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Relationship between soil composition and the distribution of three *Manfreda* (Agavaceae) in Mexico

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Abstract. The *Manfreda spp* are an herbaceous plants which grown on limestone and rocky outcrops. This work presents a Z > 12 elemental composition study by PIXE of soils in some places where three species of Manfreda grown in Mexican Territory: *M. scabra, M. maculate* and *M. nachititlensis*. The last one corresponds to a specie endemic of the Temazcaltepec region at the Estado de México. The soil samples from the Temazcaltepec region present lower conductivity, higher acidity and the lowest concentration of Ca, Cr and Mn. For this lack on mineral nutrients the *M. nachititlensis* should be a plant adapted to live optimizing the absorption of metallic minerals as much as it can. Also its metabolic processes should be slower than for the other two species of *Manfreda*.

Keywords: Manfreda, soil, PIXE, environment.

INTRODUCTION

The *Manfreda spp* are xerophilous herbaceous plants corresponding to the Agavaceae family which grown in places composed by limestone soil and on rocky outcrops [1-3]. They are widespread from Central America to United States. However the *M. nanchititlensis* is a species endemic of the Temazcaltepec region located 130 km west of Mexico City and botanists do not have enough information about its growth conditions yet. As soil is one of the fundamental parts of the environment for vegetation support, the plants conditions of life are closely related to the soil characteristics. Make a comparison of Temazcaltepec soil characteristics with the soil of other places where Manfreda grown can give some information about the *M. nachititlensis* conditions of life and adaptation to this region.

The aim of this work is to contribute presenting a Z > 12 elemental PIXE study of the soil composition at Temazcaltepec region in places where there is predominant presence of *M. nanchititlensis*. In order to make a comparison of the soil characteristics with other places, two species well known were selected: *M. scabra and M. maculate*. The *M. scabra* was considered because it has a wide distribution along the Mexican territory and it is a species resistant to non-consolidated soils exposed to changes in chemical or mechanical composition due to weathering and soil forming factors. The *M. maculta* was chosen because it is a species located mainly in the central part of Mexico, growing in altitudes from 1400 to 3000 m over the sea level and in locations surrounding the Temazcaltepec region.

EXPERIMENTAL

Soil samples collection

The soil samples were collected in spots located at places where one of these *Manfreda* species is predominant. Samples were extracted from the ground and maintaining separated the different sublayers. The National System of Soil Classification of the U.S. Department of Agriculture was considered to describe the soil taxonomy [4] and profile. Figure 1 shows the place locations where the soil samples were collected. For the *M. nanchititlensis* three different spots separated by few kilometers were taken in the Temazcaltepec region to obtain the soil samples. These spots are designated as N1, N2 and N3. In the case of regions where the *M. maculata* is predominant three places were considered: Almoloya de las Granadas (M1), Tejupilco (M2) and San Simon de Guerrero (M3). Finally, for the *M. scabra* the soil collection were done at Zacualtipan (S1), Sombrerete (S2) and Loma Ancha (S3). The geographical position for each place is indicated in table 1.

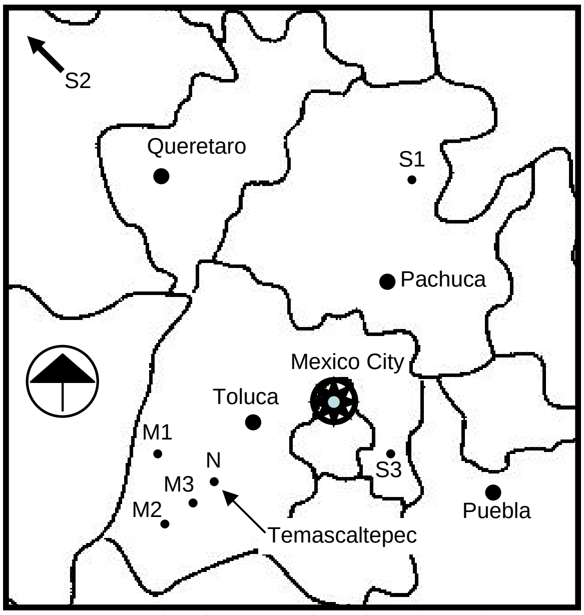

FIGURE 1. Place locations where the soil samples were collected. The name of each place corresponding to every code number designation is indicated in the text. S2 is located outside the map at 620 km Northwest from Mexico City

TABLE 1. Position of the sampling places.

Location	Geographical coordinates
M. scabra	
S1	98°42'00"W / 20°40'17"N / 2090mosl
S2	103°41'34"W / 23°40'42"N / 2423mosl
S3	98°46'00"W / 19°19'00"N / 2900mosl
M. maculate	
M1	100°07'30"W / 19°07'18"N / 1716mosl
M2	100°04'04"W / 18°59'08"N / 1711mosl
M3	100°02'59"W / 19°01'04"N / 1872mosl
M. nachititlensis	
N1	100°00'26"W / 19°04'14"N / 2060mosl
N2	100°03'22"W / 19°03'10"N / 1917mosl
N3	100°02'40"W / 18°56'07"N / 2137mosl

To expose the soil horizons in every spot a 1 m depth hole is made in the ground. These holes were dug in a surface of 1.0 x 1.3 m^2. Once the soil horizons were determined, the samples were extracted directly from each layer. The pH and electric conductivity of the soils were measured using conventional methods.

PIXE set up and analysis

For PIXE analysis a typical experimental set up was employed [5]. Samples were located in a vacuum chamber and the X-ray were registered outside the vacuum by a Si(Li) detector placed at 90° from the particle beam in front a Mylar Window. The irradiated samples consisted in compressed pellets of soil. The X-rays were induced by 750 keV proton beam produced with the 0.7 MV Van de Graaff at the Instituto de Fisica, UNAM. A NIST 2704 Buffalo River Sediment reference standard was used to calibrate the detection system. PIXE spectra were analyzed using the AXIL computer code [6].

RESULTS

The classification for the soil samples collected is shown in table 2. In many cases the soil horizons of type A were thin (<12cm). The soil samples of Temazcaltepec present higher acidity and the lowest conductivity among all the samples. For the locations of *M. scabra* the soils are more alkaline and present a higher conductivity. The typical elements detected by PIXE were Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Cu and Zn. The uncertainty values in the measurements range from 8% to 15%, except for Al with 30%. The concentrations for the most significant elements observed are shown in figure 2. The average elemental concentration values for soils corresponding to each species are indicated in table 3. The standard deviations are indicated in brackets.

TABLE 2. Classification of the soil samples.

Location	Soil sublayer horizons	Kind of Soil
M. scabra		
S1	A, C	Lithosol
S2	A	Molisol
S3	A, B	Andosol
	M. maculate	
M1	A, C	Leptosol
M2	A, B	Luvisol
M3	A, C	Leptosol
	M. nachititlensis	
N1	A1, A2, B	Leptosol
N2	A, C	Leptosol
N3	A1, A2, C	Alfisol

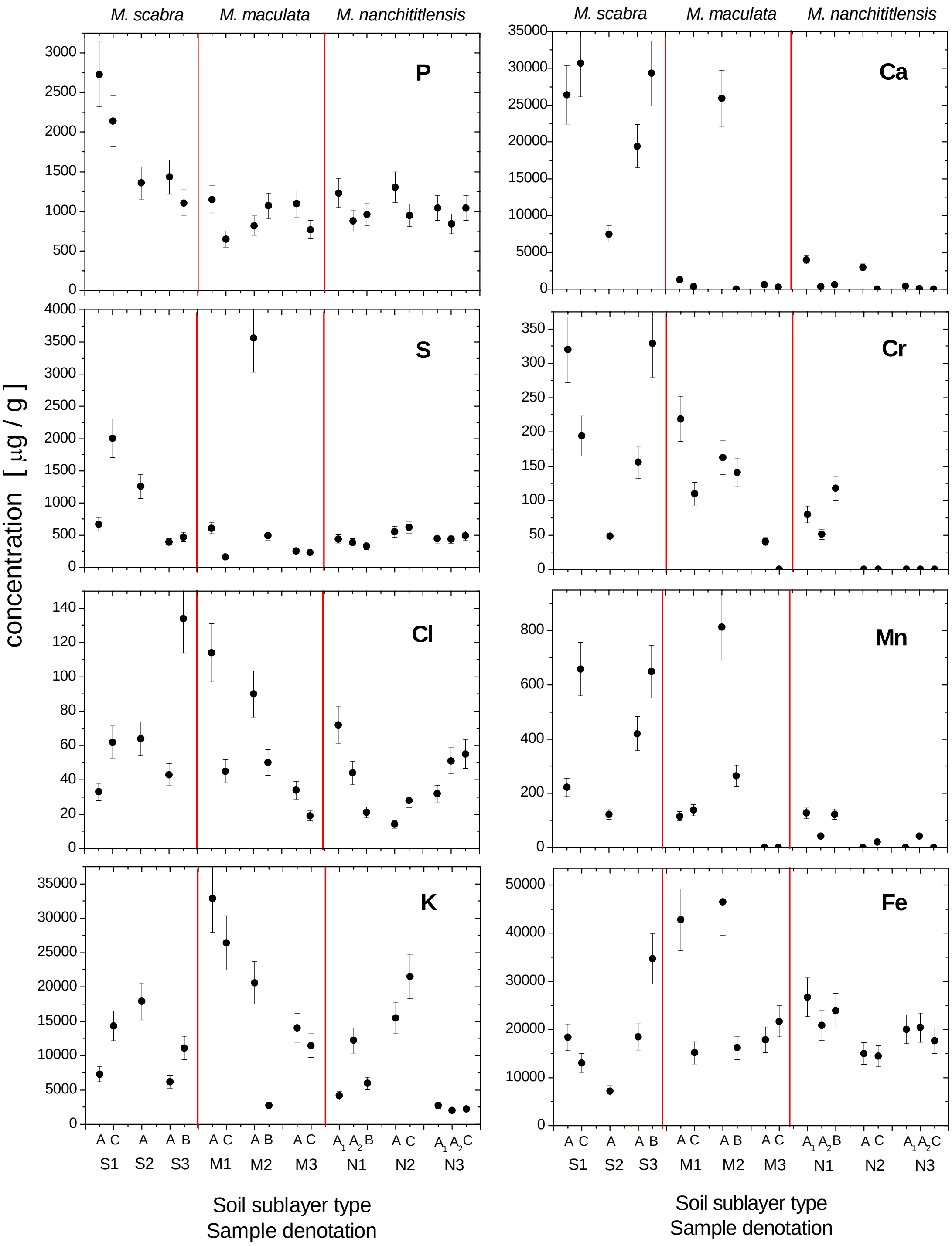

FIGURE 2. Elemental concentration determined by PIXE for P, S, Cl, K, Ca, Cr, Mn and Fe. Graphs are divided in three parts: the left correspond to places were *M. Scabra* is dominant, the middle for the *M. maculate* and the right for the *M. nachititlensis*. The code number for each place is indicated in the bottom of the scale and their corresponding soil sublayers are indicated above by letters A,B and C. The name of each place corresponding to every code number designation is indicated in the text.

TABLE 3. Average soil elemental concentration for each species. The standard deviation is indicated in brackets.

Element	*M. scabra*	*M. maculata*	*M. nachititlensis*
P	**1752**	**925**	**1032**
	(666)	(205)	(162)
S	**957**	**885**	**463**
	(677)	(1326)	(93)
Cl	**67**	**59**	**40**
	(39)	(36)	(19)
K	**11363**	**17996**	**8288**
	(4873)	(10836)	(7272)
Ca	**22698**	**4920**	**1104**
	(9574)	(10132)	(1492)
Cr	**209**	**112**	31
	(118)	(81)	(47)
Mn	**414**	**222**	**44**
	(243)	(307)	(53)
Fe	**18385**	**26695**	**19884**
	(10239)	(14136)	(4175)

DISCUSSION

The poor conductivity for the soil of the Temascaltepec region is an indication of few ionic salts in the ground. In this case less mineral nutrients are available for the physiological process of the plants. These results are corroborated with the data presented in table 3, where the lowest metallic elemental concentrations correspond to the soils of the *M. nanchititlensis*.

The soils related to the *M. scabra* present the higher element concentration for P, Ca, Cr and Mn, while the soils associated to *M. nachititlensis* have the lowest amount of Ca, Cr and Mn. The soils for the *M. maculata* have the higher presence of Fe. From figure 2 is possible to observe that for the three *Manfreda*, their corresponding soils have similar concentrations of Cl and K. Same situation is observed for S with some exceptions in the spots S1-C, S2-A and M2-A.

The mineral nutrients, as Mn, Fe and Zn, are associated with the activation of many enzymes of the plants [7]. Due to the lack in minerals nutrients for the soils related to *M. nanchititlensis*, this plant should be adapted to have an efficient physiological absorption process to obtain from ground the most mineral it can; or in other way, it is a plant adapted with a physiologic system which requires few metallic ions to live. Also its metabolic processes may be slower than for the other two species of *Manfreda*. For these reasons, a better understanding about the endemic conditions of the *M. nanchititlensis* to the Temazcaltepec region require more studies about its physiological processes in order to relate them to the soil characteristics.

For example, the amount of the proline amino acid in root cells is associated directly to the osmotic potential, and then to the capacity of the plants to extract more water from the ground [7]. A greater amount of proline increases the capacity to obtain more mineral nutrients. A comparison of the quantity of proline in the root cells for the three *Manfreda* species studied may give some information about the ability of *M. nanchititlensis* for growing in soils with lower concentration of mineral nutrients.

CONCLUSIONS

The *M. scabra* is a plant which grows in places with soils more alkaline and rich in nutrients than for the other two species studied. From the electrical conductivity measurements and elemental concentration obtained by PIXE for the analyzed soils, is possible to establish that the *M. nanchititlensis* grows in places with lower mineral nutrients content than the other two species. Especially a lack in Mn nutrients was determined. Further studies about the physiological conditions of this specie are required in order to relate the metabolic characteristics of the plant with the soil properties where they grow.

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