Vegetation associates of the endangered *Randonia africana* Coss. and its soil characteristics in an arid desert ecosystem of western Egypt

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Randonia africana Coss. (Resedaceae) is a perennial endangered vascular plant species in Egypt. It inhabits the sandy plains along the Mersa Matruh-Siwa Oasis road crossing the Western Desert of Egypt, where it represents the easternmost limit of distribution in North Africa. The vegetation associates within each of the five known population sites of *R. africana* were studied, and their edaphic correlates were analysed. Eight soil variables were included: electric conductivity, pH, calcium carbonate, soil moisture, organic matter, sand, silt and clay. Classification and ordination techniques were employed to the importance values (IV) of the recorded 29 species in 25 stands. Application of TWINSPAN classified the floristic data into five vegetation groups: (A) *Randonia africana-Capparis spinosa* var. *aegyptia*, (B) *R. africana*, (C) *R. africana-Pulicaria undulata*, (D) *R. africana-Zilla spinosa* subsp. *biparmata* and (E) *R. africana-Zygophyllum coccineum*. These groups were separated along Detrended Correpondence Analysis (DCA) axes 1 and 2. Group E was the most diversified (10.0 ± 5.6 species stands-1) among the vegetation groups, while monotypic stands of *R. africana* (group B) were the least (5.1 ± 2.3). Stands of *R. africana* group (group B) were characterised by the highest levels of soil salinity and fine sediments, and the lowest levels of moisture content and sand. Detrended Canonical Correspondence Analysis (DCCA) indicated that the distribution of *R. africana* and its associates was mainly controlled by soil salinity, percentages of surface sediments of different size classes, calcareous deposits, and organic matter. The resulted gradients were related closely to the first three canonical axes, and accounted for 68.5% of the species-environment relationship among stands.

Keywords: *Randonia africana*, desert, vegetation, soil, conservation, Egypt

Introduction

Randonia africana Coss. (Resedaceae) is a spinescent perennial deciduous woody shrublet. It has a fairly continuous range of distribution in the African continent, extending from Senegal, Mauritania eastwards to North Africa, Ethiopia and Somalia. It is definitely Saharo-Arabian with some trends to Sudanian territories. In Egypt, the distribution of this

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species represents a restricted geographical range (FAHMY 1990). It inhabits the sandy plains along the Mersa Matruh-Siwa Oasis road crossing the Western Desert of Egypt (Fig. 1), and represents the easternmost limit in North Africa (QUÉZEL 1978).

The plant is currently endangered (EL HADIDI et al. 1992). Road construction, over--grazing by camels and intensive search for oil in this area resulted in the depletion of the small populations of this species, and significantly contributed to its gradual decline. Ecological disasters such as several successive seasons with lower than average precipitation, and over-exploitation of mature plants by desert dwellers and herbalists for use in folk medicine may also have in part led to its threatened status. Only five populations of *Randonia africana* were known in the southern part of Mersa Matruh-Siwa Oasis road (c. 300 km).

During the last few decades, the biology and ecology of threatened or rare taxa in danger of extinction have been intensively studied in different regions of the world (GRUBB 1976, SOULÉ and WILCOX 1980, GRIGGS and JAIN 1983). In Egypt, several studies on the demography and phytosociological behaviour of common desert and saltmarsh plants e.g.. BATANOUNY (1968) for *Deverra tortuosa*, AYYAD and HILMY (1974) for *Asphodelus microcarpus*; HEGAZY (1990) for *Cleome droserifolia*; EL-GHAREEB (1990) for *Zygophyllum album*; SHALTOUT et al. (2003) for Nitraria retusa, and their biology (e.g., HEGAZY et al. 1994 for *Heliotropium curassavicum*; SHALTOUT 2003 for *Nitraria retusa*) are known. However, few data on the ecology and conservation of threatened and rare species have been compiled (e.g., HEGAZY 1992, HEGAZY and ESSA 1991). The present study was undertaken to analyse the vegetation associates with *Randonia africana*, in relation to the prevailing soil gradients. It provides the baseline data on the vegetation structure of *Randonia africana*, and the communities in which the species occurs. It is hoped that our results may provide, also, insights useful to establish the most appropriate management and recovery measures for conserving these species.

Methods

The study area

The study area extends for a distance of about 30 km (between km 194 and km 222) along the Mersa Matruh-Siwa Oasis road crossing the Western Desert in the NE-SW direction (Fig. 1). It lies in the extreme desert vegetation zone (zone III, Fig. 1) that extens between latitude 30.5° N and 28° N (BORNKAMM and KEHL 1990). This zone bears vegetation characters of both full desert and hyperarid desert types (BORNKAMM and KEHL 1985). In general, the landscape of the study area is consistent with the Central Sahara (SCHIFFERS 1971). It is principally located in the inland part of the Middle Miocene plateau that extends from south Siwa Oasis towards the north and rises to about 100 m above the depression floor (which reaches 20 m below sea level). As compared with other parts of North Africa, the uniformity of the surface of the Western Desert is one of its physiographic characters. The interior plateau is flat; there is nothing but plains or rocks either bare or covered with sand and detrital material, abruptly broken by any conspicuous relief feature. The importance of the study area from both floristic and conservation point of views lies in the fact that it represents the limits of the distribution range of two other taxa; viz., *Capparis spinosa* L. subsp. *canescens* Coss. (Capparaceae) and *Zilla spinosa* (L.) Prantl subsp.
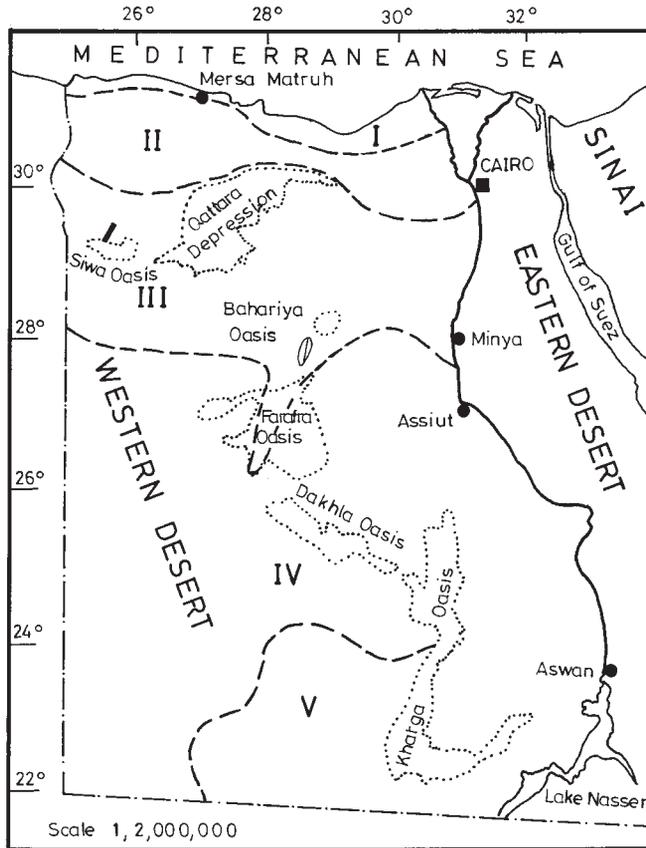
Fig. 1. Map showing the five vegetation zones of the Western Desert of Egypt (after BORNKAMM and KEHL 1990), indicating the position (shaded part) of the study area.

biparmata (O.E. SCHULZ) Maire et Weiller (Cruciferae). These two taxa were recorded in the 5 population sites of *Randonia africana*.

According to WALTER and BRECKLE (1984) the study area lies in the zone of subtropical arid deserts. Mild winters and very hot summers characterise the temperature regime. Whereas average January temperature remains rather constant, between 12°C and 14°C, the July mean rises to approximately 31°C. Precipitation is erratic, variable and unpredictable with frequent long dry periods, the mean annual total ranging from 9.6 mm year^{-1} in Siwa Oasis (the nearest station to the study area) and 144.0 mm year^{-1} in Mersa Matruh on the Mediterranean coast.

Vegetation sampling and analysis

The distribution of this species, as shown by EL HADIDI et al. (1992), represents a restricted geographical range in the Western Desert of Egypt. Between 1996 and 2001, numerous visits were made to each of the 5 population sites that supported *Randonia africana*

in varying degrees of abundance to compile a list of plant species associated with it. A reasonable distance (100–150m) away from the motor road was ensured in each site to eliminate any possible disturbance to the vegetation. A stratified random sampling method is employed (GREIG-SMITH 1983, LUDWIG and REYNOLD 1988) within each of the 5 studied sites. Taking into account the highly variable abundance of plants (in space and time) in this extreme arid desert environment, where the vegetation comprises only widely spaced shrubs and trees, the size of the studied sites varied depending on the growth of *Randonia*. At each site, five stands (20 × 20 m) were randomly positioned outwards from the centre of the site to the edge of the surrounding areas till *Randonia* vanished or another community type appeared. Ten sample plots (5 × 5 m) were randomly positioned within each stand, thus, 50 sample plots were established at each site, resulting in 250 plots in total for the study. A floristic-count list was taken from 250 sample plots. Voucher specimens of each species were collected, identified by us in the Herbarium of Cairo University (CAI) where they are preserved. The taxa have been assigned to five constancy classes (I–V), where species that occur in 0–20% of the stands are assigned to class I, 20.1–40% in class II, 40.1–60% in class III, 60.1–80% in class IV, and 80.1–100% in class V.

In each stand, density (individuals 100 m-2) and frequency (occurrences/100 sample plots) of the present species were calculated. Plant cover (m 100 m-1) was determined using the line-intercept method (CANFIELD 1941, MÜLLER-DOMBOIS and ELLENBERG 1974). For this purpose, five parallel lines distributed randomly across the stand, the intercept lengths (cm) were summed. Relative density, frequency and cover of each species were summed to give its importance value (IV) out of 300. Nomenclature follows TÄCKHOLM (1974), updated by BOULOS (1995, 1999–2002).

Soil sampling and analysis

Five soil samples (0–50 cm) were collected from each site. These samples were then pooled, forming one composite sample, air-dried, thoroughly mixed and passed through a 2 mm sieve to remove gravel and debris. Finer samples were analysed especially for texture and moisture. Soil texture was determined by the hydrometer analysis (BOUYOUCOS 1962), and the results were used to calculate the percentages of sand, silt and clay. Drying and then ignition at 600°C for 3 hours estimated organic matter content and soil moisture. The $CaCO_3$ content was determined using 1N HCl (JACKSON 1967). Soil-water extracts (1:5) were prepared for the determination of electrical conductivity (EC) using electric conductivity meter and soil reaction (pH) using a pH-meter.

Data analysis

Polythetic divisive classification was conducted with Two-Way Indicator Species Analysis (TWINSPAN) on a data matrix comprising 25 stands X 29 species using their importance values. All the default settings were used for TWINSPAN of the computer program PC-ORD for Windows version 4.14 (McCUNE and MEFFORD 1999). An ordered two-way table, which expresses succinctly the relationships of the stands and species within the data set, is constructed. Indicator species refer to the preferential species used by TWINSPAN to distinguish the sample groups. The stands are ordered first by divisive hierarchical clustering, and then the species are clustered based on the classification of stands

(GAUCH and WHITTAKER 1981). The TWINSPAN groups were subjected to ANOVA based on soil variables to find out whether there are significant variations among groups. Species richness (alpha-diversity) within each separated TWINSPAN vegetation group was calculated as the average number of species per stand. Sørensen's index of similarity (MÜLLER--DOMBOIS and ELLENBERG 1974) was used to calculate community coefficients (floristic similarity) among the TWINSPAN groups.

The computer program CANOCO 3.12 (TER BRAAK 1987–1992) was used for all ordinations. Preliminary analyses were made by applying detrended correspondence analysis (DCA, HILL and GAUCH 1980) to check the magnitude of change in species composition along the first ordination axis (i.e., gradient length in standard deviation (SD) units). DCA (indirect gradient analysis) estimated the gradient to be larger than 4 SD-units for all subset analyses. A form of direct gradient analysis, detrended canonical correspondence analysis (DCCA), was used to examine the relationships of the floristic composition in the studied stands to the measured environmental variables (TER BRAAK and PRENTICE 1988). DCCA has some advantages over other ordinations in that it makes the interpretation of the axes easier (TER BRAAK 1986). DCA and DCCA were used together to see how much of the variation in species data is accounted for by the environmental data. All data variables were assessed for normality prior to the DCCA analysis, and appropriate transformations were performed when necessary to improve normality according to ZAR (1984). Due to the high inflation factor of % sand, it was removed from the analysis. Thus, seven soil variables were included: electrical conductivity (EC, mS cm^{-1}), pH, %$CaCO_3$, % soil moisture content (MC), %organic matter (OM), and % silt and % clay. Monte Carlo permutation tests (99 permutations) were performed to test the significance of the first canonical axis. All the default settings were used for DCCA. The variables in the DCCA biplots were represented by arrows pointing in the direction of maximum variation, with their length proportional to the rate of change (TER BRAAK 1986). Each arrow determines an axis on which the species points can be projected. In general, these projection points estimate the optima of species distribution for each environmental variable. Intra-set correlations were used to assess the importance of the environmental variables, since the canonical coefficients are unstable. All the statistical techniques were made using SPSS version 10.0 for windows.

Results

Species composition of population sites

Twenty-nine taxa from one gymnosperm and 14 from angiosperm family were recorded in this study. They consisted of 17 perennials and 12 annuals. The largest families were Cruciferae (17.2%), Caryophyllaceae (13.8%), Compositae and Chenopodiaceae (20.7%), Leguminosae, Resedaceae and Zygophyllaceae (20.7%), while the other 7 families shared 24.1%. Surprisingly, Gramineae was not represented. *Capparis spinosa* var. *aegyptia*, *Pulicaria undulata, Zilla spinosa* subsp. *biparmata* and *Zygophyllum coccineum* were the most associated perennials. Less common perennials were *Deverra tortuosa, Helianthemum lippii, Fagonia arabica* var. *arabica*, *Anabasis articulata, Alhagi graecorum* and *Tamarix nilotica*. Common annuals included *Trigonella stellata, Cotula cinerea, Eremobium aegyptiacum* and *Opophytum forsskaolii*. There is a core of rather few vascular

plant species that are frequently associated with *R. africana*, but there is a wide range of other species that occur more rarely (Tab. 1).

Classification of vegetation data

Based on the importance values of 29 species recorded in the 25 studied stands of *Randonia africana*, TWINSPAN technique helped to distinguish five vegetation groups (A–E) at the third level of hierarchical classification. A dendrogram is depicted in Fig. 2, along with the indicator species characterising the stand groups.

Fig. 2. TWINSPAN classification of the 25 stands of *Randonia africana*. A–E are the five vegetation groups. For indicator species abbreviations, see Table 1.

The five vegetation groups were named after their characteristic species as follows: (A) *Randonia africana-Capparis spinosa* var. *aegyptia*, (B) *R. africana*, (C) *R. africana--Pulicaria undulata*, (D) *R. africana-Zilla spinosa* subsp. *biparmata* and (E) *R. africana-Zygophyllum coccineum*. The stands of group A have the lowest amount of importance value (91), while those of groups B and E were the highest (IV=138 and 137, respectively). Some taxa exhibited a certain degree of fidelity, e.g., *Deverra tortuosa* in group A *and Schouwia thebaica* in group E. Although not co-dominants and with low IV estimates, certain species have higher constancy levels in their groups, e.g., *Anabasis articulata* (group B), *Fagonia arabica* var. *arabica* and *Tamarix nilotica* (group C), and *Zilla spinosa* subsp. *biparmata* (group E). Although the *Randonia africana-Zygophyllum*

Tab. 1. Species composition of the five population sites of *R. africana*, arranged in order of occurrence in the five TWINSPAN groups. The five constancy classes (I–V) and their mean importance value (IV) rounded to the nearest integer are given in each group. Entries in **bold** are indicator and preferential species in each group.

TWINSPAN group	Species Abb.	A	B	C	D	E
Group size		5	7	6	4	3
Total number of species		15	19	20	12	15
Mean species richness		6.0 ± 1.4	5.1 ± 2.3	7.2 ± 2.6	5.2 ± 0.5	10.0 ± 5.6
Total number of annuals		5	9	9	5	5
% of annuals/total species		35.7	47.4	45.0	41.7	33.3
Randonia africana Coss.	Ra	**91.V**	**138.V**	**103.V**	**101.V**	**137.V**
Capparis spinosa L. var. *aegyptia* (Lam.) Boiss.	Cs	**53.IV**	3.I	3.I	–	–
Deverra tortuosa (Desf.) DC.	Dt	30.III	–	–	–	–
Trigonella stellata Forssk.	Ts	5.III	1.1	–	3.II	10.II
Helianthemum lippii (L.) Dum. Cours.	Hl	5.III	2.I	–	–	3.II
Cotula cinerea Delile	Cc	4.II	4.I	3.I	9.III	–
Eremobium aegyptiacum (Spreng.) Asch. et Schweinf.ex Boiss.	Ea	5.II	3.I	6.II	–	11.II
Atriplex leucoclada Boiss. Var. *inamoena* (Aellen)Zohary	Al	5.II	3.I	1.1	–	–
Monsonia nivea (Decne.) Webb	Mn	7.II	5.II	–	–	5.I
Fagonia arabica L.var. *arabica*	Fa	–	6.III	6.IV	–	–
Reseda pruinosa Delile	Rp	2.I	6.III	1.I	–	–
Erucaria hispanica (L.) Druce	Eh	–	6.III	5.II	–	2.II
Anabasis articulata (Forssk.) Moq.	Aa	1.1	**15.IV**	–	–	8.II
Pulicaria undualata (L.) C.A. Moq. subsp. *undulata*	Pu	2.I	–	**65.IV**	6.II	–
Tamarix nilotica (Ehrenb.) Bunge	Tn	2.1	–	15.IV	–	13.II
Paronychia arabica (L.) DC. subsp. *arabica*	Pa	–	1.1	5.III	–	–
Farsetia aegyptia Turra	Fg	–	–	3.II	–	13.II
Opophytum forsskaolii Boiss.	Of	–	–	3.II	1.II	–

Tab. 1. – continued.

TWINSPAN group	Species Abb.	A	B	C	D	E
Heliotropium digynum (Forssk.) C. Chr.	Hd	1.I	–	6.II	5.II	–
Polycarpon tetraphyllum (L.) L.	Pt	–	5.II	4.II	–	–
Alhagi graecorum Boiss.	Ag	–	2.II	2.I	2.II	8.II
Zilla spinosa (L.) Prantl subsp. *biparmata* (O.E.Schulz) Maire et Weiller	Zs	–	–	–	**55.V**	11.IV
Carduncellus mareoticus (Delile) Hanelt	Cm	–	3.II	2.I	5.II	–
Bassia indica (Wight) A.J. Scott	Bi	–	2.II	2.I	2.II	–
Zygophyllum coccineum L.	Zc	–	2.II	–	11.III	**67.V**
Pteranthus dichotomus Forssk.	Pd	–	–	–	4.III	3.I
Ephedra alata Decne.	El	1.I	–	1.I	–	–
Schouwia thebaica Webb	St	–	–	–	–	4.II
Rumex vesicarius L.	Rv	–	2.I	3.III	–	–

Tab. 2. The range and mean ± standard deviation (S.D.) of the soil variables for the five vegetation groups associated with *R. africana* in the study area. EC= electric conductivity, CaCO$_3$ = calcium carbonate, MC = moisture content and OM= organic matter. **$p<0.01$.

Soil variable	Mean ± S.D.	Range	TWINSPAN groups					F-ratio	P
			A	B	C	D	E		
EC (mS cm^{-1})	0.61 ± 0.48	2.31	0.59 ± 0.2	0.93 ± 0.7	0.45 ± 0.5	0.40 ± 0.2	0.5 ± 0.6	1.22	0.33
pH	7.8 ± 0.4	1.5	7.8 ± 0.5	7.9 ± 0.5	7.7 ± 0.5	7.7 ± 0.3	8.2 ± 0.5	0.63	6.4
% CaCO$_3$	13.9 ± 5.8	21.5	18.8 ± 4.8	15.4 ± 6.2	10.7 ± 4.5	9.0 ± 3.1	16.0 ± 4.9	2.94	0.05**
% MC	2.7 ± 0.8	3.00	2.9 ± 0.9	2.5 ± 0.9	2.5 ± 0.6	2.8 ± 0.9	3.5 ± 0.2	0.9	0.5
% OM	0.13 ± 0.007	0.27	0.1 ± 0.005	0.09 ± 0.005	0.2 ± 0.009	0.2 ± 0.006	0.05 ± 0.002	3.1	0.04**
% Sand	91.6 ± 0.9	4.9	90.9 ± 0.9	91.0 ± 1.3	92.0 ± 0.8	91.08 ± 0.6	91.6 ± 0.2	0.74	0.6
% Silt	3.0 ± 0.7	2.90	2.9 ± 0.3	3.2 ± 0.9	3.1 ± 0.9	2.9 ± 0.6	2.5 ± 0.7	0.32	0.9
% Clay	5.4 ± 0.6	3.00	5.2 ± 0.7	5.7 ± 0.6	5.0 ± 0.7	5.3 ± 0.3	5.7 ± 0.5	1.2	0.33

coccineum group (group E) was the most diversified (10.0 ± 5.6 species stand^{-1}) of the vegetation groups, it had the lowest share of annuals (33.3% of the total, Tab. 1).

Soil characteristics of each of the five vegetation groups of *R. africana* are summarised in table 2. Most of the soil variables were slightly under or around the total mean. Of the measured soil factors, calcium carbonate and organic matter contents showed highly significant differences among groups. It can also be noted that $CaCO_3$ attained its highest levels in group A, organic matter in groups C and D, and moisture content in group E. The soil of the stands of *R. africana* (group B) were characterised by the highest levels of salinity and fine sediments, and the lowest levels of sand and moisture content.

Stand ordination

DCA analysis of the floristic data set presents 25 site scores plotted along axes 1 and 2, and tend to cluster it into the five groups that were obtained from TWINSPAN analysis (Fig. 3). The sites were spread out 4.6 SD units along the first axis (eigenvalue = 0.72), indicating a complete turnover in species composition had taken place (JONGMAN et al. 1987). The four DCA axes explained 21.6%, 8.0%, 3.9% and 2.2% of the total variation in species data, respectively. This low percentage of variance explained by the axes is attributed to the many zero values in the vegetation data set. The eigenvalue for the first DCA axis was high
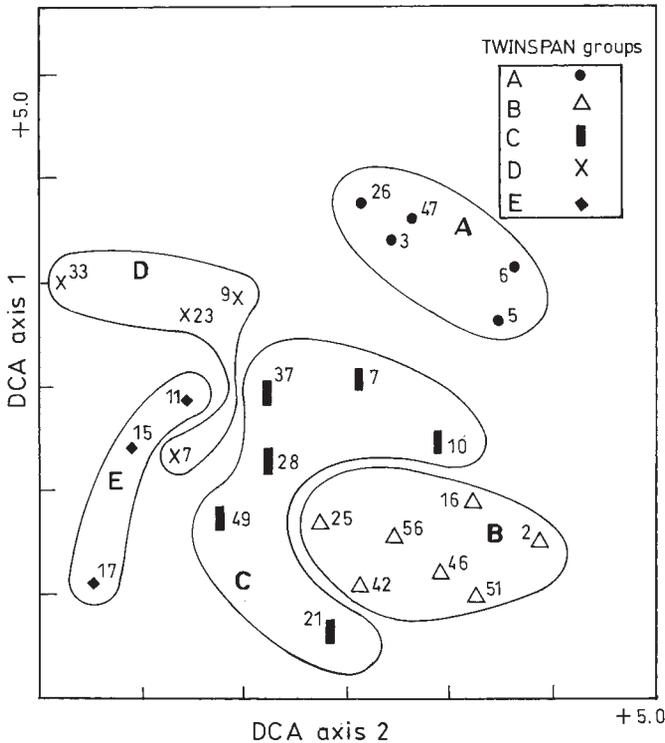
Fig. 3. DCA ordination of the 25 stands of *Randonia africana* on DCA axes 1 and 2 as classified by TWINSPAN.

Tab. 3. Comparison of the results of ordination for the first three axes of DCA and DCCA. Intra-set correlation of the soil variables, together with eigenvalues and species-environment correlation coefficients. For soil variable abbreviations and units, see Table 2. ** = $p < 0.01$.

Soil variables	DCA axis			DCCA axis		
	1	2	3	1	2	3
Eigenvalues	0.72	0.27	0.13	0.40	0.21	0.11
Species–environment correlation coefficients	0.47	0.64	0.61	0.91	0.71	0.68
EC	0.15[*]	–0.35[*]	–0.034	0.29[*]	–0.08	0.06
pH	–0.20[*]	–0.26	0.16	0.24	–0.24	0.45[*]
$CaCO_3$	0.11	0.29[*]	0.22	–0.32[*]	0.03	0.50[*]
MC	–0.16[*]	0.16	0.07	–0.17	0.11	0.20
OM	0.002	0.45[*]	0.05	0.30	0.62*	0.07
Silt	0.08	–0.13	–0.26	0.48[*]	0.25	–0.21
Clay	0.20[*]	–0.39[*]	–0.18	0.25	–0.48[*]	0.46[*]

indicating that it had captured the greater proportion of the variation in species composition among stands, but the species-environment correlation coefficients were low for the DCA axes (Tab. 3).

To compare classification and ordination results, the TWINSPAN groups were superimposed onto the DCA diagram (Fig. 3), which displayed graphically stands that were transitional in their composition within the groups differentiated by classification. Stands of groups A and B were separated toward the positive end of DCA axis 1, groups D and E were separated out along the other end, and those of group C were transitional in their composition between the other groups. DCA axis 2 (eigenvalue = 0.27) and a gradient length of 2.6 SD was less important. DCA axis 1 showed significant positive correlations with salinity, $CaCO_3$ and clay, and negative correlations with pH and moisture content. This axis can be interpreted as calcium carbonate-clay gradient. DCA axis 2 was positively correlated with organic matter, and negatively with salinity, pH and clay. This axis can be interpreted as the clay-organic matter gradient.

Soil-vegetation relationships

The successive decrease of the eigenvalues of the first three DCCA axes (Tab. 3) suggest a well-structured data set. These eigenvalues were lower than for the DCA axes, indicating that important explanatory site variables were not measured and included in the analysis or some of the variation was not explained by environmental variables (FRANKLIN and MERLIN 1992, MCDONALD et al. 1996). However, the species-environment correlations were higher for the first three canonical axes, explaining 68.5% of the cumulative variance. From the intra-set correlations of the soil factors with the first three axes of DCCA shown in Table 3, it can be noted that DCCA axis 1 was positively correlated with soil salinity (EC) and silt, and negatively with $CaCO_3$. We interpret DCCA axis 1 as the electric conductivity-calcium carbonate gradient. This fact becomes clearer in the ordination biplot (Fig. 4).
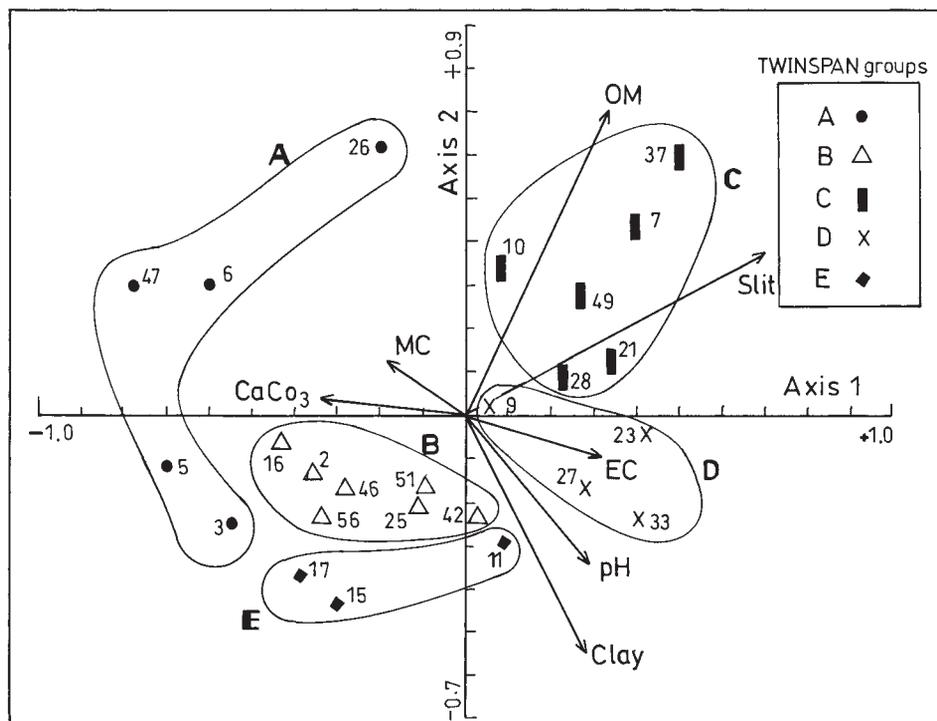
Fig. 4. DCCA ordination biplot of the first two axes showing the distribution of *Randonia africana* stands, with their TWINSPAN groups and soil variables.

A test for significance with an unrestricted Monte Carlo permutation test (99 permutations) found the F-ratio for the eigenvalue of axis 1 and the trace statistics to be significant ($p < 0.001$), indicating that observed patterns did not arise by chance. It is worthwhile noting that the results of DCA demonstrated patterns very similar to those of DCCA, suggesting that there might be no other important environmental variables missed in sampling. DCCA axis 2 is clearly positively related to organic matter, and negatively to clay. We interpret DCCA axis 2 as organic matter-clay gradient. DCCA in figure 4 shows the pattern of ordination similar to that of the floristic DCA (Fig. 3), with most of the sites remaining in their respective TWINSPAN groups. As a result of the significant differences between groups in relation to certain soil factors, their species and space have been arranged along axes 1 and 2 of the DCCA scatter diagram.

Discussion

Despite its very limited range of distribution in Egypt (30 km along the Mersa Matruh-Siwa Oasis road, *Randonia africana* is a rather tolerant species that is not connected to any particular plant community. Environmental variation often produces modifications in the pattern of vegetation (ARONSON and SHMIDA 1992). In arid and semi-arid ecosystems, one of the main components of environmental change is water availability, which

is controlled by infrequent and largely unpredictable precipitation outputs (NOY-MEIR 1973, FISHER and TURNER 1978). Along gradients of decreasing precipitation, vegetation varies from grasslands to shrublands (WESTOBY 1980). As presented in the results, the dominance of shrubby plant species over the grasses was evident. They constitute about 59% of the floristic composition, and therophytes the remaining 41%. On the contrary, the floristic composition of some wadis of Mersa Matruh (EL HADIDI et al. 1986, KAMAL and EL-KADY 1993, EL GARF 2003) on the western Mediterranean coast (Fig. 1), revealed more annuals that reached 92% on the average of their flora, of which 13% were grasses. A comparable study of the life-form spectrum of the same 5° of the northern latitudes in the corresponding Eastern Desert of Egypt (25°N–30°N), therophytes constitute 38.3%, while hemicryptophytes and chamaephytes constitute 51% (ABD EL-GHANI 1998).

Spatial distribution of plant species and communities over a small geographic area in desert ecosystems is related to heterogeneous topography and landform pattern (PARKER 1991). The heterogeneity of local topography, edaphic factors, microhabitat conditions lead to variation of the distributional behaviour of *R. africana* and its associates. In terms of classification, the vegetation that characterises *R. africana* can be divided into five vegetation groups: (A) *Randonia africana-Capparis spinosa* var. *aegyptia*, (B) *R. africana*, (C) *R. africana-Pulicaria undulata*, (D) *R. africana-Zilla spinosa* subsp. *biparmata* and (E) *R. africana-Zygophyllum coccineum*. In their detailed study on the plant communities of the Western Desert of Egypt, BORNKAMM and KEHL (1990) described *Capparis aegyptia--Randonia africana* association to cover the southern part of the Marmarica plateau. Certainly, the identified vegetation groups belong to this association. Some of the recognised groups may be related to the *Thymelaeetum hirsutae* and *Anabasidetum articulatae* associations (TADROS and ATTA 1958). Other groups could be related to the alliance *Salicornion tetrandrae* (ZOHARY 1973*). Pituranthetalia tortuosi*, however, is a new order suggested by BORNKAMM and KEHL (1990) to include all the plant communities of the Western Desert. Although they recorded *Anastatica hierochuntica, Salsola baryosma* subsp. *gaetula*, *Stipagrostis plumosa, Salsola tetrandra* and *Astragalus trigonus* in their association, we recorded none of these species. It is interesting to note that *Anabasis articulata, Cotula cinerea, Opophytum forsskaolii* and *Helianthemum lippii* were only included in this study. The invasion of the area by such species to during the last two decades may be attributed to the new land use system in the region (e.g., tourist resorts, construction of highways, water pipelines, land reclamation projects, medicinal and ornamental plantations).

The habitat investigated in this study is a relatively simple one, in which the species capable of surviving have to withstand harsh environmental conditions. The vegetation cover of the landscape of the study area was less than 5% on the average (STAHR et al. 1985). A part of the limestone formations (white desert) of the Western Desert of Egypt, the study area showed the presence of *Zygophyllum coccineum, Capparis spinosa* subsp. *aegyptia* and *Anabasis articulata* (calcicolous species) common to limestone desert landforms (KASSAS and GIRGIS 1970). Except for the latter, those species were also recorded in wadis of the Eastern Desert (SPRINGUEL et al. 1991, ABD EL-GHANI 1998). A group of salt-tolerant plants including *Tamarix nilotica*, *Alhagi graecorum* and *Bassia indica* were found in the relatively saline stands, and form phytogenic mounds of variable size. *Alhagi graecorum* is a widely distributed species that seems to grow in different habitats (KASSAS 1952). It is also considered a groundwater-indicating plant (GIRGIS 1972). The xero-psammophytes

Fagonia arabica var. *arabica*, *Farsetia aegyptia, Pulicaria undulata* and *Heliotropium digynum* were found in dry non-saline stands where infiltration is higher and water accumulated in deeper layers. This group of species is of common occurrence in Egypt (ZAHRAN and WILLIS 1992), in neighbouring countries of North Africa (FRANKENBERG and KLAUS 1980, WOJTERSKI 1985) and in the Middle East (YAIR et al. 1980) as well.

The community coefficients show that there is a considerable amount of variation in floristic similarities among the five groups that resulted from the TWINSPAN technique (Tab. 4). A similarity of less than 50% was obtained in most of the comparisons. Such low similarities among the groups were due to (1) differences in size of the sites, and (2) the fact that sites (necessarily) were selected based on the presence of *R. africana* which occurs in several stages of succession within its narrow geographic range. It appears, thus, that *R. africana* is not part of a coherent group of species that always occurs together. The 25 studied stands, in which *R. africana* occurs, belong to five vegetation groups (communities). The percentages of species in the five constancy classes were rather typical for plant communities (CAIN and CASTRO 1959). That is, some species have a high degree of presence, some have an intermediate degree, and a relatively high percentage belong to classes II and I.

The ordination technique was applied using detrended correspondence analysis (DCA) for all stands, and detrended canonical correspondence analysis (DCCA) to assess the relationship between the different species and their soil characteristics. The DCCA of all stands and abiotic variables produced a different ordination (Fig. 4) from that produced by DCA. The limited number of abiotic environmental factors used, with the species data left with c. 30% unexplained variation, and possibly related to disturbance or competition. This conclusion is in accordance with JEAN and BOUCHARD (1993) who found that only half of the species variation could be related to abiotic variables. In this study there is no evidence of recent disturbance in the stands of *R. africana*, suggesting that the development of plant communities have been mainly influenced by edaphic conditions for a long time. Analysis of the relationship between variations in vegetation composition of the 25 stands supporting *R. africana* and those edaphic factors indicated that species distribution was mainly controlled by soil salinity, percentages of surface sediments of different size classes, calcareous deposits, and organic matter. The percentage of surface sediments of different size classes plays a paramount role in determining the spatial distribution of soil moisture (YAIR et al. 1980, EL-GHAREEB and SHABANA 1990). The role of organic matter as a key element in soil fertility is well known. Many studies provided evidence of the importance of soil organic matter in delimiting vegetation groups not only in the Eastern (SHARAF EL DIN and SHALTOUT 1985, ABD EL-GHANI 1998) and the Western Desert (ABD EL-GHANI 2000) of

Tab. 4. Community coefficients among the five TWINSPAN vegetation groups of *Randonia africana*.

Vegetation group	A	B	C	D
A				
B	36			
C	42	53		
D	49	40	51	
E	43	48	33	71

Egypt, but also in the Sinai Peninsula (MOUSTAFA and ZAGHLOUL 1996, ABD EL-GHANI and AMER 2003).

Currently, considerations of the exploitation and conservation of wild plant resources must be take ecological principles into account. The last two decades have witnessed a substantial change in the land use system in and around the oases of the Western Desert of Egypt. Moreover, in the southeastern part of this Desert, Egypt's giantToschka Project is in operation. With the completion of this project (between the years 2005–2010), the water of the Nile will be transferred from the Toschka depression (south-west of Aswan) through a long canal crossing the oases. The spread of resort villages and other tourist facilities and the clearing of natural vegetation for agricultural development projects that are now in action are changing the habitat rapidly. This has taken place with complete indifference to the fate of rare or endemic species. The intensive trampling of vegetation by people inhabiting or visiting the developed areas causes destructive changes to plant life. It is necessary to involve conservationists and ecologists in the planting of these development scheme areas to ensure the conservation and regular monitoring of the flora and vegetation of *R. africana* habitats.

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