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PHYTOSOCIOLOGY OF THE SABKHA OF ZUARA

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Four plant communites were recognised in the Sabkha of Zuara. Sodium was the predominant cation in all sites yet on comparative basis following correlations are apparent: *Limoniastrum – Salicornia* Community, high SAR and ESP; *Salicornia-Arthrocnemum* Community, high sodium, nitrates and high water table; *Arthrocnemum-Limoniastrum* Community, high Calcium, SAR and ESP; *Limoniastrum-Salicornia-Zygophyllum* Community, high potassium, total salinity and chlorinity. *Arthrocnemum glaucum* and *Salicornia fruticosa* were found to be reproducing well therefore they are likely to predominate the "Sabkha" of Zuara in future.

Introduction

Zuara is located in the northwestern part of Libya near the coastal line along the Mediterranean sea. The climate of Zuara is considered to be warm arid Mediterranean maritime type (Hajaji, 1965). The maritime influence is the predominant factor reducing the extreme heat in summer and mitigating to some extent the winter minima. The hottest month is August and the coldest January. The relative humidity is rather high especially during summer. A high relative humidity of 90% might change in the course of few minutes to less than 5% under the effect of "Ghibli" wind which blows most frequently in the begining of spring and late autumn. The rainy season is between October and March. The mean annual rainfall is 244 mm.

Physiographically the area around Zuara is a saline flat and covered with halophytic species. Locally, such saline flats are called "Sabkhah". According to Walter (1971) the "Sabkhah" are undrained flat salt pans which are sometimes flooded after rains and frequently contain pure salt on soil surface in summer.

Little work has been done on the ecology of Zuara region. Walter (1971) on the basis of work of Migahed *et al* (1955) and Ayyad (1957) at Ras el Hakma and Cairo respectively observed that *Arthrocnemum glaucum, Zygophyllum album, Aeluropus lagopus,* were associated on soils with ground water at 80-200 cm depth, pH 8.3-8.7, calcium content 20-30%, humus 0.25%, soluble salts 2-5% and chlorides 0.5%. Nutonson (1961) reported two communities from Zuara that were used for extensive grazing by camels and goats. Zohary (1962) studied halophytic communities in Israel and classified them into two main classes. Waisel (1972) also classified halophytic communities

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of Israel. He also dealt with the physiological ecology of a number of halophytic species common to Libya. Rotty (1968) surveyed the grazing potential of the North Africa. Le Floch (1975) also indicated the grazing potential of halophytic communities.

Materials and Methods

Four sites around Zuara were selected for quantitative study. These sites supported vegetation which occupied considerable area and showed no signs of disturbance. The sampling of communities was carried out by the random pairs method (Cottam & Curtis 1949 & 1956), the sampling was done at 300 different points in each community. Bray & Curtis (1957) index of similarity was used to compute inter-community similarly. Cover per hectare values of species were used in the calculation of similarity. These values are more suitable for indicating differences in community structure than the relative values. The use of importance value is also questionable as it is itself an index. To use this index to obtain another index (index of similarity) is not a sound proposition. Moreover, the cover per hectare values represent an integration of both cover and density. Plant communities were recognized on the basis of Bray & Curtis' (1957) index of similarity and Lindsey's (1955) importance value.

Community maturity was found out for each community by Pichi-Sermolli's (1948) index. Cain's (1932) density-size class table was modified to suit the shrubby communities of Zuara for studying the regeneration of vegetation. The following size classes were used:-

Size class I	< 100 cm	circumference
Size class II	101 – 200 cm	"
Size class III	201 – 300 cm	"
Size class IV	301 – 400 cm	"
Size class V	401 – 500 cm	"
Size class VI	> 500 cm	"

The soil samples were collected using soil auger in each community, from surface (0-15 cm depth) and sub-surface (15-30 cm depth). No soil profile development was observed in any of the soil studied. The bed rocks, mainly carbonates, were reached around 34 cm depth. The soil samples were analysed according to the methods outlined in U.S.D.A. handbook No. 60(1954).

Results

The phytosociological analysis of the four sites indicated the presence of four plant communities (Table 1) which are as follows,

Table 1. Phytosciological attributes.

Name of species	D_2	D_3	C_2	C_3	F	F_3	Y_3
Stand I.							
Limoniastrum monopetalum	6843.65	33.33	9155.72	77.33	50.00	37.5	49.40
Salicornia fruticosa	1334.47	65.00	2084.97	17.61	80.00	60.0	47.54
Zygophyllum album	340.83	1.66	600.26	5.07	3.33	2.5	3.08
	D9=8518.95		C9=11840.95		C.M.I.= 44.44%		
Stand II.							
Salicornia fruticosa	15410.47	55.00	13060.37	41.25	73.33	50.00	48.82
Arthrocnemum glaucum	10271.76	36.66	7354.96	23.23	56.66	38.64	32.9
Limoniastrum monopetalum	1400.93	5.00	6070.00	22.33	10.00	6.81	11.14
Salsola sp.	924.62	3.33	4191.98	13.24	6.66	4.55	7.60
	D9= 28007.78		C9=30677.31		C.M.I. =36.66%		
Stand III.							
Arthrocnemum glaucum	40372.97	56.66	5776.68	11.26	73.33	50.00	39.30
Limoniastrum monopetalum	23748.87	33.33	16622.06	32.40	20.00	13.64	26.45
Salicornia fruticosa	18996.25	26.66	3252.59	6.34	46.66	31.81	21.60
Salsola sp.	3562.67	5.00	14929.07	29.09	6.66	4.45	12.84
	D9= 86680.76		C9=40580.40		C.M.I.=36.66%		
Stand IV.							
Limoniastrum monopetalum	803.47	26.66	4495.10	59.90	40.00	29.30	38.62
Salicornia fruticosa	1556.92	51.66	806.70	10.75	63.50	46.33	36.24
Zygophyllum album	552.41	18.33	2123.70	28.30	26.60	19.50	22.04
Salsola sp.	100.35	3.33	75.80	1.03	6.66	4.90	3.08
	D9= 3013.15		C9= 7501.30		C.M.I.= 34.2%		
Interstand similarity.*							
Stand I and II		38.35		Stands II and III			54.14
Stands I and III		42.88		Stands II and IV			28.17
Stands I and IV		61.02		Stands III and IV			22.36

* Bray & Curtis' (1957) index computed using cover per hectare values of species.

D_2= Density per hectare, D_3= Relative density, D_9= Stand density per hectare, C_2= Cover per hectare, C_3= Relative cover, C_9= Stand Cover per hectare, F= Frequency, F_3= Relative frequency, Y_3= Importance value= $(D_3 + C_3 + F_3)/3$, C.M.I.= Community maturity index.

I. *Limoniastrum- Salicornia* Community
II. *Salicornia- Arthrocnemum* Community
III. *Arthrocnemum- Limoniastrum* Community
IV. *Limoniastrum- Salicornia- Zygophyllum* Community

The communities I and IV appear to be floristically similar but they differ from one another in overall community structure, both the stand cover and density per hectare values differ widely (Table 1). *Limoniastrum monopetalum* and *Salicornia fruticosa* have a combined importance value of 97% in community I, while these two species along with *Zygophyllum album* constitute 97% combined importance value in community II. Moreover, the real difference between these communities is better revealed by the inter community similarity than the mere floristic composition (Table 1). The similarity (61%) is not high enough to merge them together. The dominant species in other communities were *Salicornia fruticosa* and *Arthrocnemum glaucum* (Community II) and *Arthrocnemum glaucum* and *Limoniastrum monopetalum* (Community III).

The dominant species of all the communities were succulent halophytic shrubs. Community III has the highest stand cover and density values, followed by community II, community I and community IV, the latter being the lowest.

The inter community similarities did not indicate high values. The communities I and IV showed 61% similarity and communities II and III indicated 54% similarity. The index of similarity between other pairs was less than 50% (Table 1). If the data of more halophytic communities of Libya are available, then the communities I and IV may be merged together in a heirarchy above the level of a plant association.

The communities of Zuara were similar in having low community maturity. The index ranged between 34% and 44% (Table 1).

Future Trends In The Communities:

According to Cain's (1932) density-size class table the following future trends are apparent in the study area:-

The present dominants of community I are reproducing well so it is expected that the present dominants (*Limoniastrum monopetalum* and *Salicornia fruticosa*) will continue to hold the ground in the future (Table 2).

The situation is same in community II where *Salicornia fruticosa* and *Arthrocnemum glaucum* will maintain their dominance in future too (Table 2).

Table 2. Density-Size Class

Name of sp.	Size Classes					
	I	II	III	IV	V	VI
Site I						
Limoniastrum monopetalum	–	1	5	3	8	3
Salicornia fruticosa	18	18	3	–	–	–
Zygophyllum album	–	–	–	–	1	–
Site II						
Limoniastrum monopetalum	–	1	2	–	–	–
Salicornia fruticosa	27	4	1	1	–	–
Arthrocnemum glaucum	17	4	1	–	–	–
Salsola sp.	–	1	–	1	–	–
Site III						
Limoniastrum monopetalum	3	2	2	–	–	–
Salicornia fruticosa	15	1	–	–	–	–
Arthrocnemum glaucum	31	3	–	–	–	–
Salsola sp.	–	1	1	1	–	–
Site IV						
Limoniastrum monopetalum	–	–	6	2	8	–
Salicornia fruticosa	18	12	1	–	–	–
Zygophyllum album	–	3	3	5	–	–
Salsola sp.	–	2	–	–	–	–

In community III *Salicornia fruticosa* is likely to replace *Limoniastrum monopetalum* in dominance, while *Arthrocnemum glaucum* which is one of the present dominants will maintain its dominance in future too (Table 2).

In community IV *Salicornia fruticosa* which is a second dominant at present, will be a predominant species in future as it is reproducing very well, whereas *Limoniastrum monopetalum* (first dominant) is not reproducing (Table 2).

The plant communities of Zuara segregate well from one another on the basis of soil conditions which are described as under:

I. *Limoniastrum-Salicornia* community:

The water table was found at 27 cm. The soil of this community had 33% moisture content, pH 7.85, sodium 1950 ppm, potassium 987.5 ppm, calcium 330 ppm, magnesium 199.6 ppm, total salinity 9.1‰, total chlorinity 5.1‰ nitrities 1.25 μgm/l and nitrates 32.75 μgm/l (Table 3).

II. *Salicornia-Arthrocnemum* Community:

The water table was at 12 cm depth, the soil moisture content 21.35%, pH 8.1, sodium 3750 ppm, potassium 800 ppm, calcium 257.5 ppm, magnesium 329.8 ppm, total salinity 6.2‰, total chlorinity 3.4‰, nitrites 0.225 μgm/l and nitrates 67.07 μgm/l.

III. *Arthrocnemum-Limoniastrum* Community:

The depth of water table was 19 cm, moisture content 22.35%, pH 7.8, sodium 2150 ppm, potassium 937.5 ppm, calcium 380 ppm, magnesium 382.7 ppm, total salinity 10.9‰, total chlorinity 6.02‰, nitrite 3.2 μgm/l and nitrates 53.35 μgm/l.

IV. *Limoniastrum-Salicornia-Zygophyllum* Community:

The water table was found at a depth of 34 cm, soil moisture content was 15.8%, pH 8.1, sodium 1295 ppm, potassium 1470 ppm, calcium 310 ppm, magnesium 521.5 ppm, total salinity 14.4‰, total chlorinity 8.4‰, nitrites 0.0 μgm/l and nitrates 25.0 μgm/l.

The sodium adsorption ratio was high in communities I and III, ranging between 42.12 to 37.17/100gm respectively while it was medium in communities II (18.50/100gm) and IV (20.92/100gm). Similarly, the exchangeable sodium percentage was high in communities I and III (37.88 and 32.1/100gm) and moderate in communities II and IV (20.65 and 21.77/100gm).

Discussion

The plant communities of Zuara exhibit lot of floristic similarity but they are different from one another on the basis of community structure as is indicated by the index of similarity (Table 1) and on the basis of edaphic factors (Table 3). The use of cover per hectare values of species in computing the index of similarity is definitely better than the relative phytosociological data in projecting both floristic as well as structural differences between communities. The stand density and cover per hectare values of the four communities clearly demonstrate the real differences between the communities. The index of similarity was not high enough to merge the communities I and IV and II and III.

Table 3. Soil Characteristics of the study area.

	Community			
	I	II	III	IV
Depth of water table (cm.)	27	12	19	34
Moisture content (%)	a. 32.18	20.24	21.64	13.87
	b. 34.04	22.22	23.06	17.76
Sodium (ppm)	a. 2500	4000	2300	1563
	b. 1400	3500	2000	1027
Average	1950	3750	2150	1295
Potassium (ppm)	a. 1150	960	1100	1800
	b. 825	640	775	1140
Average	987.5	800	937.5	1470
Magnesium (ppm)	a. 98.2	292.2	467.0	348
	b. 301.0	367.4	289.4	695
Average	199.6	329.8	382.7	521.5
Calcium (ppm)	a. 290	245	350	300
	b. 370	270	410	320
Average	330	257.5	380	310
SAR/100gm soil	42.12	18.50	39.17	20.92
ESP/100gm soil	37.88	20.65	32.10	21.77
Soil pH	7.9	8.2	7.8	8.1
			7.85	8.1
Total Salinity	9.1‰	6.2‰	10.9‰	14.4‰
Total Chlorinity	5.1‰	3.4‰	6.02‰	8.4‰
Nitrate μkm/l	1.25	0.225	3.25	0.00
Nitrate μgm/l	32.75	67.07	53.35	25.0
Phosphate μgm/l	0.0	0.0	0.0	0.0

a. = Surface Soil, b. = Sub-surface soil, SAR = Sodium adsorption ratio, ESP = Exchangeable sodium percentage.

On the other hand these pairs of communities may be grouped together into higher classificatory units as and when more halophytic communities of Libya are described. The four communities also show good correlation with the edaphic factors which adequately support the conclusion drawn on the basis of index of similarity.

The low percentages of the community maturity indices may be attributed to the fact that communities of Zuara represent successional stages. With the lapse of time the maturity is most likely to improve as the vegetational development progresses further toward climax stage. Relatively speaking, the community I has slightly better maturity because the dominance is rather concentrated to two species, *Limoniastrum monopetalum* and *Salicornia fruticosa* with 49% and 47% imprtance values respectively.

As regards the future trends in the communities, it is seen that only *Arthrocnemum glaucum* and *Salicornia fruticosa* are reproducing well in all the communities. It may therefore be concluded that these species are likely to predominate the "Sabkha" of Zuara in years to come. The seeds of *A. glaucum* are highly salt resistant (Waisel 1972). Similarly the seeds of *S. fruticosa* exhibit high salt tolerance and can germinate even in 10% sodium chloride solution (Walter 1971). Because of this fact, the two species are placed in a very advantageous position in competition with other halophytic species of Zuara.

The plant communities of Zuara reveal interesting correlations with the edaphic factors. Although sodium is the predominant cation in all the sites, yet each community has its own set of edaphic controls. *Limoniastrum-Salicornia* community (I) occurred on soil containing high potassium, calcium and moisture content and high sodium adsorption ratio and exchangeable sodium percentage (Table 3). *Salicornia-Arthrocnemum* Community (II) was found on soil having high sodium and nitrate contents and high water table . *Arthrocnemum-Limoniastrum* community (III) seems to be correlated with high sodium, magnesium, calcium and nitrate contents, high sodium adsorption ratio, high exchangeable sodium percentage and high water table. The *Limoniastrum-Salicornia-Zygophyllum* community (IV) occured on soil containing high potassium and magnesium contents, high total salinity and chlorinity and low moisture content.

It is evident that there is a lot of overlapping in the ecological amplitude of the dominants of the communities but still there is a clear segregation of communities on the basis of edaphic factors. *Limoniastrum monopetalum* and *Salicornia fruticosa* appear to have wider ecological amplitude than *Arthrocnemum glaucum*. L. *monopetalum* seems to prefer high potassium and calcium or high potassium and magnesium or high sodium, magnesium and calcium contents but it is less sensitive to variation in soil moisture and the height of water table. *A. glaucum*, appears to favour situations where the water table, sodium and nitrate contents are relatively high. *S. fruticosa* on the other hand, was sensitive to the edaphic factors studied. Most of the halophytes in Israel had also wide ecological amplitude as to soil salinity but the communities segregated on the basis of their water requirements (Waisel, 1972). In the present study only two communities (II & III) appear to be influenced, to some extent, by the height of water table. But the other edaphic factors seem to be equally important in governing the distribution of these communities.

Nuttonson (1961) reported two communites from Zuara region. According to him, *Salicornia fruticosa* community was found on saline soil, while *Suaeda fruticosa-Limoniastrum monopetalum* community occurred on salt marshes and margins of salt marshes. Data of edaphic factors are, however, not available for comparison. It is very surprising that Nuttonson did not find *Arthrocnemum glaucum* as one of the dominant species in Zuara. Similarly, *Suaeda fruticosa* reported by him was not encountered in the present study. It is possible that succession or grazing might have introduced change in the dominance of species.

From the point of view of classification of plant communities, the community III (*Arthrocnemum-Limoniastrum*) shows a very close affinity with the *Arthrocnemetum* association of Waisel's (1972) classification of halophytic communities. The community II (*Salicornia-Arthrocnemum*) apparently seems to be intermediate between Waisel's Salicornietum and Arthrocnemetum associations, while the communities I and IV in which *Limoniastrum monopetalum* is the first leading dominant, appear to be peculiar to Zuara region.

Zohary's 1962) classification of halophytic communities included two main classes, *Suaedetea deserti* and *Salicornietea fruticosa. Arthrocnemum glaucum-Tamarix tetragyna* association grouped in the former class was reported to be confined to badly drained depressions and wadis inundated for a certain period in winter. The soil moisture ranged between 14-23% and the soluble salts ranged between 5-9.5%. *Arthrocnemum glaucum-Sphenopus divaricatus* association included in the latter class occupied sites less flooded but more saline than the first association. The soil moisture in communities II and III in which *A. glaucum* is one of the dominants was around 21-23%, the height of water table ranged between 12-19 cm and the sodium content ranged between 2000-4000 ppm. These results concide very closely with Zohary's observations. An another community (*A. glaucum-Zygophyllum album*) reported from Egypt by Walter (1971) appears to occur on less saline soil than at Zuara and Palestine. This indicates that *A. glaucum* also has a wide ecological amplitude.

References

Bray, J.R. and J.T. Curtis. 1957. An ordination of the upland forest communities of Southern Wisconsin. *Ecol. Monogr.* 27: 325–349.

Cain, S.A. 1932. Density and frequency of the woody plants of Donaldson's Woods, Lawrence County, Indiana. Proc. *Ind. Acad. Sci.*, 41: 105–122.

Cottam, G. and J.T. Curtis. 1949. A method of making rapid surveys of woodlands by means of pairs of randomly selected trees. *Ecology*, 30: 101–104.

Cottam, G. and J.T. Curtis 1956. The use of distance measures in phytosociological sampling. *Ecology*, 37: 451–460.

Hajaji, M. 1965. *The new Libya.* Govt. Printing Press, Tripoli.

Keith, H.G. 1965. *Libyan Flora.* Vol. I & II. Agric. Res. Coun., Tripoli.

Le Floch, E. 1975. *Ecological studies in the Libyan Arab Republic.* Agric. Res. Coun. & FAO Bull.

Lindsey, A.A. 1955. Testing the line strip method against full tallies in diverse forest types. *Ecology*, 36: 485–495.

Nuttonson, M.Y. 1961. The physical enviornment and agriculture of Libya and Egypt with special reference to their regions containing areas climatically and latitudinally analogous to Isreal. *Amer. Inst. Crop Ecol.*, Washington, D.C.

Pichi-Sermolli, R. 1948. An index for establishing the degree of maturity in plant communities. *J. Ecol.*, 36: 85–90.

Polunin, O. and A. Huxley 1965. *Flowers of the Mediterranean.* Chatto & Windus, London.

Rottry, J.M. 1968. *The grass cover of Africa,* FAO Report No. 49, Rome.

U.S.D.A. 1954. Diagnosis and improvement of saline and alkali soils. *Agric. Handbook* NO. 60. Washington D.C.

Waisel, Y. 1972. *Biology of halophytes.* Academic Press, U.S.A.

Walter, H. 1971. *Ecology of Tropical and Sub-Tropical vegetation.* Oliver and Boyd, U.S.A.

Zohary, M. 1962. *Plant life of Palestine.* Ronald Press, N.Y.

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