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RESEARCH PAPER

Impact of waste water discharge on the plant communities and size structure of Wadi El-Shees, Al-Jabal Al-Akhdar, Libya

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The present study assesses the impact of waste water discharge on the plant communities and size structure of the common woody species in Wadi El-Shees, Al-Jabal Al-Akhdar, Libya. Thirty stands were selected along two adjacent tributaries (polluted and un-polluted) in Wadi El-Shees. Sixty-five species belonging to 60 genera and 34 families were recorded, predominated with therophytes and mono-regional taxa and only one endemic species (*Arbutus pavarii*). The application of TWINSPAN on the data set, led to the recognition of 4 vegetation groups, two represented each of the polluted and un-polluted regions. Soils of the polluted area have significant higher values of organic matter, salinity, chloride and iron. Ten common woody perennials were selected for estimating the variation in their size structure in the polluted and un-polluted tributaries. These species include one shrublet, two shrubs and 7 trees. It was found that the density and volume of all species except *A. pavarii* and *Sarcopoterium spinosum* were higher in the polluted than the un-polluted area. Four size distributions were recognized: inverse J-shaped, bell-shaped, positive and negative skewed distributions. It was concluded that pollution had significant impact on the plant density and sizes structure of the common woody plants in Wadi El-Shees. Such study may help in managing and conserving plant diversity in Northern Libya.

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1 Introduction

Increased urbanization and industrialization in recent years in many developing countries have led to corresponding increases in the concentrations of environmental pollutants (Chauhan and Joshi, 2010; Mage et al., 1996). This rapid urbanization, though contributed to economic development, had resulted in heavy losses to economic welfare in terms of effects on agricultural activities, human health and ecosystem. Over the years, there was a continuous increase in human population, road transportation, vehicular traffic and industries, which has resulted in further increase in the concentration of pollutants (Joshi et al., 2009). This type of pollution is among the most limiting factors to plant production and survivorship (Seyyednejad and Koochak 2011; Woo et al., 2007). Improper management of solid waste is one of the main causes of environmental pollution (Kimani, 2007). Land pollution is one of the major forms of environmental catastrophe that our world is facing today (Khan and Ghouri, 2011). In developing countries where environmental regulation is fragile, the wastes from different sectors are randomly discharged into the

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ecosystems (Appasamy and Nelliyat, 2007). Wastewater strategies are often not adequate in many developing countries. Therefore the impact of wastewater on the receiving ecosystems is radically high when there is accumulation of pollutants (Khan and Ghouri, 2011).

Arid and semi-arid regions of the world are highly sensitive to human-induced climate and/or land transformation (Evans and Geerken, 2004; Nicholson and Farrar, 1994; Nicholson et al., 1998). They exhibit great temporal variability both in water availability and vegetation dynamics (Snyder et al., 2004). The distribution and abundance of a plant species within a particular climatic zone is determined by the environmental factors, especially soil conditions, interaction with other species and dispersal. Survivorship and fecundity appear to be primarily determined by the size and the developmental stage, rather than age, of individuals within a plant population (Silvertown, 1981; Werner and Caswell, 1977). Thus the status of a plant population will be reflected by its density and size structure. Comparisons of the size structure of populations of a species in different localities may provide an insight into the relationship between the species and communities in which it lives.

Al-Jabal Al-Akhdar (Green Mountain) area is a highland along the northern eastern Libya (Cyrenaica). It is a crescent-shaped ridge attaining a height of more than 850 m a.s.l. in its central part. The northern flank consists of step-like plateaus bordered by escarpments. The southern flank dips gently towards a depression extending from Ajdabiya to Al-Jaghbub, which is marked by several large sabkhas. To the east and mostly to the west, a coastal plain is well developed between the foot of the first escarpment and the sea (Pallas, 1978). The flora of Libya is not rich in the number of species; however, the Green Mountain landscape comprises the richest vegetation and the highest number of species known from Libya (Boulos, 1997, 1972). This mountainous landscape confines about 50% of the endemic species in Libya (Qaiser and El-Gadi, 1984). Few studies were carried out on its ecology (Abusaief and Dakhil, 2013; Al-Sodany et al., 2003; Boulos, 1997, 1972; Drar, 1963; Gimingham and Walton, 1954; Hamad, 2012; Hegazy et al., 2011; Le Houérou, 1997, 1986).

The impacts of waste water discharge on terrestrial ecosystems in arid and semiarid regions and the practice of using untreated wastewater for irrigation have hardly been studied. In the light of increased water scarcity, lack of money for treatment and a clear willingness by farmers in some places to use untreated wastewater, studies that look into these impacts are urgently needed. The present study aims at assessing the impact of waste water discharge pollution on the plant density and population structure in Wadi El-Shees along Al-Jabal Al-Akhdar, Libya. It aims also to evaluate the impact of pollution on the size structure of the common woody perennials recorded in this wadi.

2 Materials and methods

2.1 Study area

El-Baida city is located at Al-Jabal Al-Akhdar mountainous area, eastern Libya, at elevation of about (600 m) between longitude 32°46′08.17 N and altitude 21°45′39.56 E. With population of more than 200,000 inhabitants practicing different activities, the increment of the urban area caused several problems causing environmental hazards in the study zone, one of these the leaking of sewage water. Due to the topographic characteristics of El-Baida, which is dissected by several valleys (Wadis) affected by pollution due the leaking of waste water, one of these wadis is El-Shees. Wadi El-Shees is divided into two tributaries, one with a length of 9 km and the other with nearly 8 km ending with deltas at the Ouseita plain north of El-Baida. One of these tributaries is impacted with the leaking of waste water discharge of Al-Baida city. The distinctive features of the climate of the study area are a concentration of rainfall during the cool winter season and a very marked summer drought. The average annual rainfall is 400 mm year^{-1} with a maximum reaches 650 mm year^{-1}. The average relative humidity approximates 60% in the period from April to September and 90% from December to January. The average annual temperature is 16 °C. January is the coldest month; August is the warmest (El-Tantawy, 2005).

2.2 Data collection

Thirty stands, each of 25 × 25 m, were selected along two different tributaries of Wadi El-Shees (15 polluted and 15 un-polluted stands). In each stand, the species list, the number of individuals and visual cover (%) of each species were recorded. Identification and nomenclature were according to Boulos (2009, 1999–2005) and Jafri and El-Gadi (1977–1993). Voucher specimens of all the recorded plant species were collected, identified and deposited in Alexandria University Herbarium. Life forms of the species were identified following the Raunkiaer scheme (Raunkiaer, 1937). The global geographical distribution of the recorded species was gathered from Täckholm (1974), Zohary (1966, 1973) and Wickens (1977).

Ten common woody perennials were selected for estimating their size structure. The number of individuals of each species in each stand was counted and the height (H) and mean crown diameter (D) were measured (based on 2–4 diameter measurements per individual). The size index of each individual was calculated as the average of its height and diameter [(H+D)/2] and its volume was calculated as a cylinder. The size estimations were then used to classify each population into 6 size classes; 0.2 m < size < 0.6 m for shrublets, 0.5 m < size < 1.5 m for shrubs and 2.0 m < size < 4.0 m for trees. 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 and Ayyad, 1988).

Three soil samples were collected from each stand as profiles of 0–50 cm. Soil texture was determined by Bouyoucos hydrometer method. Soil-water extracts of 1:5 were prepared for the determination of soil salinity (EC) using conductivity meter and soil reaction (pH) using pH meter. Chlorides were determined by direct titration against silver nitrate solution using 5% potassium chromate as an indicator. Bicarbonates were estimated by titration against 0.01N HCl and sulphates were determined turbidimetrically as barium sulphate at 500 nm. Total N and P were estimated using a spectrophotometer (CECIL CE 1021) by applying Indo-Phenol blue and molybdenum blue methods, respectively. Calcium and Magnesium were determined by titration against 0.01N versenate solution using meroxide and erichrome black T as indicators, while sodium and potassium were determined using flame photometer. Moreover, Zinc, copper, iron and manganese were determined with Pye Unicam Sp 1900 Recording Flame Atomic Absorption Spectrophotometry. All these procedures are outlined Allen et al. (1986).

Two-way indicator species analysis (TWINSPAN) and Detrended Correspondence Analysis (DCA) were applied to the matrix of cover estimates of 65 species in 30 stands in Wadi El-Shees (Hill, 1979a, 1979b). Species richness (alpha-diversity) for each vegetation group was calculated as the average number of species per stand, while species turnover (beta-diversity) was calculated as a ratio between the total number of species recorded in a certain vegetation group and its alpha diversity (Whittaker, 1972). The data were statistically treated using ANOVA and the simple linear correlation coefficient (SPSS, 1999).

3 Results

Sixty-five species (22 annuals and 43 perennials) belonging to 60 genera and 34 families were recorded along the polluted and un-polluted tributaries of Wadi El-Shees (Table 1). A total of 64 species (98.5% of the total species) were recorded in the polluted area, four of them were exclusively recorded; *Ajuga chamaepitys, Calycotome villosa, Ricinus communis* and *Urtica urens*. On the other hand, 61 species were recorded in the unpolluted area with *Linum usitatissimum* was restricted to

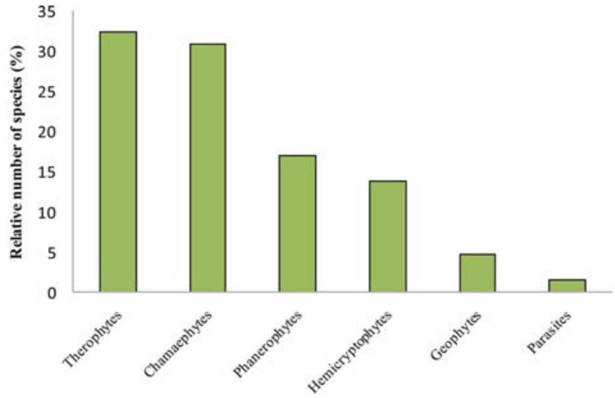


Figure 1. Life form spectrum of the total species recorded in Wadi El-Shees, Al-Jabal Al-Akhdar.

this area. Asteraceae had the highest contribution (15.4% of the total species), followed by Labiatae (12.3%), Brassicaceae, Poaceae and Fabaceae (6.2%).

The life form spectrum showed that therophytes had the highest contribution represented by 32.3% of the total species (Fig. 1), followed by chamaephytes (30.8%), phanerophytes (16.9%) and hemicryptophytes (13.8%). The chorological analysis of the recorded species indicated the predominance of mono-regional taxa represented by 40.0% of the total species (Fig. 2), followed by bi-regional (30.8%), pluri-regional (21.5%) and cosmopolitan elements (6.2%). *A. pavarii* is an endemic species recorded in both polluted and un-polluted areas.

The application of TWINSPAN on the cover estimates of 65 species recorded in the 30 sampled stands, led to the recognition of 4 vegetation groups (Fig. 3). In addition, the application of DCA on the same set of data indicates a reasonable segregation among these groups along the ordination plane of axes 1 and 2 (Fig. 4). Two vegetation groups (VG A and B) represented the polluted stands, while other two (VG C and D) represented the un-polluted ones (Table 1). Vegetation group A was the most diverse, represented by 62 species (*Pistacia lentiscus, S. spinosum* and *Avena sativa*) and had the

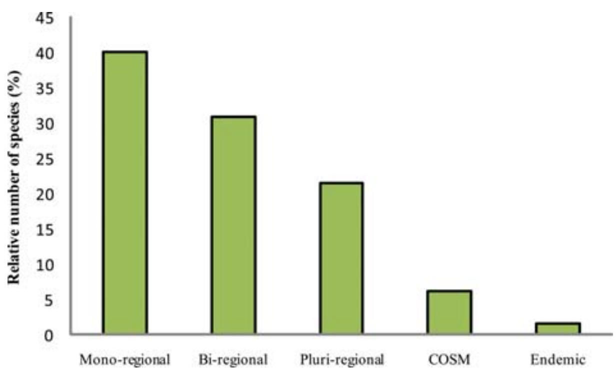


Figure 2. Chorotypes of the species recorded in Wadi El-Shees, Al-Jabal Al-Akhdar.

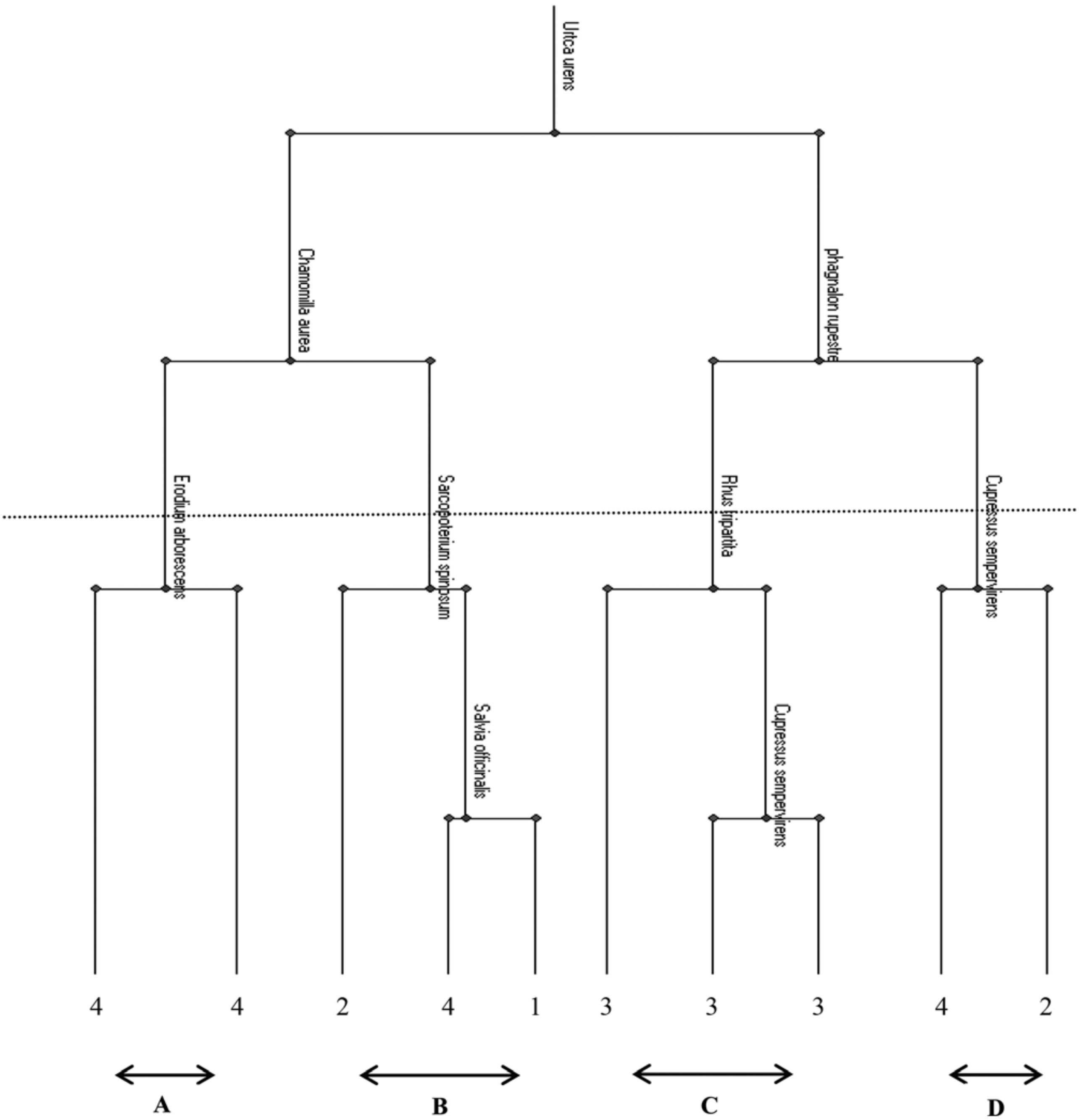


Figure 3. The dendrogram resulting after the application of TWINSPAN on the 30 sampled stands in Wadi El-Shees, Al-Jabal Al-Akhdar. Indicator species and number of stands of each group were indicated. Dotted line indicates the level of classification.

highest species richness (47.6 species stand^{-1}), but the lowest species turnover (1.3) (Table 2). On the other hand, VG D was the lowest diverse with 58 species (*S. spinosum, Brassica juncea* and *Bromus diandrus* var. *rigidus*) and had species richness of 35.9 species stand^{-1} and species turnover of 1.6.

Soils of the polluted area had significant higher values of organic matter (4.7%), salinity (2.1 mS cm^{-1}), chloride (34.6 µg g^{-1}) and iron (3.3 µg g^{-1}) than that of the un-polluted ones (2.1%, 1.9 mS cm^{-1}, 26.2 µg g^{-1} and 2.5 µg g^{-1}) (Table 3). On the other hand, the un-polluted area had higher values of sulphate (10.5 µg g^{-1}), calcium

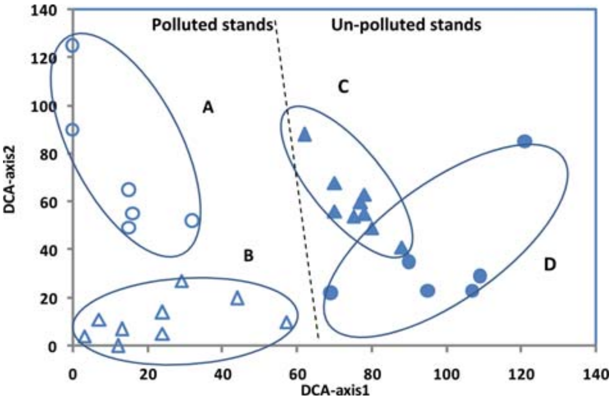


Figure 4. DCA ordination of the four vegetation groups identified after the application of TWINSPAN on the 30 sampled stands in Wadi El-Shees, Al-Jabal Al-Akhdar.

(51.3 μg g^{-1}) and zinc (3.9 μg g^{-1}) than the polluted one (9.0, 42.3 and 3.0 μg g^{-1}).

Ten common woody perennials were selected for estimating the variation of their size structure in the polluted and un-polluted tributaries (Table 4). These species are: one shrublet (*S. spinosum*), two shrubs (*C. villosa* and *Phillyrea angustifolia*) and 7 trees (*Juniperus phoenicea, Ceratonia siliqua, Rhamnus lycioides, P. lentiscus, Cupressus sempervirens, Olea europaea* and *A. pavarii*). It was found that the density and volume of all species except *A. pavarii* and *S. spinosum* were higher in the polluted area than in the un-polluted one. The relationship between individual heights and diameters of the 10 species were simple linear with significant *r* values ranged between 0.06 for *S. spinosum* and 0.79 for *C. villosa* (Fig. 5). On the other hand, the mean of height/diameter ratio varied between 0.24 for *S. spinosum* and 3.38 for *C. villosa.* In addition, there was a significant difference between these variables in both polluted and un-polluted stands.

The diagrams illustrating the size distribution of the 10 examined species indicated that some species had the same size distribution in both polluted and un-polluted stands, while others have different patterns (Fig. 5). *R. lycioides* and *O. europaea* had inverse J-shaped, while *A. pavarii* was positively skewed and *C. villosa* had approximately symmetrical (i.e. bell shaped) distribution in both the polluted and un-polluted areas. On the other hand, *P. angustifolia* and *P. lentiscus* had positive skewed distribution in the polluted and inverse J-shaped in the unpolluted stands, while *J. phoenicea* and *C. siliqua* had bell-shaped distribution in the polluted, but inverse J-shaped in the un-polluted stands. Moreover, *S. spinosum* had inverse J-shaped in the polluted and positive skewed distribution in the un-polluted stands, while *C. sempervirens* had negative skewed distribution and inverse J-shaped in the polluted and un-polluted areas.

4 Discussion

Wadis dissecting the northern side of the Green Mountain landscape have specific topography creating localized microclimate favorable for richer vegetation, regarding the number of species and percentage of shrub and tree composition in the community (El-Bana and El-Mathnani, 2009). In contrast to the northern slope, which is exposed to direct wind coming from the sea, the wadi vegetation is protected within the wadi channels. Sixty-five species belonging to 60 genera and 34 families were recorded along the polluted and un-polluted stands of wadi El-Shees. This number represents 37.1% of the species recorded in El-Mansora (Abusaief and Dakhil, 2013), 58.6% of that recorded by Hegazy et al. (2011), 34.4% of that recorded by El-Barasi et al. (2011) and 54.6% of that recorded by Al-Sodany et al. (2003) in Al-Hamama and Al-Baida, (Al-Jabal Al-Akhdar). Asteraceae had the highest contribution to the flora of Wadi El-Shees. This result coincided with Abusaief and Dakhil (2013) who reported that Asteraceae had a worldwide distribution, and is most common in the arid and semi-arid regions of subtropical and lower temperate latitudes.

The life form spectra provide information which may help in assessing the response of vegetation to the variations in the environmental factors (Ayyad and El-Ghareeb, 1982). The Mediterranean climate was designated by Raunkiaer (1937) as a "therophyte climate type" because of the high percentage (>50% of the total species) of this life form in several Mediterranean floras (Raven, 1971). The present study indicated that therophytes had the highest contribution followed by chamaephytes, phanerophytes and hemicryptophytes. Heneidy and Bidak (2001) pointed out that the dominance of therophytes over the other life forms seems to be a response to the hot-dry climate, topographic variation and biotic influence. In addition, Wang et al. (2002) and Da Costa et al. (2007) found that therophytes were the most dominant life form in arid and semi-arid areas.

The floristic categories of the recorded species showed that mono-regional taxa had the highest contribution, followed by bi-regional, pluri-regional and cosmopolitan. In addition, 51 species were Mediterranean and 10 species were Saharo-Arabian taxa. According to Zohary (1973), the Mediterranean territory of the Middle East occupies a comparatively narrow belt along the Mediterranean Sea and there is a gap in this belt between southern Palestine and Libya in which the Saharo-Arabian belt closely approaches the Mediterranean coast. The presence of the phytogeographical elements other than the Mediterranean, in the study area is believed to be a reflection of the intense climatic changes and/or the degradation of the Mediterranean ecosystem, which facilitated the invasion of some elements from the adjacent regions (Madi et al., 2002). *Arbutus pavarii* was

Table 1. Plant density (individual ha^{-1}) of the four vegetation groups resulted from the application of TWINSPAN on the 30 polluted and un-polluted sampled stands in Wadi El-Shees, Al-Jabal Al-Akhdar

Species	Floristic category	Polluted area		Unpolluted area	
		A	B	C	D
Phanerophytes					
Arbutus pavarii Pamp.	Endemic	1.4 ± 1.3	0.8 ± 0.2	0.4 ± 0.1	2.4 ± 1.7
Calycotome villosa (Poiret) Link	ME	0.4 ± 0.1	0.2 ± 0.1		
Ceratonia siliqua L.	ME	2.7 ± 2.1	1.8 ± 1.6	2.4 ± 1.8	
Cupressus sempervirens L.	ME	2.9 ± 1.8	4.2 ± 3.6	2.0 ± 0.9	1.6 ± 1.0
Ephedra aphylla Forssk.	SA-AR	16.9 ± 7.0	3.5 ± 2.9		1.0 ± 0.4
Juniperus phoenicea L.	ME+SA-AR	5.7 ± 3.6	21.7 ± 19.8	3.0 ± 1.5	2.1 ± 0.9
Nerium oleander L.	ME	3.1 ± 1.7	2.2 ± 1.7	0.6 ± 0.2	0.3 ± 0.1
Olea europaea L.	ME	3.7 ± 2.2	0.7 ± 0.2	2.0 ± 1.4	1.3 ± 1.1
Phillyrea angustifolia L.	ME+ER-SR	0.7 ± 0.3	0.5 ± 0.1		
Rhamnus lycioides L.	ME	2.2 ± 1.6	2.3 ± 1.7	2.9 ± 1.6	0.9 ± 0.3
Ricinus communis L.	PAN	4.0 ± 3.4	6.0 ± 3.8		
Chamaephytes					
Capparis spinosa L.	SA-AR	4.6 ± 2.3	2.0 ± 1.1	1.8 ± 1.4	0.3 ± 0.1
Cynara cardunculus L.	ME+ER-SR	2.3 ± 1.2	5.8 ± 3.1	9.9 ± 7.2	4.0 ± 2.7
Cynara scolymus L.	ME+IR-TR	6.3 ± 2.4	4.7 ± 2.7	4.9 ± 1.6	3.0 ± 1.4
Globularia alypum L.	ME+ER-SR	6.9 ± 4.6	1.3 ± 0.3	3.6 ± 1.9	1.9 ± 0.5
Mirabilis jalapa L.	Trop.	0.7 ± 0.3		1.3 ± 0.5	2.3 ± 1.5
Pallenis spinosa (L.) Cass.	ME+ER-SR+IR-TR	2.0 ± 1.2	0.3 ± 0.1	1.4 ± 0.4	1.3 ± 0.9
Phagnalon rupestre (L.) DC.	ME+IR-TR	5.8 ± 3.2	0.2 ± 0.1	3.8 ± 1.9	0.4 ± 0.1
Phlomis floccosa D. Don	ME+SA-AR	13.4 ± 8.5	3.3 ± 2.7	8.8 ± 7.1	1.3 ± 0.4
Pistacia lentiscus L.	ME+ER-SR+Trop.	43.8 ± 11.0	33.5 ± 13.6	13.8 ± 7.6	18.7 ± 8.8
Rhus tripartita (Ucria) Grand.	ME+SA-AR+S-Z	3.1 ± 2.9	9.3 ± 6.3	1.9 ± 0.5	2.6 ± 1.5
Rosmarinus officinalis L.	ME	1.3 ± 1.1	1.2 ± 0.5	6.3 ± 3.9	4.1 ± 2.7
Ruta graveolens L.	ME+Temp.+Trop.	6.4 ± 3.6	9.8 ± 5.9	2.1 ± 0.9	7.3 ± 5.5
Salvia officinalis L.	ME		0.7 ± 0.1	1.4 ± 0.5	2.3 ± 0.8
Salvia spinosa L.	PAN	4.7 ± 2.4	2.0 ± 1.1	0.5 ± 0.1	4.0 ± 2.8
Sarcopoterium spinosum (L.) Spach	ME	60.3 ± 13.5	65.8 ± 32.5	56.1 ± 35.9	65.1 ± 28.0
Solanum nigrum L.	ME+ER-SR+IR-TR	2.6 ± 1.7	0.5 ± 0.2	0.1 ± 0.1	
Teucrium polium L.	ME+IR-TR		1.3 ± 0.8	4.0 ± 2.7	3.3 ± 1.1
Thapsia garganica L.	ME+ER-SR	6.1 ± 4.4	1.8 ± 0.4	5.9 ± 3.2	1.1 ± 0.7
Thymus capitatus (L.) Hoffmans & Link	ME		1.3 ± 0.9	1.5 ± 0.2	2.0 ± 1.3
Thymus vulgaris L.	ME	0.3 ± 0.1	1.3 ± 0.5	0.9 ± 0.2	0.6 ± 0.1
Geophytes-Helophytes					
Polygonum equisetiforme Sm.	ME+IR-TR	2.0 ± 1.3	2.7 ± 1.5	1.3 ± 0.3	2.4 ± 1.6
Urginea maritima (L.) Baker	ME	4.1 ± 0.7	4.5 ± 2.9	1.5 ± 1.1	2.0 ± 1.7
Urginea undulata (Desf.) Steinh.	ME+SA-AR	3.3 ± 2.1	1.8 ± 1.1	6.3 ± 3.7	3.1 ± 2.7
Hemicryptophytes					
Ajuga chamaepitys (L.) Schreb.	ME+IR-TR	0.4 ± 0.1	0.3 ± 0.1		
Anthemis secundiramea Biv.	ME+ER-SR+PAL	10.2 ± 6.3	0.8 ± 0.3	5.6 ± 4.3	1.7 ± 1.4
Cistus parviflorus Lam.	ME	1.9 ± 1.1	1.3 ± 0.5	1.8 ± 0.3	0.6 ± 0.2
Convolvulus arvensis L.	Trop.	7.9 ± 5.5	24.8 ± 4.5	4.8 ± 2.8	6.9 ± 4.2
Diplotaxis muralis (L.) DC.	SA-AR	10.4 ± 7.2	5.8 ± 3.3	5.0 ± 3.9	3.7 ± 1.3
Erodium arborescens (Desf.) Willd.	ME+SA-AR	5.2 ± 3.1	9.5 ± 2.5	8.6 ± 4.1	2.9 ± 1.5

Table 1. (Continued)

Species	Floristic category	Polluted area		Unpolluted area	
		A	B	C	D
Helichrysum stoechas L.	ME+ER-SR	1.8 ± 1.1	0.8 ± 0.3	0.9 ± 0.4	1.4 ± 1.1
Rumex acetosa L.	ME+ER-SR+IR-TR	0.9 ± 0.4			
Scolymus hispanicus L.	ME	10.7 ± 6.4	11.5 ± 3.1	3.0 ± 1.7	3.4 ± 1.5
Therophytes					
Amaranthus graecizans L.	PAL	4.7 ± 3.9	0.8 ± 0.3	1.5 ± 1.1	4.3 ± 3.1
Anagallis arvensis L.	ME+ER-SR+IR-TR	10.7 ± 4.9	5.3 ± 2.9	12.5 ± 6.7	7.1 ± 4.2
Astragalus hamosus L.	ME+SA-AR+IR-TR	1.9 ± 1.2	1.7 ± 0.9	1.6 ± 0.5	1.4 ± 1.1
Avena sativa L.	COSM	68.7 ± 18.6	61.3 ± 20.2	23.6 ± 9.9	36.6 ± 18.8
Brassica juncea (L.) Czernj. & Coss.	IR-TR	3.4 ± 1.7	6.7 ± 1.9	13.5 ± 5.4	16.0 ± 8.9
Bromus diandrus var. *rigidus (Roth) Sales.*	ME	22.6 ± 8.9	18.3 ± 9.1	11.3 ± 3.4	14.0 ± 5.9
Capsella bursa-pastoris (L.) Medik.	COSM	0.9 ± 0.7		7.3 ± 3.8	3.0 ± 1.9
Chenopodium ambrosioides L.	COSM	17.0 ± 5.7	14.7 ± 7.4	0.3 ± 0.1	0.7 ± 0.2
Conyza aegyptiaca (L.) Dryand.	ME+IR-TR+Trop.	2.8 ± 1.5	1.3 ± 0.9	1.9 ± 1.1	1.3 ± 1.0
Erodium cicutarium (L.) L'Her	ME+ER-SR+IR-TR	4.9 ± 2.4	3.8 ± 1.2	0.6 ± 0.2	0.6 ± 0.3
Glebionis coronarium (L.) Tzvelev.	ME	2.0 ± 1.5	1.3 ± 0.8	1.5 ± 0.5	1.9 ± 1.4
Hordeum vulgare L.	ME+IR-TR	16.4 ± 7.5	15.0 ± 7.3	17.3 ± 6.0	9.7 ± 3.1
Linum usitatissimum L.	ME			1.6 ± 0.5	3.1 ± 2.6
Malva parviflora L.	ME+IR-TR	6.2 ± 3.5	6.3 ± 4.1	3.8 ± 1.7	4.3 ± 2.3
Matricaria aurea (Loefl.) Sch. Bip.	ME+ER-SR+IR-TR	11.4 ± 5.2	3.2 ± 1.2	8.5 ± 4.1	1.1 ± 0.2
Matthiola longipetala (Vent.) DC.	ME+IR-TR	15.4 ± 6.2	14.0 ± 7.4	7.5 ± 5.4	4.1 ± 1.5
Papaver rhoeas L.	ME+ER-SR+SA-AR	0.7 ± 0.2	1.8 ± 0.5	11.0 ± 7.3	7.3 ± 4.9
Phalaris minor Retz.	ME+IR-TR	7.1 ± 3.1	11.3 ± 3.7	8.0 ± 6.9	2.3 ± 1.9
Portulaca oleracea L.	COSM	4.7 ± 3.2	4.0 ± 2.8	3.5 ± 2.5	3.1 ± 1.5
Rapistrum rugosum (L.) All.	ME+ER-SR+IR-TR	5.8 ± 2.9	4.8 ± 1.9	5.3 ± 2.1	1.0 ± 0.3
Urtica urens L.	ME+ER-SR	14.1 ± 6.6	13.5 ± 6.1		
Parasites					
Cuscuta campestris Yunck	ME+Temp.	13.3 ± 3.9	13.2 ± 7.9	0.8 ± 0.1	0.3 ± 0.1
Total species	65	64		61	

Table 2. Characteristics of the 4 vegetation groups derived after the application of TWINSPAN on the 30 stands of the polluted (P) and un-polluted (U) sites of Wadi Al-Shees

Vegetation group	No. of stands	No. of species	Sites		Species richness	Species turnover
			P	U		
A	9	62	100	–	47.6 ± 1.5	1.3
B	6	62	100	–	40.5 ± 2.5	1.5
C	8	60	–	100	37.0 ± 4.8	1.6
D	7	58	–	100	35.9 ± 1.9	1.6

Table 3. Variation in the mean ± standard deviation of the soil characteristics of the polluted and un-polluted sites in Wadi El-Shees, Al-Jabal Al-Akhdar

Soil variable		Polluted area	Un-polluted area	F-value
Coarse sand	%	7.0 ± 1.0	6.6 ± 1.1	0.74
Fine sand		17.7 ± 1.1	18.6 ± 1.3	3.11
Silt		62.3 ± 1.5	61.8 ± 1.5	0.52
Clay		12.9 ± 1.4	13.4 ± 1.4	0.37
Organic matter		4.7 ± 0.8	2.1 ± 0.7	55.56***
Organic carbon		2.1 ± 1.1	3.3 ± 0.9	6.75**
N		0.2 ± 0.1	0.2 ± 0.1	1.96
P		0.2 ± 0.1	0.2 ± 0.1	0.01
K		1.1 ± 0.5	0.9 ± 0.3	0.63
pH		7.9 ± 0.1	7.9 ± 0.1	0.91
EC (mS cm^{-1})		2.1 ± 0.3	1.9 ± 0.2	4.34*
CO_3		0.3 ± 0.1	0.3 ± 0.1	1.05
HCO_3		4.2 ± 1.3	3.5 ± 1.3	1.48
Cl		34.6 ± 10.9	26.2 ± 7.2	3.70*
SO_4		9.0 ± 1.2	10.5 ± 2.5	2.54
Ca		42.3 ± 15.9	51.3 ± 16.0	1.42
Mg		12.6 ± 1.9	12.4 ± 1.9	0.06
Na	μg g^{-1}	94.9 ± 18.3	91.5 ± 33.9	0.07
Cu		10.8 ± 2.8	9.1 ± 1.5	2.58
Zn		3.0 ± 0.9	3.9 ± 1.3	3.01
Mn		13.7 ± 2.5	12.6 ± 2.2	0.96
Cr		4.8 ± 1.8	4.2 ± 1.3	0.60
Fe		3.3 ± 0.6	2.5 ± 0.6	8.54**
Cd		6.3 ± 1.1	5.5 ± 1.3	1.62

exclusively recorded in the present study as an endemic species to Al-Jabal Al-Akhdar, which is one of the four major centers of endemism that holds about 50% of the total endemic species in Libya (Boulos, 1997).

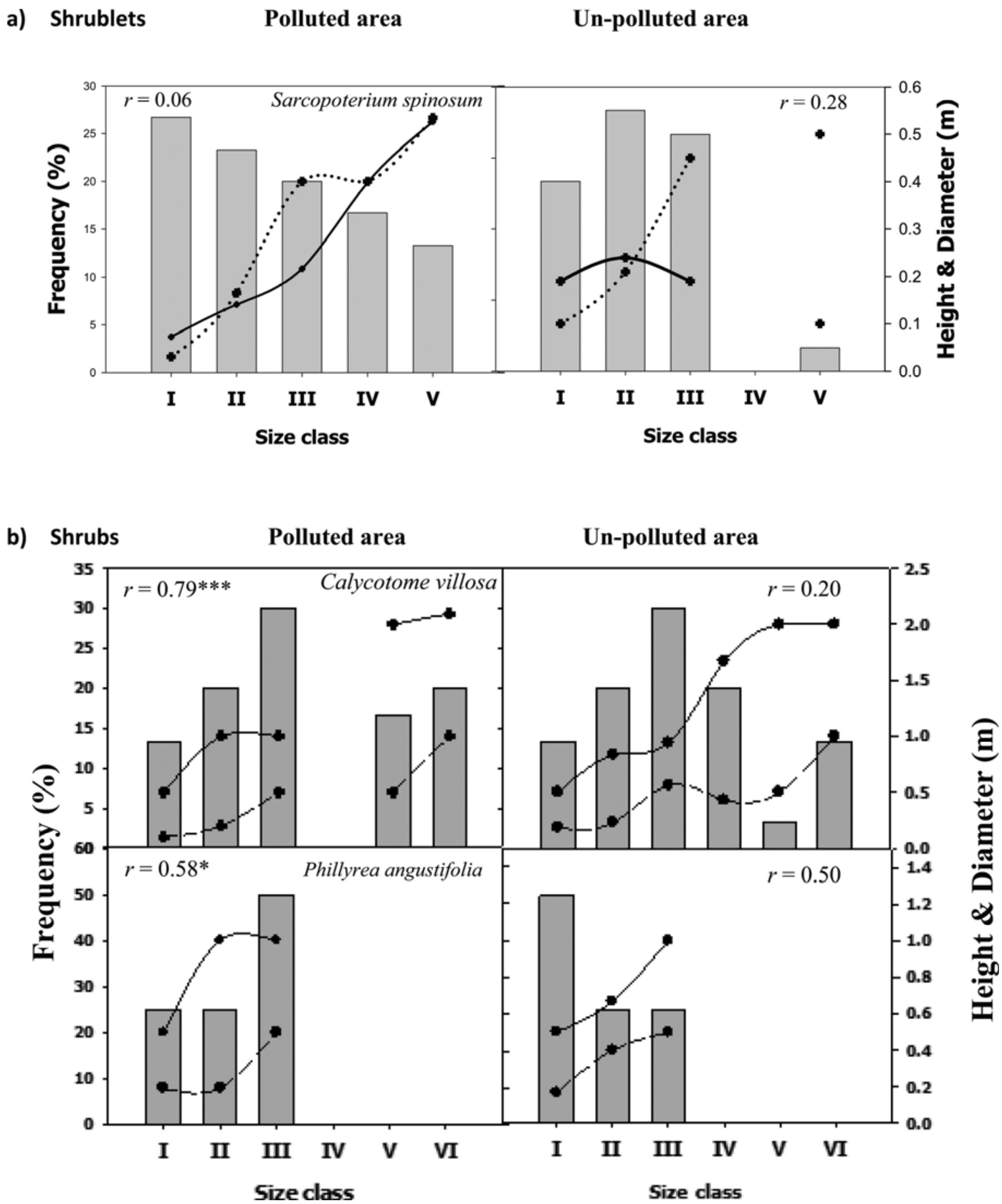
TWINSPAN classification technique resulted in four vegetation groups dominated by *S. spinosum* and *P. lentiscus* with the higher densities recorded in VG A and B representing the low elevated polluted areas and the lower in VG C and D representing the high elevated un-polluted ones. On the contrary, Zunni (1977) reported that, *Sarcopoterium, Pistacia, Juniperus* and other species were common in the plant communities of all his sampled plots, but suggested that the community attains better development on the high plateau where it may more properly be considered a 'disclimax'. Similar findings were recorded by Al-Sodany et al. (2003) and Hegazy et al. (2011).

The height and stem diameter of individuals from different species are particularly important because they reveal the maximum size attained by phyletically or functionally different species groups, which are crucial to a variety of ecological and evolutionary hypotheses (Niklas et al., 2006). The height-to-diameter ratio gives an idea about the growth habit of the plant. In the present study, this ratio is more than unity for most of the recorded species except *S. spinosum* in the un-polluted habitat. This means that the individual height exceeds their diameter, i.e. these individuals tend to expands vertically rather than horizontally and this may be attributed to the high density and consequently high intra-specific competition of this plant. Moreover, Lentz (1998) found that intraspecific competition significantly affected plant height and total mass, both independently and interactively. He emphasized that plant height decreased with increasing density. A similar finding was reported by El-Midany (2014) on *Calotropis procera* in the urban habitats of Greater Cairo. On the other hand, *S. spinosum* expands horizontally and this behavior may 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 the soil moisture (Shaltout and Mady, 1993). This result is in accord with Shaltout et al. (2003) for *N. retusa* along the Red Sea Coastal land and Al-Sodany (2003) on the common shrubs in the western Mediterranean coast of Egypt and Galal (2011) on some woody perennials in Wadi Gimal (Red Sea – Egypt).

Table 4. Mean (upper line) ± standard deviation (lower line) of the dimensions of 10 common woody species recorded in the polluted (P) and un-polluted (U) sites in Wadi El-Shees, Al-Jabal Al-Akhdar. H: height, D: diameter, S: size index and V: volume. *: $P < 0.05$, **: $P < 0.01$, ***: $P < 0.001$

Species	H (m individual^{-1})			D (m individual^{-1})			H/D			S (m individual^{-1})			V (m^3 individual^{-1})		
	P	U	*t*-test	P	U	*t*-test	P	U	*t*-test	P	U	*t*-test	P	U	*t*-test
Sarcopoterium spinosum	0.41	0.22	3.9***	0.18	0.27	2.6*	2.50	0.24	4.4***	0.29	0.03	1.8	0.03	1.26	0.2
	0.22	0.10		0.09	0.17		1.05	0.08		0.13	0.01		0.01	0.87	
Juniperus phoenicea	3.27	2.30	5.1***	1.90	0.90	5.5***	1.83	2.70	3.4**	2.58	1.64	5.7***	23.34	5.14	4.7***
	0.83	0.75		0.67	0.50		0.48	1.24		0.71	0.54		19.27	2.79	
Ceratonia siliqua	3.90	2.67	5.5***	2.70	1.30	9.8***	1.46	2.30	4.7***	3.30	1.98	8.0***	49.97	9.02	6.9***
	0.92	0.71		0.60	0.52		0.30	0.97		0.70	0.53		31.44	6.49	
Rhamnus lycioides	2.54	1.75	4.7***	1.54	0.77	6.0***	1.79	2.58	2.7*	2.04	1.26	6.1***	11.06	2.11	5.5***
	0.59	0.68		0.51	0.36		0.59	1.38		0.46	0.41		7.56	1.58	
Calycotome villosa	1.86	1.42	0.9	0.96	0.61	0.1	2.61	3.38	0.8	1.41	1.02	0.7	5.76	1.37	0.8
	0.59	0.67		0.51	0.36		0.59	1.38		0.46	0.41		3.56	0.58	
Phillyrea angustifolia	0.81	0.67	1.8	0.33	0.31	0.5	2.75	2.75	0.2	0.57	0.49	1.4	0.20	0.15	0.8
	0.25	0.24		0.15	0.17		1.14	1.45		0.19	0.18		0.18	0.11	
Pistacia lentiscus	2.60	1.70	4.4***	2.28	1.23	4.1***	1.31	1.69	2.3*	2.44	1.47	4.8***	26.98	7.70	3.0**
	0.77	0.79		1.03	0.81		0.58	0.86		0.72	0.72		19.06	14.33	
Cupressus sempervirens	3.73	2.47	4.9***	2.53	1.01	9.6***	1.51	2.87	7.2***	3.13	1.74	7.2***	41.81	7.15	6.5***
	0.91	0.78		0.57	0.61		0.42	0.99		0.67	0.65		22.46	3.72	
Olea europaea	3.10	2.30	4.1***	1.87	1.05	7.0***	1.78	2.43	3.1**	2.48	1.68	6.0***	20.04	5.66	5.1***
	0.88	0.65		0.57	0.48		0.62	0.83		0.63	0.53		16.16	6.79	
Arbutus pavarii	2.67	2.26	1.2	2.58	1.71	1.1*	1.08	1.43	2.3	2.63	2.00	1.7	29.18	11.67	2.2
	0.75	0.45		0.49	0.45		0.36	0.42		0.46	0.38		13.61	5.99	

Plant population structure such as the distribution of plant size and reproductive effort, and success has important evolutionary and conservation implications. For example, plant size distribution has frequently been shown to affect survivorship and reproduction (Harper, 1977; Wessilingh et al., 1997) and can be related to inter- and intra- specific competition (Harper, 1977). In the present study, all species except *C. villosa* had inverse J-shaped or positive skewed distribution in the un-polluted habitats, of them *S. spinosum, P. angustifolia, R. oleoides, P. lentiscus, O. europaea* and *A. pavarii* have the same distribution in the polluted habitat. 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 could expect an excess of juvenile over mature individuals (Goldberg and Turner, 1986; Shaltout and Ayyad, 1988). Moreover, these distribution patterns are caused, through variations in growth rate, by factors such as: competition, heterogeneity of resources, genetic variation and small differences in the rate of emergence (Weiner and Solbrig, 1984). Furthermore, the individuals of *P. angustifolia* and *P. lentiscus* had positive skewed size distribution in the polluted habitat combined with higher species density and soil salinity, while inverse J-shaped distribution in the un-polluted with lower density and salinity. This may indicate stability of its population as well as the predominance of juveniles over mature individuals. Under high densities, small individuals may die, resulting in fairly predictable relationships between average plant size and density (White and Harper, 1970), through a process commonly referred to as self-thinning.



a) Shrublets
Polluted area
Un-polluted area
r = 0.06
Sarcopoterium spinosum
r = 0.28
Frequency (%)
Height & Diameter (m)
I II III IV V
Size class
b) Shrubs
Polluted area
Un-polluted area
r = 0.79***
Calycotome villosa
r = 0.20
r = 0.58*
Phillyrea angustifolia
r = 0.50
Frequency (%)
Height & Diameter (m)
I II III IV V VI
Size class

Figure 5.

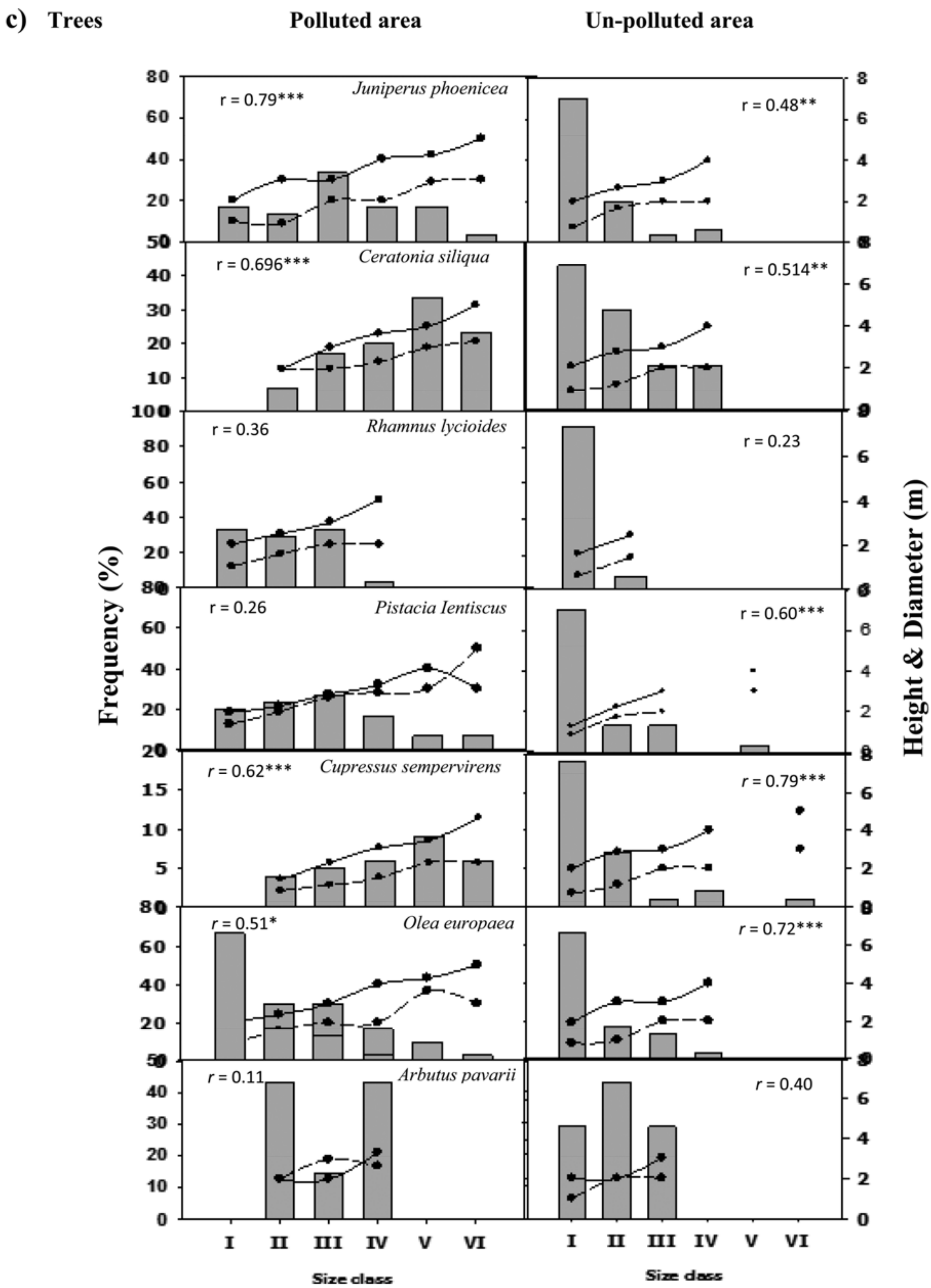


Figure 5. Size frequency distribution for the population of 10 perennial plants in the polluted and un-polluted areas of Wadi El-Shees, Al-Jabal Al-Akhdar. r: the correlation coefficient between height and diameter. The range of size classes are: (a) shrublets: 0.2 m < size < 0.6 m, (b) shrubs: 0.5 m < size < 1.5 m, (c) trees: 2.0 m < size < 4.0 m. Solid line = height, dashed line = diameter.

The bell shaped size distribution of *C. villosa* in both polluted and un-polluted habitats and *J. phoenicea* and *C. siliqua* in the polluted habitats indicated comparable representation of the juvenile and mature individuals. If the current situation continues, a reduction in population size of these species is expected in the future. These results coincide with the studies of Shaltout and Mady (1993) in their study on the size distribution of *Lycium shawii* in Central Saudi Arabia, Al-Sodany (2003) in his study on the size structure of *Phlomis floccosa* in the Western Mediterranean Coast of Egypt and Galal (2011) on *Leptadenia pyrotechnica* along wadi Gimal, Red Sea, Egypt. The negative skewed distribution of *C. sempervirens* 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 these species is rare which may be related to hyper-aridity and low fertility. Similar conclusions were made by Al-Sodany (2003) and Galal (2011).

In the course of this study, it can be concluded that the recorded alteration in distribution patterns of *C. sempervirens*, *J. phoenicea* and *C. siliqua*, negative skewed size for the former and bell shaped distribution for the laters, in the polluted habitat may indicate that these species suffer from population decline and limited regeneration capacity as a result of pollution. Thus measures should be taken for the proper management and conservation of these species. Moreover, waste water treatment facilities should be provided and strict legislation must be enforced to protect this ecosystem. Also, impacts on public health and underground aquifers should be identified. Finally, it was concluded that pollution had significant impact on the plant density and sizes structure of the common woody plants in Wadi El-Shees. Such study may help in managing and conserving plant diversity in Northern Libya.

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