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Ecological studies of *Commiphora* genus (myrrha) in Makkah region, Saudi Arabia

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ABSTRACT

Commiphora, myrrha, is a pantropical genus and perform well in arid and semi-arid environments. This genus has economic importance. Distribution of *Commiphora* species and their associated species in Saudi Arabia has not been studied to date. The current study report on (a) characterization and distribution of plant communities including *Commiphora* species and (b) assessment of factors influencing ecological preferences of these species. Five species of *Commiphora* are recorded inhabiting mountain slopes, steep escarpments or hills consisting of igneous rocks, either granites or basalt with drought prone shallow soil. One hundred and twenty-six plant species belonging to 95 genera and 35 families were found associated with different *Commiphora* species. Therophytes showed the most frequent life form class and Sudanian region elements recorded the highest phytogeographical units (28%) followed by Tropical elements. Field study showed that *Commiphora gileadensis* and *C. quadricincta* preferred granite and basalt rocks exposed to erosion, while *C. myrrah*, *C. kataf* and *C. habessinica* grow on resistant coarse pink granite. The analysis of 240 sampling stands with TWINSPAN revealed the vegetation of *Commiphora* habitats into eight vegetation groups; each group represented a distinct microhabitat. Dendrogram obtained from a hierarchical classification showed that habitats of *C. gileadinsis* and *C. quadricincta* are more similar than those of other species. This similarity was confirmed by Jaccard and Sorenson similarity indices and by Pearson correlation coefficient. This investigation compiled the information/data to facilitate future range management of *Commiphora* species.

1. Introduction

Commiphora genus, Myrrha, is small trees or shrubs with short thistly branches. It is one of the most diverse genera of Burseraceae family. Myrrha trees have gained great economic importance since ancient times [31]. Their resinous exudates used as perfume, incense, or humankind [2, 19, 31, 46]. *Commiphora* is a pantropical in distribution performing well in arid and semi-arid environments occupying an ecological range; between 1 and 2100 m above sea level; striving best on aridisols [23, 49]. It is codominant over huge areas of the Horn of Africa and supports the large livestock populations of pastoral and agro pastoral communities. Some species of this genus are well adapted to a narrow ecological range [47]. Saudi Arabia is a huge arid land area covering major part of the Arabian Peninsula with a geologic structure contemporary of Alps [42]. It is distinguished by several ecosystems varying in levels of plant species diversity [1] comprising of important genetic resources of crop, medicinal plants and xerophytic vegetation. These make up the prominent features of the plant life in the kingdom [5, 6, 7, 53]. The flora of Saudi Arabia has about 2250 species [17] and include six *Commiphora* species inhabiting rocky stone hills. The trees and shrubs are scarce in arid environment of Saudi Arabia due to infrequent availability of water. However, due to rough topography, there is some order of grooving where runoff water gathers in specific habitats. These favored sites support lives of shrubs and trees like *Commiphora* species. Despite the great economic importance of *Commiphora* and other endangered species their phytosociology has not been studied in Saudi Arabia. Limited work is research is done in the world [21, 27, 28, 29, 30]. Our knowledge of *Commiphora* status and distribution in Saudi Arabia is inadequate. There is need for descriptive and ecological investigations. We know that vegetation classification is a widely used tool for the interpretation and explanation of natural ecosystems and habitats [14]. This also facilitates decision making for the management of protected areas [13]. We studied characteristics and distribution of plant communities including *Commiphora* species. Assessment of factors influencing ecological preferences in

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the area as a step for their conservation and propagation is presented.

2. Materials & methods

2.1. Study area

About 10^4 km^2 were selected, including three governorates, Khulais, Osfan and Makkah, in Makkah region, western Saudi Arabia, (Fig. 1). The study area is located between 21°21′ to 22°11' (latitude) and from 39°34′ to 40°11' (longitude). The area belongs geologically to the Arab Shield unit, which is complex in its geological composition, consists generally of pre-Cambrian rocks, where underground rocky rocks are found in sedimentary rocks. In addition, Arabian lava fields (locally known as harrats) which were contemporary with the opening of the Red Sea predominate large part of the studied area.

The rainfall in the area is scarce and highly inconstant depends on elevation. The maximum annual precipitation is 18 mm through November to January. The average minimum and maximum annual temperature are 21 °C and 36.5 °C. The maximum temperature often reaches 41.9 °C during June, while the lowest minimum temperature touches below 16.4 °C during winter (Table 1).

2.2. Sampled stands

A thorough survey of the study area was conducted to determine the *Commiphora* habitats and their distribution. 240 stands, each 50 m × 50 m in size, were distributed to cover the various habitats including *Commiphora* species. Due to the hot climate of the study area, samples were collected during January to April, prior to the disappearance of annuals. In each stand, listing of all species and their life forms and chorotypes were determined. The collected plant samples were identified and named according to [18, 35]; and [16]. Life forms of the identified species were determined depending upon the location of the regenerative buds and the parts that were shed through the unfavorable season [44]. The biogeographic affinities of the recorded species were determined according to [54] and [52]. In each stand, species present was recorded and plant cover was estimated visually. The density and frequency of different *Commiphora* and the associated species were determined by the data recorded from the sample stands following the methods described by [36].

2.3. Soil samples and analyses

Five soil samples were gathered from zero to 25 cm depth under different *Commiphora* species.

These five soil samples were pooled to form one composite sample, which was air-dried and thoroughly mixed. Soil texture was determined by the Bouyoucos hydrometer method, which provided quantitative data on the percentage of sand, silt, and clay. Soil water extracts of 1: 2.5 were prepared for soil pH determinations using a pH meter Model HI 8519, and electrical conductivity (Soil: water ratio, 1:1) was detected by a CMD 830 WPA conductivity meter. Soluble sulfates, chlorides, and bicarbonates (soil:water ratio, 1:5) were estimated according to [25]. Soil water extracts of 1:5 were prepared for detection of potassium and sodium cations by a flame photometer [4] and for determination of magnesium and calcium cations determination via EDTA (0.01 N) according to [25]. The least significant differences (One-WayANOVA) among the mean values for soil analysis were calculated as recommended by [11]; terms were considered significant at P = 0.05.

2.4. Data analysis

Vegetation classification technique was employed; the stand-species data matrix was classified into vegetation groups using the importance values of species by means of the Two Way Indicator Species Analysis (TWINSPAN) computer program [24]. Plant communities were named after their dominant species. Gamma species diversity (γ -diversity) was calculated as the total species number in each landscape or vegetation group. Species richness (α -diversity) of the vegetation cluster was calculated as the average number of species per stand. Species turnover

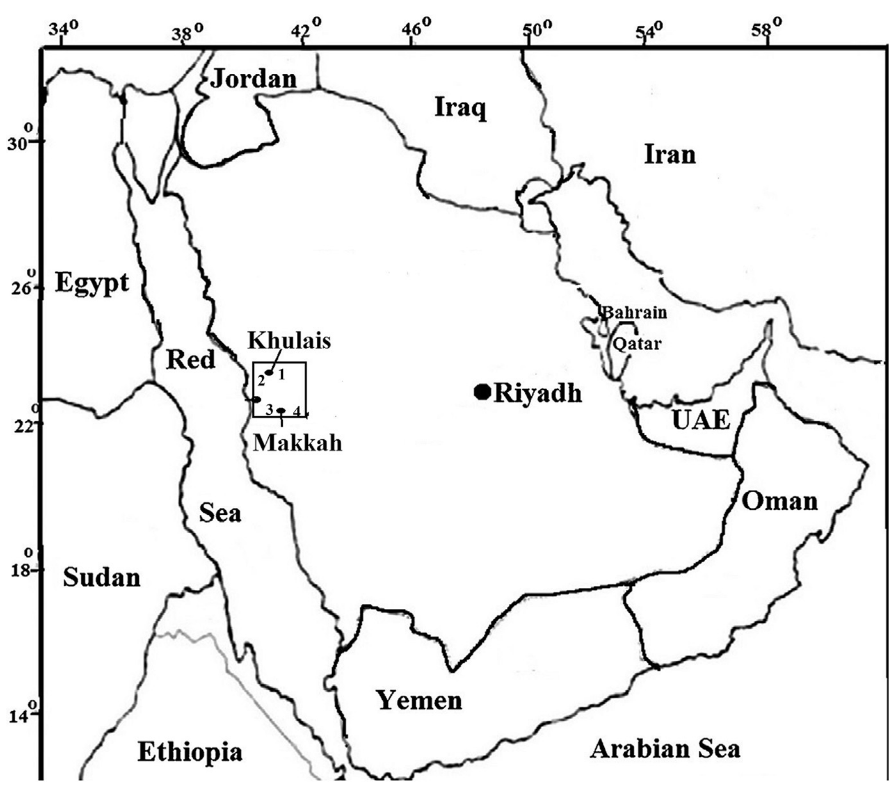

Fig. 1. Location map of the studied area, numbers indicates sites where *Commiphora* species are dominant.

Table 1
Rainfall, temperature and relative humidity of the study species habitat during the study (from January 2016 to December 2018).

	Avg. Temperature (°C)		Min. Temperature (°C)		Max. Temperature (°C)		Precipitation/Rainfall (mm)	
	Khulais - Usfan	Makkah	Khulais - Usfan	Makkah	Khulais - Usfan	Makkah	Khulais - Usfan	Makkah
January	23.3	23.5	16.5	17.2	30.2	29.9	10	12
February	23.3	24.1	16.4	17.4	30.2	30.8	1	2
March	25.3	27.1	18.4	20.4	32.3	33.9	2	5
April	27.3	29.7	20	22.7	34.7	36.8	4	9
May	29.9	33.2	22.6	26.2	37.2	40.3	1	5
June	30.7	34.9	23.3	28	38.1	41.9	0	0
July	32	35.2	25.4	29.1	38.7	41.3	0	0
August	32.1	34.7	26	29	38.2	40.5	0	1
September	31.1	34.4	24.5	28	37.8	40.8	0	1
October	29.2	31.2	22.4	24.5	36.1	38	0	3
November	27.2	27.7	20.5	21.2	33.9	34.2	18	18
December	24.8	24.7	18.3	18.5	31.3	31	16	14

(β -diversity) are calculated as (α γ^{-1}). Shannon–Wiener index $\widehat{H} = -\sum_{i=1}^{s} p_i \log p_i$, for the relative evenness was calculated for each stand on the basis of the relative cover pi of the ith species [33, 39].

A hierarchical classification analysis based on presence/absence data with Wards' (minimum variance) method and Euclidean distances as a dissimilarity measure [50] were determined, the analysis was performed with the Statistica statistical software package ver. 8 (StatSoft, Inc., Tulsa, OK, USA). Depending on associated taxa of different *Commiphora* species, Pearson's simple linear correlation coefficient (r) were determined. In addition, two similarities indices, Jaccard and Sorenson, were applied based on presence/absence of species [15].

3. Results

3.1. *Commiphora* habitats and their associated taxa

Five species were recorded; *C. gileadensis* (L.) C.Chr., *C. habessinica* (O.Berg) Engl., *C. kataf* (Forssk.) Engl., *C. myrrha* (Nees) Engl. and *C. quadricincta* Schweinf. In general, the all recorded *Commiphora* species were recorded in Rocky habitats, mountain slopes, steep escarpments or hills which consists of igneous rocks, either granites or basalt, with drought prone shallow soil at an elevation ranged between 80 and 1200 m a.s.l. *Commiphora* species were never recorded in either inland or coastal plains with deep soil. Table 2 Soil analysis shows that there are differences in Geological substratum. *C. gileadensis* and *C. quadricincta* were found in granite and basalt rocks that were exposed to erosion, while *C. myrrha*, *C. kataf* and *C. habessinica* were found in resistant, coarse pink granite, mixed with grey diorite and granodiorite. A total of 126 plant species belonging to 95 genera and 35 families were identified as associated with different *Commiphora* species (Appendix). The major associated families were Poaceae and Fabaceae (13 species for each) followed by Lamiaceae (eight species). While 13 families were represented by only one species. More than 64% of the recorded species (Appendix) belong to only nine species rich families. *Blepharis attenuate* Napper, *Acacia ehrenbergiana* (Forssk.) Hayne, *Indigofera spinosa* Frossk, *Boerhavia diffusa* L., *Cenchrus ciliaris* L. and *Fagonia indica* Burm. f. were recorded as an associated species with all *Commiphora* species. Table 3 shows eleven species that recorded more than 50% (frequency) with at least one *Commiphora* species, five of them were recorded with all *Commiphora* species, namely *Acacia mellifera, Caralluma retrospiciens, Grewia tenax*, *Indigofera spinosa,* and *Lycium shawii*. The highest frequent species was *A. hamulosa* with *C. giladeansis* while, *Indigofera spinosa* recorded the highest frequencies with the other four species. Life forms of the associated species were exhibited a great diversity and reflects a typical desert flora. The most frequent life form class was Therophytes with the maximum number of species (48.8%), followed by Chaemophytes (23.9%), Phanerophytes (18.9%) and Hemicryptophytes (7.8%), while the least frequent life form class was Geophytes (0.8 %) (Fig. 2). Biogeographical affinities (phytogeography) of the recorded associated flora showed that Sudano-Zambezian region elements exhibited the highest number (28%) followed by Tropical elements and Saharo-Arabian elements, 22% and 17%, respectively (Fig. 3). In addition to plant species that belong to the Sudano-Zambezian elements and the Saharo-Arabian associated with *Commiphora* species in the target region, it has numbers of plant species which dominate in the other uniregional region, such as Mediterranean and Irano-Turanian (5 species for each). The highest Bioregional elements were recorded by Saharao-Arabian-Sudano-Zambezian (15%), followed by Saharo-Arabian – Tropical

Table 2
Soil parameters registered along different sites where *Commiphora* species grow. The results are the means of 5 replicates.

	C. giladensis	*C. quadricincta*	*C. myrrha*	*C. kataf*	*C. habessinica*	L.S.D. ($P < 0.05$)
Coarse sand (%)	7.1	0.57	5.6	3.8	8.2	2.10
Fine sand (%)	79.4	87.13	79.3	83.6	80.1	11.30
Silt (%)	9.8	9.3	10.9	9.2	8.2	1.74
Clay (%)	3.7	3	4.2	3.4	3.5	1.30
pH	7.70	7.60	7.50	7.70	7.40	0.40
E.C. (mS/cm)	1.43	1.13	1.43	1.05	1.40	0.51
SO_4^- (mg/Kgm)	90.1	86.0	135.0	89.0	42.0	4.2
Cl^- (mg//Kgm)	22.5	82.0	110.1	89.0	39.1	1.3
HCO_3^- (mg//Kgm)	33.8	67.8	79.0	119.0	90.3	1.6
K^+ (mg//Kgm)	4.0	11.8	3.40	2.0	2.1	0.1
Na^+/Kgm)	2.0	11.4	4.30	45.1	9.4	3.0
Mg^{++} (/Kgm)	15.5	28.0	39.1	26.5	22.2	2.1
Ca^{++} (/Kgm)	15.0	42.4	41.0	42.8	23.1	1.4
Topography	Mountain slops, Mountain cliffs	Lava hills - Mountain slops	Mountain slops	Escarpment slope	Escarpment slope	
Altitude range (m)	100-750	80–300	250–1200	260–1200	500–1150	
Geological substratum	Eroded granite and black basalt	Eroded granite and black basaltic	Coarse pink granite mixed with diorite	Coarse pink granite mixed with diorite	Coarse pink granite mixed with diorite	

Table 3
Frequencies (%) of the major associated species with the different recorded *Commiphora* species.

	C. giladensis	*C. quadricincta*	*C. myrrha*	*C. kataf*	*C. habessinica*
Acacia hamulosa	95	80	60	50	50
Acacia mellifera	45	65	17	10	5
Acacia etbaica	0	0	30	20	20
Cadaba farinosa	50	55	25	0	0
Cadaba glandulosa	66	40	20	0	0
Caralluma retrospiciens	10	5	10	15	10
Euphorbia cuneata	75	70	0	0	0
Grewia tenax	30	25	80	50	50
Indigofera spinosa	85	90	90	95	95
Lycium shawii	50	50	30	50	50
Tephrosia nubica	30	10	40	0	0

while, the cosmopolitan were eight species.

3.2. Vegetation groups

During the long dry period, there are many dry woody herbs and grasses, which are not clearly apparent among rocks. Next rains fall, an incredible flush of plant growing and many plants, previously dry, become unmistakable while others not obvious before appear. Classification of the recorded species in the 240 stands with TWINSPAN separated the vegetation of *Commiphora* habitats into two main divisions, which further divided at five level to eight vegetation groups (Fig. 4); each group represented a distinct microhabitat.

3.2.1. VG (I)

Acacia hamulosa- Cadaba farinosa community in a granite outcrop habitats, 103 m a.s.l., represented this group, which exhibited the lowest species number. The most frequent species was *Indigofera spinosa*, while *Euphorbia cuneata* was abundant and each of *Blepharis attenuate*, *Tripulus macropterus, Senna italica* and *Commiphora quadricincta,* with a density of 2/hectare, were prominent.

3.2.2. VG (II)

This group occurred in a mountain escarpment, 300–600 m a.s.l., in Makkah city. The community found in this group was *Commiphora gileadinses- Acacia mellifera* community. *A. hamulosa, A. tortilis* and *Euphorbia arabica* have been usually abundant; also a variety of annual grasses grow, including *Aristida mutabilis*, *Tephrosia nubica, Stipa capensis* and *Cenchrus ciliaris* among the most abundant species, *C. gileadinses* recorded a density of 30/hectare.

3.2.3. VG (III)

This group was recorded at a stony plateau, 140 m a.s.l., covered with lava flows, which are divided into a sheet of rocks known as 'harra'. In this vegetation group *Commiphora quadricincta- A. hamulosa* community was distinguished with *A. mellifera, C. gileadensis* and *Euphorbia cuneate* as codominant species. Among the woody herbs, which form a natural

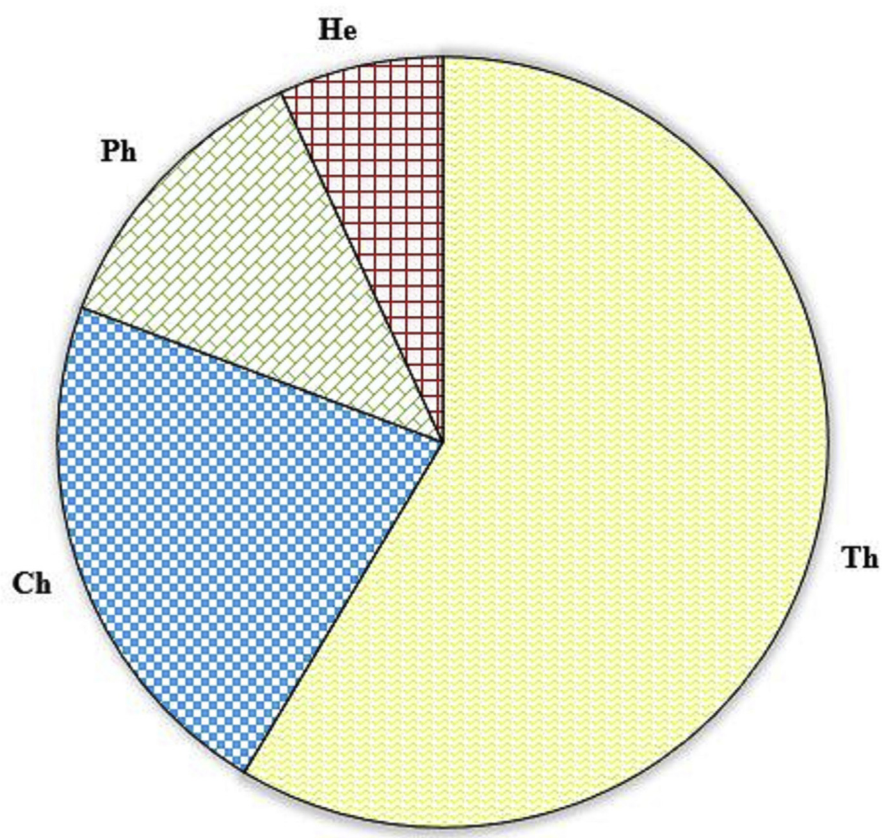

Fig. 2. Proportinal percentage of life forms for the associated species.

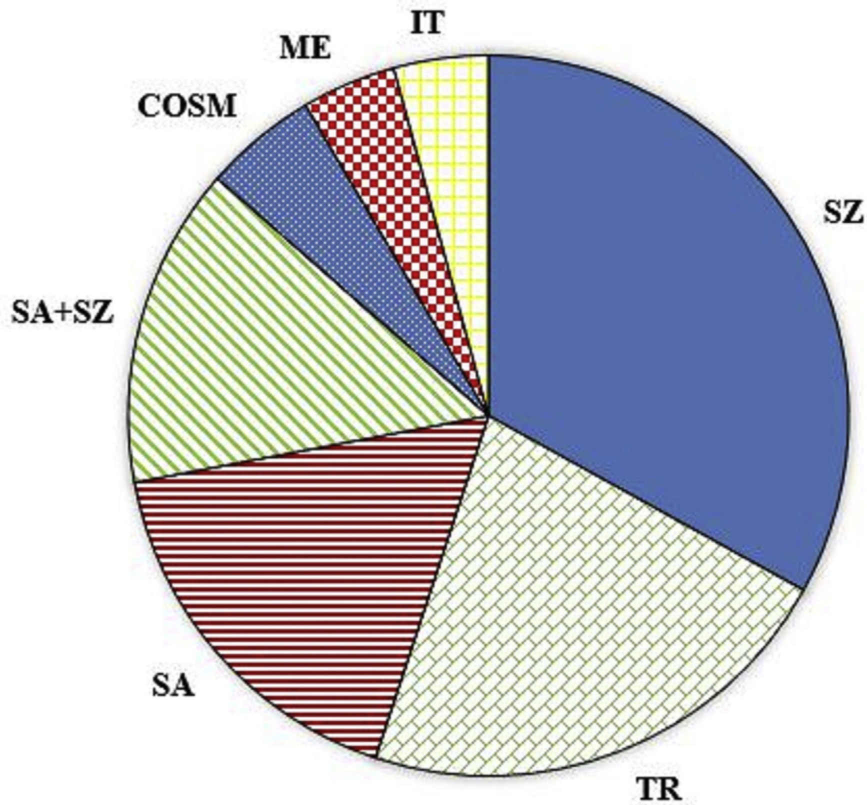

Fig. 3. Chorological types of the the associated species. Abbreviations are in the appendix.

rockery of great beauty, after rainfall, are included *Aerva javanica* and *Tribulus macropterus*, in patches colonies. The most distinguishing perennial herbs of the hills were *Cymbopogon schoenanthus*, *Anastatica hierochuntica*, *Aizoon canariense* and *Blepharis attenuate* while Leguminosae was well represented with *Indigofera spinosa*. *C. quadricincta* and *C. gileadensis* were recorded in this community with a density of 50 and 3/hectare, respectively.

3.2.4. (IV)

Likewise the previous group, this group included two *Commiphora* species, C. *quadricincta* and *C. gileadensis*. The group was found on a mountain slopes, 105–140 ma.s.l., covered by lava rocks. Surprisingly, it is characterized by a larger number of plant species than the previous group, upper plateau, because of the accumulation of soil particles between the rocks in larger quantities than harra plateau. The community, which recorded in this group, was *Cadaba glandulosa- Commiphora quadricincta* community with *A. hamulosa*, *A. melliferea* as codominant. The most frequent species were *Tephorosia apollineae*, *Ochradenus baccatus*, and *Forsskaolea tenacissima*, while *C. gileadensis* was frequent in this vegetation group. *C. quadricincta* and *C. gileadensis* were recorded in this community with a density of 20 and 5/hectare, respectively.

3.2.5. VG (V)

This group was found in a hill covered with weathering basalt rocks, 130–270 m a.sl. Two different communities were recorded in this vegetation group. The first community was *A. tortilis - A. ehrenbergiana* community occurred on the stony slopes at 130 m a.s.l., with *E. cuneata* and *A. hamulosa* as common small trees on the stony slopes. In sheltered glens, *Commiphora gileadensis*, *Lycium shawii* and *Cadaba glandulosa* were abundant, the trees often spaced as close as 6×6 m, though they do not form a canopy. The second community, *C. gileadensis - Lycium shawii* was recorded at 235 m a.s.l. *A. tortilis* disappeared in this community and *C. gileadensis* increased with increasing elevation, furthermore *Indigofera spinosa*, *Stipa capensis*, *Lindenbergia indica*, and Grewia *tenax* were frequent. *C. gileadensis* was recorded in this group with a mean density of 25/hectare.

3.2.6. VG (VI)

This vegetation group showed the highest species number (Table 4), gamma diversity, and include three *Commiphora* species (*C. Myrrha*, *C. kataf* and *C. habessinica*) in three different plant communities:

(A) *Commiphora myrrha-Acacia etbaica* community, between 12000 and 800 m trees occur on the hillsides at orchard spacing (5–20 m), among which, *C. kataf*, *A. ehrenbergiana* and *Ficus cordata* were frequent, together with *Grewia tenax,* and others, all of which become more closely spaced in small ravines. *Cucumis prophetarum*, *Lycium shawii* and *Pupalia lappacea* were almost abundant. In some small narrow valleys, the trees were almost thick enough to shape a light woodland. *C. myrrha* and *C. kataf* were recorded in this community with a density of 30 and 20/hectare.

(B) *Acacia ehrenbergiana*- A. hamulosa community.

This community was appeared at elevation (1000- 700 m) at a north facing mountain slope.

Few individuals of *Commiphora habessinica* were recorded in this community with a density of 2/hectare. *Commelina benghalensis*, *Ocimum forsskaolii*, *Phlomis brachyodon* and *Scrophularia argute* were abundant in higher elevation, where high water content present.

(C) *Acacia hamulosa* - Triumfetta flavescens community.

This community was appeared along the base of the foothills where the substratum is coarser (600–700 m), small-scattered trees of *Acalypha fruticosa* and *Commiphora myrrha* occur, furthermore *Blepharis attenuate*, *Indigofera spinosa*, *Abutilon pannosum* and *Tephrosia purpurea* were frequent.

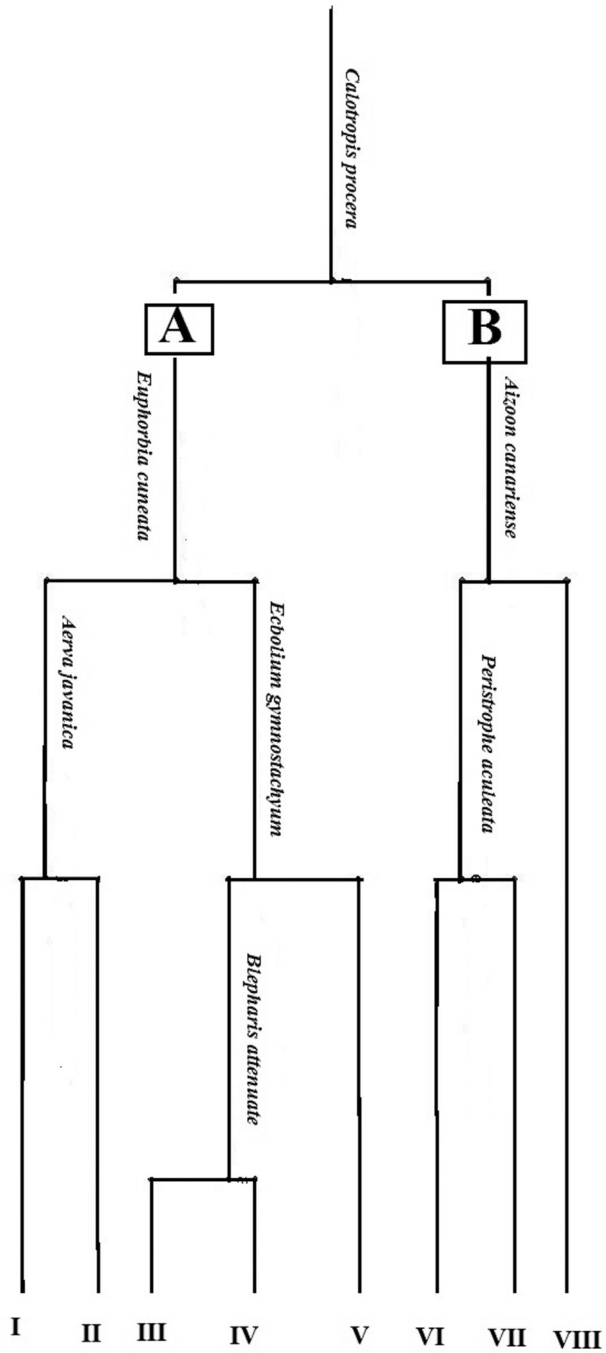

Fig. 4. Vegetation clusters resulting from the TWINSPAN classification.

3.2.7. VG (VII)

A. hamulosa- Commiphora myrrha community was recorded in this group on more gentle granite slopes, 450 m a.s.l, with *Lycium persicum, Grewia tenax* and *Acacia etbaica* were abundant, also *Heliotropium strigosum*, *Euphorbia Arabica*, *Anticharis glandulosa*, all become more frequent. *C. myrrha* recorded its highest density (35/hectare) in this community.

3.2.8. VG (VIII)

A. mellifera- C. myrrha community was recorded in this group and found at an escarpment consisted of granite and marble at the upstream of a tributary of al-Nu'man valley, 600 m a.s.l,. The most common species that always occurred were *Grewia tenax*, *Rhazya stricta*, *Caralluma retrospiciens*, *Ephedra foliata* and *Ochradenus baccatus*. *Lindenbergia indica, Cocculus pendulus, Corbichonia decumbens* and *Tephrosia nubica* were frequent, whilst *Premna resinosa* and *Cleome chrysantha*, which recorded just in this group.

3.3. Similarity

The hierarchical classification of *Commiphora* species, according to their associated species, (Fig. 5) resulted a dendrogram of two main groups, one included *C. gileadinsis* and *C. quadricincta* and the second included the other three species. Jaccard and Sorenson similarities (Table 5) were highest between *C. gileadensis* and *C. quadricincta*, followed by that obtained between *C. kataf* and *C. habessinica*. The previous similarities results were confirmed by both Pearson correlation coefficient (Table 6).

4. Discussion

The field survey of this study and also earlier investigation revealed that *Commiphora* species inhabit rocky habitats with soil accumulated in pockets and crevices. Geologically, the study area characterized by Precambrian basement rocks that have been deformed, and then eroded over hundreds of millions of years. The study area is distinguished by late Precambrian outcrops of granitic gneisses and Arabian lava fields (locally called harrat), creating scattered rock as habitats suitable for *Commiphora* species. We recorded five species of *Commiphora* in the study area out of six species of *Commiphora* of Saudi's flora indicating the availability of appropriate habitats for *Commiphora*. In the habitats of *Commiphora* the soils receives water steadily almost independent of rainfall changes. The relatively large surface area of the rocks harvest water to saturate the nearby soil pockets with water even in moderately dry years. Worldwide, a large number of plant species are confined to relatively open, shallow-soil, rocky habitats [12, 26, 34, 38, 41]. There is growing evidence that during the dry season, water held within the underlying bedrock is essential for meeting the transpiration demands of shrubs and trees [43, 45]. [40] suggested that the strong habitat specificity of many shallow soil endemics related to the degree of edaphic specialization needed to establish and survive in these harsh habitats and the incompatibility of these adaptations with deeper soil environments explaining the absence of *Commiphora* species in the deep soil of sandy plains. *Commiphora*

Table 4
The recorded vegetation groups with their biodiversity indices and densities (individual/hectare) of different *Commiphora* species.

	Vegetation groups							
	I	II	III	IV	V	VI	VII	VIII
C. giladensis	0	30	3	5	25	0	0	0
C. quadricincta	2	0	50	20	0	0	0	0
C. myrrha	0	0	0	0	0	30	35	5
C. kataf	0	0	0	0	0	20	0	0
C. habessinica	0	0	0	0	0	2	0	0
Number of stands	10	20	40	10	40	40	40	40
Total species number (Gamma species diversity	21	17	25	31	28	71	59	36
Species richness (sp stand-1	5.3 ± 0.03	5.1 ± 0.02	4.5 ± 0.02	2.57 ± 0.01	10.5 ± 0.95	11.5 ± 0.91	8.3 ± 0.90	7.4 ± 0.8
Shanon index	1.10 ± 0.08	1.06 ± 0.7	0.93 ± 0.07	0.53 ± 0.02	2.1 ± 0.09	2.4 ± 0.09	1.73 ± 0.07	1.54 ± 0.08

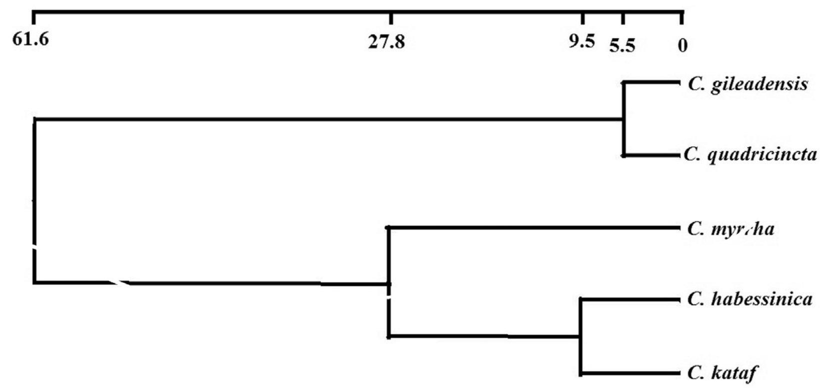

Fig. 5. Hierarchical classification of the *Commiphora*'s habitats based on their floristic composition (incidence data), obtained using Ward's method and Euclidean distances as measures of Linkage Distance.

Table 5
Sorenson (bold) and Jaccard similarities between different *Commiphora* species.

	C. gileadensis	*C. myrrha*	*C. quadricincta*	*C. habessinica*	*C. kataf*
C. gileadensis	1	**0.56**	**0.91**	**0.49**	**0.48**
C. myrrha	0.39	1	**0.55**	**0.69**	**0.47**
C. quadricincta	0.84	0.38	1	0.47	**0.47**
C. habessinica	0.32	0.53	0.30	1	**0.82**
C. kataf	0.31	0.53	0.31	0.70	1

Table 6
Pearson correlation coefficient between different *Commiphora* species.

	C. gileadensis	*C. myrrha*	*C. quadricincta*	*C. habessinica*	*C. kataf*
C. gileadensis	1	−0.2256	0.8259	0.02758	−0.02437
C. myrrha	−0.2256	1	−0.2122	0.4243	0.3708
C. quadricincta	0.8259	−0.2122	1	0.004584	−0.01291
C. habessinica	0.02758	0.4243	0.004584	1	0.6951
C. kataf	−0.02437	0.3708	−0.01291	0.6951	1

species were not recorded in earlier study by [7] of habitat with similar rock type, but with higher elevation, differing in temperature and rainfall. Rock type, rainfall and temperature have a strong effect on the distribution of plant species [9, 10]. The presence associated species exhibited that a few families are of floristically importance as in most tropical and subtropical regions, where majority of plant species belong to a restricted number of plant families, a distinguishing character of the floristic structure of Saudi's flora [6]. Our data revealed that of the 35 families, 13 families (37%) are represented by one species per family. This is a common character of desert flora indicating that only a few of species of individual families have adapted and survived the harsh environment. The other species that could not adapt and endure did not survive. Therophytes as expect showed more than 48% of the total associated species, they usually bloom and form luxurious growth, when moisture collect after rainfall. These results explain that the life form/spectra of desert habitats in many parts of Saudi Arabia (e.g. [3, 7, 8, 16, 18, 20, 22]. The presence of five species of *Commiphora* in the study area could be attributed to the fact that the present-day flora of the West Saudi Arabia are the result of the evolutions taken place in the palaeotropical flora of ancient times [48, 51]. The Southwestern Arabian Peninsula and the northeastern region of Africa belong to a single phytogeographic entity and more than half of *Commiphora* species are native to the Horn of Africa [47]. Sudano-Zambezian region elements recorded the highest number as the studied area belongs to The Nubo-Sindian Province, which is a part of the Sudano-Zambezian Region [54]. Saharo-Arabian elements showed a high species number because plant species in this region adapted to aridity and very high temperatures. The ecological optimum of species is well reflected in the density of its individuals and dominance, as it reflects optimal conditions of the habitats. It is a reliable marker of phytosociolgical units [32]. stated that species with narrow ecological ranges, such as *Commiphora*, in their habitat are highly competitive with a plant of wider ranges, which explain the dominance of *C. gileadensis*, *C. quadricincta* and *C. myrrah*, for some communities.

A number of narrow ranged species of rocky habitats in the desert provide description of the plant communities confining to these habitats. These could be classified as exclusives and some of them are even endemic to these habitats. TWINSPAN classification divided the vegetation of *Commiphora* habitats into two main divisions, one includes *C. gileadensis* and *C. quadricincta* and the second includes the other three species. The difference between the two divisions habitats is clear in rock type, the first division characterized by granite and basalt rocks that were exposed to erosion, while the second division characterized by resistant, coarse pink granite, mixed with grey diorite and granodiorite. This indicates that the type of rock has an effect on *Commiphora* species distribution. Vegetation group (VI) exhibited the highest species number because of its geomorphological heterogeneity due to the range of differing aspects and slopes (topography). Difference in aspect and soil drainage has proven to be an important predictor of plant diversity [37]. In addition, dense fog at high altitudes condenses on the surface of the rocks and turns into water absorbed by the soil collected between the cracks of the rocks increases soil water content at high places. On the other hand, vegetation group (II) recorded the lowest species number because of its small area. The distribution of some plant species overlaps many groups, in some cases, owing to a wider ecological role of these species or the similarities between some habitats. The similarity between

C. gileadinsis and *C. quadricincta* may be due to the degree to which they tolerate drought more than other species.

5. Conclusion

The present study is an attempt to compile the current available knowledge of *Commiphora* specie probably to be broadly representative of many parts of western Saudi Arabia. Investigations underline the significance of local sites for *Commiphora*. It is suggested that the description and classification of the different vegetation groups will facilitate understanding of the *Commiphora* life in the study area in particular and of Saudi Arabia as a whole. Our results can be usefully applied in the conservation and management of the area.

Declarations

Author contribution statement

Emad A. Alsherif: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

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Appendix A. Supplementary data

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