FLORISTIC COMPOSITION OF *ZYGOPHYLLUM COCCINEUM* L. ASSOCIATES IN ZLITEN COAST, LIBYA

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Abstract
Zygophyllum coccenium is a perennial halophyte widely-distributed in coastal areas and arid desert wadis in Libya with wide-ecological amplitude. In the current study, 40 sampled stands, the floristic features and chorology of *Z. coccenium* and its associated species along the coastal zone of Zliten City, Libya were addressed. In each stand, a list of all species with their families and life-span were documented. Agglomerative Hierarchical Clustering (AHC) and Principle Component analysis (PCA) ordination were applied for the sampled stands and plant samples. A total of 49 species belonging to 47 genera and 23 families were recorded. Four families (Asteraceae, Fabaceae, Poaceae and Chenopodiaceae) were the leading families, collectively contributing by 44.89% of the total number of surveyed species. Therophytes had the highest contribution (20 species, 40.82%), followed by phanerophytes (12 species, 24.49%), cryptophytes and chamaephytes (6 species each, 12.24% each), then hemicryptophytes (5 species, 10.2%). Mono-regional taxa were represented by 32.65%, bi-regional taxa by 30.61%, worldwide taxa by 18.37% and pluri-regional taxa by 14.29%. Three plant groups/clusters were obtained and named after the dominant and codominant species with the highest importance values as follows: group A: *Tamarix nilotica- Zygophyllum coccineum*, group B: *Acacia cyanophylla- Zygophyllum coccineum* and group C: *Zygophyllum coccineum- Cakile maritima*.

Keywords: Libya, Flora, Mediterranean, *Zygophyllum*, life forms.

الغطاء النباتي المصاحب لنبات الرطريط على طول ساحل مدينة زليتن, ليبيا

الملخص
نبات الرطريط نبات ملحي معمر منتشر على نطاق واسع في المناطق الساحلية والوديان الصحراوية القاحلة في ليبيا مع مدى بيئي واسع. في الدراسة الحالية، تم مسح 40 موقعا، حيث تم تسجيل السمات الأنواع النباتية المصاحبة لنبات الرطريط على طول المنطقة الساحلية لمدينة زليتن، ليبيا. في كل موقع، تم تسجيل قائمة بجميع الأنواع مع عائلاتهم وفترة النمو. تم تطبيق تنسيق التكتل الهرمي التجميعي (AHC) وتحليل المكونات الأساسية (PCA) على المواقع والنباتات المسجلة. تم تسجيل 49 نوعًا تنتمي إلى 47 جنسًا و 23 عائلة. كانت أربع عائلات (المركبة والقرنية والنجيلية والرمرامية) هي العائلات السائدة، حيث ساهمت مجتمعة بنسبة 44.89 ٪ من إجمالي عدد الأنواع التي تم مسحها. كانت النباتات الحولية أعلى مساهمة (20 نوعًا، 40.82٪)، تليها الشجيرية 12 نوعًا، 24.49٪، المختفيات 6 أنواع 12.24% (ثم شبة المختفيات 5 أنواع، 10.2٪). تم تمثيل الأصناف أحادية المنطقة بنسبة 32.65٪، والأصناف ثنائية الإقليم بنسبة 30.61٪، والأصناف العالمية بنسبة 18.37٪، والأصناف متعددة المناطق بنسبة 14.29٪. قد أمكن التعرف على ثلاثة

مجموعات من النباتات (A, B, C) سميت حسب النبات السائد وشبه السائد كالتالي مجموعة (أ) يسودها نباتى الرطريط والأثل بينما المجموعة (ب) يسودها الأكاسيا والرطريط وأخير المجموعة (ج) يسودها نباتى الرطريط ورشاد البحر.

الكلمات المفتاحية: ليبيا، الفلورة، البحر المتوسط، الرطريط، أشكال الحياة.

INTRODUCTION

Human being in their quest for economic development and enjoyment of the riches of nature must come to term with the reality of the limited resources and the absorptive capacities of ecosystems and must take account of the needs of future generations, especially in arid region. Recently, nearly half of the plant species in the world, especially in highly biodiversity regions may be categorized as threatened as a result of degraded and altered habitats [1]. For a foreseeable future, expanding demands for natural resources will proceed to change in habitat conditions with local extinction native species [2].

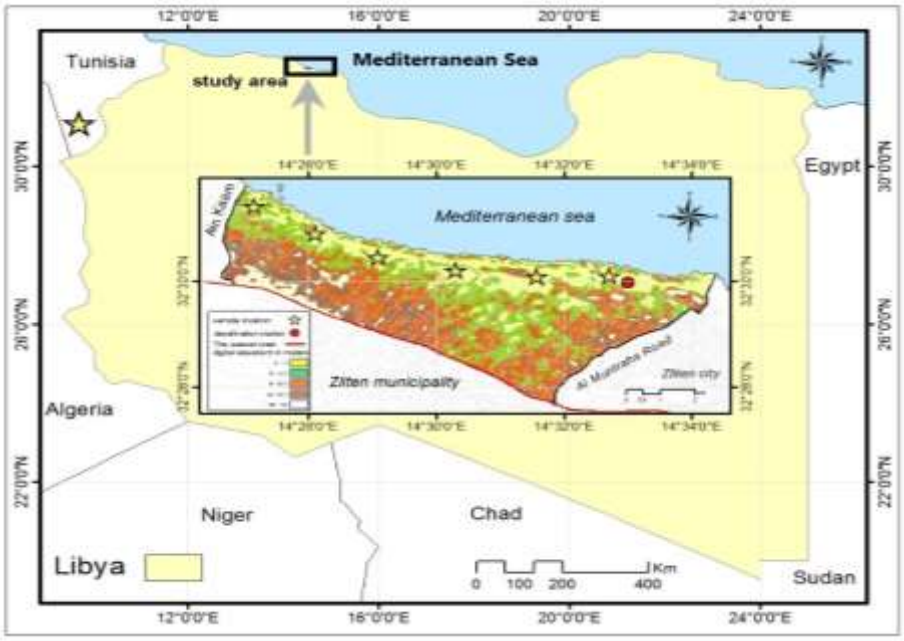
The purpose of nature conservation is to safeguard earth's capacity to endure development and support biodiversity. Disturbances by natural factors and human activities are the main drivers for shaping and distribution of ecological communities [3]. Habitat loss due to land use changes is considered as one of the main drivers of biodiversity depletion and can push native populations to local/regional extinction and enable invasion of alien species [4].
The flora and vegetation survey in Libya is still an open field of study, and the ease and continuous recording of new species demonstrate the necessity to document the bibliography of the flora and conduct more detailed investigations. In Libya, there are two main phytogeographical regions: the desert, which spreads over most of the country's land (Sahara region), and the narrow coastal strip in the north (Mediterranean region) [5]. In Libya, about 94:96 % of the land is desert [6]. Relatively, these northern areas are characterized with higher rainfall and more soil fertility, making it appropriate for the existence of abundant wildlife, thus differing from the rest of the country. These northern areas are part of the Mediterranean Sea and have been classified as a local centre of plant diversity and endemism. They are amongst 36 globally distinguished biodiversity hotspots [7]**;** [8], and are amongst the threatened habitats in Libya that suffer land degradation and extreme biodiversity loss [9]**.** *Zygophyllum* genus is annual or perennial herbs; it includes 49 species, widely distributed in the Mediterranean region, Australia and Asia in desert and saline areas. *Zygophyllum coccineum* (family Zygophyllaceae) is a perennial halophyte herb widely distributed in coastal areas and desert wadis. This plant is propagated by cuttings and seeds and contains many erect stems with 2-foliate, bright green and glabrous leaves. *Z. coccineum* is among the medicinal plants, it has antioxidant and antidiabetic effects as well as its ability as bioaccumulator for heavy metals [10]**;** [11]**;** [12]. Due to prevailing arid conditions in Libya and unpalatability of this plant, it is expected to have low dispersal for its seeds. Remarkably, this plant has the largest distribution and abundance in Egypt and Libya compared to other *Zygophyllum* species; it invades various habitats and different soil types [13]. Regardless of the significance of *Zygophyllum* in addition to its abundance in the Mediterranean and Middle East areas, there are not sufficient studies and information about them. Therefore, the present investigation offers an overview of species associated with *Z. coccineum* along the Mediterranean coast of Zliten City, Libya.

MATERIALS AND METHODS

STUDY AREA

The Mediterranean coastal area of Libya is about 1770 km. Zliten is a coastal city located along the Mediterranean region of Libya, east of the capital Tripoli with an area of ca. 30,000 km^2 **Figure (1)**. It is located within the coordinates of 32°27′50″N and 14°34′21″E. It is regarded as a semi-arid region. The Mediterranean climate of Zliten showed that, the average temperature is ranged between 20.1 °C in winter to 38.2 °C in summer, the average rainfall is fluctuated between 60 and 75 mm per year. Coastal environment is considered as sites of elevated ecological risk due to the biogeochemical processes and the severe human activities, which intensely decrease biodiversity, species richness and increase pollutants.

Figure (1). Map of Libya shows the Zliten City and sampled locations



FlORISTIC SAMPLING

During Spring 2021, a total of six field trips in six locations were carried out to address the associated species with *Z. coccineum*. A total of 40 randomly-located stands, each of 10 m^2 were sampled. In each stand, a list of all species with their families, life-span and chorology was recorded. Nomenclature of plant species was documented according to [14], [15] and updated after the World Flora Online [16]. Life-forms and floristic category of the surveyed species were established according to [17]**,** [18] and [19]. Relative density (number of individuals per unit area) and relative cover of each recorded species were estimated and summed up to the importance value index (out of 200).

DATA ANALYSIS

Two multivariate analyses were applied, Agglomerative Hierarchical Clustering (AHC) and Principle Component analysis (PCA). A matrix of all recorded vascular plant species (49) x 40 stands was classified by Agglomerative Hierarchical Clustering (AHC) with Euclidean distance as a dissimilarity index and Ward's method as an agglomeration method [20]. All statistical analyses were carried out in XLSTAT, 2016.

RESULTS AND DISCUSSION

A total of 48 plant species were documented as associated species with *Z. coccineum* in the study area. These species belonging to 47 genera and 23 families **Table (1)**. *Acacia* and *Euphorbia* were the most represented genera (two species each). Out of 48 species, 29 species (59.2%) were perennials and 20 species were annuals **Figure (2)**. Asteraceae, Fabaceae and Poaceae were the most abundant families with 8, 6 and 5 species each, respectively. This result is approved with [21]. who stated that, Asteraceae, Fabaceae and Brassicaceae are the dominant families for dicotyledons while Poaceae is the most prevalent family for monocotyledons. These families represent the most common in the Mediterranean North African flora [22]. Poaceae is the 5th largest family among flowering plants families, following the Asteraceae and Fabaceae [23]**;** [22]. Out of 48 species, 29 species (59.2%) were perennials and 20 species were annuals. In contrast to our findings, [24] attained higher perennials (123 species) than annuals (108 species), while [25] recorded only 64 perennial species in Al-Heroj Mountain, in central desert of Libya. In addition, the dominance of perennials may be linked to the nature of the habitat types in the current study area in which the reproductive capacity, morphological, ecological and genetic plasticity are the controlling factors [26]. These findings display the effect of climate, topography, hot-arid variation and biotic agents in the study area [27].

Table (1). Floristic composition of the associated species with *Z. coccineum*.

Species	Family	Life span	Life form	Floristic category
Acacia cyanophylla Lindley.	Fabaceae	Per	Ph	SA-SI
Acacia nilotica (L.) Delile	Fabaceae	Per	Ph	SA-SI
Alhagi maurorum Medik.	Fabaceae	Ann	Ph	ME+IR-TR+SA-SI
Ammophila arenaria (L.) Link	Poaceae	Per	G	COSM
Atriplex halimus L.	Chenopodiaceae	Per	Ph	ME+SA-SI
Avena fatua L.	Poaceae	Ann	Th	COSM
Cakile maritima Scop.	Brassicaceae	Ann	Th	ME+ER-SR
Calotropis procera (Aiton) W. T. Aiton	Apocynaceae	Per	Ph	SA-SI+S-Z
Carduus getulus Pomel	Asteraceae	Ann	Th	SA-SI
Chenopodium murale L.	Chenopodiaceae	Ann	Th	COSM
Cynodon dactylon (L.) Pers.	Poaceae	Per	G	COSM
Cyperus capitatus Vand.	Cyperaceae	Per	G	ME
Echium angustifolium Mill.	Boraginaceae	Per	H	ME
Emex spinosa (L.) Campd.	Polygonaceae	Ann	Th	ME+SA-SI
Erodium glaucophyllum (L.) L Her.	Geraniaceae	Per	Ch	IR-TR+SA-SI
Eryngium maritimum L.	Apiaceae	Per	G	ME+ER-SR
Euphorbia paralias L.	Euphorbiaceae	Per	H	ME
Euphorbia terracina L.	Euphorbiaceae	Per	Ch	ME+ER-SR+SA-SI
Helichrysum stoechas (L.) Moench	Asteraceae	Per	Ch	ME
Heliotropium europaeum L.	Boraginaceae	Ann	Th	ME+IR-TR
Herniaria hirsute L.	Caryophyllaceae	Ann	Th	COSM
Hordium marinum Huds.	Poaceae	Ann	Th	ME+IR-TR
Juncus acutus L.	Juncaceae	Per	He	ME+IR-TR+ER-SR

Launaea mucronata (Forssk.) Muschl.	Asteraceae	Per	H	ME+SA-SI
Lotus cytisoides L.	Fabaceae	Per	Ch	ME
Lycium schweinfurthii Dammer	Solanaceae	Per	Ph	ME
Malva parviflora L.	Malvaceae	Ann	Th	ME+IR-TR
Mesembryanthemum crystallinum L.	Aizoaceae	Ann	Th	ME+ER-SR
Neurada procumbens L.	Neuradaceae	Ann	Th	SA-SI
Nicotiana glauca Graham	Solanaceae	Per	Ph	COSM
Nitraria retusa (Forssk.) Asch.	Nitrariaceae	Per	Ph	SA-SI
Ononis variegate L.	Fabaceae	Per	Th	ME
Onopordum arenarium (Desf.) Pomel	Asteraceae	Per	Ch	SA-SI
Pancratium maritimum L.	Amaryllidaceae	Per	G	ME
Peganum harmala L.	Nitrariaceae	Per	H	ME+IR-TR+SA-SI
Phoenix dactylifera L.	Arecaceae	Per	Ph	CULT and NAT
Poa annua L.	Poaceae	Ann	Th	COSM
Pseudorlaya pumila (L.) Grande	Apiaceae	Ann	Th	ME
Reichardia tingitana (L.) Roth	Asteraceae	Ann	Th	ME+IR-TR+SA-SI
Retama raetam (Forssk.) Webb & Berthel.	Fabaceae	Per	Ph	ME+IR-TR+SA-SI
Ricinus communis L.	Euphorbiaceae	Per	Ph	CULT and NAT
Rumex pictus Forssk.	Polygonaceae	Ann	Th	ME+SA-SI
Salsola kali L.	Chenopodiaceae	Ann	Th	COSM
Senecio gallicus Vill. ex Chaix	Asteraceae	Ann	Th	ME+IR-TR+ER-SR
Silene succulent Forssk.	Caryophyllaceae	Per	H	ME
Sonchus tenerrimus L.	Asteraceae	Ann	Th	ME+ER-SR
Tamarix nilotica (Ehrenb.) Boiss.	Tamaricaceae	Per	Ph	SA-SI+S-Z
Verbesina encelioides (Cav.) Benth. & Hook. F. ex A. Gray	Asteraceae	Ann	Th	COSM
Zygophyllum coccineum L.	Zygophyllaceae	Per	Ch	ME+SA-SI

Per: perennial, Ann: annual, Th: therophyte, Ch: chamaephyte, H: hemicryptophyte, Ph: phanerophyte, G: geophyte, He: Helophytes, ME: Mediterranean, SA-SI: Saharo-Sindian, IR-TR: Irano-Turanian, S-Z: Sudano-Zambezian, ER-SR: Euro-Siberian, COSM: Cosmopolitan, PAN: Pantropical, CULT and NAT: Cultivated and Naturalized.

The life-form spectrum of the recorded species is displayed in **Figure (3a)**. Therophytes had the highest contribution (20 species, 40.82%), followed by phanerophytes (12 species, 24.49%), cryptophytes and chamaephytes (6 species each, 12.24% each), then hemicryptophytes (5 species, 5.5%). The predominance of therophytes is an indicator of the prevailing arid climate as those elements are characterized by high reproductive capacity, ecological and genetic plasticity and high adaptation to mild moist winter and hot dry summer. This is in accordance with the studies of [24]**,** and [28] on relevant study areas and they confirmed the predominance of therophytes over other life-forms.

After exclusion of the two cultivated and naturalized plant species, the chorotypes of the recorded species are displayed in **Figure (3b)**. Mono-regional taxa were represented by 32.65%, bi-regional taxa by 30.61%, worldwide taxa (including Cosmopolitan) by 18.37% and pluri-regional taxa by 14.29% **Figure (3a)**. In addition, the floristic categories were mainly made up of 29 Mediterranean species, 18 Saharo-Sindian, 10 Irano-Turanian taxa, 9

Cosmopolitan, 6 Euro-Siberian taxa. The Mediterranean elements that extending into Saharo Sindian element attained relatively high contribution as compared with the Mediterranean taxa extending into the Euro-Siberian element. These results support that, the presence of a transitional Mediterranean chorotype in Libya between the Mediterranean and the Euro-Siberian chorotype at north, and between the Saharo-Sindian chorotype at south. Commonly, the present investigation favors that, the flora of north Nile Delta is mainly belonging to the Mediterranean chorotype. This opinion is supported by the findings in different directions such as the climatic constitution of the area, life form spectra, floristic features, distribution patterns, altitudinal zonation, and historical-floral events.

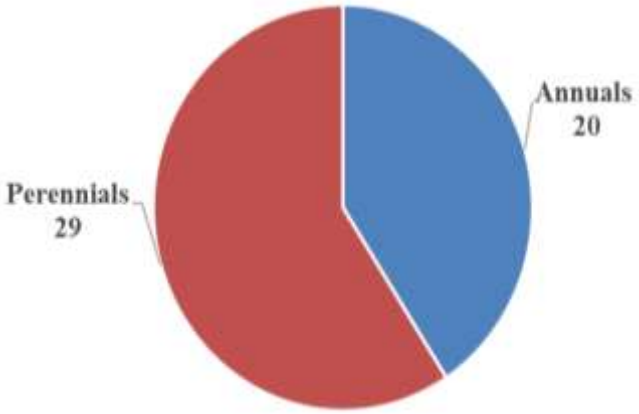


Figure (2). Life span (in number) for the surveyed species in the study area.

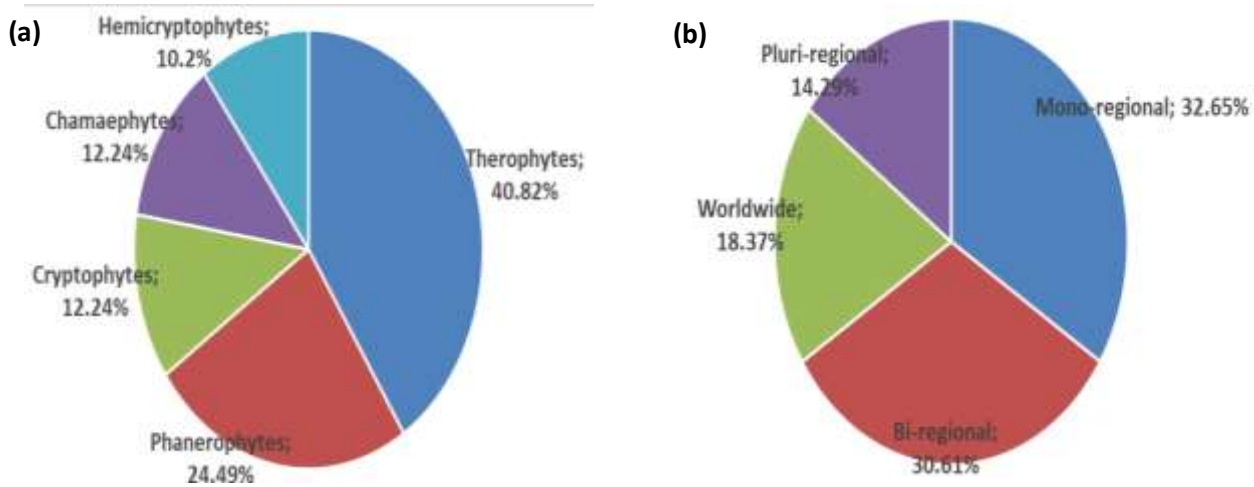


Figure (3). (a) life-form (%) of the surveyed plant species in the current study.

(b) chorological analysis for the recorded species.

PLANT CLUSTERS

Based on the importance values (out of 200) and dissimilarity of the *Z. coccineum* and its associates, classification of the 40 stands using AHC and PCA led to the recognition of three

plant clusters (A, B, and C) **Figures (4 & 5)**. These plant groups/clusters were named after the dominant and codominant species with the highest importance values as follows: group A: *Tamarix nilotica- Zygophyllum coccineum*, group B: *Acacia cyanophylla- Zygophyllum coccineum* and group C: *Zygophyllum coccineum- Cakile maritima* **Table (4)**.

Plant cluster A included 46 species, distributed in 17 stands, group B contained 43 species in 15 stands while group C comprised 8 stands and 40 species. PCA ordination diagram showed that, Group A is separated in the lower positive right part of PCA, group B at the upper right part while group C is located at the center where superimposed with the two groups A and B. This agrees more or less, with the findings of [29].

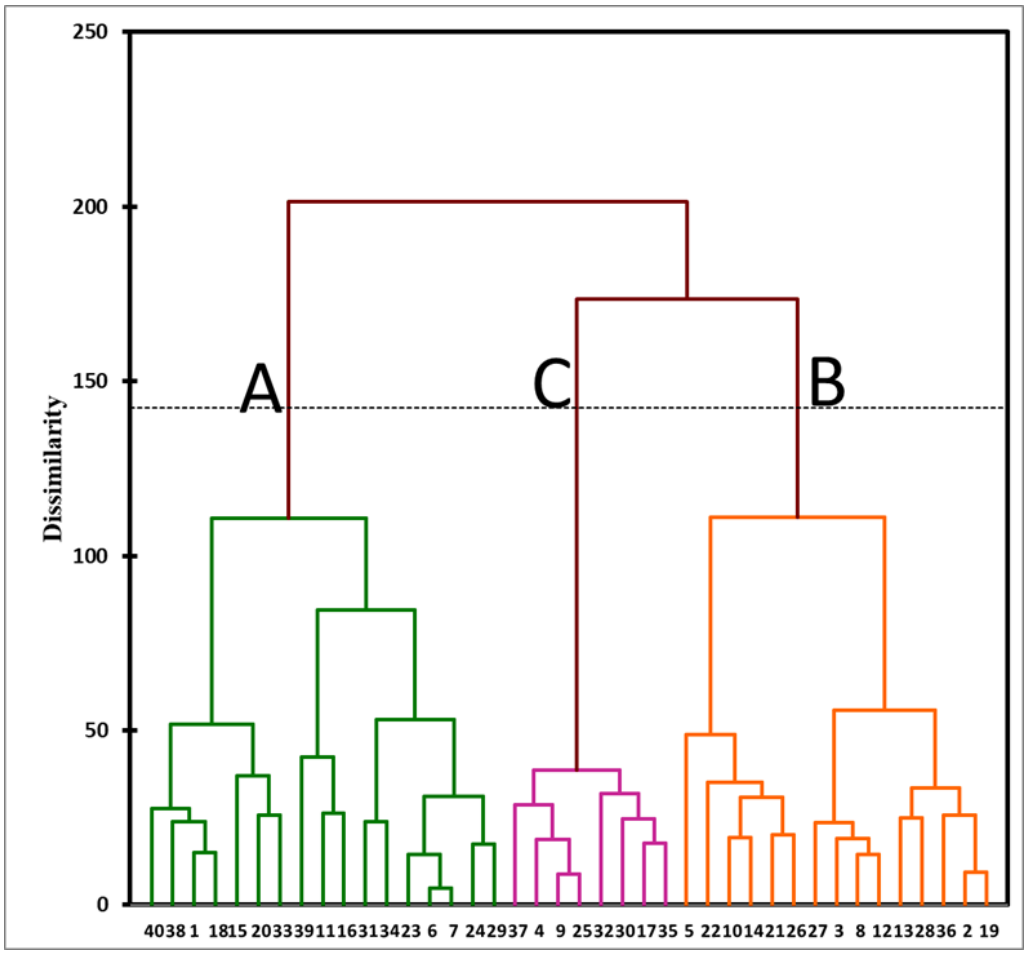


Figure (4). Agglomerative hierarchical clustering (AHC) based on dissimilarity Euclidean distance and Ward's method. Different numbers indicate the stands number.

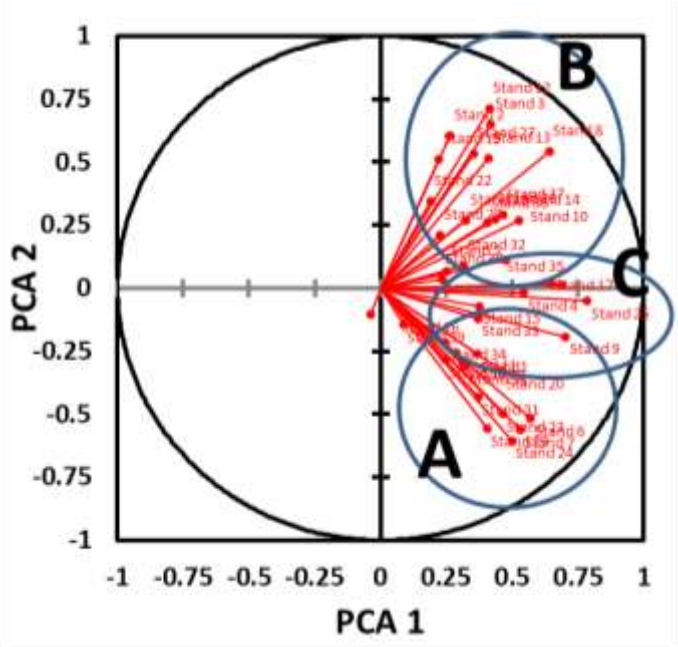


Figure (5). Principle Component Analysis (PCA) based on Pearson coefficient explaining the segregation and interconnection of the three plant clusters (A, B and C).

Table (4). Main characteristics of the four vegetation clusters (A, B and C), obtained after AHC.

Groups	A	B	C
No. of stands	17	15	8
No. of species	46	43	40
Dominant and codominant species with their importance values	*Tam nil* (IV= 18.79), *Zyg coc* (IV=18.45)	*Aca cya* (IV=23.04), *Zyg coc* (IV=17.78)	*Zyg coc*(IV=15.82), *Cak mar*(IV=10.04)

CONCLUSION

A total of 49 species belonging to 47 genera and 23 families were recorded in the study area. Therophytes and Mediterranean taxa had the highest contributions. It is crucial to understand the composition of native plant communities along the coastal zone and consequence identify the main drivers for vegetation destruction and habitat fragmentation.

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