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The Distribution and Coexistence of Some Wild Plants in Relation to Mineral Nutrient Availability in a High Sodium Polluted Site in Central Sudan

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Abstract: The factors affecting the distribution and coexistence of *Cyperus laevigatus*, *Typha angustata* and *Paspalum viginatum*, in a high sodium polluted site in central Sudan, were investigated. The high sodium content of the site was mainly due to effluents from a near by textile factory where high quantities of Na compounds, like: NaOH, Na_2CO_3, Na_2SiO_3 and $NaHCO_3$ were used in the textile processes. The investigation was carried out by chemical analysis of soil and plant samples and computation of correlation coefficients between soil nutrients and ion uptake by the investigated plants. Soil and plant samples, from the investigated site, were collected from 35 sampling points of 80×120 m rectangular grid, each point is 20 m distant from the other neighboring points. Soil chemical analysis data showed that the investigated site was moderately alkaline and characterized by very high content of Na, reasonably high content of Ca, adequate quantities of Mg, K and Fe, low content of NH_4-N and P and very low content of Mn. The plant chemical analysis results clearly reflect the different nutritional requirements of the examined plant species. Correlation analysis between soil nutrients and ion uptake by the investigated plants showed that the uptake of a mineral ion by any of the three investigated plant species may be accelerated, slowed down, or may have no obvious effect by another ion in the soil. Moreover, correlation and regression analysis clearly reflect the different patterns of mineral nutrient uptake by the investigated species and hence niche differentiation and coexistence between the investigated species in the investigated site.

Key words: Mineral nutrients, distribution, coexistence, *Cyperus laevigatus*, *Typha angustata*, *Paspalum viginatum*

INTRODUCTION

The effects of mineral nutrients availability on plant distribution have been widely investigated (Hayati and Proctor, 1990; Taiz and Zeiger, 1998). Actually, much of the variation commonly seen in natural vegetation of the semi-arid climatic zone of central Sudan can be related to availability and cycling of mineral nutrients (Hayati and Yahia, 2002).

The disposal of high levels of minerals and chemicals from industrial activities on natural soils often alters the natural environment and may change the levels of the soil mineral ion concentrations (Smith *et al*., 1996; Sparks, 2003). In other words, the disposal of high levels of minerals on natural soils alter soil chemistry and set new conditions for plant distribution and abundance.

The objective of this study was to examine the factors affecting the distribution and coexistence of *Cyperus laevigatus*, *Typha angustata* and *Paspalum viginatum*, in an area polluted by high sodium content from a textile factory at Al-Bagair Industrial compound, in central Sudan. No detailed work had been done on the distribution of these species and so little is known about their ecological behavior. It is hoped that this investigation will contribute to a better understanding of the ecology of the investigated species and to highlight the significant aspects of plant nutrient responses that can be used for subsequent investigations.

MATERIALS AND METHODS

Description of the study site: The site chosen for this study in central Sudan, is about 35 km Southeast Khartoum. The site was characterized by very high content of Na. The high sodium content of the site was mainly due to effluents from a near by textile factory where high quantities of Na compounds, like: NaOH, Na_2CO_3, Na_2SiO_3 and $NaHCO_3$ were used in the textile processes. The climatic regime at the site is typical to that of the southern fringes of the African tropical semi-desert. Rainfall is low with the mean annual of 150 mm. The brief rainy season, which usually occurs in the summer season (June-September), consists mainly of erratic showers and few rainstorms. Air temperatures were characterized by large daily and annual ranges. The mean maximum temperature ranges between 31°C in December and

January and 42°C in April and May. Relative humidity is generally low, reached a maximum of 50% in August and a minimum of 18% during March, April and May.

The site represents the northern part of the Gezira clay plain. It is part of the Nubian Sandstone formation which is covered with alluvial deposits called Gezira clay that consists of clay, sand and gravel (Kheiralla, 1966). It has been concluded that the Gezira soil formation was polygenetic, i.e., the clays were brought about by the rivers flowing from the Ethiopian volcanic plateau and the coarse fraction was probably derived from the erosion of the Nubian sandstone formation and basement complex (Hayati and Abd-Elrahman, 2006).

The study site located in the semi-arid region of the Sudan, was described as part of the *Acassia* Desert Scrub characterized by some woody species like: *Acassia ehrebergiana*, *Acassia tortiles*, *Acassia spirocarpa* and *Acassia seyal*; one perennial, *Panicum turgidum* and few annuals like: *Schoenfeldia gracilis*, *Eragrostis pilosa* and *Cassia senna* (Hayati and Abd-Elrahman, 2006). Within the study area a site was selected for this study. This site was affected by disposals of chemical effluents from a textile factory and characterized by the following dominant plant species: *Cyperus laevigatus*, *Typha angustata* and *Paspalum viginatum.*

Chemical analysis of soil and plant samples: Soil and plant samples, from the investigated site, were collected from 35 sampling points of 80×120 m rectangular grid, each point is 20 m distant from the other neighboring points. The samples were taken from the plough depth (15-20 cm), because the plough layer is thought to be the most useful part of the soil and will best represent its ability to supply nutrients. The samples were placed in plastic bags and stored in the laboratory at temperature of about 25°C.

To estimate the mineral nutrient uptake of the examined plant species, the newly formed leaves of each plant were collected from the sampling points of the investigated site. The samples were dried at 45°C for several hours in an oven and ground to produce sufficiently homogenous materials for representative quantities to be taken for analysis.

Cations, Ammonium nitrogen and phosphorus (expressed in mg/100 g soil), were extracted from a measured volume of soil (5 g from each sample). Cations were extracted with ammonium acetate at pH = 7; Ammonium nitrogen was extracted with 6% sodium chloride and extractable phosphorus with 2.5% acetic acid.

Samples of an oven-dry plant material were digested with a sulphuric acid-hydrogen peroxide mixture, using selenium as a catalyst, in a digestion block apparatus. After digestion, the cold digest was diluted slightly and boiled to redissolve any precipitated ferric sulphate, filtered and made up to volume with deionized water.

Analytical procedures, in general, followed those of Hayati and Proctor (1991), Hendry and Grime (1993) and Harris (2002). K and Na were estimated by flame emissions and other metallic cations by atomic absorption spectrophotometer. Ammonium-nitrogen was estimated colorimetrically using the Nessler reaction method. Phosphorus was analysed colorimetrically by the molybdenum blue method using the spectrophotometer. The pH of the collected soil samples was determined on a 1:2 suspension of a soil sample in deionized water, using a glass electrode.

Correlation coefficients between soil and plant variables were computed using the subprogram FACTOR of SPSS (Oliver, 2007).

RESULTS AND DISCUSSION

Soil chemical analysis data showed that the investigated site was moderately alkaline and characterized by very high content of Na, reasonably high content of Ca, adequate quantities of Mg, K and Fe, low content of NH_4-N and P and very low content of Mn (Table 1).

C. laevigatus was present at 23 sampling points of the 80×120 m rectangular grid, which contains 35 sampling points at the investigated site: whereas, *Typha angustata* and *Paspalum viginatum* were present at 10 sampling points each. Actually, *C. laevigatus* and *P. viginatum* were mainly found at the periphery of the experimental grid; whereas, *T. angustata* was mainly located at the central part of the grid.

Taken as a whole, the results of the chemical analysis of the plant material were broadly within the expected range of the elements reported in the literature (Epstein, 2004). The chemical analysis results showed some differences in the uptake of mineral ions between the investigated species. For instance, *C. laevigatus* showed relatively higher uptake of Ca and Mn and low uptake of P; *P. viginatum* showed high uptake of Fe and low uptake of Ca: whereas, *T. angustata* showed relatively lower uptake of Fe and Mn (Table 2).

Table 1: Summary of the soil chemical analysis data: pH and extractable ions expressed in mg/100 g soil of the investigated site

Minerals	Values
Fe	17.96±2.53
NH_4-N	5.86±1.25
P	4.75±1.31
K	63.44±150.13
Na	280.58±118.72
Mn	0.52±00.20
pH	8.32±00.78
Ca	193.58±046.45
Mg	60.83±020.0

Values are means±SD, calculated from 35 samples

Table 2: Chemical analysis of plant material from the investigated site

	No. of samples		
	23	10	10
Minerals	*Cyperus laevigatus*	*Typha angustata*	*Paspalum viginatum*
Mn	0.041±0.020	0.029±0.014	0.036±0.013
Fe	0.054±0.022	0.039±0.025	0.155±0.059
P	0.353±0.056	0.377±0.037	0.417±0.122
N	1.331±0.380	1.730±0.360	2.081±0.510
Mg	0.743±0.222	0.819±0.251	0.817±0.227
K	0.987±0.366	0.939±0.199	0.951±0.178
Ca	2.148±0.608	2.004±0.650	1.565±0.488
Na	2.626±0.630	2.361±0.366	2.630±0.272

Values given are mean±SD, expressed as percentage dry-weight of plant material

Table 3: Summary of correlations (r) between the element content of the investigated plant species (in the left column of the table) and extractable nutrient concentration of the investigated site (in the cells of the table)

	Species		
Minerals	*Cyperus laevigatus*	*Typha angustata*	*Paspalum viginatum*
Mn	Na^{+}**	P^{-}*	-
		Fe^{-}*	
Fe	Ca^{-}*	-	pH^{+}
			Na^{+}**
			Mg^{-}*
P	-	Ca+ *	pH^{+}**
			NH4-N^{-}*
			P^{+}*
			K^{-}**
			Fe^{-}*
N	-	-	-
		-	P^{-}*
Mg	K^{+}*	-	K^{+}*
	Na^{+}*		
	Mn^{-}*		
	pH^{+}*		
K	Mg^{+} *	Fe^{-}**	NH4-N^{+}*
		Mg^{-}*	Na^{+}*
		pH^{-}*	
Ca	Na^{+}**	-	NH4-N^{+}*
	P^{+}**		
Na	Mn^{+}*	Ca^{-}*	-

*: $p<0.05$; **: $p<0.01$

Calculated correlation coefficients between soil mineral nutrient factors and ion uptake by the three investigated plant species for all combinations of elements gave 72 comparisons for each species (216 comparisons for the three investigated species). Of these only 30 significant correlations were emerged; 5 with r corresponding to $p<0.01$ and 25 with r corresponding to $p<0.05$ (Table 3).

The distribution of *Cyperus laevigatus*, *Typha angustata* and *Paspalum viginatum* in the examined site was very much related to the availability of soil mineral nutrients. For instance, *C. laevigatus* and *P. viginatum* cover the periphery of the investigated site which was characterized by relatively high levels of pH, Ca, Mn and Na and they avoid the central part of the experimental area characterized by relatively low levels of pH, Ca, Mn and Na. The central part of the investigated site was mainly covered by *T. angustata.*

The soil chemical analysis data showed that the investigated site was characterized by very high content of Na. This was mainly due to effluents from a near by textile factory where high quantities of Na compounds, like: NaOH, Na_2CO_3, Na_2SiO_3 and $NaHCO_3$ were used in the textile processes. These high Na levels have great impact on the uptake of Na and K ions by the investigated plant species, which showed high levels of sodium uptake accompanied by a considerable potassium decline. This halophytic feature happened as a regulatory mechanism (Turhan and Eris, 2004; Wang *et al*., 2006), by the plants to avoid the toxic and osmotic effects caused by high Na concentrations.

The chemical analysis data of the examined plant species showed only limited variation of chemical composition in relation to differences in the extractable elements in the soil. From one point of view, this was not surprising, because plants regulate their uptake of essential elements (Taiz and Zeiger, 1998). On the other hand some differences in the uptake of mineral ions between the investigated species were observed (Table 2). For instance, *C. laevigatus* showed relatively higher uptake of Ca and Mn and low uptake of P; *P. viginatum* showed high uptake of Fe and low uptake of Ca: whereas, *T. angustata* showed relatively lower uptake of Fe and Mn. These differences were most likely due to the fact that the examined plant species have different requirements for the essential elements.

The results of correlation analysis showed that the uptake of a mineral ion by any of the three investigated plant species may be accelerated, slowed down, or may have no obvious effect by another ion in the soil. These three possibilities represent all the possible kinds of interactions between the different elements envisaged by Epstein (2004). For instance, the results of this study showed that, soil Na was found to be positively associated with Ca uptake by *C. laevigatus* (Fig. 1) and soil Mg was found to be positively associated with Na uptake by the same species (Fig. 2). On the other hand soil Mg showed negative association with K uptake by the *T. angustata* (Fig. 3) and soil K showed negative association with P uptake by *P. viginatum* (Fig. 4). The great deal of non-significant correlations between soil mineral nutrient factors and ion uptake by the investigated species, however, represent the third possibility of interaction between the different elements i.e., a soil ion may have no obvious effect on the absorption of another ion.

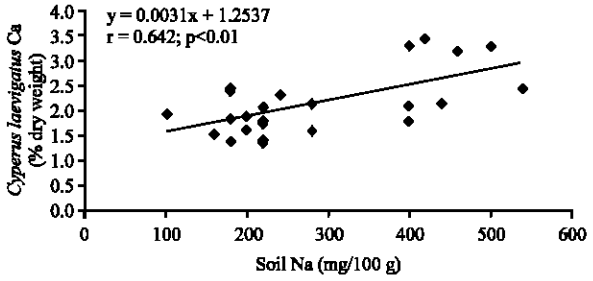

Fig. 1: The relation of *Cyperus laevigatus* Ca to soil Na

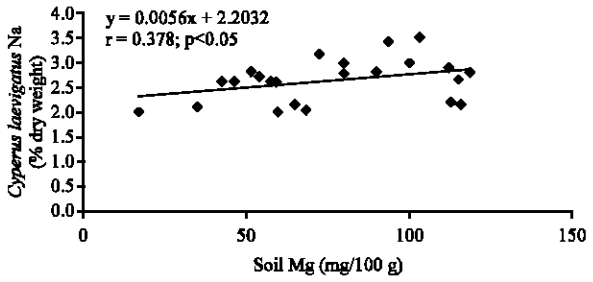

Fig. 2: The relation of *Cyperus laevigatus* Na to soil Mg

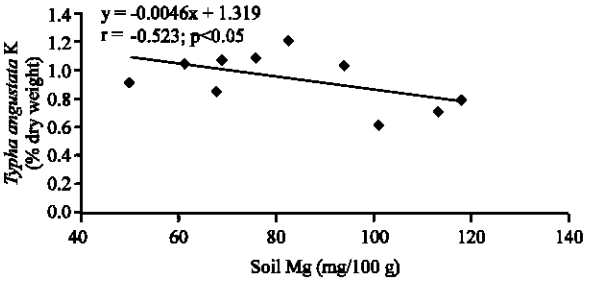

Fig. 3: The relation of *Typha angustata* K to soil Mg

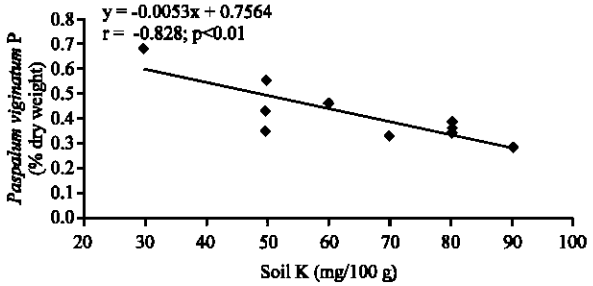

Fig. 4: The relation of *Paspalum viginatum* P to soil K

The great deal of non-significant correlations revealed in this study was in line with the findings of Hayati and Proctor (1990), who found that the leaf material of wild plant species in South-west England had limited variation of chemical composition in relation to differences in the extractable elements in the underlying soil. It was also reported that tissue-nutrients concentrations of wild plants are less sensitive indicators of soil nutrient availability than those of crop species (Epstein, 2004; Semmartin *et al*., 2007). This may imply that either, the nutrient elements of wild plants in natural communities are close to their limiting concentrations or wild plant species are more efficient in regulating their uptake of minerals than crop plants.

The results of correlation and regression analysis clearly reflect the different patterns of mineral nutrient uptake by the investigated species. These different patterns bring about niche differentiation between the investigated species and hence their coexistence in the investigated site.

In conclusion, this study showed that the distribution and coexistence of examined plant species at the experimental site were mainly related to their different patterns of mineral nutrient requirements and different patterns of mineral nutrient uptake.

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