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Habitat Differentiation between two Brassicaceae Cakile Maritima Scop and Brassica Tournefortii Gouan in the Nile Delta Coast, Egypt

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Abstract

Zonation pattern and habitat differences of two wild crucifer plant species were studied in a relation to soil variables at 20 sites. The two species have different distributions range of *Cakile maritima* Scop is restricted to the coastal zone near to the seashore, the other species *Brassica. tournefortii* Gouan is more distributed landward. The habitats of *C. maritima* were distinct from the habitats of *B. tournefortii*.

Four vegetation groups representing both *C. maritima* and *B. tournefortii* were identified in the study area. The *C. maritima* community is growing on sand bar and fore dunes. The *B. tournefortii* community is representing the sandy roadsides, cultivated land, and stabilized sand dunes. We have found that there is little ecological overlap between *C. maritima* and *B. tournefortii* (Group I).

The cover abundance of *C. maritima* was positive correlated with conductivity, Na^+, and K^+ negative correlated with $CaCO_3$, conductivity and pH. While *B. tournefortii* showed positive correlated trend with $CaCO_3$, total soluble salts and pH and negative correlated with conductivity, Na^+ and K^+.

Results suggest that the coastal *C. maritima* has narrower ecological amplitude than widespread *B. tournefortii*. These results indicated that the habitat differentiation of both wild relative species. Further extensive for the adaptive mechanism are required.

Keywords: Ecological amplitude, multivariate analysis, soil variables, salinity, Zonation pattern.

Introduction

Plants belong to the family Brassicaceae are highly economically valuable because they have the greatest potential to produce erucic acid in their oil (Meakin, 2007). The ecological significance of their wild members—some of which grow on and stabilize drifting sand. This family has ca. 53 genera and 103 species, including the common genera like *Cakile, Diplotaxis, Lepidium*, and *Zilla* (Taeckholm, 1974, and Boulos, 2009). The greatest potential of these wild members are rich in erucic acid in their roots (Davy et al., 2006, Danlami et al., 2016).

These family is economically significant for a variety of reasons, including food, fodder, medicines, high-yielding crops, ornamental plants, and research model plants. The Brassicaceae family contains a wide variety of edible species, such as oilseeds, vegetables, sauces, and fodder (Wink and Van Wyk 2008). Many plant species in the family Brassicaceae are fortunate enough to have therapeutic properties, and native peoples utilize these plants in folk medicine. Examples include broccoli, cabbage, green mustard, and cauliflower (Wang et al. 2004).

Sand beaches all over the world are home to the yearly wild maritime plant known as sea rocket, or *C. maritima* (Clausing et al., 2000). This species confined to marine strandlines. By capturing blowing sand, especially on coastal beaches, it may aid in the early stages of dune succession and the formation of fore dunes (Kadereit et al. 2005). According to Pateman and Lee (1991a, b), it gains nitrogen from the soil. Agudelo, et al. (2021) report that it possesses a high capacity for withstanding osmotic stress and has considerable promise as a crop rich in nutrients (Houmani et al. 2016 and Belghith et al. 2019). *Cakile. maritima* is an interesting species due to its ability to produce several secondary metabolites and compounds such as oils and considered as an energy crop (Arbelet et al. 2019).

Sandy coastal habitats are known for their high rates of nutritional absorption, their ability to substitute Na+ for K+ in a variety of biological processes, and the potency of their antioxidant system. *Cakile maritima* is similar to many halophytic plants in response to salinity resistance, such as uptake, and accumulation of salts (Hamed-Louati et al., 2016; Arbelet-Bonnin et al., 2019). Depending on the prevailing environment factors and the habitats, leaf shape can change during development (Cousens et al., 2013). According to Davy et al. (2006), *C. maritima* leaves grown in drier climates have a tendency to be more pinnatifid than those grown in wet climate.

Brassica tournefortii is an annual herb plant and being dominant species in the Mediterranean region of North Africa and the Middle East (Minnich & Sanders, 2000). All phytogeographic regions, with the exception of the Sinai Peninsula, are home to *B. tournefortii*, a common weed in Egypt's recently reclaimed land (Boulos, 1995 and Abd El-Gawad, 2014). In some parts of the world e.g. North America, *B. tournefortii* is an invasive species which has widespread distribution and affect the native flora and fauna (Hulton VanTassel et al., 2014). According to Sanchez-Flores (2007), it grows best in regions with sandy and aeolian soils. Egypt is home to many species of the genus *Brassica*. These are namely: *B. nigra* (L.) Koch, *B. tournefortii* Goauan, *B. juncea* (L.) Czernj. & Coss. and *B. rapa* L.

At elevations below 1000 m, stabilized dunes, sandy plains, and gravel dry desert and road sides are common habitats for *B. tournefortii* (Bangle et al. 2008). The Sahara mustard (*B. tournefortii*) distribution is rapidly expanding in the southwestern United States and threatening natural ecosystems, according to many studies (Bangle et al. 2008; Barrows et al. 2009 and VanTassel et al., 2014). It also inhabits sandy beaches, which are typically located in the coastal habitats (Thanos et al., 1991). It travels from the side of the road into towns, grasslands, deserts, abandoned farms, and beaches. It has successful growth in disturbed soil of the desert environments (Suazo et al. 2012). Ecologists and land managers are concerned about invasive wild plants because of the high potential for harming native plants.

The major aim of this study is to characterize the habitat variations of the two wild members of Brassicaceae namely: *B. tournefortii* and *C. martima* in relation to soil variables governing their distribution.

Materials and Methods

Field Study

An identification of the different habitat types of *B. tournefortii* and *C. maritima* was the major aim of a field study carried out during 2023 along the coastal area of the Nile Delta, extending from Port Said to Baltim. A total of 20 stands were describe (Figure 1). These stands were selected for soil and plant samples based on the types of habitats and the minimum of human disturbance by the two species under study. The types of habitats were: sand bars, roadside, gardens, and sand flats and inter-dunes.

The study area has a typical Mediterranean climate. The average summer temperature is 32^0C, with a range of 20 to 32^0C. The average temperature during the winter is between 10 and 20^0C. The majority of the rainfall falls in the winter ca. 100mm /year (Zahran and Willis, 2009).

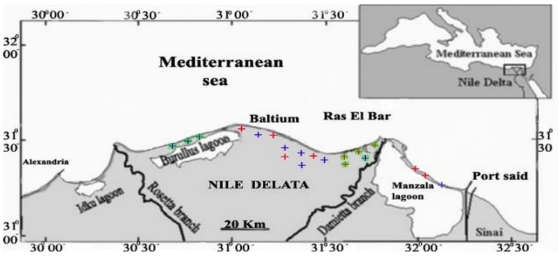

Figure 1. Location map showing the different sites of the study species in the Nile Delta Coast.

The study species

Species nomenclature and identification were according to Boulos (2009).

Cakile maritima

Cakile maritima (Sea rocket) is a coastal halophyte widely distributed in sandy habitats. This plant is confined to maritime shores where the plant plays a role in trapping blown sand, then building fore dune and dune succession stages (Ciccarelli, et al. 2012).

Brassica. tournefortii

It is an annual herb and is known by the common names African mustard, pale cabbage, and Sahara mustard, and has wide geographical distribution (Abd El-Gawad, 2014)

Figure 2. Growth of *C. maritima* (A). *C. tournefortii* growing on the sand bar of new Damietta (B).

Multivariate analyses

Vegetation data of 20 stands representing the distribution of the studied speciesi are analyzed grouped using TWINSPAN, a two-way indicator species analysis (Hill, 1979a).

The vegetation coverabundance were used to develop a sevenpoint scale values of 0, 5, 10, 20, 50, 70, and 90.

Anonical Correspondence Analysis (CCA) ordination was applied using the CANOCO program version 2.1. It is a FORTRAN program used for ordination, according to ter Braak (1988). Results of the ordination technique known as Canonical Correspondence Analysis (CCA) are based mainly on the soil variables and species abundance. The linear relations of soil variables that maximises the dispersion of the species score were used to establish the first and second CCA axes.

Soil analysis

Three soil samples 0-25 cm were taken from each stand. Calcium carbonates was determined by titration against 1 N NaOH and expressed as percentage (Jackson, 1962). A soil solution (1:5) was prepared for each soil sample. Conductivity (EC) and pH were determined according to Jackson (1962). Extractable cations Na^+ and K^+ were determined using a Flame Photometer (Model PFP7, Jenway, Essex, UK

Results

Multivariate Analysis

The classification of 20 stands representing the cover abundance values of two communities dominated by *C. maritima* and *B. tournefortii* using TWINSPAN program produced 4 vegetation groups (I-IV) (Table 1) and the dendrogram (Figure 2). Each group consists of a number of sites with higher similarity in terms of plant species than compared with groups.

Group I: is represented by *B. tournefortii*. Field study indicated that this species is growing on road sides and stabilized dunes. Other important species are *Urtica urens*, *Echinops spinosissimus* and *Phragmites australis*.

Group II: is indicated by *B. tournefortii* and *C. maritima*. These species dominated the sand flats and dry saline habitats, other important species were *Bassia indica*, *Arthrocnemum macrostachyum* and *Cynanchum acutum*.

Group III is indicated by *C. maritima* on mobile dunes. The dominant species were *Cyperus capitatus* and *Pancratium maritimum*

Group IV is indicated by *C. maritima*, which dominates the sand bar. Other important species are *Salsola kali* and *Elymus farctus*

The recognition of four vegetation groups of the 20 stands representing both *Cakile maritima* and *B. tournefortii* indicated different habitat types. The *B. tournefortii* community is representing the sandy roadsides, cultivated land, and fallow land habitats. The *C. maritima* community is growing on sand bar and fore dunes. On the slopes of stabilized dunes with several psammophytes as an indicator species e.g. *Cyperus capitatus* and *Pancratium maritimum*.

Table 1. Results of TWINSPAN classification of 20 representing stands 4 vegetation groups (A-D) with cover values (%) are presented and indicator species are highlighted.

Groups / Species			I						II						III				IV	
Species	19	11	13	15	17	18	4	9	12	20	6	7	2	5	8	14	3	10	1	16
Rumex pectus	-	5	5	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plantago ovata	-	10	5	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyperus capitatus	-	10	5	5	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pancratium maritimum	-	10	10	5	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Limbarda crithmoides	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-
Mesembryanthemum nodiflorum	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Senecio desfontainei	-	10	20	30	-	15	20	-	-	25	-	-	-	-	16	-	-	-	-	-
Brassica tournefortii	50	40	60	70	90	-	70	50	50	15	20	-	-	-	-	-	-	-	-	-
Tamarix tetragyna	15	-	30	10	20	60	-	-	35	22	-	50	-	-	-	-	-	-	-	-
Salsola kali	-	-	25	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20	20
Malva parviflora	-	-	-	-	30	-	4	-	-	-	-	-	-	-	-	-	33	-	-	-
Chenopodium murale	-	-	-	-	-	-	2	-	-	-	20	-	-	-	-	-	45	-	-	-
Zygophyllum aegyptium	-	-	-	-	-	-	-	-	40	-	4	-	-	-	-	-	-	20	-	-
Cakile maritima	-	-	-	-	-	9	50	70	60	70	-	80	50	70	70	50	55	75	90	40
Atriplex prostrata	30	-	-	-	-	-	-	-	-	-	-	-	-	5	-	20	-	-	-	-
Bassia indica	-	-	-	-	-	-	2	-	-	-	1	-	-	1	15	-	-	-	-	-
Phragmites australis	-	-	10	-	-	-	-	-	-	-	-	20	-	15	-	-	-	30	-	-
Urtica urens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60	10	-	-
Arthrocnemum macrostchyum	-	-	-	-	-	-	-	-	-	-	-	70	-	40	-	-	-	-	-	-
Cynanchum acutum	-	-	-	-	-	-	-	-	-	-	-	-	-	60	20	-	-	-	-	-
Launaea nudicaulis	-	-	-	-	-	-	-	-	-	-	-	-	-	20	-	-	-	-	-	-
Echinops spinosissimus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	70	-
Elymus farctus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50	46

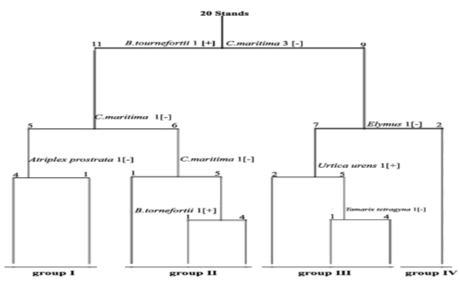

Figure 2. TWINSPAN dendrogram of 20 stands based on cover abundance values of *C. maritima* and *C. tournefortii*. Indicator species are presented at each level. Full names of the species are shown in Table 1.

Soil variables

The soil factors analyzed in this study are shown in Table 2. edaphic characteristics differed between the identified vegetation clusters. Soil salinity is the key factor controlling species distribution. The soil pH slightly varied among vegetation clusters and being in the alkaline side. Electrical Conductivity (EC) values were increased from 0.43 mS/cm to 1.22 mS/cm in group (I, II) these groups were dominated by *B. tournefortii*. On the other hand, there are only few significant correlations present between the different soil variables Table 3 (pH and Na^+, $P< 0.01$) and (TDS and K^+, $P< 0.05$).

Table 2. Means ± SD of soil variables representing the identified vegetation groups in the Nile Delta coast.

	Group I	**Group II**	**Group III**	**Group IV**
Parameter	Mean SD	Mean SD	Mean SD	Mean SD
pH	8.37±0.222	8.022±0.1117	8.34±0.1550	8.185±0.335
EC(mS/cm)	0.43±0.113	1.224±0.367	1.148±0.380	0.982±0.802
TDS mg/l	661±83.3486	532.55±98.9176	465.31±117.081	431.43±283.566
$CaCO_3$ (%)	2.77±0.961	1.259±0.4443	1.537±0.5170	1.135±0.015
Na^+ (mg/l)	6.55±1.663	4.374±0.6002	7.703±1.879	4.219±2.031
K^+ (mg/l)	1.17±0.269	1.59±0.4779	1.468±0.4130	1.43±1.28

EC= electrical conductivity, SD=Standard deviation, TDS= Total Dissolved Solids.

Table 4 displays the eigenvalues of the canonical correspondence analysis's first four axes. These values were obviously lower, indicating that the data collection was well structured. This provides insight about the ordination's stability. By comparing the species-environment relationship, the eigenvalues provide a far more accurate indicator of the strength of the relationship and the quality of the ordination.

Table 3. Multiple correlation coefficients (r) between soil variables representing 20 stands.

pH	**1**					
EC(ms/cm)	-0.0683	1				
TDS mg/l	0.0459	0.32	1			
CaCO3 (%)	0.0816	0.065	0.4167	1		
Na+ (mg/l)	0.6205**	0.3451	0.2875	0.0622	1	
K+ (mg/l)	-0.0291	-0.2931	0.461*	-0.2599	-0.3155	1
	pH	EC	TDS	CaCO3	Na $^{+}$	K $^{+}$

*=P<0.05, **=P<0.01

Species –environment relationship

Figure 3 showed the relationship between species abundance along the gradients of 6 soil variables as presented by the CCA ordination diagram. Triangle points represent species and arrows represent soil factors. The high the length of the arrow the more importance of that variable. The length of the arrow is produced from Eigen values of the CCA axes due to variance variation in the data (Table 4). The direction of an arrow representing the gradient of environmental change, for that variable. The species points occurring near the arrowhead are highly positively correlated with higher values of this variable. The species points found near the arrow base are not correlated with this variable.

The results of Figure 3 showed a high correlation between *C. maritima* and EC and Na^+ in the upper right part of the diagram. The obligate halophytes e.g. *Arthrocnemum macrostachyum, Atriplex halimus* and *Bassia indica* follow the same trend. On the lower left side of the diagram *B. tournefortii* showed *correlation with* TDS and $CaCO_3$. The psammophytic species *Pancratium maritimum*, *Cyperus capitatus* and *Rumex pectus* showed similar trend.

The CCA ordination diagram (Figure 3) demonstrated the position of *C. maritima* and *B. tournefortii* and associated species along the gradient of six soil variables.

The distribution of *C. maritima* is concentrated at the lower end of the gradient of electrical conductivity (EC) and Na^+ and in an intermediate position on the pH, K^+, TDS and calcium carbonates in the soil. The species *Tamarix tetragyna*, *Atriplex prostrata*, *Phragmites australis* and *Launaea nudicaulis* showed a similar trend, these species occur in saline habitats with high Na^+ and EC in the soil. *B. tournefortii* showed an opposite trend to that of *C. maritima*. *B. tournefortii* was concentrated at the upper end of the gradient from soil variables (TDS, $CaCO_3$ and pH). The species *Salsola kali*, *Plantago ovata* and *Cyperus capitatus* showed a similar trend.

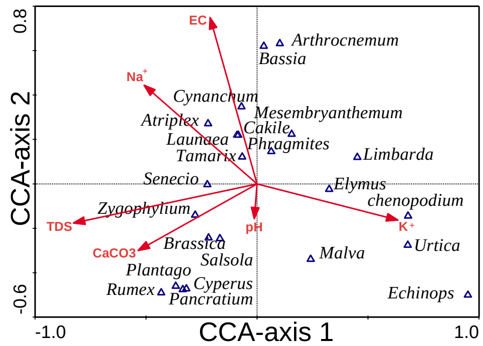

Figure 3. Canonical Correspondence Analysis (CCA) ordination of indicator and preferential plant species associated with *Cakile* and *C.* along the gradient of soil factors in the Nile Delta coast.

Table (4): Results of CCA ordination with % of Eigen values, species variance, and inter set of species- environment correlation (r S/E)

Axes	Axis 1	Axis 2	Axis 3	Axis 4
Eigenvalue	0.339	0.316	0.206	0.090
% of species variance	32.5	30.4	19.7	8.6
r (S/E)	0.821	0.825	0.768	0.772

Species response to soil factors

The results in Figure (4) is used to predict the general trend of variation between species abundance of both *C. maritima* and *B. tournefortii* and the soil factors in the study area. The coastal habitats in the Nile Delta at the showed a noticeable physiognomic heterogeneity. The cover abundance of *C. maritima* was positively correlated with EC, Na^+, and K^+ and negative correlation with $CaCO_3$, TDS and pH; while *B. tournefortii* showed a positive correlation with $CaCO_3$, TDS and pH and a negative correlation with EC, Na^+ and K^+.

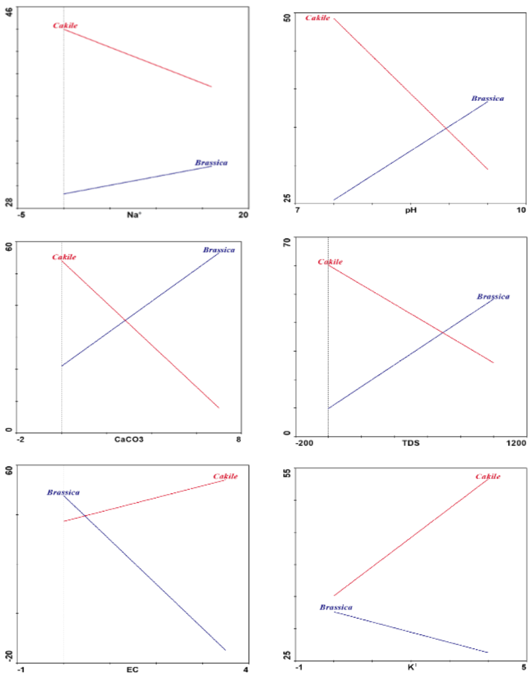

Figure 4: Modelling the response curves for *C. maritima* and *B. tournefortii* along the gradient of soil variables.

Discussion

Habitat, species, growing conditions, prevailing climate, and soil variables exert significant influence on the vegetation of the Mediterranean coastlal region. Plants primarily distribute along sandy coastlines, salt marshes, and windward or leeward sandy dunes (Serag, 1986, Serag, 1999, Zahran and Willis 2009).
The current distribution of the studied species, *B. tournefortii*, is characterized by its dominance of disturbed sites and roadside habitats in a more landward direction (Brooks et al., 2006).
Imperata cylindrica, *Mesembryanthemum crystallinum*, *Senecio glaucus*, and *Cynodon dactylon*, among other significant weeds, were found to be associated with the *B. tournefortii* community (Minnich and Sanders, 2000). These weeds, with their high ecological amplitude, intense competition, and rapid reproduction, exert a significant impact on the *B. tournefortii* community, shaping its ecological dynamics. The associated flora identified in the current investigation may be consistent with the findings of numerous previous studies (Gomaa et al. 2023; El-Halawany et al. 2010).
In the current study, *B. tournefortii* was found to be highly susceptible to salinity and was able to persist in sandy soil (Abdel Gawad 2014). This is consistent with the findings of other researchers (Thanos et al., 1991; Minnich and Sanders, 2000).
The Sea Rocket, *C. maritima*, is a pioneer species of dune habitat that is primarily found on the strandline of beaches (Davy et al., 2006). It is endowed with a variety of intriguing characteristics that enable it to persist in the coastal region. Sea Rocket is regarded as the most closely related halophytic or salt-tolerant species to the significant *Brassica* crop species (Beilstein et al., 2008).
Environmental heterogeneity can be a significant factor in shaping species variation, which may result in variations in selective pressures across a species' range. Consequently, it is crucial to comprehend the potential variations in environmental conditions that may occur throughout this system's range.
Soil variables significantly influence the distribution of plant communities in the coastal region. Extensive research on arid environments has examined the strong relationship between soil development, dominant vegetation types, and geomorphology (Buxbaum and Vanderbilt, 2007).
The present investigation observed that the *B. tournefortii* community was in opposition to *C. maritima* in response to the soil factors that were examined. *B. tournefortii* is classified as an invasive species and is less tolerant to high salinity (Abd El-Gawad, 2014). Conversely, the *C. maritime* community, which is situated on sand beaches, and its seeds are transported from the sand beaches' habitat to the neighboring fore dunes as a result of their high reproductive output and survivorship. The obtained results are consistent with prior investigations (Mashaly et al. 2009, Abdel Gawad 2014). This discovery is crucial for comprehending the adaptive molecular mechanisms of these highly economically significant species, as both wild relatives are members of the Brassicaceae family. Additional research is necessary in the near future to maximize the benefits of these species.

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الملخص العربي

عنوان البحث: تباين الموائل بين نوعين من الفصيلة الصليبية ، صاروخ البحر والشلطام في ساحل دلتا النيل ، مصر

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يهدف البحث الى دراسة نمط التباين والاختلافات في الموائل لنوعين من النباتات الصلبية البرية وعلاقتها بعوامل التربة في ٢٠موقعا. النوعان هما صاروخ البحر والشلطام. أظهرت النتائج ان نبات صاروخ البحر لديه نطاق توزيع مختلف وانه يسود االمنطقة الساحلية القريبة من ساحل البحر، والنوع الاخر اكثر انتشارا نحو اليابسة تختلف في الموائل، وقد وجدنا ان هناك القليل من التداخل البيئي بين المجموعة الاولي والثانية من نتائج التحليل الإحصائي.
المجموعة الأولى يسودها نبات الشلطام ويرافقه نبات الحريق وشوك الجمل والبوص (الحجنه) اما المجموعة الثانية يسودها صاروخ البحر والشلطام وأهم الأنواع المرافقة لهدة المجموعة نبات الكوخيا والحطب الأحمر والمديد. والمجموعة الثالثة يسودها نبات صاروخ البحر ويرافقه نبات البنكرشيم والسميرة كدلك أظهرتهرت نتائج التحاليل الإحصائية للبينات بان المجموعة الرابعة يسودها صاروخ البحر ويرافقه نبات السالسولا.
تم تحديد أربع مجموعات نباتيه تمثل كلا من صاروخ البحر والشلطام في منطقة الدراسة يمتل مجتمع نبات الشلطام جوانب الطرق الرملية والأراضي المزروعة والكثبان الرملية المجموعة الثانية صاروخ البحر ينمو على المصاطب الرملية والكثبان الرملية.
ارتبطت وفرة الغطاء النباتى لصاروخ البحر بشكل إيجابي مع (الصوديوم والأملاح الكلية الدائبة والبوتاسيوم) وارتبطت سلبا مع (الأملاح الكلية الدائبة وكربونات الكالسيوم).
بينما أظهرت نبات الشلطام اتجاها إيجابيا مع (كربونات الكالسيوم والاملاح الكلية الدائبة) وارتبطت سلبيا مع الصوديوم والبوتاسيوم ودرجة التوصيل الكهربي.