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Size Structure of *Zygophyllum album* and *Cornulaca monacantha* Populations in Salhyia Area, East of Egypt

HOSENY A.M. MOSALLAM
Botany Department, Faculty of Science, Ain Shams University, Cairo, Egypt
E-mail: hosnymosallam@yahoo.com

ABSTRACT

Vegetation in Salhyia area is characterized by paucity of trees and shrubs. Aridity and severe impact of human activities, including overgrazing, over cutting, severe reclamation and uprooting are the main reasons of the depletion of these important woody resources. The present work aims to study the size structure of *Zygophyllum album* and *Cornulaca monacantha* populations in relation to their physiographic and soil conditions in Salhyia area, north east of Egypt. Cover percentage of the two species was assessed in ten selected quadrates (20 x 20 m) representing three habitats. Vegetation, physiograpahic environmental factors (altitude, latitude and elevation above sea level) and soil conditions (pH, 0.M, $CaCO_3$, salinity, cations and anions) were also studied. The total size structure of *Cornulaca* in the study area is characterized by the preponderance of the young individuals comparing with the old ones, while that of *Zygophyllum* showed a reverse pattern (i.e. preponderance of mature individual compared with the young ones). Soil of the sand depression has the highest values of pH, EC, K^+, $SO_4^{--}$and HCO_3^- while sand dunes has the lowest values except K^+ which is the lowest in the sand sheets. The increased human activities have adversely affected both the size structure and species diversity in the area under study.

Key Words: Population dynamic; Size distribution; *Zygophyllaum album; Cornulaca monacantha;* Salhyia

INTRODUCTION

Desert communities are especially sensitive to natural and human interventions. Many shrubs and trees are of structural and economic importance in the arid regions (Crisp & Lange, 1976). They play an important role in soil protection and stabilization against movement by wind or water, provide a source of forage for animals and fuel for local inhabitants, and have medicinal and potential industrial value (Thalen, 1979). Many roads and buildings have been constructed, some irrigation canals have been digged, and vast lands have reclaimed in addition to severe human activities. No doubt that these activities have adversely affect not only size structure but also species diversity in the area under study.

The structure of plant populations can be described in terms of ages, size and forms of the individuals that compose it (Harper & White, 1974). Since the fecundity and survival of plants is often much more closely related to size than to age (Harper, 1977; Watkinson & White, 1985; Caswell, 1986; Weiner, 1986; Shaltout & Ayyad, 1988), it is better to classify the life history of plants by size rather than age which is the most widely used classification for unitary organisms (Werner & Caswell, 1977; Kirkpatrik, 1984; Casell, 1986). Size differences may be caused directly or through differences in growth rates due to age differences, genetic variation, heterogeneity of resources, herbivory, and competition (Weiner, 1985).

Little studies have been carried out on the size structure of the shrubby populations in Egypt. The studies of such as Abdel Razik (1976), Shaltout (1983), Shaltout (1985), Abdel Razik (1988), Shaltout and Ayyad (1994) and Al-Sodany (2003) dealt with the vegetation analysis and species diversity of the western Mediterranean desert. The present study aimed at analyzing the population structure of *Zygophyllum album* and *Cornulaca monacantha* along Ismalia Salhyia area in relation to some environmental factors.

Cornulaca monacantha Del. is a blue green intricate shrub, with short leaves, recurved, tapering from a clasping base into a rigid spine and grows on sandy and stony grounds. It is distributed in Egyptian desert, Sinai, eastern Mediterranean coastal regions and Oases of the western desert (Tackholm, 1974). *Zygophyllum album* L.f. is a succulent cushion-shaped undershurb frequently reaching one m in height. The branches and leaves are blue-green mealy pubescent, and present in oases, Eastern Egyptian desert, Red sea coastal region and Sinai (Tackholm, 1974).

The study area is located in the northern part of the Eastern Desert along Ismailia-Salhyia (Fig. 1). The main habitat types of the study area are depressions, sand sheets and sand dunes. The climatic data were obtained from Metereological station of Salhyia areas. Climate of this region belongs to the Eastern warm desert of Egypt. The warmest summer month (August) has a mean temperature of 29.5^{o}C, and the coldest winter month (January) has a mean temperature of 10^{o}C. Occasional short rainfall occur mainly in winter with total annual rainfall of 26 mm. (Fig. 2). The present work aims to study the size structure of *Zygophyllum album* and *Cornulaca monacantha*

Fig. 1. Location map of the study area in Salhyia, East of Egypt (Solid area)

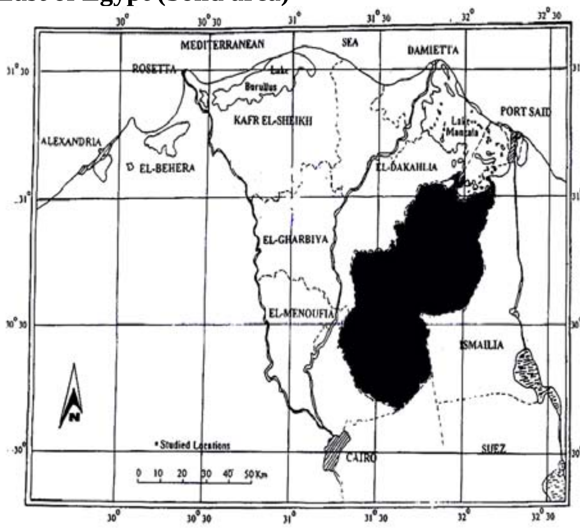
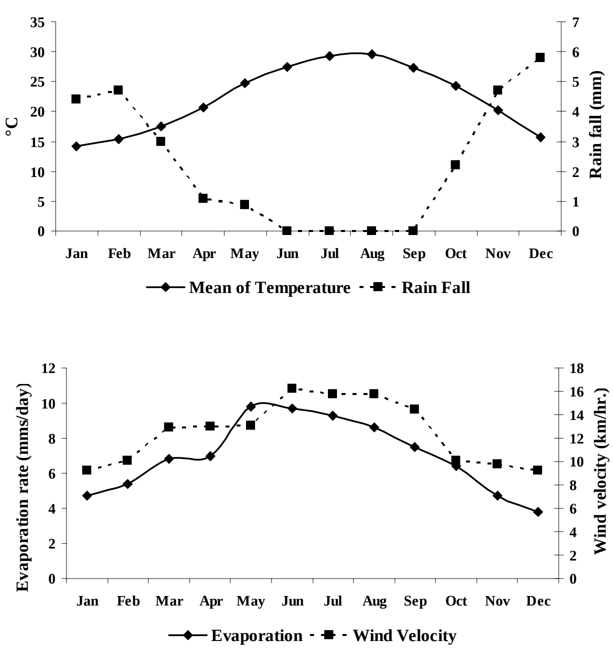


Fig. 2. Meteorological data of Salhyia station



populations in relation to their physiographic and soil conditions in Salhyia area, north east of Egypt.

MATERIALS AND METHODS

Ten quadrates (each of 20x20m) were selected to represent the main habitats of *Cornulaca monacantha* and *Zygophyllum album* populations along Ismailia-Salhyia area. Homogeneity of each stand was secured by visual judgment to comprise uniform habitat dominated by *Cornulaca* and *Zygophyllum* species. A list of the accompanied species (inside and outside the studied quadrates) was made to give an idea about the plant diversity in the study area. Nomenclature was according to Tackholm (1974) and Boulos (1995, 1999 & 2000).

The population structure of *Cornulaca monacantha* and *Zygophyllum album* species were evaluated in terms of size distribution. For achieving this, the height and mean crown diameter of each individual of the two studied species in the whole stand was measured (based on 2-4 diameter measurements/ ind.), and its volume was calculated as a cylinder. The volume estimates were then used to classify the population of each species into 10 size classes: <1, 1-5, 5-10, 10-30, 30-50, 50-100, 100-200, 200-500, 500-1000 and > 1000 dm^3. The size index of each of *Cornulaca* and *Zygophyllum* individuals was calculated as the average of its height and diameter (H+D/2). The absolute and relative frequency of individuals and mean height, diameter and height to diameter ratio per individual in each size class were then determined (Shaltout & Ayyad, 1988).

A composite soil sample was collected from each stand as a profile of 50 cm depth and air dried. Organic matter was determined by the loss on ignition method. $CaCO_3$ was estimated using Collin's calcimeter. Soil-water extracts (1:5) were prepared for the estimation of electric conductivity (EC) using electric conductivity meter, soil reaction using pH meter, chlorides by direct titration against silver nitrate using 5% potassium chromate as indicator, and bicarbonates by titration against HCl using methyl orange as an indicator. Soil extracts of five grams air dried soil were prepared using 2.5% v/v glacial acetic acid for estimation of sodium, potassium and calcium by flame photometer and magnesium by atomic absorption (Allen *et al.,* 1974). Relationships between the different variables of the studied species were tested using Pearson's simple linear correlation coefficient (r). One way analysis of variance was applied to assess the significance of variations in soil. Simple linear regressions were calculated to predict the relationship between height and diameter of the studied species (SAS, 1985).

RESULTS

Forty two species were accompanied with both *Cornulaca monacantha* and *Zygophyllum album* populations in the study area. Regarding the life form spectrum, chamaephytes have the highest contribution (31%) followed by therophytes (23.8%), geophytes (19.1%), hemicryptophytes (14.3) and phanerophytes (9.5%). The most representative families in the present study are Gramineae (8 species) followed by Chenopodiaceae (7 species). Table I revealed also that 17 plant species belonging to bi-regional, 12 plant species were monoregional while only 11 plant species were pluriregional.

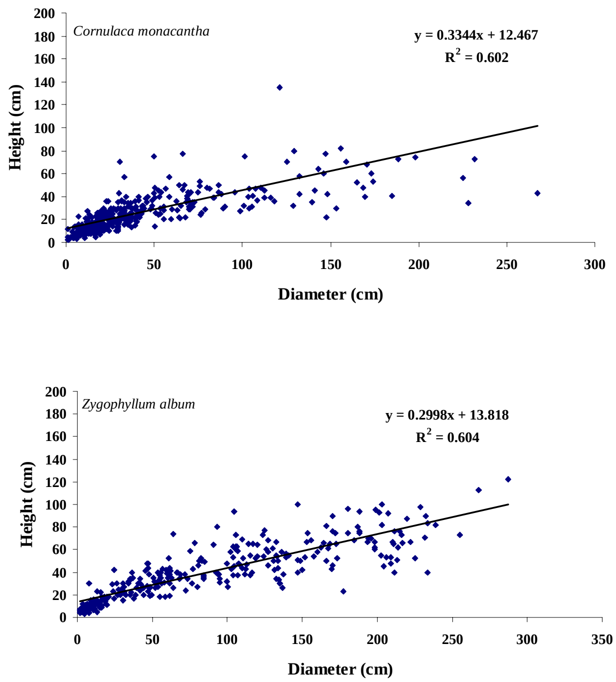
Table I. List of species associated with the distribution of *Zygophyllum album* and *Cornulaca monacantha* in Salhyia area. Life forms are: Ch, Chamaephytes; H, Hemicryptophytes; G, Geophytes; Ph, Phanerophytes; Th, Therophytes. Floristic categories are: ME, Mediterranean; SA, Saharo-arabian; SU, Sudanian; ES, Euro–Sibarian; IT, Irano–Turanian

Species	Family	Life from	Floristic category
Aeluropus lagopoides (L.) Trin-ex Thwaites	Gramineae	G	ME + S + IT
Alhagi maurorum Medic	Leguminosae	Ch	ME + SA + IT + SU
Anabasis articulata (Forssk.) Mog. in Dc.	Chenopodiaceae	Ch	SA + IT
Artemisia monosperma Del.	Compositae	Ch	ME + SA
Bassia indica (Wight) A.J.Scott.	Chenopodiaceae	Th	IT + SV
Calligonum comosum L'Her.	Polygonaceae	Ph	SA + IT
Centaurea aegyptiaca L.	Compositae	Th	ME
Cistanche phelypaea (L.) Cout.	Orobanchaceae	(Parasite)	ME + S
Convolvulus lanatus Vahl	Convolvulaceae	H	SA
Cornulaca monacantha Del.	Chenopodiaceae	Ch	SA + SU + IT
Diplotaxis harra (Forssk.) Boiss	Cruciferae	G	SA
Ephedra alata Decne	Ephedracee	Ch	SA + IT
Eremobium aegyptiacum (Spreng.) Asch. in Boiss	Cruciferae	G	SA
Erodium hirtum Willd	Geraniaceae	Th	SA
Farsetia aegyptiaca Turr	Cruciferae	G	SA + SU
Filago desertorum Pomel	Compositae	Th	SA + It
Frankenia revoluta Forssk.	Frankeniaceae	H	ME + IT + TR
*Gymnocarpos decandr*e Forssk.	Caryophyllaceae	Ch	SA
Halocnemum strobilaceum (Pallas) M.Bieb.	Chenopodiaceae	Ch	ME + SA + IT
Hamada elegans (Bunge) Botsch.	Chenopodiaceae	Ch	ME
Helianthemum lippii (L.) Pers.	Cistaceae	Ch	SA + SU
Imperata cylindrical (L.) Beauv.	Gramineae	G	ME + SA + IT
Inula crithmoides L.	Compositae	Ch	SA
Launaea nudicaulis (L.) Hook.f	Compositae	H	SA + IT + SU
Limonium pruinosum (L.) Ktze	Plumbaginaceae	H	ME
Mesembryanthemum forsskalei Hochst	Aizoaceae	Th	ME + ES
Moltkiopsis ciliata (Forssk.) Johnst.	Boraginaceae	H	ME + SA + SU
Neurada procumbens L.	Neuradaceae	Th	SA + SU
Nitraria retusa (Forssk.) Asch.	Nitrariaceae	Ph	SA + SU
Panicum turgidum Forssk.	Gramineae	G	SA + SU
Phoenix dactylifera L.	Palmae	Ph	SA + SV
Phragmites australis (Cav.) Trin ex steud.	Gramineae	G	Cosm.
Pituranthus dichotomus (Forssk.)	Caryophyllaceae	Ch	SA
Salsola kali L.	Chenopodiaceae	Th	Cosm.
Schismus barbatus (Hojer ejusd. L.) Thell	Gramineae	Th	ME + SA + IT
Senecio desfontainei Druce	Compositae	Th	ME + SA + IT
Sporobolus spicatus (Vahl.) Kunth	Gramineae	Th	ME + ES
Stipagrosits scoparia (Trin. et Rupr.) De Winter	Gramineae	H	SA + IT + SV
Stipagrostis plumose (L.) Munro ex T.Anderson	Gramineae	G	SA
Suaeda pruinosa Lange.	Chenopodiacee	Ch	ME + SA
Tamarix nilotica (Ehrenb.) Bge	Tamaricaceae	Ph	SA
Zygophyllum album L.f.	Zygophyllaceae	Ch	ME + SA

Table II. Means ± standard deviation of the individual dimensions and density (d) of *Zygophyllum album and Cornulca monacantha* populations in the studied habitats of Salhyia area

Plant Species	Dimensions	Habitat type			Mean
		Sand depressions	Sand sheets	Sand dunes	
Zygophyllum album	Height (cm)	41.0 ± 3.5	27.5 ± 2.5	8.6 ± 0.5	25.7 ± 1.7
	Diameter (cm)	87.2 ± 4.2	52.6 ± 0.6	11.1 ± 1.3	50.3 ± 3.3
	Height/ Diameter	00.5 ± 0.05	00.5 ± 0.06	00.8 ± 0.1	00.6 ± 0.06
	(Height+Diameter)/2 (cm)	64.1 ± 7.0	40.1 ± 3.0	9.9 ± 1.9	38.0 ± 4.0
	Volume (decimeter^3)	739.0 ± 40.0	216.6 ± 11.6	171.6 ± 12.0	375.7 ± 32.0
	Density (individual / ha)	5750 ± 75.4	1725 ± 55.2	200 ± 15.6	2558.3 ± 100
Cornulaca monacantha	Height (cm)	40.4 ± 2.5	20.2 ± 1.6	25.4 ± 1.9	28.7 ± 2.7
	Diameter (cm)	69.7 ± 3.7	30.3 ± 1.3	53.3 ± 2.1	51.1 ± 1.2
	Height/ Diameter	00.6 ± 0.07	00.7 ± 0.09	0.5 ± 0.04	00.6 ± 0.05
	(Height+Diameter) /2 (cm)	55.1 ± 2.4	25.3 ± 2.5	39.4 ± 1.05	39.9 ± 1.7
	Volume (decimeter^3)	434.4 ± 4.1	40.0 ± 2.3	351.1 ± 3.2	275.2 ± 19.0
	Density (individual / ha)	4375 ± 5.0	3350 ± 13.0	1875 ± 25.0	3200 ± 41.0

Fig. 3. The relationships between the individual heights and diameters of *Zygophyllum album* and *Cornulaca monacantha* species



The relationships between the individual heights and diameters of *Zygophyllum album* and *Cornulaca monacantha* species are simple linear with r values of 0.777 for *Zygophyllum album* and 0.399 for *Cornulaca monacantha* (Fig. 3). On the other hand, the mean height to diameter ratio for both *Zygophyllum album* and *Cornulaca monacantha* species was 0.8 (Table II). Regarding the variation in relation to habitat type, both height and diameter of *Zygophyllum album* (41.0 & 87.2 cm) and *Cornulaca monacantha* (40.4 & 69.7 cm) have the highest values in sand depression, respectively, and the lowest values in sand dunes for *Zygophyllum album* species (8.6 & 11.1 cm respectively). *Cornulaca monacantha* show the lowest value for height and diameter in the sand sheets (20.2 & 30.3 cm respectively). With regard to the density of individuals, the populations of *Zygophyllum* from sand depressions has the highest density (5750 ind/ha) and that of sand dunes has the lowest population density (200 ind/ha). On the other hand, the highest densities of *Cornulaca monacantha* population was recorded in sand depressions (4375 ind/ha) while the lowest density was in sand dunes (1875 ind/ ha) (Table III).

The diagrams illustrating the size distribution of *Zygophyllum* and *Cornulaca* populations in the three habitats could be classified into (Fig. 4):

1) more or less stationary size distribution for *Cornulaca monacantha* populations in the depressions and J-shape for *Zygophyllum album* populations in the same habitat.
2) more or less bimodal shape for *Zygophyllum album populations* in the sand sheets.
3) inverse J shape for *Cornulaca monacantha* populations in the sand dunes.
4) positively skewed distribution towards the small (i.e. young) individuals *Zygophyllum album* populations in the sand dunes.

Soil of the sand depression has the highest values of pH, EC, K^+, SO_4^{--} and HCO_3^- (7.54, 0.53 mS, 10.04 ppm, 51.8 ppm and 96.1 ppm, respectively), while that of the sand dunes has the lowest values except K^+ which is the lowest in the sand sheets (7.3, 0.28 mS, 3.92 ppm, 14.06 ppm, and 38.13 ppm, respectively). Magnesium and calcium have the highest values in the soil of sand depressions (9.72 & 39.83 ppm respectively), while the lowest values in sand sheet (5.17 & 17.88 ppm, respectively). Both of organic matter and $CaCO_3^{--}$ have lowest content in the sand depressions (0.27 and 0.47%, respectively), while the highest content was detected in sand dunes (0.45 & 0.67 %, respectively). Sand sheets had the highest values of Na^+ and Cl^- (86.0 and 109.9, respectively), while the sand dunes had the lowest contents (22.1 & 65.61 ppm) (Table IV).

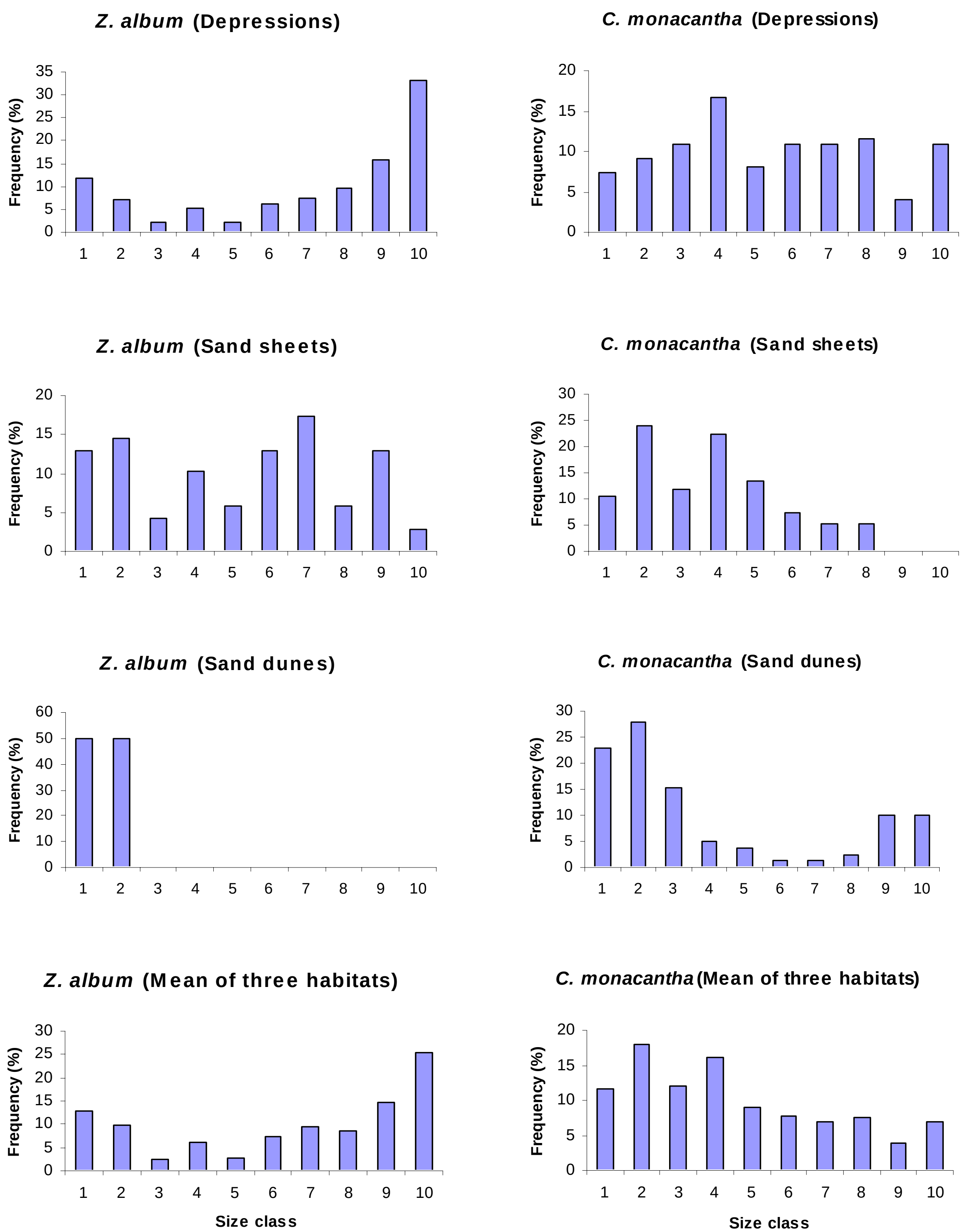
Table III. Simple linear correlations between the different variables of *Zygophyllum album* and *Cornulaca monacantha* in Salhyia area. H, height; D, diameter; V, volume. Significant r values are indicated as follow * : $p \leq 0.05$

Plant Species	Variables	*Zygophyllum album* H	D	H / D	$\frac{H+D}{2}$	V
Cornulaca monacantha	H	0.784*	0.755*	- 0.300	0.772*	0.745*
	D	0.673*	0.591	- 0.189	0.621	0.711*
	H/ D	- 0.357	- 0.406	0.388	- 0.397	- 0.541
	$\frac{H+D}{2}$	0.745*	0.678*	0.238	0.705*	0.760*
	V	0.616	0.486	- 0.048	0.528	0.602

Table IV. Means ± standard errors of some soil variables in each of the three habitats recognized in the study area

Habitat / Chemical constituents		Depressions	Sand sheets	Sand dunes
pH		7.54 ± 0.11	7.32 ± 0.09	7.30 ± 0.12
O.M (%)		0.27 ± 0.03	0.41 ± 0.01	0.45 ± 0.01
$CaCO_3$ (%)		0.47 ± 0.03	0.64 ± 0.06	0.67 ± 0.03
EC (mS)		0.53 ± 0.08	0.51 ± 0.15	0.28 ± 0.00
Mg^{++}	(ppm)	9.72 ± 0.64	5.17 ± 0.52	6.23 ± 0.18
Ca^{++}		39.83 ± 1.37	17.88 ± 2.99	22.30 ± 0.29
K^+		10.04 ± 0.69	3.92 ± 1.35	7.14 ± 1.24
Na^+		53.43 ± 1.20	86.02 ± 6.94	22.06 ± 0.93
SO_4^{--}	(ppm)	51.80 ± 1.39	38.82 ± 3.17	14.06 ± 0.42
Cl^-		96.33 ± 1.79	109.91 ± 3.72	65.61 ± 2.14
HCO_3^-		96.08 ± 1.91	76.25 ± 2.46	38.13 ± 3.8

Fig. 4. Size frequency distribution of *Zygophyllum album* and *Cornulaca monacantha* populations from three habitats. The mean volume within each size class is also indicated. The ranges of size classes are: 1: <1, 2: 1-5, 3: 5-10, 4: 10-30, 5: 30-50, 6: 50-100, 7: 100-200, 8: 200-500, 9: 500-1000 and 10:> 1000 dm^3



DISCUSSION

Regarding the biological spectrum in the present study, chamaephytes were the most frequent (31%). Our results agree with those of El-Sodany *et al.* (2003) who report that hemicryptophytes was the low frequent among the populations of their study. The density of a population without an indication of its size distribution has little meaning in the demography of plants as compared to organisms with a more restricted variation in morphological features, such as higher animals (White, 1980). The size and age of some plant life forms (notably trees) may be correlated in a general way, but unless there is an evidence on this point, the interpretation of size as age may lead to simplistic or even inaccurate conclusions (White, 1980; Caswell, 1986).

The present study indicated that density of *Cornulacea monacantha* is greatly higher than that of *Zygophyllum album* in the sand dunes. The same results obtained by Helmy *et al*. (1991). Similar results of size structure of *Zygophyllum album* disagree with the conclusion obtained by Harper (1977) but it is in accordance with his results in case of *Cornulaca monacantha* since in most stable populations one would expect an excess of juvenile over mature individuals.

The population of *Zygophyllum* in the sand dunes and to a lesser extent that of *Cornulaca* inhabiting the same habitat, in the present study, have positively skewed size distribution. This distribution may represent rapidly-growing populations with high reproductive capacity. Such distributions may indicate a high juvenile mortality as well (Harper, 1977) but they nevertheless seem to represent long-term stability, since in most stable populations one would expect an excess of juvenile over mature individuals (Leak, 1965; Crisp & Lange, 1976; Moore & Bahadresa, 1978; El-Ghonemy *et al.,* 1980; Goldberg & Turner, 1986). On the other hand, the population of *Cornulaca* in sand depressions, which has the highest density in the present work, has more or less the same densities allover size classes. In contrast, Shaltout and Ayyad (1988) indicate that the recruitment of *Thymelaea hirsute* individuals is rare in saline depressions.

Competition is one of the factors affecting size variability in plant populations. If it is important, we would expect the spatial pattern of plants to have an effect on size distributions (Weiner, 1985). Plants with neighbours closely will grow less than plants with few or distant neighbours (Weiner, 1984). This may be related to the decrease of the area available for each individual with increasing density (Mithen *et al.,* 1984). In the present work, there is non-significant results between diameter of both *Zygophyllum album* and *Cornulaca monacantha.* With this regard, the Height and diameter of *Zygophyllum* and *Cornulaca*, give a positive correlation while the diameter of the two plants has a negative correlation. Comparable observations and conclusions were made by Moore and Bahadresa (1978) in their study on *Zygophyllum eurypetrum*, a semi-desert shrub, and by Schlesinger and Gill (1978) regarding *Ceanothus megacarpus*, a chaparral shrub.

The volume is particularly convenient measure for the size of shrubby species in the deserts. Size differences in plant populations may be caused directly or through differences in growth rates due to age difference, genetic variation, heterogeneity of resources, herbivory, and competition (Weiner, 1985). In the present study, *Cornulaca* in sand dunes have positively skewed size distributions towards the small (i.e. young) individuals. These may represent rapidly growing populations with high reproductive capacity. Such distributions may indicate also a high juvenile mortality (Harper, 1977), but nevertheless, they seem to represent long-term stability, since in most stable populations one would expect an excess of juvenile over mature individuals (Crisp & Lange, 1976; Goldberg & Turner, 1986; Shaltout & Ayyad, 1988). Furthermore, Gray (1975) reported that the positively skewed distribution is indicative of a self-perpetuating species, with markedly more frequency of the smaller (younger) size classes. Similar conclusion was made by Shaltout and Ayyad (1988).

Bimodal size distribution may result from initially unimodal size distribution when there is discontinuous variation in exponential growth rates among individuals. Normally distributed variation in exponential rates will not produce bimodality. Sources of discontinuous variation may be genetic and/or environmental heterogeneity, or dominance-and-suppression competition. Such competition may be considered asymmetric because the resulting negative effects are experienced only by the smaller plants (Huston, 1986). In the present study, sand sheets support *Zygophyllum album* has a bimodal size distribution. The J-shaped distribution of *Zygophyllum album* in depressions indicated the dominance of mature individuals over the juvenile ones. This distribution characterizes a declining population, because the population has a large proportion of larger individuals than smaller ones (i.e. limited regeneration capacity). This may indicate that the recruitment of *Zygophyllum* in depression habitat is rare which may be related to hyper-salinity level.

The height/diameter ratio gives an idea about the growth habit of the plant. In the present study, this ratio is less than unity for both *Zygophyllum* and *Cornulaca* species which means that the individual diameter exceeds, in average, its height and hence individuals of these species tend to expand horizontally rather than vertically. This may be a strategy of the desert 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 the soil moisture (Shaltout & Mady, 1993).

In conclusion, the total size structure of *Cornulaca* in the study area is characterized by the preponderance of the young individuals comparing with the old ones, while that of *Zygophyllum* showed a reverse pattern (i.e. preponderance of mature individual compared with the young ones.

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