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Abiotic and edaphic factors influencing the settlement of the sands of the mobile dunes by the beetle fauna at the Northern fringe and the Eastern region of Morocco.

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Abstract

The present work concerns the study of the physico-chemical characteristics of the sands of the mobile dunes populated by the beetle fauna at the level of the northern fringe and the Eastern region of Morocco. This study is spread over a route of 4000 km from dunes of Guercif (North) to the large dunes of Merzouga (Sahara), while passing by the dunes of the following stations: North East of Missour, Midelt, Ain Beni Methar, Tendrara, Rich, Boulmane, Bouârfa, Boudnib and Erfoud.

The granulometry of these sands allowed us to distinguish three groups of stations. The first group is formed by the Guercif station and that of the N-E of Missour with a fine and well calibrated texture. The second group is formed by the Tendrara, Bouârfa, Boudnib, Bouânane, Midelt, Rich, Ain Beni Methar and Boudnib stations, which have a high silt content which gives the soil great cohesion. The last group is formed by the Saharan stations (Merzouga, Erfoud and Figuig) characterized by coarser sand than the other stations.

The highest temperatures are noted on the surface of the bare ground, however the lowest values are noted at 30 cm deep. The porosity thus appears higher in the fine sands with very small differences between the stations studied varying between 38% in Guercif, North-East of Missour, Bouârfa and Tendrara and 36% in Erfoud. The humidity values are low to very low at the surface and at 30 cm depth with the presence of an increasing depth moisture gradient at the surface. The pH of these sands is neutral between 7.4 and 7.8. The salinity of these sands is low at 0.5% N-E from Missour and a value of 0.85% at Guercif less than 1%.

This analysis of factors A in the abiotic environment shows for the most part a North-South evolution either in the direction of increase (Temperature, particle size, evapotranspiration ...) or in that of decrease (rainfall, humidity, porosity).

Keywords: Edaphic factors, mobile dunes, northern fringe, eastern region, Morocco, Sahara.

I- Introduction

The majority of the work devoted to the study of the settlement of the sandy environment was limited and was devoted at the beginning to establishing the systematics and the geographical distribution of the different cataloged species (Antoine, 1955, 1957, 1959, 1961, 1962, 1943; Alluaude, 1924; Bruneau de mire¸ 1958; Cassola, 1973, Chessel et al., 1975; Joly et al., 1951; Peyerimhoff, 1923, 1925a, 1925b, 1943, 1947a, 1947b, Pierre, 1958; Sarsarl, 1992; Chavanon et al., 1995, Bouraada, 1996; Bouraada et al., 2015; Dubief, 1943; Reymond, 1950;… .etc.

Knowledge of arthropods in the Moroccan sand dunes has made extraordinary progress over the past hundred years, its wealth of beetles is remarkable. It is due to the diversity of geographic and geological regions: Eastern Morocco, the Rif massif which gave birth to many northern forms, the atlases, the coastal domain which stretches for almost fifteen hundred kilometers, the Atlantic steppe, the Sub and finally the Saharan and pre-Saharan regions.

The construction of continental sandy formations follows a very specific process, so the sands of North-Western Sahara are the products of successive erosions, the process of which was described in broad outline by Pierre (1958).

He understands :

The formation of these dunes is a consequence of the desertification of the environment. This is above all linked to an irreversible reduction of the plant cover, leading to the denudation of the soil. Bare soil is prey to wind erosion. On the ground thus stripped comes then accumulates, under the combined action of the relief, the wind,…., Sandy deposits of exogenous origin which, gradually, constitute mobile dunes.

This present work constitutes the continuation of our research for a better knowledge of the abiotic factors controlling the life of the entomological groupings of beetles of the mobile dunes of eastern Morocco and of the western northern fringe of the Sahara, in particular on the faunistic and ecological plan. It thus extends our previous study (Bouraada, 1996). This study is spread over a period of 3 years (1997, 1998 and 1999), the surveys were concentrated on the spring period (April and May and covered various stations in the East and South East of Morocco (Guercif, Aïn Beni Methar, NE Missour, Tendrara, Boudnib, Bouârfa, Rich, Figuig, Erfoud, Merzouga).

I) Description of the stations studied

The present study concerns aspects of abiotic factors of the settlement of mobile sandy formations (dunes, nebkhas, etc.) in Eastern Morocco and the western northern fringe of the Sahara. For this we have chosen 12 stations roughly distributed along a North-South axis, from the northern zone to the Saharan borders (Figure 1).

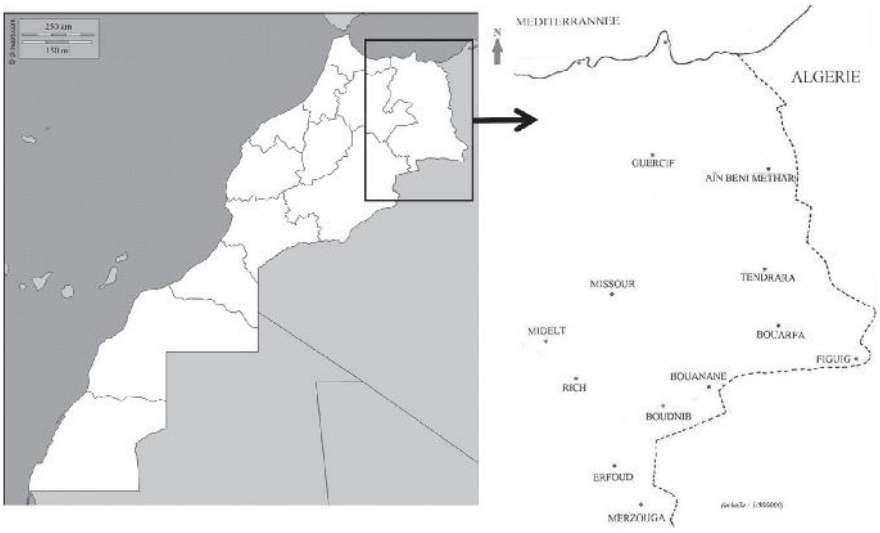

Figure 1 - Location of study stations (Bouraada et *al.*, 2016)

Distributed over a trajectory of almost 4000km, for the choice of our 12 stations we took into account various criteria. The first is the fact that all of these sandy formations are at least partially mobile. We also chose these stations according to geographic, climatic and accessibility parameters. The stations are classified according to the affinity obtained by the factorial correspondence analysis (Bouraada, 2003).

Thus, we are led to group the stations studied according to the climate and according to the following north-south geographic gradient:

1) the northern and central west stations: Guercif, Midelt and Aïn Beni Methar, characterized by a moderate or warm semi-continental climate;
2) the stations in the center-east: northeast of Mis¬sour, Rich, Bouârfa and Tendrara, characterized by a moderate or hot continental climate;
3) the central and southern stations: Boudnib, Bouânane, Figuig, Merzouga and Erfoud, characterized by a warm continental climate.
The twelve stations therefore have in common the presence of mobile sandy formations and a height generally not exceeding 2m (except for the Merzouga and Erfoud stations).

II) Material and Method

The physico-chemical factors of the environment exert a direct influence on the spatio-temporal distribution of the wildlife stand. We therefore took into account, in our study, a certain number of parameters and in particular those which seemed to us to be the most important and the most determining with regard to the physiognomy of the populations of fauna, in particular the temperature measured at the level air and substrate at different depths, the pH of the substrate, its humidity, its salinity, its organic matter content, its particle size, its porosity and its cohesion.

We measured the air temperature at a height of 1m, at the level of the bare sand outside of a dune as well as at various places on the dune: surface sand, sand at 5 cm, 10 cm and 15 cm deep.

The granulometry of the sand in the dunes of our stations was studied using the technique of Vergeg (*in* River, 1977) (series of sieves of AFNOR standard NF.X.II.504, n ° 21 to 38, corresponding to mail 100µ to 5 mm), on the surface and 15 cm deep.

The porosity is the volume corresponds to the place that can be occupied in the sand by air and water.

The humidity of the substrate is recorded during each campaign by taking, in each station, a fraction of sand on the surface, one at 15 cm and one at 30 cm deep (PIERRE, 1958). The samples, kept in an airtight container, are taken to the laboratory and weighed before and after drying in an oven for 48 hours at 45 °C.

The pH of the sand samples were prepared according to the method used by Soudi and *al*. (1990).

The organic matter was evaluated by calcination in an oven at a temperature of 600 °C for 2 hours, the sand samples were taken in the 12 stations on the surface, at a depth of 15 cm and 30 cm (Bouraada, 1996).

The salinity given by the correlation between the Na^+ and Cl^- concentrations, we only referred to the concentrations of the second ion measured by a salinometer.

III) Results and Discussion

III-1) Dune sand temperature

Temperature is one of the main limiting factors on the surface of the sand for the sabulicultural fauna (Pierre, 1958; Bouraada, 1996).

Up to about 10 cm deep, this parameter depends essentially on air temperature, sunshine, exposure, soil color and the density of the plant cover (Brun, 1968).
Furthermore, it seems that very small dunes have a particular thermal regime, certainly warmer than that of large groups (Pierre, 1958).

As our measurements were not made at the same time, it is not possible for us to study the thermal variations in each station according to the different campaigns.
Similarly, for this reason and the fact that the surveys for the same campaign were taken on slightly different dates, the comparison of the thermal values between the various stations for a campaign is unreliable (Bouraada, 1996). For the most part, we will limit ourselves to studying thermal variations depending on the different environments for each station and for each statement.

For the same station and for the same campaign and in the 46 surveys carried out, the highest temperature values are recorded on the surface of the bare ground outside the dune (51.5 °C at Merzouga in May), while the lowest are noted at air level (19.7 °C northeast of Missour in May) (Table I).

The greatest thermal difference between this medium and the air is observed at Erfoud in April (11 °C measured at 3 p.m.). Deviations of more than 8 °C are also recorded northeast of Missour in May and March, Merzouga in March and Bouânane in April. On the contrary, the smallest difference is recorded in Aïn Beni Mathar in April (0.2 °C) and in Tendrara in April. Deviations of less than 1 °C are noted at Rich in March and April and at Tendrara in March.

In general, the temperature on the surface of the slope of the dunes is slightly lower than that of the bare soil outside the dunes. Only in 8 out of 46 records did the difference between these two media exceed 1 °C (Erfoud in March, Bouânane in May ... etc.). The thermal differences between these two media are generally quite small. The biggest difference is around 2.5 °C noted at Bouânane in May and Merzouga in May. No difference was noted at Guercif in March, at Merzouga in April and at Boudnib in March.

At the dune, there is a decreasing thermal gradient from the surface to 15 cm deep. The temperature drops doc, as we sink into the dune sand. However, the magnitude of this drop varies widely from survey to survey, variability which, at first glance, seems quite random. The greatest difference (8.5 °C) was obtained in Merzouga in May.

Table I, Variation in temperature (°C) during the study campaigns

[Guercif (S_1), N.E. Missour (S_2), Midelt, (S_3), Aïn Beni Mathar (S_4), Tendrara (S_5), Bouârfa (S_6), Rich (S_7), Bouânane (S_8), Figuig (S_9), Boudnib (S_{10}), Erfoud (S_{11}), Merzouga (S_{12})].

Stations / Companion	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}
						May						
Hour	15h30’	11h45’	14h	16h	10 30’	10h	10h	14h10’	14h30’	9h45’	15h	15h30’
Température (°C)												
Air :	28	19,7	23,5	30,5	29,9	27,5	28	37,5	40,1	35	35	40
Bare sand outside a dune :	32,7	30,1	31	33		29,5	29,5	45,5	46,5	39,5	40,5	51,5
Dune :												
Area :	32,2	29,1	30,7	32,5	33,3	29	29	43	45	38,5	40	49
-5cm :	32,1	29,9	30,2	31	32,5	28,5	28,7	40,7	44,2	37	39,8	48,5
-10cm :	31,7	29,8	30	31	32	28	28 2	40 7	43 7	36 1	39 8	44
-15cm :	31,7	29,7	29	29,5	25,8	28	28	39	40	36	39	40,5

Stations / Companion	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}
						March						
Hour	10h10’	14h30’	14h	14h30’	10h5’	11h5’	10h15’	14h5’	16h5’	10h10’	15h45’	16h
Température (°C)												
Air :	22	20,2	23,5	31,5	25,9	26,5	22,3	30	35,5	30,5	30	30,7
Bare sand outside a dune :	27	31	31	37,1	26,7	27,5	25,7	35,2	38,5	35	40,5	41
Dune :												
Area :	27	30,8	30,7	35,8	26,5	27,2	25,4	34,2	38,2	35	38,9	40,1
-5cm :	27,8	30,6	30,2	35,5	26	27	25,1	34,1	38	34,5	38,7	39,5
-10cm :	27,8	30 6	30	35,4	26	27	25,1	34,1	38	34,5	38,7	39,5
-15cm :	27,8	30,5	29	35,2	25,8	26,8	25	34	37,5	34,1	38,6	39,5

Stations / Companion	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}
						April						
Hour	16h	14h	16h	11h10’	11h30	9h30’	10h30’	15h10’	15h30’	9 h5’	16h30’	15h15’
Température (°C)												
Air :	28	22	27	30,5	30,7	26,6	25	33	38,2	28,7	26,7	37
Bare sand outside a dune :	30,2	32,2	31,1	31,2	31,1	28	28,9	41,1	42	34,1	40,1	40
Dune :												
Area :	30,1	32,1	30	30,7	30,9	27,5	28,7	41	41,7	34	37,7	40
-5cm :	29,9	32	30,7	30,5	30,7	27,2	28,5	40,8	41,2	33,5	37,5	39,7
-10cm :	29,8	30,9	30,7	30,5	30,6	27,1	28,5	40,7	41,2	33,5	37,5	39,7
-15cm :	29,7	29,9	30,6	28,4	30,5	27	28,4	40	41,2	33,2	37,3	39,5

These readings were taken in the middle of the day (around 3 p.m.). On the other hand, the smallest difference (0.2 °C) was recorded in Bouânane in March 1998 at 2:05 p.m. In general, the decrease in temperature is very modest and for more than three quarters of the readings it does not exceed 2 °C.

Overall, our results are consistent with the authors who have worked on this medium (Pierre, 1958, Reymond (1950). The influence of the thermal depth gradient, the thermal conditions prevailing at 10 cm depth have therefore been confirmed.

The greater or lesser thermal differences between the air and the ground surface can, in part, be linked to sunshine, orientation, cloud cover, etc. Likewise, the variation in temperature noted on the ground surface outside the dunes and on the flanks of the dunes, from one campaign to another, can be linked to the exposure of the slopes of the dunes, to the wind, etc.

The great variability, from one campaign to another and from one station to another, in the amplitude of the thermal differences between the ground surface and the underlying sand seems rather random and difficult to explain.

For practical reasons, it was not possible for us to take temperature measurements at regular intervals in the different environments during a nycthemeral cycle. For that, the circadian thermal variations, can be very important on the ecological level, could not be approached here.

III-2) Granulometry of sands

The grain size is an important factor in sandy environments because it governs most of the physical properties of sand: void volume (aeration, water content), rigidity, cohesion, mobility. The behavior of the sabulicoles is closely conditioned by these factors (Pierre, 1958).

In order to facilitate the analysis, similarities and differences, we have ranked our stations in descending order according to the factor studied.

The size of the grains plays a key role in the distribution of psammophilic organisms, particularly those that are burrowers (Bouraada, 1996). We sampled the sand in the twelve stations on the surface and at a depth of 30 cm in order to detect possible differences between these two levels and between the different stations studied (Figure 2).

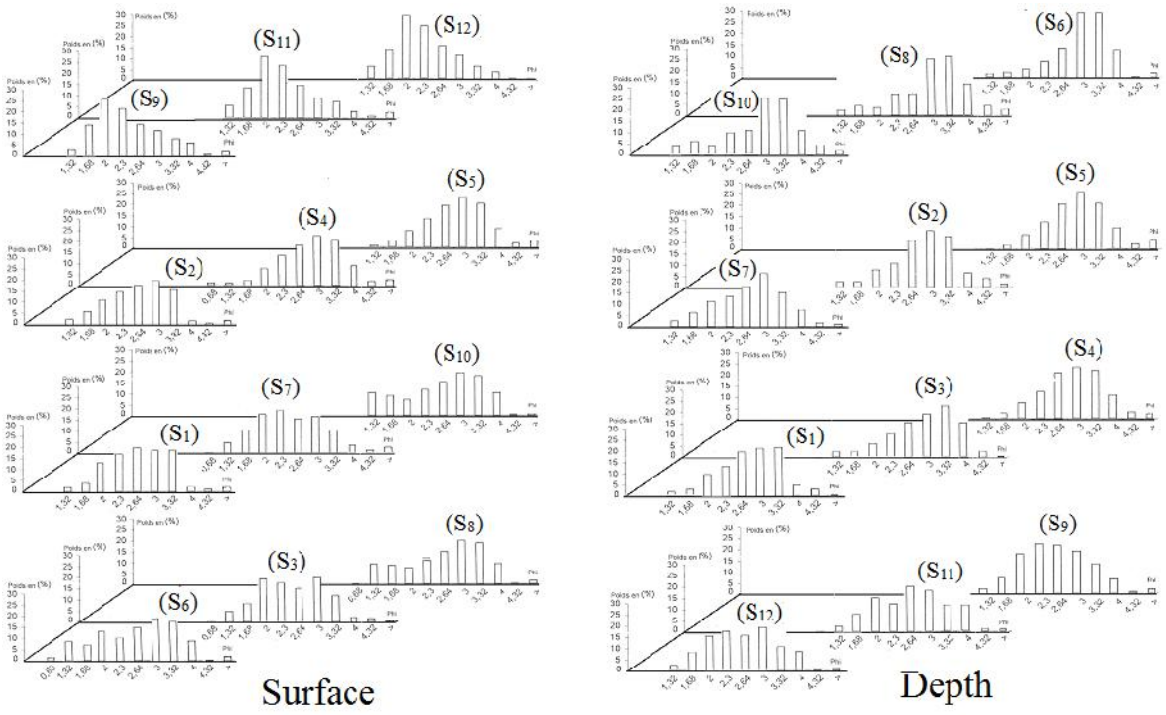

Figure 2, grain size distribution of surface and depth sands
(The figures are grouped in order of increasing similarity)
[Guercif (S_1), N.E. Missour (S_2), Midelt (S_3), Aïn Beni Mathar (S_4), Tendrara (S_5), Bouârfa (S_6), Rich (S_7), Bouânane (S_8), Figuig (S_9), Boudnib (S_{10}), Erfoud (S_{11}), Merzouga (S_{12})].

The granulometry of the sands studied generally shows that it is pure sand, well classified of the monodisperse type characterized by a high percentage of grains of identical or very similar size and almost always dominated by fine sands of size less than 0.2mm.

The grain size of surface sands is generally coarser than that of depth (Bouraada and Essafi, 2015).

Tendrara is characterized by its relatively high silt content and, with the Aïn Beni Mathar station, does not show any difference between the particle size of the surface and that of depth. On the other hand, in the Saharan stations (Figuig, Merzouga and Erfoud) there is a higher proportion of coarse sand.

III-3) Porosity

The porosity of the sands presents values very close between the studied stations ranging between 38% in Guercif, North-East of Missour, Bouârfa and Tendrara and 36% in Erfoud the differences are therefore very small (Figure 3).. This factor is in fact more or less linked to the granulometry, in particular to the size of the grains and their heterogeneity. It thus appears higher in fine sands (Bouraada, 1996).

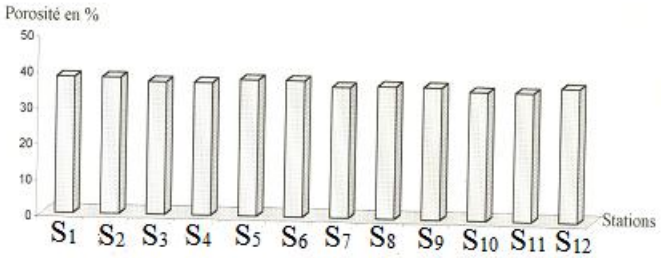

Figure 3, variation of the porosity of the stations studied
[Guercif (S_1), N.E. Missour (S_2), Midelt, (S_3), Aïn Beni Mathar (S_4), Tendrara (S_5), Bouârfa (S_6), Rich (S_7), Bouânane (S_8), Figuig (S_9), Boudnib (S_{10}), Erfoud (S_{11}), Merzouga (S_{12})].

III-4) Sand humidity

In all stations the values of this parameter are low to very low both at the surface and at 30 cm deep. For all stations, the highest humidity is recorded at a depth of 30 cm. So, we are in the presence of an increasing surface-depth hygrometric gradient.

The greatest value is noted at 30 cm deep in the Midelt station (8.9%) followed by those of North-East Missour (8.1%) and Guercif (7.9%) therefore marking the Nordic stations (except for Tendrara and Aïn Beni Mathar). The lowest values are observed on the surface of the ground during the campaign of the month of May, in the stations of Merzouga, Figuig (0.01%; 0.02% and 0.25%) followed by the other neighboring stations (Table II).

For the other stations, the humidity values are more or less amortized because they are intermediate stations and the measurements are made during the month of April or March.

Table II, variation in the humidity of the sands during the study campaigns

(The stations are classified in decreasing order of humidity)
[Guercif (S_1), N.E. Missour (S_2), Midelt, (S_3), Aïn Beni Mathar (S_4), Tendrara (S_5), Bouârfa (S_6), Rich (S_7), Bouânane (S_8), Figuig (S_9), Boudnib (S_{10}), Erfoud (S_{11}), Merzouga (S_{12})].

Stations / Companion	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}
						March						
Humidity (%)												
Area :	1,85	1,3	1,85	0,98	0,9	0,57	0,9	0,6	0,1	0,5	0,19	0,09
-15cm :	5,5	6,75	7,65	8,5	7,7	2,1	4,45	2,3	1,9	0,59	0,85	0,9
-30cm :	7,9	8,1	8,9	7,9	6,9	5,9	6,65	6,5	2,5	0,59	2,3	1,9

Stations / Companion	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}
						April						
Humidity (%)												
Area :	1,55	1,1	1,7	0,35	0,4	0,2	0,75	0,25	0,07	0,3	0,1	0,07
-15cm :	4,5	6,2	7	4,2	5,1	1,4	4,4	1,1	1,1	0,35	0,65	0,75
-30cm :	5,9	6,9	6,5	5	5,3	4,9	5,9	4	1,7	0,45	1,4	1,1

Stations / Companion	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}
						May						
Humidity (%)												
Area :	1	0,8	1,1	0,7	0,65	0,35	0,35	0,4	0,02	0,25	0,08	0,01
-15cm :	4,5	5,5	6,55	7	6,7	1,7	3,35	2	1,5	0,35	0,75	0,7
-30cm :	7,2	7,3	8	6,1	5,3	5,3	3,99	6,2	2,1	0,39	1,85	1

III-5) pH

At the 12 stations surveyed, we have a pH between 7.4 and 7.8; which proves the neutral nature of these sands (Figure 3).

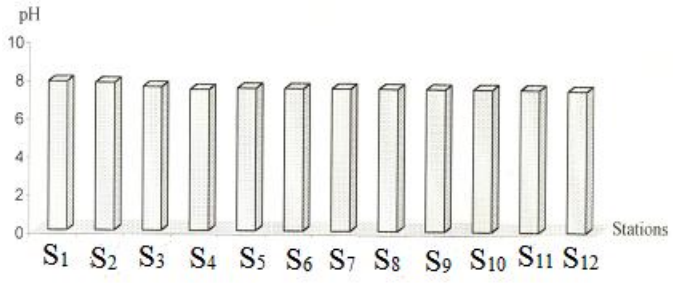

Figure 3, pH variation of the stations studied

[Guercif (S1), N.E. Missour (S2), Midelt, (S3), Aïn Beni Mathar (S4), Tendrara (S5), Bouârfa (S6), Rich (S7), Bouânane (S8), Figuig (S9), Boudnib (S10), Erfoud (S11), Merzouga (S12)].

III-6) Soil salinity

The percentage of salinity in these sands is between a value of 0.5% at the N-E of Missour and a value of 0.85% at Guercif. These values are less than 1% therefore low.

The strictly Saharan stations have relatively higher values of around 0.8% in Merzouga and 0.75% in Figuig. In high altitude stations this parameter is around 0.5% at N-E of Missour, 0.55% at Midelt and 0.75% at Aïn Beni Mathar (Table III).

This is probably related to the effects of the rains which result in the leaching of part of the salt deposited by wind erosion on the parts at high altitude.

Table III, Percentage of salinity in the stations surveyed.

[Guercif (S_1), N.E. Missour (S_2), Midelt, (S_3), Aïn Beni Mathar (S_4), Tendrara (S_5), Bouârfa (S_6), Rich (S_7), Bouânane (S_8), Figuig (S_9), Boudnib (S_{10}), Erfoud (S_{11}), Merzouga (S_{12})].

(The stations are grouped in decreasing order of salinity)

Stations/	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}
Cl^- (%)	0.85	0.8	0.77	0.75	0.75	0.7	0.65	0.6	0.6	0.57	0.55	0.5

Conclusion

The analysis of the grain size allowed us to distinguish three groups of stations.

The first group is formed by the Guercif station and that of N-E de Missour and has a fine and well calibrated texture. The second group of stations (Tendrara, Bouârfa, Bouânane, Midelt, etc.) has a notable content of silt which gives the soil great cohesion. The last group is formed by the Saharan stations (Merzouga, Erfoud and Figuig) and is characterized by coarser sand than the other stations.
For all stations, the highest temperatures are noted on the surface of the bare ground and the lowest are 30 cm deep. The temperature also decreases more or less with depth.
Pour l'humidité, on note un un gradient d'humidité de profondeur en surface croissant. Au niveau de la surface du sol nu, les températures sont plus élevées sont notées. Dans les sables fins présentent, a porosité apparaît plus élevée. Le pH de ces sables est de nature neutre et la salinité de ces sables est faible et inférieure à 1%.

In general, these factors show for the most part a North-South evolution either in the direction of increase (temperature, particle size, evapotranspiration ...) or in that of decrease (rainfall, humidity, porosity) evolution which reflects a increase in the severity of environmental conditions, particularly aridity, from the North to the South.

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