EFFECT OF PHYTOREMEDIATION WITH *Atriplex nummularia* IN IRRIGATED SOILS WITH SALINE WASTE

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SUMMARY

In the semi-arid region of northeastern Brazil, the *Atriplex* plant genus has been efficient in removing salts from soils irrigated with saline wastewater. However, this removal might not be significant compared with the amount of salts added to the soil by the wastewater irrigation. Considering this aspect, the aim of this work was to evaluate the effectiveness of *Atriplex nummularia* Lindl plants in the remediation of a soil submitted to saline wastewater irrigation. Despite the known inhibition effect of saline wastewater on soil enzyme activity, the cultivation of *Atriplex nummularia* Lindl maintained the treated soil enzyme activity levels similar to the ones found in natural soils.

1. INTRODUCTION

In rural areas of the semi-arid northeast region of Brazil, the salty well-water is passed through a desalinization process resulting equal parts of potable water for human consumption and residual saline wastewater. This is a highly salty environment-damaging residue, which alternative uses might be the selective salt crystallization, citrus seedling irrigation, tilapia fish growth (*Oreochrimis sp*) and shrimp growth. Fishes and shrimps recycle the water salts. However, as they need constant water oxygenation, part of the tank water must be daily renewed. The wastewater from the fish and shrimp growing tanks is used for the *Atriplex nummularia* Lindl irrigation, known as a highly salt tolerant halophyte plant (Porto et al., 2006[1]). Nevertheless, the use of this wastewater for irrigation might induce a secondary soil salinization, causing adverse effects on the soil chemical and physical attributes and biological processes (Tejada & Gonzalez, 2005[2]). Thus, the aim of this work was to evaluate the effects of saline wastewater irrigation, from 'Tilapia-rosa' fish growing tanks, on the chemical, physical and microbiological attributes of a soil cultivated with *Atriplex nummularia*, Lindl.

2. MATERIAL AND METHODS

This study was carried out in the Experimental Field of "Caatinga", of Embrapa-Semi-Arid, at Petrolina, State of Pernambuco, Brazil. The soil was classified as an abrupt plinthic eutrophic Yellow Argissol, containing: 10% clay, 14% silt and 76% sand. In the experimental area, the average rainfall is 400 to 600 mm year^{-1}, mostly during summer, with average air temperature between 28 and 35^{o}C. The average annual potential evapotranspiration is 2,680 mm.

Four areas were identified and soil samples were collected for analysis: (I) area with native vegetation without irrigation; (II) area cultivated with *Atriplex nummularia* without irrigation; (III) area cultivated with *A. nummularia* and irrigated with saline wastewater during one year; (IV) area cultivated with *A. nummularia* and irrigated with saline wastewater during five consecutive years. The wastewater was applied by dripping irrigation. The soil samples were collected at 0-10 and 10-20 cm depth, close to the plants, during April, 2005, in the end of the rainy season; in August, 2005, in the dry season; and in March, 2006, in the rainy season. The soil physical and chemical attributes such as pH and electrical conductivity (EC) were measured in soil/water extracts (1:2.5 w/v). Organic carbon content was determined by the combustion method at 540^{o}C. The total-N content was determined by Kjeldahl-digestion. The available-P was extracted with bicarbonate and the available and exchangeable cation contents (Na, Ca, Mg, K) were determined by Atomic Absorption Spectrophotometry after acid digestion. The sodium adsorption rate (SAR) was calculated according to Lafuente (1990[3]). The following microbiological factors were evaluated: microbial biomass carbon (Cmic); enzymatic activities of β-glucosidase, acid and alkaline phosphatase, protease, L-glutaminase and L-asparaginase. Data was submitted to analysis of variance and means were compared by the Multiple Range Test ($P < 0.05$), using the Statgraphics Plus 5.0 software.

3. RESULTS

The saline wastewater analysis results were: pH between 6.7 and 8.1; average electrical conductivity (EC) of 9.32 dS m^{-1}; high average contents of Na^{+} (49.88 mmol$_c$ L^{-1}), Mg^{2+} (32.67 mmol$_c$ L^{-1}) and Ca^{2+} (20.83 mmol$_c$ L^{-1}); and moderate contents of K^{+} (0.94 mmol$_c$ L^{-1}).

The soil analysis results were: low pH (5.2-6.1); low organic matter content (5.9 g dm^{-3}); high available P content (6.33 mg dm^{-3}) and low available cation contents (Na^{+} = 0.21 $mmol_c$ L^{-1}; Mg^{2+} = 2.7 $mmol_c$ L^{-1}; Ca^{2+} = 2.8 $mmol_c$ L^{-1}; and K^{+} = 0.31 $mmol_c$ L^{-1}).

The physical and chemical attributes of soil samples from III treatments (one year of irrigation) and IV (five years of irrigation) were affected by the wastewater salt content (Table 1). In IV treatment, the exchangeable Na-content was higher in the superficial soil layer than the available Na content (in the soil solution). Nevertheless, after five years of wastewater irrigation (treatment IV), the soil presented much higher values of EC and exchangeable-Na as compared to the III treatment. In both treatments (III and IV), the soil tended to show saline-sodic characteristics. The soil pH did not exceed 7.2 and there were no significant differences between treatments and soil layers.

Soil porosity (P) increased around 10% (no significant differences between III and IV treatments) indicating that the disaggregating salt effect favored the soil structure. In III treatment, the superficial soil layer presented increased EC values (from 0.1 dS m^{-1} to 2.8 dS m^{-1}) and increased exchangeable-Na (%). The pH values did not exceed 5.9. The same results and data variability were observed in the subsuperficial soil layer.

The treatments without wastewater irrigation showed no variation in the EC, exchangeable Na and SAR values. For all treatments, the regression analyses of exchangeable-Na (% E-Na) versus porosity (P) in the soil superficial layer were not significant. The same was observed for EC vs P. However, there was correlation between SAR and P and between SAR and % E-Na (significant r^2= 0.79 and 0.92, respectively), indicating the influence of the salt in the soil structure and in the progressive soil salinization.

TABLE 1. Physical and chemical parameters in soils cultivated with *Atriplex nummularia* Lindl and irrigated with saline wastewater during one and five years (III and IV treatments, respectively).

Variables*	Depth (cm)	Assessment period					
		III Treatment		IV Treatment			
		2005	2006	2000	2004	2005	2006
	0-30	0,1	2,75	0,3	4,6	7,0	11,5
EC (dS m-1)	30-60	0,8	3,25	0,6	5,4	5,7	5,9
	60-90	0,8	2,98	0,6	6,7	7,2	8,2
	0-30	0,37	13,75	0,2	7,7	13,9	8,5
SAR (mmol(+) L-1)	30-60	0,44	15,64	0,2	13,5	17,2	12,8
	60-90	0,36	14,75	0,2	15,7	15,4	12,8
	0-30	0,26	13,92	0,7	1,0	51,7	35,7
E-Na (%)	30-60	0,31	17,13	0,5	1,5	38,9	30,9
	60-90	0,37	18,06	0,4	1,5	30,2	31,4
	0-30			46,9	49,4	47,3	53,9
Porosity (%)	30-60			46,7	51,4	48,5	48,3
	60-90			48,7	49,4	46,6	54,4

* EC = electrical condutivity in 1:2.5 soil solution (w/v); SAR = Sodium absorption rate; E-Na= exchangeable-Na.

Os teores de carbono orgânico total, nitrogênio total e fosfato disponível, analisados antes e depois das determinações enzimáticas estão descritos na Tabela 2.

TABLE 2. Chemical properties mensured at the onset and at the end of experimental period.

Parameters	Treatments*							
	I	II	III	IV	I	II	III	IV
	At the onset of experimental period				At the end experimental period			
	Depth 0-10 cm							
Organic carbon (%)	0,68b	0,82a	0,52d	0,64c	0,72b	1,46a	1,48a	0,76b
Total Nitrogen (%)	767b	892a	520c	575c	476c	1252a	465c	656b
Phosphorus (mmol L^{-1})	28,3ab	34,5a	25,4ab	13,7c	19c	129,9a	14,4d	22,9b
	Depth 10-20 cm							
Organic carbon (%)	0,68b	0,87a	0,50d	0,61c	0,76c	1,13b	1,45a	0,73c
Total Nitrogen (%)	716b	880a	512d	610c	419c	825a	455c	538b
Phosphorus (mmol L^{-1})	25,0b	34,5a	16,7c	10,1c	11,8c	56,4a	14,3bc	15,7b

*(I) area with native vegetation without irrigation; (II) area cultivated with *Atriplex nummularia* without irrigation; (III) area cultivated with *A. nummularia* and irrigated with saline wastewater during one year; (IV) area cultivated with *A. nummularia* and irrigated with saline wastewater during five consecutive years.

Means followed by the same letter(s) in each line are statiscally the same at $P \leq 0.05$ (LSD´s Test)

The increasing soil salinity usually affects plants and soil microbiota. Nevertheless, in the present work, Cmic was not significantly affected by salinity stress. The obtained results for the six enzyme activities analyzed in all treatments are presented in Table 3. Although there were significant differences among treatments, in general, the enzyme activities did not respond in any period to a more favorable edaphic environment. It was observed that the highest values for the enzymatic activities ($P < 0.01$) were found in the soil samples from II treatment, cultivated with *Atriplex* and without saline wastewater irrigation, indicating that this area presented a more active microbiota, including bacteria and fungi.

However, the native vegetation soil without irrigation presented a differentiated values and behavior (in relation to the soil cultivated with *Atriplex nummularia*, that is, the enzymatic activities levels were similar to or significantly lower than the activities found in the saline wastewater irrigated soil ($P < 0.01$), as it was the case of the alkaline phosphatase.

TABLE 3. Eletric conductivity (EC), microbial biomass carbon (Cmic) and enzymatic activities of β-glucosidase, acid and alkaline phosphatases, protease, L-glutaminase and L-asparaginase in soils with and without saline wastewater irrigation.

Parameters	Treatments*			
	I	II	III	IV
	Depth 0-10 cm			
EC (dS m^{-1})	0.38c	0.28c	1.56b	1.99a
Cmic (□g g^{-1} de solo)	109.9c	267.2b	71.9c	325.9a
β-glucosidase	19.64b	60.0a	8.55d	12.8c
Acid phosphatase	25,7c	43.8a	30.8b	16.0d
Alkaline phosphatase	19.4d	64.8a	27.5c	34.4b
Protease	22.31b	167.8a	35.7b	53.3b
L-glutaminase	220.0b	257.5a	103.1d	171.9c
L-asparaginase	18.0c	24.3a	16.6c	20.8b
	Depth 10-20 cm			
EC (dS m^{-1})	0.49c	0.39c	1.16b	1.44a
Cmic (□g g^{-1} de solo)	145.8b	232.8a	97.8c	144.7b
β-glucosidase .	16.0b	32.6a	7.1c	14.2b
Acid phosphatase	36.9b	43.0a	31.6c	20.3d
Alkaline phosphatase	20.6d	48.7a	26.9c	38.1b
Protease	42.4c	106.8a	45.9c	96.3b
L-glutaminase	207.4b	245.2a	105.1c	197.8b
L-asparaginase	13.9c	15.3b	16.4b	17.5a

*(I) area with native vegetation without irrigation; (II) area cultivated with *Atriplex nummularia* without irrigation; (III) area cultivated with *A. nummularia* and irrigated with saline wastewater during one year; (IV) area cultivated with *A. nummularia* and irrigated with saline wastewater during five consecutive years.

Means followed by the same letter(s) in each line are statiscally the same at $P \leq 0.05$ (LSD's Test)

4. CONCLUSION

In general, the *Atriplex* cultivation promoted the enzyme production. The root exudates contain enzymes and other substances that can increase the soil nutrient availability to the plants (Lambers et al., 2002). Besides, the root exudates can also stimulate the microorganism growth in the rhizosphere (Dakora & Phillips, 2002).

5. REFERENCES

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