Journal of Coastal Research	3	2	179-187	Charlottesville	Spring 1987

Distribution of *Halopeplis perfoliata* (Forssk) Bunge ex Schweinf. in the Red Sea Coastal Salt Marshes: Phytosociological Relations and Responses to Soils

M.N. El-Shourbagy[a, b], O.H. Al-Eidaros[a], and H.S. Al-Zahrani[a]

[a](Present Address) Department of Botany
Faculty of Science
University of Tanta
Egypt

[b]Faculty of Science
King Abdul-Aziz University
Jeddah, Saudi Arabia

ABSTRACT

EL-SHOURBAGY, M.N.; AL-EIDAROS, O.H. and AL-ZAHRANI, H.S., 1987. Distribution of *Halopeplis perfoliata* (Forssk) Bunge ex Schweinf. in the Red Sea coastal salt marshes: phytosociological relations and responses to soils. *Journal of Coastal Research*, 3(2), 179-187. Charlottesville, ISSN 0749-0208.

The distributional patterns of *Halopeplis perfoliata* (Forssk) Bunge ex Schweinf., one of the dominant salt marsh halophytes of littoral vegetation, has been studied with several environmental variables. The study area is located as a transitional zone between the Mediterranean and tropical coastal salt marshes. Ten sites (stands) were described, each is well defined and represents a sociologically distinct entity. Application of cluster analysis and the Wisconsin two-dimensional ordination technique led to the recognition of 4 sets of stands. The distributional pattern of *H. perfoliata* seems to be controlled by seasonal changes in a complex of interrelated environmental variables, such as soil moisture, pH, EC, total nitrogen, and some mineral ions. Analysis of the relationship between these variables and those of *H. perfoliata* showed highly significant correlations regarding K^+ in all seasons, which would provide evidence for its role in the adjustment mechanism of this halophyte.

ADDITIONAL INDEX WORDS: Halopeplis perfoliata, *Red Sea, Coastal salt marshes, halophyte, distributional pattern, cluster analysis, ordination technique, seasonal changes, adjustment, environmental variables.*

INTRODUCTION

Salt marshes of the Red Sea coast occur on shorelines around the margins of lagoons and estuaries. The frequency and duration of tidal submergence change markedly with elevation across each marsh, and the dynamic interaction between salt-water flooding fresh-water runoff is modified by pronounced variations in precipitation, temperature and evaporation (WEISS *et al.*, 1979).

The vegetation of the Red Sea coastal salt marshes is dominated by a rather small number of halophytes. These halophytes are not only well adapted to these environments but they also exhibit a remarkable ability to exploit auxiliary energy sources provided by tides to perform work of mineral cycling and food transport (ODUM and FANNING, 1973) to compensate for the energy cost of coping with the stress factors. ODUM (1974) considered halophytic communities such as those of salt marshes in tidal estuaries to have a productivity in a range from 10,000 to 40,000 kilocalories per m^2 per year, averaging about 20,000 and are clearly subsidized by the energy of the tides, waves and other water flows.

It should be emphasized that ecological investigations are urgently needed to understand the sociological behaviour of the coastal salt marsh halophytes in relation to environmental variations. Such an understanding is essential for their preservation in that they are ecologically as well as economically important. They can be either used to improve salt tolerance of some conventional economic plants (LE RUDULIER and VALENTINE, 1982), or utilized as raw material for novel economic products (MUDIE, 1974). One of the dominant coastal halophytes is *Halopeplis perfoliata*. There is little information on its

85042 received 15 October, 1985; accepted in revision 5 February 1986.

phytosociological relation with other associated species and the environmental gradients. The purpose of the present study is to document a relationship between the distributional pattern of *H. perfoliata* and the seasonal changes of several environmental variables such as soil moisture, pH, EC, total nitrogen and some mineral ions in a sector along the Red Sea coast between Jeddah and Rabegh, Saudi Arabia.

STUDY AREA

The study area is located in the shoreline of the central section of Tihama Plain of Saudi Arabia and bounded by the Red Sea shelf area which is marked by the raised littoral surface of the reefal limestone (Figure 1). This zone attains a maximum width of 2 km. The landscape is distinguished into a western portion which is formed of depositional coralline limestone which ranges from 0.5 to few kilometers in width and an inland gypsiferous sand. Along the shoreline salt marshes (*Sabkhas*) are distinguished behind the raised reefs, which are flat plains with an average elevation of 1 m above sea level, and frequently flooded at high tides. These salt marshes are formed in lagoonal areas under arid conditions (GAVISH, 1974 and LEVY, 1977).

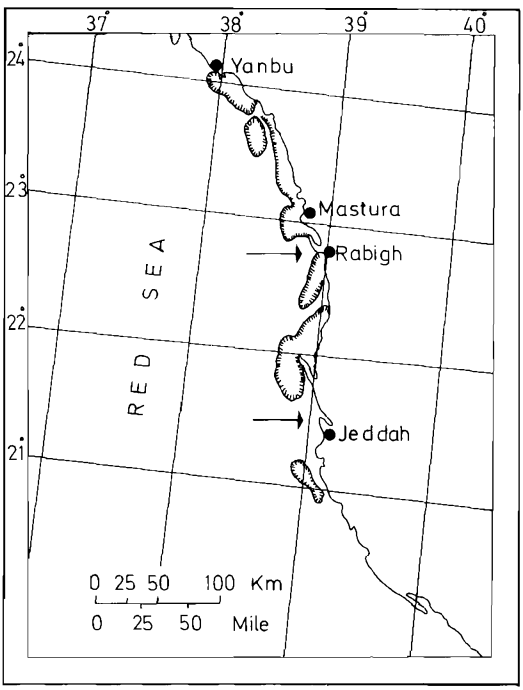

Figure 1. Map showing the location of the study area on the Red Sea coast (enclosed between arrows perpendicular to the sea shore.)

The climate of the study area is a transitional type between the monsoon and Mediterranean which is modified by the Red Sea and the Sarawat Mountains. Annual precipitation ranges from 70 mm at Jeddah to 12.6 mm at Yanbu (Table 1). During summer the mean maximum air temperature is 37.6 °C at Jeddah and 36.5 °C at Yanbu, while the mean minimum temperature is 25.3 °C at Jeddah and 21.0 °C at Yanbu In winter the mean maximum air temperature is 29.7 °C at Jeddah and 29.9°C at Yanbu, while the mean minimum is 18.9 °C and 13.4 °C respectively. During summer the area is influenced by the advancing Intertropical front. This front is associated sometimes with a low pressure trough which extends from Sudan, introducing moist air from south east and south west. The south east monsoon current is channeled along the Red Sea trench before its divergence towards the land mass. During winter air originating from either the Mediterranean or Atlantic cyclonic belts passes over the relatively warm Red Sea water and becomes charged with moisture before its divergence towards the land mass, where it joins the winter wind coming from the east.

MATERIALS AND METHODS

Halopeplis perfoliata (Forssk) Bunge ex Schweinf. (Chenopodiaceae) is a perennial succulent halophytic shrub, with a rather narrow ecological amplitude, occupying the first zone of the Red Sea salt marshes (MIGAHID, 1978). Selection of stands were made according to physiographic and physiognomic homogenity and were distributed in the study area so as to cover the whole climatic gradients and to represent different salt marsh sites, ranging from a few meters to about 1.5 km inland. Vegetation was sampled in each stand using 50 1-m squares. These were distributed at random using coordinate random numbers. Individuals of each species were recorded in each quadrant and their frequency and density were calculated. Five 20-m lines were established in each stand and the sum of lengths of interception by each species was calculated. This sum was then expressed as percentage of the total lengths. Relative values of frequency, density, and cover was calculated for each species and summed to give the importance value (IV), which may vary for each

Table 1. *Air temperature and rainfall of Jeddah and Yanbu*[1].

	Jeddah				Yanbu			
	Air temperature °C				Air temperature °C			
Month	Mean daily maximum	Mean daily minimum	Mean of day	Rainfall (mm)	Mean daily maximum	Mean daily minimum	Mean of day	Rainfall (mm)
January	28.5	18.9	23.3	23.6	29.9	13.4	23.3	3.1
February	29.3	18.9	23.9	11.1	28.4	14.5	21.3	0.0
March	31.0	20.5	25.4	0.4	29.2	16.3	24.7	1.3
April	33.3	22.2	27.4	7.3	32.9	19.9	27.6	0.9
May	35.4	24.5	29.7	1.5	34.4	22.7	27.7	0.1
June	36.4	25.3	30.7	0.0	35.5	24.0	31.0	0.0
July	37.6	26.8	32.0	0.1	36.3	25.8	31.4	0.1
August	37.1	27.2	32.0	0.0	36.5	24.9	32.8	0.0
September	35.8	26.1	30.8	0.1	34.9	24.0	30.4	0.0
October	34.9	24.2	29.1	0.5	34.4	22.8	29.3	2.3
November	32.5	22.3	27.1	15.6	31.4	18.7	25.8	4.3
December	29.7	20.0	24.7	10.2	27.9	14.4	21.9	0.5
Year				70.4				12.6

[1]From records of the General Directorate of Meteorology, Jeddah, Saudi Arabia (averages of 1970-1979).

species from zero to 300.

Similarity between different stands was assessed with the use of SPATZ's (1970) formula as given by DOMBOIS and ELLENBERG (1974). Jaccard's index of community similarity was applied as an index of association between the perennial species recorded in the study sites. A classification technique was used to analyze the similarity matrix indices and a dendrogram was constructed as described by SNEATH and SOKAL (1974). Stands were clustered into cells regardless of whether they form discrete groups in nature or whether they are merely parts of a continuum. An ordination technique was used according to BRAY and CURTIS (1957) as modified by BEALS (1960) using the dissimilarity matrix indices.

Collections of *H. perfoliata* were made 3 times (autumn, winter and spring) during the period from September 1983 until April 1984. Uniform sized plants were selected and composite samples were taken from several individuals collected at random. Fresh material was cleaned, separated into shoot and root, oven-dried at 70 °C to constant weight, and finally ground. Total nitrogen was determined using the micro-Kjeldahl method (PAECH and TRACEY, 1956). Organic matter determination was carried out by ignition at 500 °C for 2 hours. Chloride concentration was estimated after extraction from the ashed-powdered sample at 500 °C with 0.1 N nitric acid using the $AgNO_3$ titration method (JACKSON and THOMAS, 1960). For the other elements the "wet ashing procedure" was applied and measurements of Na^+, K^+, Ca^{++}, Mg^{++} and iron were carried out by means of Perkin-Elmer atomic absorption Model 5000, while phosphorus was determined colorimetrically using the ammonium molybdate method.

Soil samples were collected in each stand from at least 3 trenches (25 x 50 cm) extending across the shrub clump and the bare area between clumps. Each was dug to a depth of 50 cm or to the level of standing water. Samples of uniform color and texture were mixed, air-dried, and passed through a 2-mm sieve. The hydrometer method was used for the particle fractionation and the percentage of sand, silt, and clay was calculated. Organic matter was determined by the loss on ignition at 500 °C, and total nitrogen by micro-Kjeldahl method after digestion (PRINCE, 1958). Soil water extracts (1:5) were prepared and cations and anions (Na^+, K^+, Ca^{++}, Mg^{++}, phosphorus, and Cl^-) were measured as described above. The electrical conductivity (EC) was measured by means of conductivity bridge, and pH by a pH-meter. All above procedures are according to ALLEN *et al.* (1974) and U.S. SALINITY LABORATORY STAFF (1954). Statistical treatments of results follow procedures outlined in STEEL and TORRIE (1980).

RESULTS

In the present study twelve perennial species were encountered. None of these can be considered as a leading dominant for the whole study area. The species of Chenopodiaceae form 66.7% of the total species recorded. *Halopeplis perfoliata* exhibited local dominance in certain stands. The most common perennial species recorded with *H. perfoliata* were: *Suaeda pruinosa, Salsola baryosma, Suaeda monoica, Limonium axillare, Aeluropus massauensis, Salsola longifolia, Zygophyllum coccineum, Arthrocnemum glaucum, Atriplex favinosa, Anabasis setifera and Avicennia marina.*

The importance value (IV) of each species varies between 0 and 300. In spite of the fact that number of stands studied in this investigation is quite low it was found possible to distinguish between them clearly. Stands 1, 2, 3 and 8 are relatively close to the shoreline (less than 100 m inland), stands 4, 5, 9 and 10 are located between 500-1500 m inland, while stands 6 and 7, though near to shoreline, are located on elevated land compared to others. *H. perfoliata* was recorded in eight stands and showed the highest importance value in stand 10 (IV 300), stand 3 (IV 296) and stand 8 (IV 263). The high IV of *H. perfoliata* in stands 3 and 10 reflects the non-significance of the other associated species.

Association between Species

Quantitative analyses between salt marsh species of the Red Sea coast has received little attention. In the present study Jaccard's index of species association has been chosen (IA_p). Most species in the study area overlap in their distribution with *H. perfoliata* but the degree of association is variable and mostly below 50%. The highest values are those between *Atriplex favinosa* and *Anabasis setifera* (100%), followed by 75% between *Limonium axillare* and *Zygophyllum coccineum* and each of *A. favinosa* and *A. setifera.*

Relationships between Stands

Relations between different stands had been expressed in terms of similarity indices (IS) for pairs. The similarity between different stands was obtained with the use of SPATZ's (1970) formula as given by DOMBOIS and ELLENBERG (1974). This coefficient has greater sensitivity to quantitative difference than any other index. Similarity coefficients between stands are generally low. Among the highest coefficients are those between stands 3 and 5 (68.9) and between stands 8 and 9 (67.6). There are some relatively high similarity coefficients between stands 3 and 8 (52.4), stands 1 and 5 (46.2), stands 3 and 10 (49), stands 2 and 5 (45.8) and stands 8 and 10 (41.2). It is interesting to notice that the lowest similarities obtained are those between each of stand 4, 6 and 7 and other stands.

Classification of Vegetation Data

The dendrogram shown in Figure 2 is derived from the cluster analysis, using the unweighted pair-group method of agglomerative clustering. Because the paired and grouped stand clusters are the result of linkages at various levels of similarity an ecologically meaningful classification is not automatically indicated. Classification can be obtained however, by setting more or less arbitrary threshold

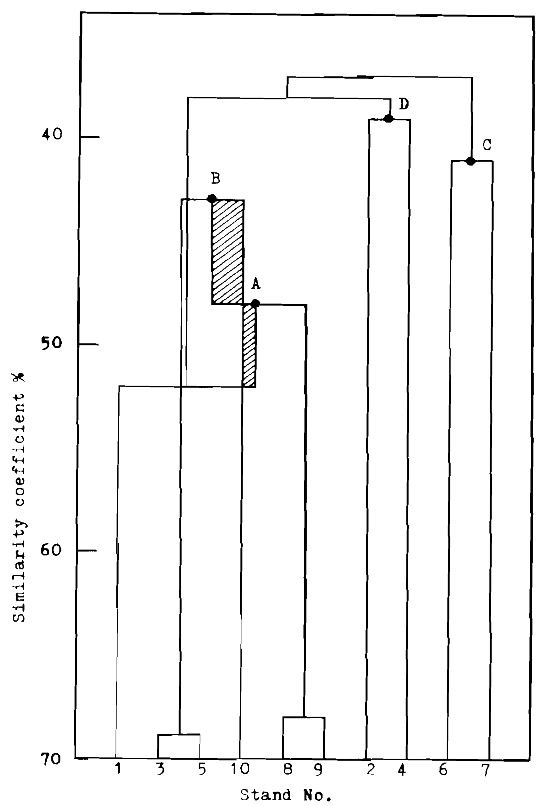

Figure 2. Dendrogram showing the result of classification of ten stands according to the cluster analysis technique. The four clusters identified are A, B, C and D.

values. At 39% similarity there are four main clusters; D, C, B, A. Cluster D links stands 2 and 4, cluster C links stands 6 and 7, cluster B links stands 3, 5 and 10, and cluster A links stands 1, 8 and 9. At 41% similarity there are three clusters; C, B and A. At 43% similarity two clusters remain (B and A) and a value of 48% is set for A only.

Ordination of Stands

The two-dimensional ordination of stands had resulted in four distinct groupings, which coincided closely with the clustering on the dendrogram of Figure 2. When the stands in the two-dimensional space of the Wisconsin ordination (Figure 3) are grouped according to the cluster to which they belong, it becomes obvious that cluster C which includes stands not having *H. perfoliata* is isolated from the other three vegetational categories where this species is present. Category A (at the right of the diagram) coincides with cluster A and category B (on the top) coincides with cluster B.

Seasonal Changes in Soil Characteristics in Relation to Groups of Stands

The four different groups of stands differ in total nitrogen during the three seasons (Table 2). Stands of group C occupy the highest end of nitrogen gradient, while stands of group D occupy the lowest end of the gradient and stands of the other two groups (A and B) are of intermediate position. For the other variables, it is indicated that group C occupy the lowest end of EC, organic matter, Na^+, K^+, Ca^{++}, Mg^{++} and Cl^- gradients throughout the year and is characterized by higher percentage of sand compared to other groups. It is of interest to notice that stands of group C are located at the upper end of the pH gradient and the lowest end of the organic matter gradient in winter.

Statistical analyses indicated that the effects of each season, stand and their interaction were highly significant (at $P<0.01$) on all soil variables investigated, except EC and Cl^-. For these two variables the effects of stand and season by stand interaction

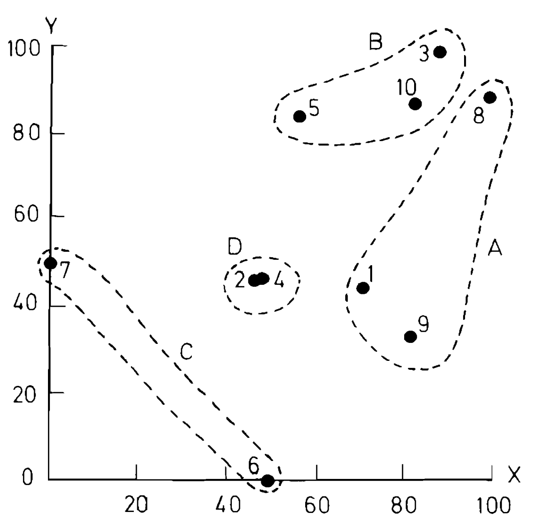

Figure 3. Ordination of stands on 1 and 2 axes from the Wisconsin ordination technique. The classification of stands according to the cluster analysis has been superimposed on the ordination diagram.

Table 2. *Soil characteristics of vegetational groupings within the ecological amplitude of* Halopeplis perfoliata.

	Vegetational groupings			
Soil variables	A	B	C	D
	Autumn			
Moisture %	13.8	7.9	7.5	11.0
pH	7.2	7.4	7.2	7.2
EC mmhos/cm	11.8	9.9	3.1	8.7
Organic matter %	7.8	9.1	4.8	5.4
Total nitrogen	9.5	12.8	34.5	6.3
Na^+	40.7	28.9	8.1	30.6
K^+	1.1	0.5	0.3	0.4
Ca^{++}	9.8	5.1	1.1	3.9
Mg^{++}	7.8	7.0	1.6	9.4
Cl^-	62.2	37.2	9.9	36.2
	Winter			
Moisture %	14.8	9.2	6.6	10.4
pH	7.5	7.4	7.9	7.5
EC mmhos/cm	10.7	8.6	2.6	9.5
Organic matter %	9.9	11.4	4.1	8.6
Total nitrogen	21.3	14.7	42.2	7.9
Na^+	107.7	95.0	17.3	102.6
K^+	3.4	3.7	2.0	3.4
Ca^{++}	5.6	6.0	0.9	5.5
Mg^{++}	5.7	5.7	1.6	4.4
Cl^-	46.6	33.1	10.4	37.7
	Spring			
Moisture %	13.7	21.3	9.4	11.7
pH	6.6	6.7	7.0	6.7
EC mmhos/cm	10.8	10.5	2.3	7.1
Organic matter %	7.9	10.5	4.3	6.7
Total nitrogen	16.3	23.4	41.0	16.0
Na^+	42.1	43.7	7.3	27.7
K^+	0.6	0.8	0.3	0.5
Ca^{++}	5.3	4.6	0.4	4.8
Mg^{++}	8.0	9.3	1.4	9.9
Cl	45.7	44.0	8.7	25.9
Particle fractionation:				
Sand %	78.7	74.5	95.0	84.4
Silt %	13.3	18.2	0.5	9.4
Clay %	8.0	7.3	4.5	6.2

(Total N in mg/100 g and Na^+, K^+, Ca^{++}, Mg^{++} and C in Meq/100 g.)

were highly significant, while that of season was not significant.

Simple linear correlation (r) between each of the soil variables in each season and both the importance values and the relative densities (abundance) of *H. perfoliata* has been calculated. The importance value of *H. perfoliata* shows negative correlations ($P < 0.05$) with total nitrogen in both autumn (-0.725) and winter (-0.648) and a positive correlation with Mg^{++} in winter (0.646). Abundance of the same species shows also a negative correlation ($P < 0.05$) with nitrogen (-0.73 in autumn and -0.611 in winter).

Nutrient Contents of Soil and *H. perfoliata* Shoot and Root in Different Stands

The ordered means of soil variables and *H. perfoliata* shoot and root variables in different stands are presented in Tables 3 and 4 according to results of one-way analysis of variance. Eight soil variables out of 11 show significant variations ($P < 0.005$); soil moisture content, EC, organic matter, total nitrogen, Na^+, Ca^{++}, Mg^{++} and Cl^-. Stands 6, 10 and 7 occupy soil with the lowest moisture percentage, stands 8, 3, 1 and 5 with the highest and stands 2 and 4 with intermediate ones. The highest EC is found in stand 9 while the lowest by stands 6 and 7. Stands 9, 3, 5, 10 and 8 show higher percentages of organic matter but those of 1, 6 and 7 have lower percentages. Stands 6 and 7 occupy the higher end of nitrogen gradient, but stands 8, 2 and 3 occupy the lower end. Stands 9, 3, 5 and 8 occupy soils having the highest Na^+ level, but stands 6 and 7 having the lower level. Stands 1, 9 and 10 having the highest Ca^{++} and stands 9, 10, 4, 3 and 8 the highest Mg^{++} levels, but still stands 6 and 7 having the lowest Ca^{++} and Mg^{++} levels. Regarding Cl^- stand 9 occupies soil with the highest, but again stands 6 and 7 are characterized by the lowest levels.

Concerning *H. perfoliata* shoot, there are 3 variables out of 11 which show significant variations between stands ($P < 0.005$); Ca^{++}, Mg^{++} and iron, whereas others do not show significant variations The shoot of *H. perfoliata* occupying stand 10 is characterized by higher Ca^{++} level and that of stands 4 and 8 by lower levels. The shoot of stand 3 has a higher Mg^{++} level and that of stands 10, 9 and 8 lower levels.

For *H. perfoliata* root, there are 5 variables out of 11 which show significant variations between stands; water content, dry matter, Ca^{++}, Cl^- ($P<0.005$) and Mg^{++} ($P<0.01$). Water content of root in stands 1, 3 and 2 is higher and in stands 10 and 4 is lower. Root-dry matter content is in contrast

Table 3. *Ordered means for soil variables that showed significant variations ($P<0.005$) among different stands according to the analysis of variance. The means with common underlines are not significantly different.*

Soil variables										
Water content %	17.09 (8)	16.48 (3)	14.75 (1)	14.45 (5)	11.02 (2)	10.99 (4)	10.39 (9)	9.44 (6)	7.50(10)	6.38 (7)
EC (mmhos/cm)	16.62 (9)	10.53(10)	10.14 (4)	9.63 (3)	8.94 (5)	8.90 (8)	7.82 (1)	6.66 (2)	3.30 (6)	1.94 (7)
Organic matter %	11.44 (9)	11.01 (3)	10.18 (5)	9.81(10)	9.74 (8)	8.47 (4)	5.30 (2)	4.40 (6)	4.39 (1)	4.31 (7)
Total N (mg/100 g)	40.33 (7)	38.11 (6)	20.44 (5)	19.67 (1)	18.56(10)	14.33 (9)	13.11 (8)	12.44 (2)	11.89 (3)	7.67 (4)
Na^+ (Meq/100 g)	93.47 (9)	67.87 (3)	67.28 (8)	62.37 (5)	60.06 (4)	47.14 (2)	37.38(10)	29.77 (1)	12.53 (6)	9.23 (7)
Ca^{++} (Meq/100 g)	8.81 (1)	8.07 (9)	7.49(10)	5.14 (4)	4.42 (3)	4.23 (2)	3.86 (8)	3.83 (5)	1.09 (6)	0.47 (7)
Mg^{++} (Meq/100 g)	9.53 (9)	9.50(10)	8.82 (4)	6.84 (3)	6.83 (8)	5.59 (5)	5.09 (1)	3.67 (2)	1.77 (6)	1.26 (7)
Cl^- (Meq/100 g)	78.67 (9)	46.67(10)	40.89 (4)	39.44 (1)	36.33 (8)	36.22 (3)	31.44 (5)	25.67 (2)	11.44 (6)	7.78 (7)

higher in the latter stands and lower in the former ones. In stands 9 and 1 roots have a higher Ca^{++} but in stands 8 and 2, lower levels. Higher Mg^{++} level is recorded in root of stand 3 and lower ones in those of stand 1, 10 and 2. Again, roots of stands 1, 3, 8, 5 and 2 are characterized by higher Cl^{-} levels compared to those of other stands.

Correlations Between Shoot/Root, Root/Soil and Shoot/Soil

Results indicated significant correlations between shoot/root for organic matter and K^{+} in the three seasons and phosphorus in winter (Table 5). Significant correlations between root/soil are indicated for moisture in winter and spring, organic matter and K^{+} in spring and Ca^{++} in autumn and winter. Significant correlations between shoot/soil are shown also for K^{+} in the three seasons, Ca^{++} in autumn, moisture in winter and organic matter and Mg^{++} in spring.

DISCUSSION

Environmental variations generally occur in the form of gradients on different spatial and temporal scales. They may be caused directly or indirectly by variations in soil texture, organic matter content, nitrogen content or any other conditions that may influence plant responses. The behaviour of the biotic communities in the Red Sea coastal zone in general, or in some of its sectors has attracted the attention of several workers. YOUNES *et al.* (1983) studied the vegetation-soil relationships of a sea landward transect at Tuwal on the Red Sea coast of Saudi Arabia and indicated that zonation in plant cover is due to variations in soil characteristics and salinity. They revealed that *Halopeplis perfoliata* is capable of withstanding extreme saline conditions. MAHMOUD *et al.* (1982) studied the ecology of the littoral salt marsh vegetation at Rabigh on the Red Sea coast of Saudi Arabia and showed that *H. perfoliata* zone is followed successively landwards by *Aeluropus massauensis* and *Zygophyllum coccineum* zones, where several edaphic differences contribute to the pattern of distribution, structure and composition of vegetation. KASSAS (1957) studied the ecology of salt marshes of the Red Sea coastal land in Sudan and recognized several plant communities, where *H. perfoliata* community type occupies a zone inland from that of *Arthrocnemum glaucum*.

In the present study the application of both the classification and ordination techniques emphasizes this approach to vegetation study and has demonstrated clearly the vegetation pattern in the

Table 4. *Ordered means for* H. perfoliata *shoot and root variables that showed significant variations* ($P<0.005$) *among different stands according to the analysis of variance. The means with common underlines are not significantly different.*

Variables								
				Shoot				
Ca^{++} (Meq/100 g)	72.64(10)	55.81 (5)	52.18 (1)	51.76 (2)	51.27 (9)	49.27 (3)	39.17 (4)	29.77 (8)
Mg^{++} (Meq/100 g)	148.6 (10)	116.2 (5)	113.2 (2)	111.2 (1)	95.1 (4)	83.3 (10)	81.6 (9)	80.6 (8)
Fe (Meq/100 g)	5.12 (4)	4.68 (9)	4.26 (3)	3.50 (5)	3.21(10)	2.79 (2)	2.07 (1)	1.87 (8)
				Root				
Water Content %	34.03 (1)	31.31 (3)	31.02 (2)	28.44 (5)	27.78 (8)	26.80 (9)	26.12(10)	25.34 (4)
Dry matter %	74.66 (4)	73.88(10)	73.20 (9)	72.22 (8)	71.56 (5)	68.98 (2)	68.69 (3)	65.98 (1)
Ca^{++} (Meq/100 g)	24.54 (9)	20.54 (1)	12.41(10)	10.36 (5)	10.17 (3)	9.36 (4)	8.09 (8)	7.33 (2)
*Mg^{++} (Meq/100 g)	45.62 (3)	45.14 (8)	40.63 (9)	36.96 (4)	36.71 (5)	32.29 (1)	24.76(10)	24.29 (2)
Cl^{-} (Meq/100 g)	86.56 (1)	81.89 (3)	80.89 (8)	67.89 (5)	58.67 (2)	47.67 (9)	46.44 (4)	39.67(10)

*Significant at $P<0.01$

study area in quantitative terms, and in the classification of more phytosociological groupings of coastal salt marshes than could be identified by other methods. The compatibility of these two approaches was pointed out by several authors (ANDERSON, 1965; GOODALL, 1970; GRAY and BUNCE, 1971; AYYAD and EL-GHONEMY, 1976 and EL-GHONEMY *et al.*, 1977). Application of these two techniques led to the recognition of four distinct vegetational groupings. The importance value (IV) of *H. perfoliata* ranges from 126 to 263 in grouping A, from 165 to 300 in grouping B and from 33 to 250 in grouping D. The decrease of IV in the latter one is associated with an increase in that of *A. massauensis* and *Salsola longifolia*. Grouping C is characterized by the absence of *H. perfoliata*, while dominated by *Suaeda pruinosa* and *Limonium axillare*. The segregation of clusters along the two-dimensional space of the ordination plane implies that distributional pattern of vegetation in the study area is controlled not only by complex inter-related factors but also by the seasonal changes of these factors. These fall into two main groups. The first relates to Mg^{++} in winter and the second relates to total nitrogen in autumn and winter. Each of these two variables is significantly correlated with the phytosociological gradients. IV and relative density of *H. perfoliata* are negatively correlated with soil nitrogen in autumn and winter and positively correlated with Mg^{++} in winter. In this regard, CHAPMAN (1960) emphasized the important role of cations and anions or their combination in vegetation zonation and GARTEN (1976) reported that chemical composition of individuals of species may vary considerably from one site to another. Group C, not supporting *H. perfoliata* (stands 6 and 7) is found to represent the highest end of nitrogen gradient and the lowest end of Na^{++}, K^{+}, Ca^{++} Mg^{++} and Cl^{-} gradients throughout the year compared to stands 2 and 4 (Group D) with the lowest nitrogen and the highest Na^{+} and Cl^{-} gradients in winter. Shoot and root nitrogen, Na^{+}, K^{+} and Ca^{++} levels vary significantly between seasons and stands. Throughout the year, however, stands vary significantly with respect to variables of each of soil and *H. perfoliata* shoot and root.

Table 5. *Simple correlation coefficients (r) for some variables that showed significant between shoot and root of* H. perfoliata, *root and soil, and shoot and soil in each season.*

Season	Moisture	Organic matter	Phosphorus	K^+	Ca^{++}	Mg^{++}
			Shoot and Root			
Autumn		0.776*		0.583**		
Winter		0.608*	0.563**	0.475*		
Spring		0.602**		0.431*		
			Root and Soil			
Autumn					0.794**	
Winter	0.661**				0.483*	
Spring	0.457*	−0.448*		0.574**		
			Shoot and Soil			
Autumn				0.508*	0.507*	
Winter	0.472*			0.563**		
Spring		−0.434*		0.462*		−0.457*

*A single asterisk denotes a significant correlation at $P<0.05$ and a double asterisk, $P<0.01$.

In the present study there are a number of significant correlations between shoot and root regarding organic matter and K^{+} in all seasons and phosphorus in winter. EL-SHOURBAGY *et al.* (1984) studied halophytes of the Mediterranean salt marshes of north Egypt and reported that each of *Halocnemum strobilaceum* and *Arthrocnemum glaucum* exhibit tendency to achieve a balanced ionic composition and are able to develop succulence, while *Limoniastrum monopetalum* depends on an active excretion process for regulating salt concentration. Accordingly, osmotic adjustment in *H. perfoliata* occurs via increased ionic dilution and volume/surface area ratio through succulence. GREENWAY and MUNNS (1980) attributed the high K/Na in the phloem to selectivity of K^{+} over Na^{+} and YEO *et al.* (1977) found much lower permeability of the tonoplast to Na^{+} than to K^{+} in *Suaeda maritima*.

The high number of significant correlations of K^{+} that characterize the shoot-root-soil system of *H. perfoliata* may suggest an important role of K^{+} for the adjustment mechanism of this halophyte.

LITERATURE CITED

ALLEN, S. E.; GRIMSHAW, H. M.; PARKINSON, J. A. and QUARMBY, C., 1974. *Chemical Analysis of Ecological Materials.* Blackwell Scientific Publication, Oxford.

ANDERSON, D. J., 1965. Classification and ordination in vegetation science. Controversy over a nonexistent problem. *Journal Ecology,* 53, 521-526.

AYYAD, M. A. and EL-GHONEMY, A. A., 1976. Phytosociological and environmental gradients in a sector of the western desert of Egypt. *Vegetatio,* 31, 93-102.

BEALS, E., 1960. Forest bird communities in the Apostle Islands of Wisconsin. *Wilson Bulletin,* 72, 156-181.

BRAY, J.R. and CURTIS, J.T., 1957. An ordination of the upland forest communities of southern Wisconsin. *Ecological Monographs,* 27, 325-349.

CHAPMAN, V.J., 1974. *Salt Marshes and Salt Deserts of the World.* Cramer, Lehre, 2nd edition, 592 p.

CHAPMAN, V. J., 1974. *Salt Marshes and Salt Deserts of the World.* Cramer, Lehre, 2nd edition, 592 p.

DOMBOIS, D. M. and ELLENBERG, H., 1974. *Aims and Methods of Vegetation Ecology.* John Wiley & Sons, New York.

EL-GHONEMY, A. A.; SHALTOUT, K.; VALENTINE, W. and WALLACE, A., 1977. Distribution pattern of *Thymelaea hirsuta* (L) Endl. and associated species along the Mediterranean coast of Egypt. *Botanical Gazette,* 138, 479-489.

EL-SHOURBAGY, M. N.; AHMED, A. M.; OSMAN, M. E. and HAMADA, E. M., 1984. Adjustment of different halophytes to Mediterranean salt marshes of north Egypt. *Phyton* (Austria), 24, 101-112.

GARTEN, J. C. T., 1976. Correlation between concentrations of elements in plants. *Nature,* 261, 686-688.

GAVISH, E., 1974. Geochemistry and mineralogy of a recent *Sabkha* along the coast of Sinai, Gulf of Suez. *Sedimentology,* 21, 397-414.

GOODALL, D. W., 1970. Statistical plant ecology. *Annual Review Ecology & Systematics,* 1, 99-124.

GRAY, E. J. and BUNCE, G. H., 1974. The ecology of Morecambe Bay. VI. Soils and vegetation of salt marshes, A multi-variate approach. *Journal Applied Botany,* 9, 111-234.

GREENWAY, H. and MUNNS, R., 1980. Mechanisms of salt tolerance in nonhalophytes. *Annual Review Plant Physiology,* 31, 149-190.

JACKSON, W. A. and THOMAS, G. W., 1960. Effect of KCl and Dolomitic limestone on growth and ion uptake of sweet potato. *Soil Science,* 89, 347-352.

KASSAS, M., 1957. On the ecology of the Red Sea coastal land. *Journal Ecology,* 45, 187-203.

LE RUDULIER, D. and VALENTINE, R. C., 1982. Genetic engineering in agriculture: osmoregulation. *Trends Biochemical Science,* 7, 431-433.

LEVY, Y., 1977. The origin and evolution of brine in coastal *Sabkhas,* northern Sinai. *Journal Sedimentary Petrology,* 47, 451-462.

MAHMOUD, A.; EL-SHEIKH, A. M. and ISAWI, F., 1982. Ecology of the littoral salt marsh vegetation at Rabigh on the Red Sea coast of Saudi Arabia. *Journal Arid Environments,* 5, 35-42.

MIGAHID, A. M., 1978. *Flora of Saudi Arabia,* 2nd edition, Riyadh University Press.

MUDIE, PETA J., 1974. The potential economic uses of halophytes. In: Reimold, R.J. and Queen, W.H. (eds.), *Ecology of Halophytes,* Academic Press Inc., New York/London.

ODUM, E. P., 1974. Halophytes, energetics and ecosystems. In: Reimold, R.J. and Queen, W.H. (eds.), *Ecology of Halophytes,* Academic Press Inc., New York/London.

ODUM, E. P. and FANNING, M.E., 1973. Comparison of the productivity of *Spartina alterniflora* and *Spartina cynosuroides* in Georgia coastal marshes. *Bulletin Georgia Academy Science,* 31, 1-12.

PAECH, K. and TRACEY, M. V., 1956. *Modern Methods of Plant Analysis,* Volume I, Springer-Verlag, Berlin.

PRINCE, A. L., 1958. Methods in soil analysis. In: Bear, F.E. (ed.), *Chemistry of the Soil,* Reinhold Publishing Corporation, New York, 328-362.

SNEATH, DH. A. and SOKAL, R. R., 1973. *Numerical Taxonomy,* W. H. Freeman, San Francisco.

SPATZ, G.,1970. *Pflanzengesellschaften, Leistungen und Leistungspotential von Allgäuer Alpweiden in Abhängigkeit von Standort und Bewirtschaftung.* Dissertation (Dr. agr.) Technical University, Munich, Germany. 160 p., 20 looseleaf tables and a 1:5,000 map.

STEEL, R. G. D. and TORRIE, J. H., 1980. *Principles and Procedures of Statistics.* McGraw-Hill Book Company, Inc., New York/London.

U. S. SALINITY LABORATORY STAFF, 1954. *Diagnosis and improvements of saline and alkali soils.* U. S. Department Agriculture. Handbook 60.

WEISS, T. E.; WHITE, D. A. and THIEN, L. B., 1979. Seasonal dynamics of salt marsh plant associations in Louisiana. *Contributions Marine Science,* 22, 41-52.

YEO, A. R.; KRAMER, D.; LÄUCHLI, A. and GULLASCH, J., 1977. Ion distribution in salt-stressed mature *Zea mays* roots in relation to ultrastructure and retention of sodium. *Journal Experimental Botany,* 28, 17-29.

YOUNES, H. A., ZAHRAN, M. A. and EL-QURASHY, M. E., 1983. Vegetation-soil relationships of a sea landward transect, Red Sea coast, Saudi Arabia. *Journal Arid Environments,* 6, 349-356.

□ RESUMEN □

Los metodos de distribución de *Halopeplis perfoliata* (Forssk) Bunge ex Schweinf., uno de los halofitos dominantes de la vegetación litoral de las marismas saladas, ha sido estudiado con varias variables medioambientales. El área de estudio está localizada en una zona de transición entre las marismas saladas del mediterráneo y las costas tropicales. Se describen diez lugares (localizaciones), cada uno bien definido y representativo de entidades sociológicamente diferentes. La aplicación del análisis de grupo y de la técnica de ordenación bidimensional Wisconsin condujeron al reconocimiento de 4 grupos de localizaciones. El modelo de distribución de *H. perfoliata* parece estar controlado por cambios estacionales y variables medioambientales interrelacionadas tales como, humedad del suelo, pH, nitrógeno total y algunos iones minerales. --*Miguel A. Losada, Universidad de Santander, Santander, Spain*

□ ZUSAMMENFASSUNG □

Die Verteilungsmuster der *Halopeplis perfoliata* (Forssk) Bunge ex Schweinf., einer der vorherrschenden Salzsumpfenpflanzen unter den Littoralpflanzen, wurden bei viele Umweltsveränderlichen studiert. Das Forschungsgebiet ist eine Übergangszone zwischen dem Mittelmeer und tropischen Küstensalzsumpfen. Zehn Lagen wurden hier beschrieben. Jeder ist wohl umgrenzt und repräsentiert ein soziologisches Einzelwesen. Anwendung der Häufungsanalyse und der Wisconsin- zweidimensionalen-Ordnungsmethode führte zur Erkennung von 4 Gruppen der Lagen. Das Verteilungsmuster des *Halopeplis perfoliata* scheint von Jahreszeitenwandlungen in einem Komplex untereinander zusammenhängender Umweltsveränderlichen vorherrscht zu sein: Erdenfeuchtheit, pH, EC, und Mineralionen u.a. --*Stephen A. Murdock, CERF, Charlottesville, Virginia, USA*