). Depressions receive relatively high water revenue and support a plant growth dominated by shrubs or small trees (*Calotropis procera* and *Capparis decidua* (Zayed & El-Karemy, 2000), *Acacia tortilis* subsp. *raddiana*, *Senna alexandrina*, *Dipterygium glaucum* inhabit depressions with fine-textured soil and high water retaining power. On the other hand, communities dominated by *Acacia hamulosa* characterized crevices of rocky slopes. *Acacia tortilis* subsp. *tortilis* and *Acacia ehrenbergiana* communities were usually found on the gravelly slopes and terraces (Fayed & Zayed, 1989).

From CCA analysis, it was found that electric conductivity, Mg^{+2}, Ca^{+2} Na^{+1} $K^{+1}$and SO_4^{-2} were important factors controlling the distribution of the vegetation in the study area. These results come with the findings of many authors, who study the phytosociology, in the inland desert plateau of the western desert of Egypt (El-Ghareeb & Hassan, 1989); in coastal plains of Jazan region of Saudi Arabia (El-Demerdash *et al*., 1995); in coastal lowland vegetation of eastern Saudi Arabia (Shaltout *et al*., 1997) and in Western Desert of Egypt (Abd El-Ghani, 2000b).

The structure of plant populations can be assessed in terms of the ages, sizes and forms of individuals that compose them (Harper & White, 1974). Size differences in plant populations may be caused directly or through differences in growth rates due to age differences, genetic variation, heterogeneity of resources, herbivory and competition (Harper, 1977; Weiner, 1985; Shaltout *et al*., 2003). In the present study, it was found that the highest values of size-index per individuals were in Wadi-Fatma

Table V. The range and Mean± S.D of some variables of *Rhazya stricta* population in western Saudi Arabia

Variables	Wadi-Fatma		El-Sharayaa		El-Taif	
	Range	Mean± S.D	Range	Mean± S.D	Range	Mean± S.D
Height (cm/ind.)	43.9-81.8	62.83±13.16	52.3-66.2	58.73±5.73	37.7-72.1	56.69±9.83
Diameter (cm/ind.)	103-608.8	304.61±166.84	141.8-215.9	181.15±34.27	90-514	226.89±116.28
Size index (cm/ind.)	75.8-343.5	183.75±89.23	97.1-141.1	119.98±19.77	67.9-293	141.82±61.22
Mean area (m^2/ind.)	0.83-29.0	9.29±9.74	1.6-3.7	2.65±0.97	0.75-20.7	5.1±5.4
Height: Diameter	0.13-0.47	0.25±0.11	0.29-0.37	0.33±0.04	0.14-0.69	0.3±0.14

Table IV. Intraset correlations of the studied soil variables and CCA axes 1, 2 and 3. For variables abbreviations and units, see Table II

	CCA axes		
	1	2	3
Eigenvalues	0.345	0.292	0.204
Correlation coefficient	0.926	0.811	0.865
Soil variables			
Sand	0.619	0.212	0.184
Silt	-0.319	-0.331	-0.466
Clay	-0.592	-0.091	-0.963
Organic carbon	0.354	-0.013	-0.203
pH	-0.207	0.256	-0.260
EC	0.290	-0.260	0.121
Ca^{+2}	0.344	-0.249	0.067
Mg^{+2}	0.272	-0.204	0.162
$Na^{+}1$	0.267	-0.280	0.094
K^{+1}	0.553	-0.252	0.133
Cl^{-1}	0.152	-0.428	-0.079
HCO_3^{-1}	0.384	-0.271	0.084
SO_4^{-2}	0.297	-0.212	0.124

(183.75± 89.23, Table-IV). The height/diameter ratio gives an idea about the growth habit of the plant. For *Rhazya stricta* populations, this ratio was less than 0.5. This means that the individual diameter exceeds its height, i.e. the individuals of this species tend to expand horizontally rather than vertically. This observation coincides with that of Shaltout and Mady (1993) in their study of woody plant populations in the central Saudi Arabia, and Shaltout *et al*. (2003) in their study on *Nitraria retusa* along the red Sea coast of Egypt. They also indicated that this behavior might be a strategy of the desert trees and shrubs in order to provide safe sites for their self-regeneration, as the horizontal expansion usually provides shade, which leads to decrease the severe heating effect and increase in the soil moisture.

Under the conditions of low and irregular rainfall which prevail in the study area, local topography is one of the overriding factors controlling sedimentation and water redistribution within the local landscape (Zohary, 1962), Therefore, topographic variations usually translate into high habitat heterogeneity and corresponding species diversity. In extreme conditions notably high aridity and high salinity, Danin (1976) summarized that low diversities of vascular plants are expected in extreme deserts, high Arctic and high alpine habitats, salt marshes and mangrove swamps. The present study indicated that the highest species richness of 16.33± 4.5 was found in group (D) that characterized by highest share of annuals (28.57%). This may be attributed to lowland wadi channels that receive considerable amount of runoff water and highest amount of silt and clay (25.75± 6.54 and 15.77± 9.31; respectively. On the other hand, group (D) showed relatively low electric conductivity (EC= 0.07± 0.006). The highly salinized soil (EC= 0.17± 0.2) with deep fine sediments, which dominated by *Acacia hamulosa* and *Acacia ehrenbergiana* (group B), had low species richness (8.33± 4.21) and low share of annuals (4.55%) as a result of highest value of chlorides (0.41± 0.08). The low species richness of group (B) may be related to the hypersalinity and substrate instability, as the soil of stands supporting them had the highest electric conductivity values. Moreover, the characteristic species of this group were sand-binding plants that encourage the building of phytogenic mounds as a result of heavy deposition of sand (74.68± 9.55, Table-II). Similarly, Shaltout and El-Gareeb (1992) in the western Mediterranean region and Khalaf *et al*. (1995) in the northern coastal plain of Kuwait came to the same conclusion.

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