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Floristic Diversity and Vegetation-Soil Correlations in Wadi Qusai, Jazan, Saudi Arabia

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Authors' contributions

This work was carried out in collaboration between all authors. The authors designed, analyzed, interpreted and prepared the manuscript.

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ABSTRACT

Aims: To study Floristic diversity, life-form, chorology, edaphic factors affecting the species distribution of Wadi Qusai.
Study Design: Several field trips were carried out to the study area – sites soil analysis.
Place and Duration of Study: Wadi Qusai - Jazan - Saudi Arabia.
Methodology: Floristic composition, vegetation diversity, life form, chorology, soil analysis and cover estimation by TWINSPAN, DCA and CCA.
Results: A total of 103 species belonging to 77 genera and 33 families were recorded from 20 sample sites. Poaceae, Euphorbiaceae and Amaranthaceae are the most highly represented families. Therophytes and phanerophytes are the dominant life forms. Chronological analysis revealed that biregional elements that belong to the Saharo-Arabian and the Sudano-Zambezian together have the highest share of species representing 36 species (35% of the total species).
Conclusion: Five vegetation groups were recognized by TWINSPAN, DCA and CCA analysis; group A (*Aloe fleurentiniorum*, *Cadaba glandulosa* and *Delonix elata*) inhabiting the high wadi slope, group B (*Anisotes trisulcus*, *Fagonia indica*, *Pulicaria undulata*, *Acacia ehrenbergiana* and *Panicum turgidum)* was occupied the low slope and wadi terraces, group C (*Ziziphus spina-christi*, *Abutilon pannosum* and *Fagonia indica)* was represented the medium wadi slope, Group D

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(*Leptadenia arborea*, *Salvadora persica*, *Dobera glabra* and *Jatropha pelargoniifolia)* was performed the dry wadi bed and group E (*Cyperus articulates, Desmostachya bipinnata, Saccharum spontaneum*, *Typha domingensis* and) was recorded in the wet wadi bed. Groups A, B and C were positively correlated with axis 2 whereas Groups D and E were positively correlated with axis 1. *Rhazya stricta* has been recorded for the first time in the wadi.

Keywords: Floristic composition; life forms; chorology; edaphic factors; Wadi Qusai.

1. INTRODUCTION

Saudi Arabia is considered the richest area in the Arabian Peninsula regarding biodiversity; it comprises important genetic resources of crop and medicinal plants. Xerophytes make up the prominent features of the plant life in the kingdom [1]. Cover vegetation of Wadies may be considered the main centers of biodiversity in desert habitats, these wadies are home to pastoral communities subtilizing the area as rangelands for different animals [2]. Establishment, growth, regeneration and distribution of the plant communities in the wadies are controlled by many factors such as geographical position, physiographic features, and human impact [3,4,5,6]. Jazan region is located in the south west part of Saudi Arabia (E: 42.0°- 43.8° and N: 16.5°-17.0°). It`s area around 13,500 km^2, it is a part of Arabian shield which is a part of the Precambrian crustal plate and consists of igneous and metamorphic rocks [7]. Jazan region is amazing for its high species diversity; this diversity is caused by variability in geomorphological characteristics, which includes islands, sand dunes, sandy plains, low rocky hills and high mountains [8]. Geomorphologically, Jazan region was recognized by three main sectors; Mountains: El-Sarwat Mountains, Plains: 'Tihamah' coastal plains, and Islands: including those between Jazan city and Farasan islands [9,10]. Five ecosystems were distinguished at Tihamah coastal plains i.e. shoreline, sand formations, salt marshes, wadis and rocky hills [11,12]. Other studies recorded the floristic diversity along with the vegetation analysis in Tihama plains [8,11,13,14,15]. Moreover, Parker [16] revealed that water availability, including annual precipitation, soil properties, and topography are biotic factors that affects the floristic diversity of any region up to certain extent. Wadi Qusai is one of the most famous wadies of Jazan, It is considered to be favorable for plant growth due to stagnant water after rainfall [10]. Because of the very limited information about the characteristics of soil and species distribution of Wadi Qusai, our aim is to provide a satisfied survey report about the floristic composition, chorotype and full vegetation structure of the wadi and to demonstrate the ecological factors affecting the species distribution.

1.1 The Study Area

Jazan region about 260 km long coastal area on the south-western part of Saudi Arabia, stretching from Al-Muwassam in the south to Al Shuqaiq in the north [10]. Wadi Qusai is the border regions (around 80 km^2) near Yemen frontier, it is located in the western part of Jazan, between the Ed-Dayer in the east and the Harub in the west, Al-Rayth in the North and Fayfa mountains in the South. It extends between 17^{0}379`N and 17$^0$407 latitudes, 42$^0$99`E and 43^{0}109 longitudes (Fig. 1). The study area, approximately situated at 370-450 km^2 above sea level (a.s.l.). The study area lies within the subtropical dry zone which in turn is characterized with hot summers and mild winters [17]. The mean average of annual temperature is 32.2°C; December is the coldest month with the lowest average temperature (23.0°C) and July is the hottest month with the highest average temperature (40.2°C) (Fig. 2). The rains on slopes of the eastern side of the mountains are also characterized by low rainfall and warm summers [10]. Precipitation is unpredictable; the mean average of annual precipitation is 12.83 mm; however, the maximum precipitation falls during July and August, 20 mm and 19 mm, respectively.

2. MATERIALS AND METHODS

2.1 Vegetation Analysis

A total of 20 sample plots were selected along Wadi Qusai during the period from October 2017 to May 2018. Chosen sample plots represent vast variations in the study area and in their tributary. In each locality, sample plots were 20×20 m^2, and were selected randomly using the method of [18]. Vegetation sampling includes list of all plant species at each sample plot. The plant cover of each species was estimated

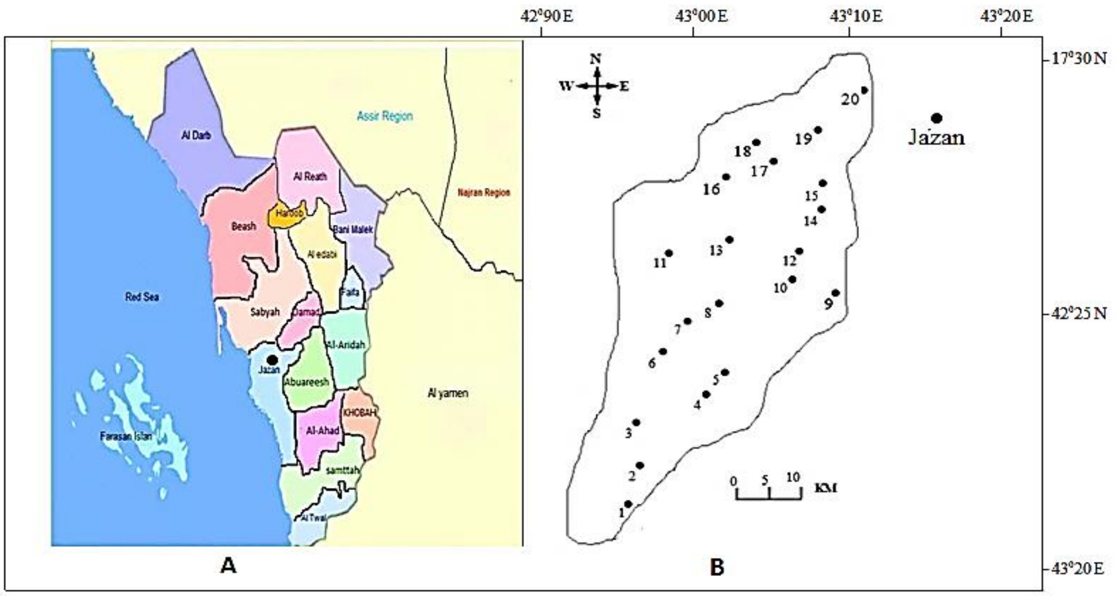

Fig. 1. Location Map of Jazan region, Saudi Arabia (A), Study area of Wadi Qusai, (B) showing sample sites 1–20

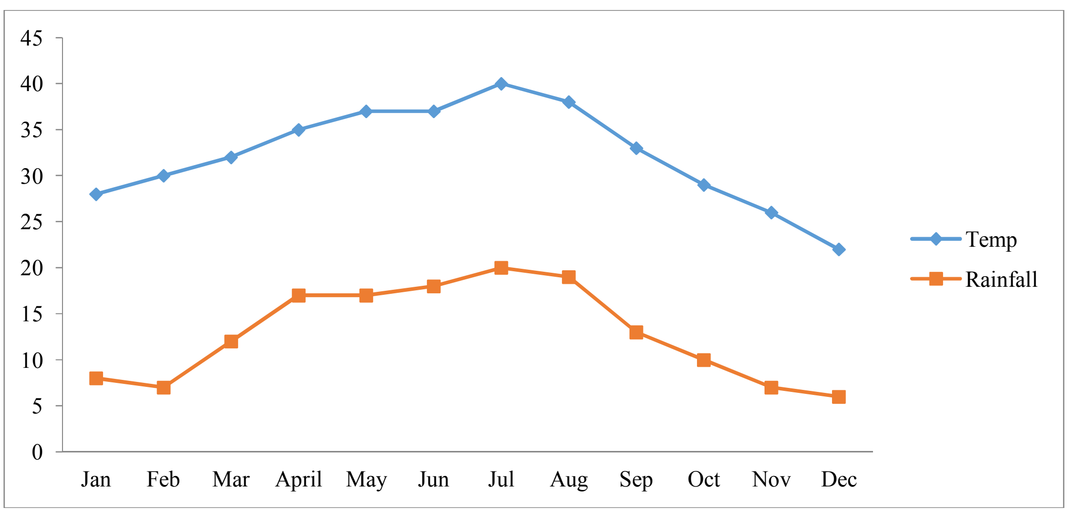

Fig. 2. Monthly average temperature and rainfall in the study area

according to the Zurich-Montpellier technique [19]. According to Shukla and Chandel [20], density (D), frequency (F), abundance (A), cover (C), relative density (RD), relative frequency (RF), relative abundance (RA), relative cover (RC) and importance value (IV) were calculated for each species in each stand. Plant specimens were identified in Jazan University Herbarium, KSA (JAZUH) and updated according to [21]. Plant specimens were deposited in Jazan University Herbarium (JAZUH), Biology Department, Faculty of Science. Life-forms were determined according to Raunkiaer [22]. The chorological analysis was assigned according to Wickens [23] and Zohary [24].

2.2 Soil Analysis

Soil samples were collected randomly from three points per each site at a depth of 0-25 cm. pH for each sample were measured according to Wilde et al. [25]. One part of the soil sample was used to determine soil moisture contents using moisture balance analyzer, the second part was air dried and sieved through 2 mm sieve before analysis and stored at room temperature for physical and chemical analysis. Soil texture was determined by method of [26]. Silt (%) and clay (%) were separated later using pipette analysis method in accordance to Carver [27]. Filtrate of 1:5 soil/distilled water (w/v) extract using HANNA HI98130 Digital Combo meter. Organic carbon (O.C.) was measured according to Piper [26]. Total dissolved salts (TDS L^{-1}), total carbonates (CO_3 %) and chlorides (Cl^- %) were analysed according to Jackson [28]; sulphates (SO_4 mg 100 ml) were precipitated gravimetrically and estimated according to Wilde et al. [25]. Calcium (Ca^{2+} mg 100 ml^{-1}) and magnesium (Mg^{2+} mg 100 ml) were determined according to the procedure of [29].

2.3 Data Analysis

Cover estimations of 103 plant species which recorded in 20 stands were subjected to multivariate analysis using the importance values (IV); by the aid of the TWINSPAN (Two Way Indicator Species Analysis) computer program [30]. The correlations between vegetation and environmental data were estimated using Detrended correspondence analysis (DCA) and canonical correspondence analysis (CCA) according to [30] and [31]. PC-ORD package 4.17 was used to perform the analysis of the data using TWINSPAN and DECORANA tools according to McCune and Mefford [32]. Variation in species diversity, plot traits, and soil variables in relation to plant community was assessed by one-way analysis of variance (ANOVA) using the SPSS software package (SPSS, 2011).

3. RESULTS

3.1 Floristic Composition

The total of 20 sample plots were selected along the study area based on different topographical features, in which different habitat types such as the top, slopes, wadi beds and different vegetation types were scanned. According to the growth type, a total of 103 species belonging to 77 genera and 33 families were surveyed from different sectors of the wadi. Perennial growth types represented the majority of the recorded species by 67 species (65%). Whereas annual plants represented by 36 species, constituted 35% (Table 2). On the other hand, Poaceae has the highest contribution to the total flora, it is represented by 13 species (13%), followed by Euphorbiaceae which represented by 11 species (10%). Five species were recorded in four families of Amaranthaceae, Aizoaceae, Asclepiadaceae and Mimosaceae constituted 19% of the total species. Caesalpiniaceae, Malvaceae, Papilionaceae, Solanaceae and Tiliaceae were represented by four species for each. While, Acanthaceae, Astraceae, Apocynaceae, Cyperaceae, Moraceae and Salvadoraceae were represented by three species each. Five families showed only two species for each, the remaining eleven families were estimated by only one species each, constituting about 11% of the total species in the study area.

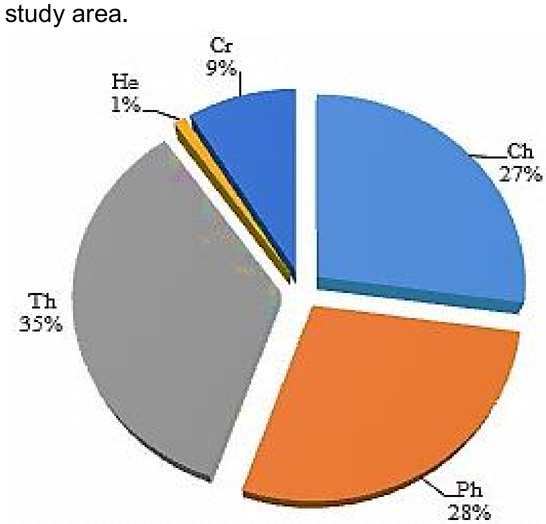

Fig. 3. Life-form relative spectrum of Wadi Qusai vegetation

Ch=chamaephyte, Th= therophyte, Ph = phanerophyte, He= hemicryptophyte, P= parasite, and Cr=cryptophyte

3.2 Life Form

Life-forms were determined according to the location of regenerative buds and the parts shed during the different seasons [22]. Life form observations in the study area revealed that, therophytes were the most frequent constituted 36 species or 35% of the total recorded species, followed by phanerophytes forms were recorded by 29 species with a percentages of 28%, Also chamaephytes were represented by 28 species accounting 12% of the total species. Furthermore, nine species of cryptophytes were recorded as with percentage of 9%. Only one species (1%) named by *Citrullus colocynthis* was recorded as hemicryptopyte (Fig. 3; Tables 1 and 2).

Table 1. List of plant species recorded in the study area with their life forms, vegetation types, chorotypes, vegetation groups and TWINSPAN level

Species	Life form	Vegetation type	Chorotype	Vegetation groups A B C D E 211 11 1 11111 1902520434536781 6789	TWINSPAN level
Portulaca oleracea L.	Th	Ann	COSM	4-------------2------	000
Tetraena simplex (L.) Beier & Thulin	Th	Ann	SA+SZ	34---------------3--	000
Acacia seyal Del.	Ph	Per	SA+TR	75-------5---------5	0010
Ecbolium viride (Forssk.) Alston.	Ph	Per	SA+SZ	-4------------------	001100
Eclipta prostrata (L.) L.	Th	Ann	SA	2-------------------	001100
Sarcostemma viminale (L.) R. Br.	Ph	Per	ME+SA	977--------2--------	001100
Zaleya pentandra (L.) Jeffrey	Th	Ann	ME+SA+IT	77------------------	001100
Adenium obesum (Forssk.) Roem.& chult.	Ph	Per	SA	968-----------------	001100
Cadaba glandulosa Forssk	Ph	Per	ME+SA	976-----------------	001100
Chamaecrista nigricans (Vahl) Greene	Th	Ann	SA+TR	2-------------------	001100
Acalypha racemosa Wall. ex Baill	Th	Ann	SA+TR	2-------------------	001100
Croton bonplandianus Baill.	Ch	Per	PAL	2-------------------	001100
Euphorbia chamaepeplus Boiss. & Gaill	Th	Ann	SA+SZ	-3------------------	001100
Heliotropium longiflorum (DC.) Jaub. & Spach	Ch	Per	SA+TR	2-------------------	001100
Aloe fleurentiniorum Lavranos & Newton	Ch	Per	ME+SA	9-------------------	001100
Malva parviflora L.	Th	Ann	ME+IT	1-------------------	001100
Delonix elata (L.) Gamble	Ph	Per	SA+TR	858-----------------	001100
Indigofera oblongifolia Forssk.	Ch	Per	SA+SZ	3-------------------	001100
Cynodon dactylon (L.) Pers.	Cr	Per	COSM	2-------------------	001100
Dactyloctenium scindicum Boiss.	Cr	Per	SA+SZ	6-------------------	001100
Enneapogon cenchroides (Licht. ex Roem. & Schult.) C.E.Hubb.	Th	Ann	SA+SZ	87------------------	001100
Corchorus depressus (L.) Stocks	Th	Ann	SA	54------------------	001100
Aerva lanata (L.) Juss.	Ch	Per	SA+SZ	73--2------1--------	001101
Trianthema portulacastrum L.	Th	Ann	PAN	72-----2------------	001101
Blepharis edulis (Forssk.) Pers.	Ch	Per	SA+SZ	8---3---------------	00111
Acacia ehrenbergiana Hayne	Ph	Per	SA+SZ	-7-----7----------3-	01000
Acacia oerfota (Forssk.) Schweinf,	Ph	Per	SA+TR	-7-----7------------	01000
Anisotes trisulcus (Forssk.) Nees	Ph	Per	SA+TR	2-1--57-------------	010010

Species	**Life form**	**Vegetation type**	**Chorotype**	**Vegetation groups** **A B C D E** **211 11 1 11111** **19025204345367816789**	**TWINSPAN level**
Amaranthus viridis L.	Th	Ann	TR+ME	----3---------------	010010
Pulicaria undulata (L.) C.A.	Ch	Per	SA+SZ	---46-3-------------	010010
Calotropis procera (Aiton) Dryand	Ph	Per	SA+SZ	---33223-3----------	010010
Sesuvium sesuvioidus (Fenzl) Verdc	Th	Ann	SA+TR+IT	----2---------------	010010
Cleome viscosa L.	Th	Ann	PAN	------23------------	010010
Senna italica Mill.	Ch	Per	SA+SZ	----61--------------	010010
Euphorbia prostrata Aiton.	Th	Ann	TR	----2---------------	010010
Abutilon fruticosum Guill. & Perr.	Ch	Per	SA+SZ	------3-------------	010010
Eucalyptus camaldulensis Dehnh	Ph	Per	Cultivated	-------4------------	010010
Boerhavia diffusa L.	Ch	Per	PAN	------1-------------	010010
Dactyloctenium aegyptium (L.) Willd	Th	Ann	COSM	------5-------------	010010
Panicum turgidum Forssk	Cr	Per	SA+SZ	----6-644-----------	010010
Portulaca quadrifida L.	Th	Ann	PAN	----4---------------	010010
Datura stramonium L.	Th	Ann	COSM	---2----------------	010010
Rhazya stricta Decne.	Ch	Per	SA+SZ	------34-2----------	010011
Cyperus articulatus L.	Cr	Per	PAN	-----2---1----------	010011
Momordica balsamina L.	Th	Ann	PAN	-------3-2----------	010011
Tephrosia purpurea (L.) Pers.	Ch	Per	SA+ TR	------4--2-1--------	010011
Ziziphus spina-christi (L.) Desf.	Ph	Per	SA+SZ	------7-5-8---------	01010
Fagonia indica Burm. f.	Ch	Per	SA	------7--5-6--------	01010
Desmidorchis retrospiciens Ehrenb.	Ch	Per	SA+SZ	-----------2--------	01011
Glinus lotoides L.	Th	Ann	TR	--------3-----------	01011
Citrullus colocynthis (L.) Schrad	He	Per	ME+SA	---------3----------	01011
Senna alexandrina Mill.	Ch	Per	SA+SZ	--------2--2--------	01011
Chrozophora oblongifolia (Del.) Juss. ex Spren	Ch	Per	ME +SA	--------1-3---------	01011
Euphorbia granulata Forssk	Th	Ann	SZ +TR	---------4----------	01011
Abutilon pannosum (G. Forst.) Schlecht.	Ch	Per	SA+TR	-2-------8----------	01011
Senra incana Cav	Ch	Per	SA+SZ	-----------4--------	01011
Ficus populifolia Vahl.	Ph	Per	SA+SZ	-----------4--------	01011
Datura innoxia Mill.	Th	Ann	SA	----------3---------	01011
Solanum incanum L.	Ch	Per	SA	---------6-4--------	01011
Solanum surattense Burm.f.	Th	Ann	ME+SA	--------4-----------	01011

Species	**Life form**	**Vegetation type**	**Chorotype**	**Vegetation groups** A B C D E 211 11 1 11111 19025204345367816789	**TWINSPAN level**
Corchorus olitorius L.	Th	Ann	Cultivated	-----------4--------	01011
Grewia velutina (Forssk.) Lam	Ph	Per	SA+SZ	-----------1--------	01011
Grewia tembensis Fresen	Ph	Per	SA+SZ	-----------1--------	01011
Cyperus conglomeratus Rottb	Cr	Per	SA	4-----32-2--4-------	0110
Acacia tortilis (Forssk.) Hayne	Ph	Per	SA+SZ	22--------54----7---	0110
Leptadenia arborea (Forssk.) Schweinf.	Ch	Per	SA+SZ	------5---4-6-------	0111
Ficus cordata ssp. *salicifolia* (Vahl) C.C.Berg	Ph	Per	ME+SA+TR	------7------6------	0111
Sansevieria ehrenbergii Schweinf.	Ph	Per	SA+TR	------4-----4-------	0111
Amaranthus graecizans L.	Th	Ann	SA+TR	2----------------2--	100
Pluchea dioscoridis (L.) DC.	Ph	Per	SA+SZ	-----------------544	1010
Tridax procumbens (L.) L.	Ch	Per	TR	-----------------2--	1010
Trianthema triquetra Rottle ex Willd.	Th	Ann	ME+SA+IT	------------------1--	1010
Cleome gynandra L.	Th	Ann	PAN	-----------------4---	1010
Cyperus laevigatus L.	Cr	Per	PAN	----------------4454	1010
Ficus palmata Forssk.	Ph	Per	ME+SA+TR	------------------5--	1010
Brachypodium distachyon (L.) P. Beauv.	Th	Ann	ME+SA+IT	----------------142-	1010
Desmostachya bipinnata (L.) Stapf	Cr	Per	SA+SZ	----------------3467	1010
Digitaria ciliaris (Retz.) Koel	Th	Ann	ME+SA+IT	----------------25--	1010
Echinochloa colona (L.) Link	Th	Ann	TR	----------------42--	1010
Eragrostis ciliaris (L.) R. Br	Th	Ann	ME+SA+TR	----------------465-	1010
Saccharum spontaneum L.	Cr	Per	SA+SZ	----------------854-	1010
Setaria viridis (L.) P. Beauv.	Th	Ann	ME+SA+IT	-----------------25-	1010
Tamarix nilotica L.	Ph	Per	ME+SA +TR	----------------27-8	1010
Typha domingensis Pers.	Cr	Per	TR	----------------583-	1010
Prosopis juliflora (Sw.) DC	Ph	Per	SA+SZ	--------------6-532-	1011
Ricinus communis L.	Ph	Per	SA+TR	----------------56---	1011
Caralluma retrospiciens (Ehrenb.) N.E.Br.	Ch	Per	SA+SZ	5-------------7----9	110
Dobera glabra (Forssk.) Juss.	Ph	Per	SA+TR	9-----------279-----	110
Digera muricata (L.) Mart	Th	Ann	SA+TR	-----------------2----	1110
Pentatropis nivalis (Gmel.) Field & Wood	Ch	Per	SA+TR	-------------414----	1110
Commiphora gileadensis (L.) C.	Ph	Per	ME+SA+TR	------------6-66----	1110
Acalypha indica L.	Th	Ann	SA+IT	--------------2-----	1110

Species	Life form	Vegetation type	Chorotype	Vegetation groups A B C D E 211 11 1 11111 19025204345367816789	TWINSPAN level
Euphorbia triaculeata Forssk.	Ch	Per	SA+SZ	---------------4----	1110
Euphorbia cactus Ehrenb. *ex* Boiss.	Ph	Per	SA+SZ	--------------6-----	1110
Jatropha pelargoniifolia Courb.	Ch	Per	SA+SZ	-----------2457----	1110
Boerhavia elegans Choisy	Ch	Per	SA+TR	--------------2-----	1110
Indigofera argentea Burm	Th	Ann	ME+SA	---------------1----	1110
Indigofera spinosa Forssk.	Ch	Per	SA+SZ	---------------2----	1110
Aristida mutabilis Trin. & Rupr	Th	Ann	ME+SA	-------------2------	1110
Salvadora persica L.	Ph	Per	SA+SZ	-------------72-----	1110
Cissus quadrangularis L.	Ch	Per	SA+SZ	-------------64-----	1110
Hyphaene thebaica (L.) Mart	Ph	Per	SA+SZ	--------3---5434--3-	1111
Opuntia dillenii (Ker-Gawl.) Haw	Ph	Per	TR	----------4-57-6----	1111
				00000000000011111111 00011111111100001111 000001111 00111	

Ph=Phanerophytes; Ch=Chamaephytes; Cr=Cryptopyte, and Th=Therophytes. COSM=Cosmopolitan, TR=Tropical, PAN=Pantropical, SA= Saharo-Arabian, SZ=Sudano-Zambezian, Me = Mediterranean and IT= Irano-Turanian

Table 2. Aggregation summary showing the chorotype, life form and vegetation types

Chorotype				Life form			Vegetation type		
Name	**Type**	**No.**	**%**	**Form**	**No.**	**%**	**Type**	**No.**	%
Monoregional	SA	7	7	Th	36	35	Annual	36	35
	TR	6	6	Ph	29	28	Perennial	67	65
	SZ	1	1	Ch	28	27	--	--	--
Biregional	SA+TR	15	15	Cr	9	9	--	--	--
	SA+SZ	36	35	He	1	1	--	--	--
	TR+ME	1	1	--	--	--	--	--	--
	SA+ME	8	8	--	--	--	--	--	--
	ME+IT	1	1	--	--	--	--	--	--
	SZ+TR	1	1	--	--	--	--	--	--
	SA+IT	1	1	--	--	--	--	--	--
Pleuriregional	ME+SA+IT	5	5	--	--	--	--	--	--
	SA+TR+IT	1	1	--	--	--	--	--	--
	ME+SA+TR	5	5	--	--	--	--	--	--
PAN	--	8	8	--	--	--	--	--	--
PAL	--	1	1	--	--	--	--	--	--
COSM	--	4	4	--	--	--	--	--	--
Cultivated	--	2	2	--	--	--	--	--	--

Table 3. Dominant and co-dominant, habitats and importance values (IV) for the studied species

Stand	Dominant			Co- Dominant		
	Species	**Habitat**	**IV**	**Species**	**Habitats**	**IV**
1	*Aloe fleurentiniorum*	High slope	103	*Enneapogon cenchrroides*	Medium slope	98.6
2	*Anisotes triculcus*	Low slopes	69.3	*Cissus quadrangularis*	Medium slope	23.9
3	*Ziziphus spina-christi*	Medium slop	62.8	*Solanum surattense*	Dry bed	55.9
4	*Abutilon pannosum*	Medium slope	92.5	*Solanum incanum*	Dry bed	78.9
5	*Ziziphus spina-christi*	Medium slop	98.6	*Acacia tortilis*	Dry bed	65.1
6	*Leptadenia arborea*	Dry bed	78.1	*Commiphora gileadensis*	Low slop	70.6
7	*Salvadora persica*	Dry bed	89.9	*Dobera glabra*	Dry bed	71.7
8	*Dobera glabra*	Dry bed	106	*Caralluma acutangula*	Medium slope	87.6
9	*Cadaba glandulosa*	High slope	89.9	*Acacia oerfota*	Medium slope	79.4
10	*Abutilon pannosum*	Medium slope	89.4	*Ziziphus spina-christi*	Medium slop	75.8
11	*Jatropha pelargoniifolia*	Dry bed	88.2	*Commiphora gileadensis*	Medium slope	71.9
12	*Pulicaria undulate*	Low slope	46.3	*Calotropis procera*	Dry bed	36.9
13	*Fagonia indica*	Medium slope	77.5	*Acacia tortilis*	Dry bed	59.5
14	*Acacia ehrenbergiana*	Low slope	89.5	*Acacia oerfota*	Medium slope	80.2
15	*Panicum turgidum*	Low slope	75.8	*Senna italica*	Dry bed	61.6
16	*Saccharum spontaneum*	Wet bed	98.5	*Acacia tortilis*	Dry bed	82.3
17	*Typha domingensis*	Wet bed	98.8	*Tamarix nilotica*	Dry bed	88.5
18	*Desmostachya bipinnata*	Wet bed	73.7	*Setaria viridis*	Dry bed	61.6
19	*Cyperus articulatus*	Wet bed	105	*Tamarix nilotica*	Dry bed	97.5
20	*Delonix elata*	High slope	97.7	*Adenium obesum*	High slope	80.7

Table 4. The mean ± standard deviation (S.D.) of the soil variables for the five vegetation groups obtained from TWINSPAN program

Variable	A	B	C	D	E	Total	F	Sig.
Ca^{2+}	10.73 ± 0.38	5.66±101	6.03 ± 1.03	4.72 ± 0.28	2.97 ± 0.30	5.77 ± 2.49	50.973	.000
Mg^{2+}	8.62± 1.95	12.16 ± 2.40	11.20 ± 0.61	9.86 ± 0.27	16.90 ± 0.53	11.93 ± 3.11	17.145	.000
Cl^{-}	0.09 ± 0.02	0.14 ± 0.00	0.17 ± 0.040	0.20 ± 0.05	0.71 ± 0.10	0.27 ± 0.23	75.513	.000
$CO3^{--}$	0.17 ± 0.01	0.16 ± 0.04	0.16 ± 0.054	0.14 ± 0.03	1.19 ± 0.12	0.36 ± 0.43	208.505	.000
O C	0.824 ± 0.14	0.82± 0.06	0.675 ± 0.32	0.81 ± 0.06	1.02 ± 0.169	0.83 ± 0.19	1.907	.162
MO	0.62 ± 0.02	1.804 ± 0.51	1.47 ± 0.23	1.95 ± 0.31	5.14 ± 0.42	2.26 ± 1.58	82.666	.000
pH	7.34± 0.03	7.32 ± 0.01	7.32 ± 0.013	7.32 ± 0.00	6.92 ± 0.19	7.245 ± 0.19	16.485	.000
Gravel	9.79 ± 0.01	18.71 ± 0.24	18.62 ± 0.04	17.7 ± 0.37	15.2 ± 0.35	16.48 ± 3.17	683.895	.000
Coarse	10.79± 1.72	16.93 ± 0.31	17.02 ± 0.50	15.8 ± 0.62	16.1 ± 0.58	15.64 ± 2.26	35.249	.000
Silt	26.62 ± 1.03	12.87 ± 1.40	12.16 ± 0.53	14.37 ± 1.33	23.9 ± 1.05	17.30 ± 6.04	129.894	.000
Clay	10.38 ± 0.20	23.25 ± 4.07	26.38 ± 1.78	14.66 ± 1.35	12.22 ± 0.25	18.02 ± 6.70	35.418	.000
Sand	26.53 ± 2.25	8.16 ± 2.56	7.63 ± 1.03	9.43 ± 1.12	13.75 ± 1.97	12.18 ± 6.79	55.854	.000
TDS	22.59± 0.58	7.85 ± 2.58	8.32 ± 0.37	10.2 ± 1.51	23.5 ± 0.99	13.77 ± 7.25	95.520	.000

A: Groups A (high wadi slope), B: Groups B (low slope and wadi terraces).C: Group C (medium wadi slope), D: Groups D (dry wadi bed) and E: Groups E (wet wadi bed). Sig: Significance = P<0.05, Sig. = Significance, O C = Organic carbon, MO = Moisture content*

3.3 Chorology

Chorological analysis classified the recorded species of the wadi under three regions (monoregional, biregional and pluriregional). Fourteen species were recorded in monoregional area, representing 14% with different affinities; the highest percentage in this area was recorded in Saharo-Arabian (7 species) followed by tropical area included six species (6%). The phytochorion Sudano-Zambezian was represented in the different sectors of the Wadi with only one species (*Euphorbia prostrata*). Biregional area included 63 species with the percentage of 61%. Among this area, the highest number of 36 species (35%) were recorded in Saharo-Arabian and Sudano-Zambezian regions. The recorded pluriregional species fall also under three main phytochoria; Mediterranean-SaharoArabian-Irano-Turanian phytochorion (5%), Saharo-Arabian, Mediterranean and Tropical (5 %) and Tropical, Saharo-Arabian and Irano-Turanian (1%) included of *Sesuvium sesuvioidus,* also, 8 species were reported as panatropical, cosmopolitan plants also had four species. Cultivated species represented by *Eucalyptus camaldulensis* and *Corchorus olitorius,* only one species of *Croton bonplandianus* was recorded in paleotropic area (Tables 1 and 2; Fig. 4).

3.4. Multivariate Analysis

Five vegetation groups were resulted from the application of TWINSPAN on the total recoded 103 species obtained from the twenty sample plots of the study area (Table 1, Fig. 5). Five vegetative groups were recognized, the high slopes of the wadi were dominated by different communities such as *Aloe fleurentiniorum*, *Acacia oerfota, Cadaba glandulosa* and *Delonix elata* (stands 1,9 and 20). The medium slopes were predominated by communities of *Abutilon pannosum*, *Caralluma acutangula, Enneapogon cenchrroide* and *Ziziphus spina-christi* inhabiting stands of 3, 4, 5 and 13. Whole low slopes and terraces of wadi inhabiting stands of 2, 10, 12, 14 and 15 were prevalent by plant communities of *Anisotes triculcus*, *Fagonia indica*, *Pulicaria undulata*, *Acacia ehrenbergiana* and *Panicum turgidum*. The dry wadi bed which dwelling stands of 6, 7, 8 and 11 were dominated by communities of *Leptadenia arborea*, *Salvadora persica*, *Dobera glabra*, *Senna italica, Acacia tortilis* and *Jatropha pelargoniifolia* and the wet habitats inhabiting stands of 16, 17, 18, and 19 of wadi bed were dominated by *Cyperus articulates*, *Desmostachya bipinnata, Saccharum spontaneum* and *Typha domingensis* communities (Table 3).

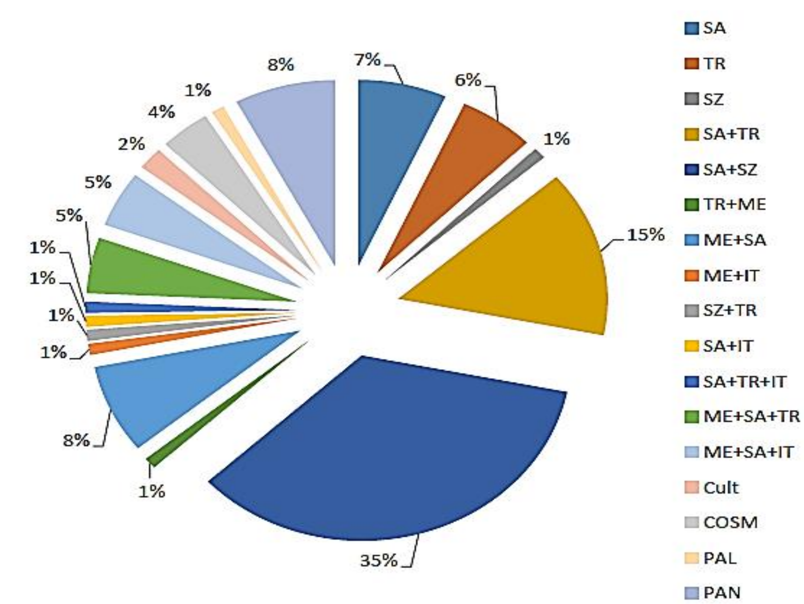

Fig. 4. Floristic category spectrum of Wadi Qusai
COSM=Cosmopolitan, TR=Tropical, PAN=Pantropical, SA=Saharo-Arabian, SZ=Sudano-Zambezian, ME=Mediterranean, and IT= Irano-Turanian

3.5 Plant Community–soil Factors Relationship

Each obtained group had a distinct indicator species and soil factors which play an important role in the distribution of these groups. Group (A) was formed at the second level of classification, it included three stands (1, 9 and 20) and represented the high slope of the wadi. The indicator species of this group were *Aloe fleurentiniorum*, *Cadaba glandulosa* and *Delonix elata*. Its characteristic soil factors were high content of calcium (10.9), silt (26.6) and fine sand (26.5). Group (B) was formed at the third level of the classification and comprised five sites (2, 10, 12, 14 and 15) and its indicator species were *Anisotes trisulcus*, *Acacia ehrenbergiana*, *Fagonia indica*, *Pulicaria undulata* and *Panicum turgidum*. Soil factors which characterise this group were high content of gravel (18.7) and coarse sand (18.6). Group (C) was formed at the third level and represented the medium wadi slope. It included four sites (3, 4, 5 and 13) the indicator species including *Ziziphus spina-christi*, *Abutilon pannosum* and *Fagonia indica,* soil factors comprised high content of clay (26.3) and coarse sand (18.6). Group (D) were formed in the second level of the classification, it included four sites (6, 7, 8 and 11), the dominant species included were; *Leptadenia arborea*, *Salvadora persica*, *Dobera glabra* and *Jatropha pelargoniifolia*, soil factors were characterized by low content of carbonate (0.14). Group (E) represented the wet wadi bed and was formed at the second level of classification and it included four sites (16, 17, 18, and 19). The indicator species were *Cyperus articulates*, *Desmostachya bipinnata, Saccharum spontaneum* and *Typha domingensis.* Soil factors which describe this group were highly content of magnesium (16.9), chlorides (0.71), carbonate (1.19), organic carbon (1.02) and a value of 5.19 was recorded as moisture content (Table 4).

DECORANA (DCA) was used to clarify the relations between the distribution of plants and soil factors along two axes to form a graph ordination which represents all factors (plants and soil variables) according to their significance. The ordination analysis of DCA revealed that Groups A which represented the high wadi slope was separated at the left center of graph, Group B which occupying the low slope and wadi terraces was separated at the let top of axis 2 and group C representing the medium wadi slope was also lied in the left center of the axis 2. Meanwhile group D which represented the dry wadi bed lied on the right center of the graph and group E inhabiting the wet wadi bed were separated on the right of axis 1 (Fig. 6).

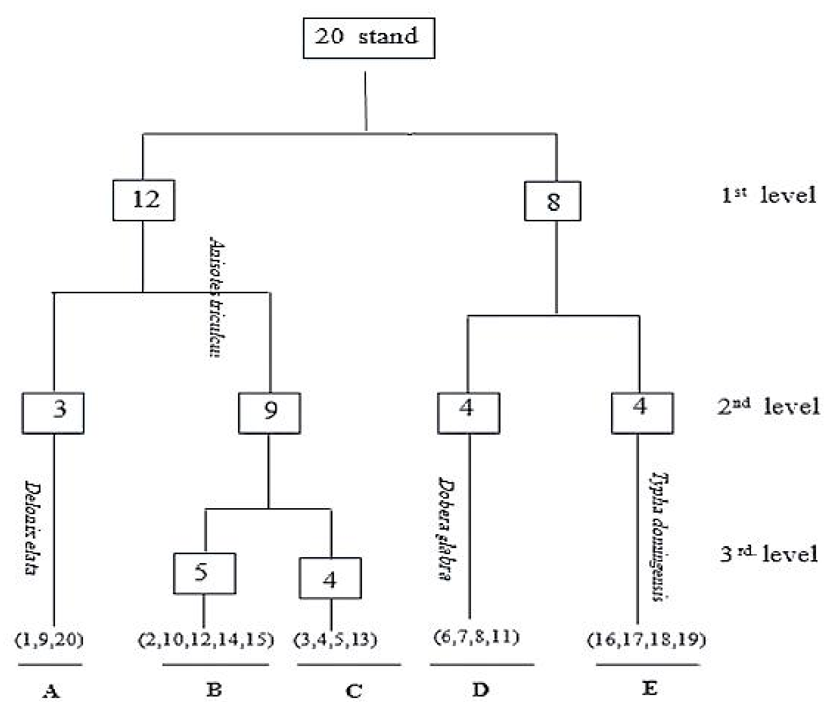

Fig. 5. TWINSPAN classification of 20 sites showing different groups of the study area

ANOVA was carried out to determine the most significant soil factors of the study area that affect the distribution of sites along the study area. The results showed that all soil factors of the present work were significant. So all soil factors were affecting the distribution of plant communities of sites (Table 4). The correlation coefficient indicated that, groups A, B and C inhabit the slope and wadi terraces was positively correlated with axis 2 and was related with high species diversity and plant cover values. These groups were correlated with calcium, gravel, coarse sand fine sand, clay and silt. The second main groups included which inhabits in wadi bed (dry and wet habitats) were positively separated on the axis 1, these groups were positively correlated with magnesium, chloride, total dissolved salts, carbonate, organic carbon and moisture content (Figs. 7 and 8).

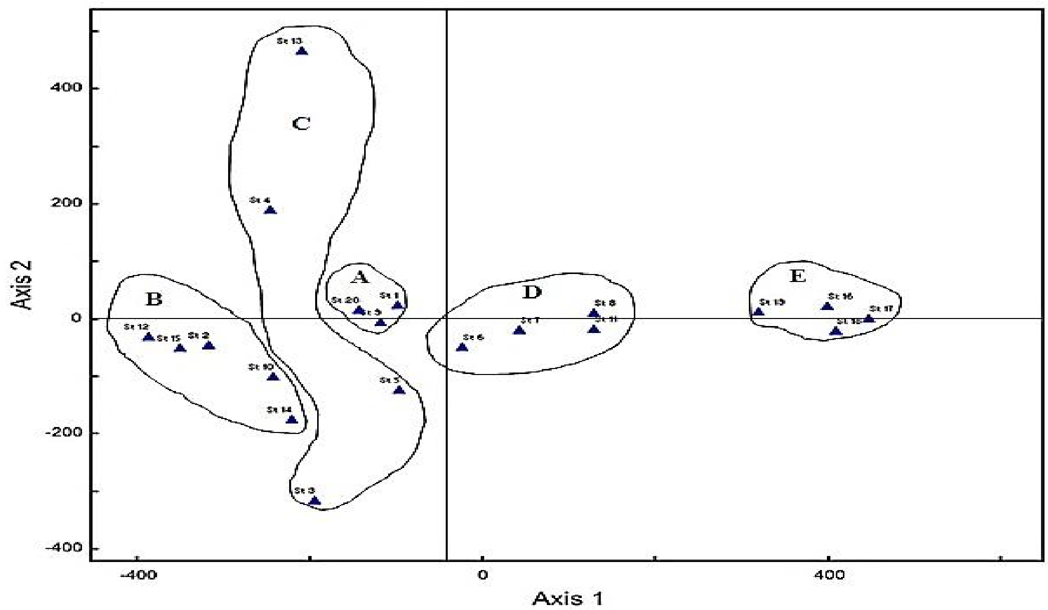

Fig. 6. DCA ordination graph for the five vegetation groups identified using TWINSPAN analysis of the 20 sites in the wadi

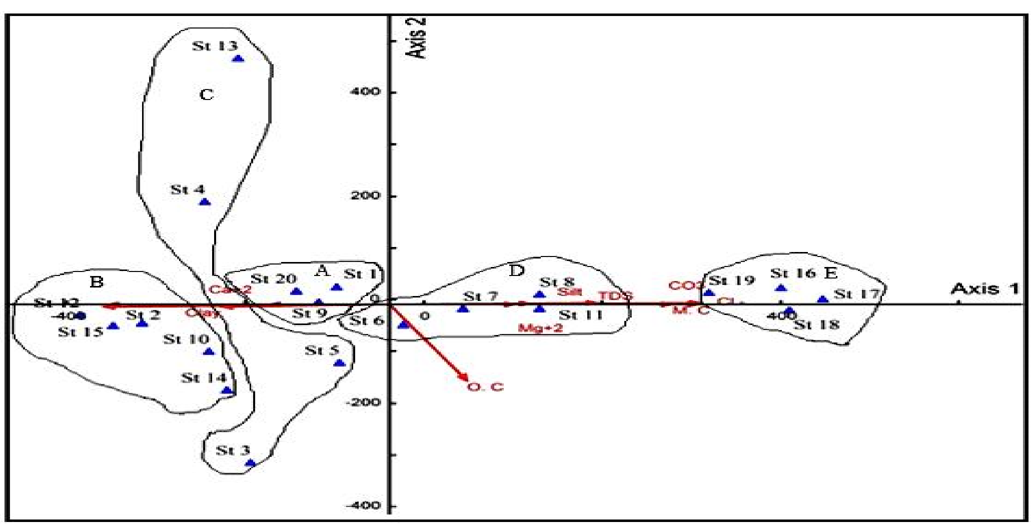

Fig. 7. CCA biplot with environmental variables (arrows) and the selected stands in the wadi

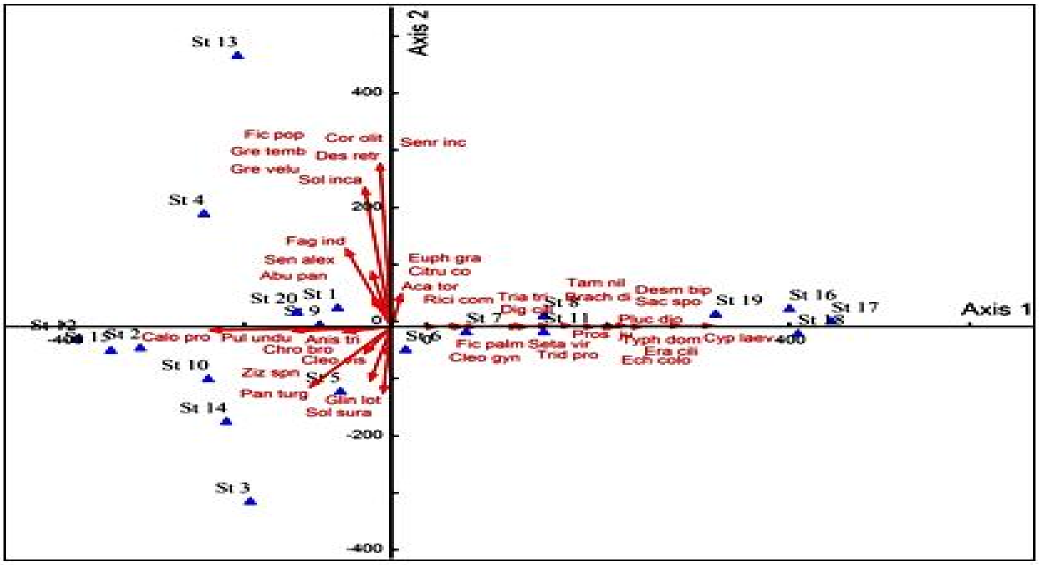

Fig. 8. CCA biplot with environmental variables (arrows), the stands and the abundant species (complete names recorded in Table 1)

4. DISCUSSION

Wadi Qusai is rich by vegetation, has a distinct number of habitats according to soil characters and plant cover. The flora of this wadi represented about 25% of the total flora of Jazan which identified and described by [8]. Floristic structure of this wadi revealed that, Poaceae and Euphorbiaceae were constituted the main bulk of the wild plants (25%). Therophytes were dominated life form and are adapted to the dryness of the region and shortage levels of rainfall in the study area [33]. These results are in accordance with the earlier vegetation spectra in the different habitats of Jazan region, Saudi Arabia by [12], [14] and [15]. The predominance of phanerophytes expresses that the flora is tertiary dominated with woody plants, i.e. shrub and trees [34] and [35]. Moreover, the dominance of therophytes, chaemophytes and phanerophytes over other life forms is the result in response of hot dry climate, topographic variation and the interference of human and animal [36]. Distribution of plant species inhabiting the arid regions is closely related to topography and landform [24,37,38]. The chorological analysis revealed that the area of Saharo-Arabian and Sudano-Zambezian are the most dominant chorotypes represented about one third of recorded total species which is in accordance with results of [15,39,40,41]. The Saharo-Arabian–Sudano-Zambezian chorotypes consider as good indicators of a desert environment therefore decrease moving north and are replaced by Mediterranean and Irano-Turanian chorotypes [42,43]. Saharo-Arabian region is characterized by the occurrence of few endemic species and genera [23, 44]. Our results indicated that Saharo-Arabian elements were predominated because this area mainly deserted and located within the belt of Saharo-Sindian also it is a part of that belt between Saharo and Sindian. Saharo-Arabian species are covered most of the deserted area of Sindian from the red sea coast to the Gulf coast through the Empty Quarter desert. The vegetation analysis revealed different microhabitats, wadi slope (high, medium low), wadi terraces and wadi bed (dry and wet). Each of these habitats supports a special type of vegetation with a characteristic floristic composition and plant cover. Group E was represented in the wet wadi bed considered as pure vegetation than the remainder groups which are less distinct because they have mixed communities of native trees, shrubs and grasses. It is known that, Vegetation, species diversity and floristic relations in south-western Saudi Arabia demonstrate remarkable change with altitude [12]. Plant Community variations in wadi Qusai resulted in a high number of plant species and different soil variable factors. It was noticed that *Acacia ehrenbergiana* is not widespread along the wadi, in fact it occurs in the coastal plain i.e. the west of the study area, which agreed with [45,46]. On the other hand [14] reported that *Acacia ehrenbergiana* communities were usually dominated on the gravelly slopes of Tihama hill slopes. The predominance of *Leptadenia arborea*, *Salvadora persica*, *Dobera glabra* and *Jatropha pelargoniifolia* in the dry wadi bed also dominance of *Typha domingensis* and *Desmostachya bipinnata* in the wet wadi bed of Tihama hill slopes were reported by [14]. The shrubby *Adenium obesum* and *Calotropis procera* were correlated along gradients of high sand content, high pH which in accordance with [47]. DCA application indicated some relationships between environmental gradients and topographic aspects of the Wadi and separated the twenty sites of wadi Qusai into two main groups, the first main group (Groups A, B and C) was recorded in slope and wadi terraces is positively correlated with axis 2. This group was correlated with calcium, gravel, coarse sand, fine sand, clay and silt. The second main group was inhabiting the wadi bed (dry and wet habitats) was positively correlated with axis 1 and correlated with magnesium, chloride, carbonate, organic carbon and moisture content; these results are in accordance with [48] who reported that soil variables that affect the species distribution are moisture contents, organic carbon, carbonates, fine sand and silt. Application of ANOVA analysis showed that all effective soil factors affected the assembly of sites into the five groups as well as aggregating the species into these groups. On the other hand, *Rhazya stricta* was first recorded in the wadi of Jazan and was not found previously by [10] and [8]. This studies could be considered as a reference for the wadi, the recommendation is to do further studies in the wadi Qusai which may lead to record other new species.

5. CONCLUSION

Wadi Qusai is one of the most important wadies in Jazan region, it is located in the south-western part of Saudi Arabia. it is situated at 370-450 km^2 above sea level (a.s.l.), around 80 km^2. The present study recorded 103 plant species belonging to 77 genera represented over one-third of the checklist recorded before in Jazan area by [8]. The present work was extended with the floristic composition, life-form, vegetation type, diversity, chorological spectrum, and community analysis in relation to the edaphic factors of Wadi Qusai, Jazan, Saudi Arabia. Floristic structure of this wadi revealed that Poaceae and Euphorbiaceae were constituted the main bulk of the wadi followed by Amaranthaceae, Aizoaceae, Asclepediaceae and Mimosaceae. Therophytes and chamaephytes were the most frequent, indicating a typical desert life-form spectrum. Chorological analysis revealed that 63 species (61%) were recorded in bioregional region native to the Saharo-Arabian and Sudano-Zambezian. The vegetation analysis demonstrated that the predominance of five vegetation groups i.e: Group A was appeared at the high wadi slope, Group B was occupied the low slope and wadi terraces, Group C was recorded in the medium wadi slope, Group D was performed the dry wadi bed and group E inhabiting the wet wadi bed. Groups A, B and C were positively correlated with axis 2 whereas Groups C and D were positively correlated with axis 1. Most distinguishing feature of this study is the record of the existence of *Rhazya stricta* for the first time in the study area.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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