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EFFECT OF SALINITY ON CARBON AND NITROGEN TRANSFORMATIONS IN SOIL

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Abstract

Powdered plant tops of *Diplachne fusca* and *Sesbania aculeata* were mixed with soil and incubated at 27-30°C for 90 days to study the effect of different salinity levels on C and N mineralization, humus formation, humification productivity and soil microflora. The results indicate that increasing salinity depressed the rate of carbon mineralization and its transformation into stable organic matter. Similarly the fungal and bacterial population was also suppressed. However, ammonia volatilization increased with the increase in salinity resulting in greater nitrogen losses which were more in case of *S. aculeata* amendment than *D. fusca*.

Introduction

Salinity and sodicity are the two major problems of agriculture in Pakistan. Such soils can be reclaimed by chemical amendments such as gypsum, $CaCl_2$, sulphur etc. (Yadav & Agarval, 1961; Hussain, 1969) or the addition of organic matter (Kanwar *et al,* 1965 ; Saubern *et al,* 1968; Hussain, 1969; Sandhu & Malik, 1975). Due to high cost of chemical amendments and non-availability of organic manure in Pakistan, Sandhu & Malik (1975) proposed a plant succession scheme whereby a salt tolerant grass *(Diplachne fusca)* is used as primary colonizer which is followed by a fast growing leguminous plant, *Sesbania aculeata.* Both the primary and secondary colonizers are used as a source of organic matter as these are ploughed under and allowed to decompose in the soil. The beneficial effects are derived from the evolution of CO_2 during microbial decomposition of plant residues (Overstreet *et al,* 1955; Goertzen & Bower, 1958, Puttaswamygowda & Pratt, 1973; Malik & Haider, 1977; Malik, 1978), which helps in the solubilization of $CaCO_3$ naturally occurring in most of saline-sodic soils; thus facilitating the replacement of exchangeable sodium from the colloidal complex which could then be easily leached down.

Since the decomposition of organic matter is an important step in the above mentioned reclamation procedure for salt affected soils, laboratory incubation studies have been conducted to see the effect of increasing saline-sodic levels of soil on carbon and nitrogen mineralization and its effect on microflora and humus composition of the soil, amended with powdered plant tops of *D. fusca* (Kallar grass) and *S. aculeata* (Dhancha) separately as a source of organic matter.

Materials and Methods

The soil used for this study was a sandy clay loam collected from the Institute campus and had previously been sown to wheat. It had 58% sand, 26% silt and 16% clay. The organic carbon was 0.6% and nitrogen was 0.10%.

Soil passed through 2 mm sieve was artificially salinized by adding a mixture of Na_2SO_4, $CaCl_2$, $MgCl_2$ and NaCl in a ratio of 10:5:1:4 and in quantities sufficient enough to obtain desired salinity levels. The electrical condutivity, pH, soluble Ca^{+2} + Mg^{+2} and Na^+, sodium adsorption ratio (SAR) and exchangeable sodium percentage (ESP) of salinized soils is summarized in Table 1.

Table 1. Chemical analysis of artificially salinized soil.

EC_e prepared Sm^{-1}	EC_e obtained Sm^{-1}	pH	C_a^{+2}+Mg^{+2} me/l	Na^+ me/l	SAR	ESP
Control	0.08	7.80	13.00	10.9	4.26	6.40
0.5	0.56	7.95	18.70	34.78	11.40	13.50
1.0	0.99	8.00	28.10	68.50	18.30	20.50
1.5	1.41	8.50	30.80	119.56	30.50	30.40
2.0	1.95	8.80	46.00	215.20	44.90	39.40

EC_{e1} = Electrical conductivity of soil saturation paste
Sm^{-1} = Siemens/meter

Artificially salinized soil samples (150 g on an air dry basis) were placed in 1 litre Erlenmeyer flasks and thoroughly mixed with 1% powdered *D. fusca* and *S. aculeata* plant material separately and brought to 60% water holding capacity. The flasks were stoppered with rubber bungs fitted with two glass rods having small cups at their ends. The two cups contained 5 ml of 0.5 N NaOH and 0.5N H_2SO_4 to absorb CO_2 and NH_3, respectively. Duplicate flasks were kept for each salinity level and organic amendment. The prevailing laboratory temperature during incubation was from 27-30°C.

The evolution of CO_2 and NH_3 were estimated titrimetrically after different periods of incubation. Each time fresh volume of NaOH and H_2SO_4 was added to the cups. After three months of incubation, at the termination of the experiment, total nitrogen, ammonical nitrogen, nitrate nitrogen (Bremner, 1965) and humus composition of the soils (Malik & Haider, 1977) were determined. Total residual organic carbon of the incubated soils was also estimated. The microflora of the soil including total bacterial and fungal counts and types of fungi associated with the decomposition of organic matter were also noted. For the determination of frequency of occurrence of cellulolytic fungi Warcup's direct plate method (Warcup, 1961) using cellulose agar (Eggins & Pugh, 1962) was adopted. For total fungal and bacterial counts, soil dilution plate method, as modified by Booth (1971), was used. Cellulose agar was used for fungal counts whereas malt extract agar was used for bacterial counts.

Results

Effect on carbon mineralization:

The results of accumulative losses of CO_2 as an index of the rate of C-mineralization over a period of 90 days (Fig. 1) indicate that the rate of CO_2 evolution declined with the increase in soil salinity as represented by electrical conductivity (EC) values. The rate of decomposition of *S. aculeata* plant material was faster than that of *D. fusca* Fig. 1) and is attributable to the high microbial activity in soil amended with *S. aculeata.* At lower salinity levels there was not much effect on CO_2 evolution; it rather increased in both the amendments at 0.5 Sm^{-1}. Salinity beyond this level affected the rate of CO_2 evolution to a great extent. After 90 days of incubation, the quantity of carbon mineralized under control was nearly double the quantity mineralized at 2.0 Sm^{-1}. The overall results show that at lower salinity levels and enhanced C-mineralization rate could be expected which then decreased with further increase in salinity level.

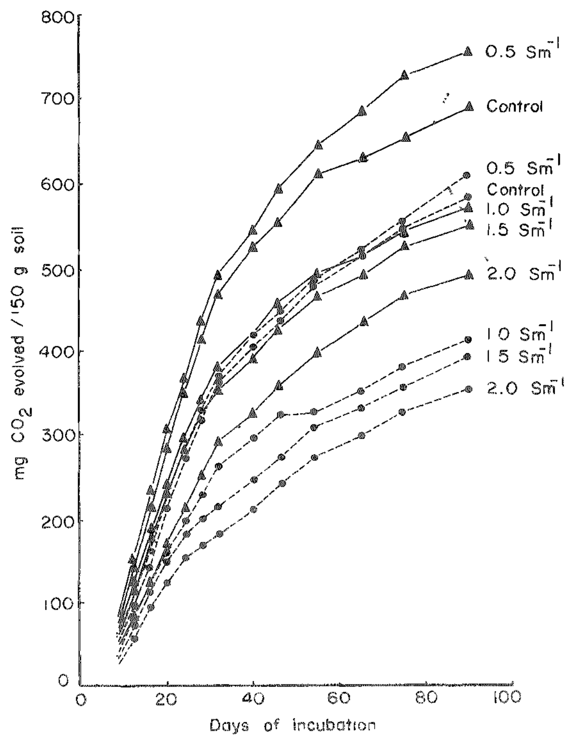

Fig. 1. Effect of different salinity levels on the carbon dioxide evolution from soil amended with *S. aculeata* (—▲—) and *D. fusca* (—●—).

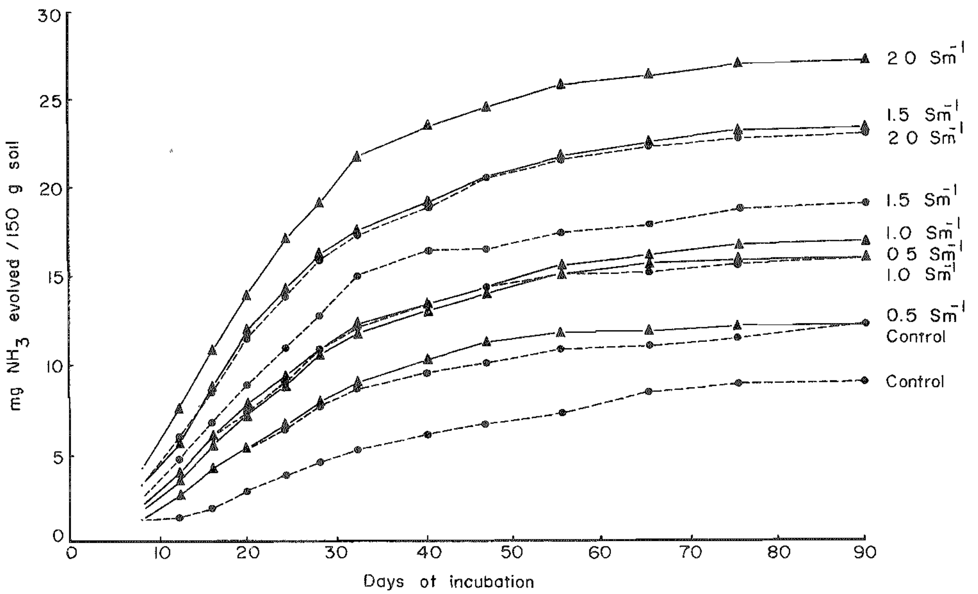

Fig. 2. Effect of different salinity levels on NH_3 volatilization from soil amended with *S. aculeata* (–▲–) and *D. fusca* (---●---).

Effect on nitrogen mineralization:

The results of ammonia volatilization are presented in Fig. 2 which indicate an inverse relationship to the carbon mineralization as the ammonia evolution increased with the increase in salinity. There was relatively high rate of ammonia evolution during the first 30 days after which it slowed down. However, more ammonia was lost in case of *S. aculeata* amendment as compared to *D. fusca* amendment. This is primarily due to higher nitrogen content of *S. aculeata*. The total amount of ammonia liberated at the end of incubation period in both the amendments at 2.0 Sm^{-1} was nearly 2.5 times the quantity evolved in the controls.

The results regarding ammonium and nitrate nitrogen are summarized in Table 2. A progressive decrease in both NH_4 and NO_3 nitrogen was observed with the increase in salinity. The decrease in NH_4 was slightly more than NO_3. Though the amount of these forms of nitrogen at the highest salinity level was nearly half of the control, complete inhibition of nitrate or accumulation of ammonium was not observed as reported by Laura (1974). However, the total mineralized nitrogen including volatilized ammonia remained in the same order of magnitude at all the salinity levels and with both the amendments. This conclusion regarding the rate of mineralization could be misleading as in this case the major mineralizable fraction is lost due to volatilization which increases with the increase in salinity and thus compensates for the decrease in ammonium and nitrate forms of nitrogen.

Table 2. Effect of organic amendment and salinity on mineralization of organic nitrogen after 90 days of incubation at 27-30°C.

EC_e Sm^{-1}	NH_4-N	NO_3-N	NH_3-N	Total
		D. fusca amendment		
Control	70	70	60	200
0.5	70	78	80	228
1.0	42	50	110	202
1.5	46	56	130	232
2.0	39	42	160	241
		S. aculeata amendment		
Control	84	84	80	248
0.5	56	73	110	239
1.0	47	50	120	217
1.5	50	53	160	263
2.0	42	45	180	267

Effects on organic matter transformations:

The results of the distribution of carbon and nitrogen in different organic matter fractions are presented in Table 3. Increased salinity had a general depressing effect on the carbon content of humic acid and fulvic acid fraction but in humin fraction, carbon content increased with increased salinity due to the less extractable carbon at higher salinity levels. However, the two amendments when compared together showed that more humic acid C was produced in case of *D. fusca* amendment. Similar results were obtained in case of fulvic acid carbon. This may be attributed to the difference in lignin content of the two organic materials. As regards the relative distribution of carbon in the three fractions, it was found that a major part of the carbon was detected in humin fraction inspite of the fact that the soil was sieved and any undecompsed plant material was removed. It is expected that a part of the undecomposed plant material might have found its way into humin fraction. Fulvic acid fraction contained nearly half the amount of humic acid carbon.

The distribution of nitrogen in different organic matter fractions was similar to that of carbon. There was a general decreasing trend with the increase in salinity. Distribution of N in different organic matter fractions behaved almost similarly at different salinity levels. More nitrogen was found in all the fractions in case of *D. fusca* amendment as compared to *S. aculeata* amendment and is evidently associated with the C content of different fractions.

Effect on microflora:

The results regarding the microbial counts and fungi isolated from soil at different

Table 3. Effect of organic amendment and salinity on the distribution of C and N in various soil organic matter fractions after 90 days of incubation at 27-30°C.

EC_e Sm^{-1}	% of the orginal C and N*					
	Humic acid		Fulvic acid		Humin	
	C	N	C	N	C	N
			D. fusca amendment			
Control	9.0	9.1	4.2	1.7	58.2	69.5
0.5	9.4	9.4	4.4	1.8	57.6	68.7
1.0	8.6	8.9	3.6	1.4	61.3	69.5
1.5	8.1	8.2	4.5	1.8	61.9	67.7
2.0	7.8	7.9	3.5	1.4	63.4	68.1
			S. aculeata amendment			
Control	7.5	8.0	3.6	1.5	50.7	63.6
0.5	6.5	6.8	3.6	1.5	51.3	66.0
1.0	6.8	7.0	3.4	1.4	52.0	56.8
1.5	6.4	7.4	3.1	1.3	54.3	47.1
2.0	5.6	6.2	3.1	1.3	56.8	57.1

*Original organic C for *D. fusca* and *S. aculeata* amendment was 11.25 mg/g soil and 13.00 mg/g soil, respectively.

Original total N for *D. fusca* and *S. aculeata* amendment was 0.506 mg/g soil and 0.61 mg/g soil, respectively.

salinity levels amended either with *D. fusca* or *S. aculeata* are summarized in Table 4. Fungal counts registered an increase at 0.5 Sm^{-1} in case of both *D. fusca* and *S. aculeata* amendment. Increased CO_2 evolution was also observed at this EC. Soil amended with *S. aculeata* had higher fungal and bacterial counts than that of *D. fusca* amendment. The number of different fungal species was higher in case of *D. fusca* amendment than *S. aculeata* treatment. The total number of fungi decreased with the increase in salinity. Among the fungi isolated *Alternaria alternata*, *Chaetomium globosum*, *Cladosporium herbarum*

Table 5. Effect of different salinity levels on humification productivity in soils amended with *D. fusca* and *S. aculeata* after 90 days of incubation at 27-30°C.

EC_e Sm^{-1}	*D. fusca* amendment	S. aculeata amendment
Control	0.34	0.20
0.5	0.33	0.17
1.0	0.32	0.18
1.5	0.32	0.18
2.0	0.32	0.17

Table 4. Effect of organic amendment and salinity on percentage frequency of occurrence of cellulolytic soil microflora and bacterial and fungal counts.

Microflora	EC_e Sm^{-1}					EC_e Sm^{-1}				
	Control	5.0	10.0	15.0	20.0	Control	5.0	10.0	15.0	20.0
	D. fusca amendment					*S. aculeata* amendment				
1. *Fungi isolated:*										
Alternaria alternata	100	50	–	100	50	100	–	–	–	–
Aspergillus flavus	17	–	–	–	–	–	–	–	–	–
A. fumigatus	–	–	–	–	–	–	100	–	–	–
A. janusbrevis	100	–	17	–	–	–	–	–	–	–
A. niger	–	–	–	–	17	100	50	–	83	50
A. niveus	17	–	–	–	–	17	–	–	–	–
A. ochraceous	–	100	–	–	–	–	–	–	–	–
A. parasiticus	50	100	–	–	–	17	17	–	50	–
A. sydowi	–	–	–	–	–	100	–	–	–	–
A. tamarii	100	50	50	–	–	–	17	–	–	–
A. terreus	100	50	50	50	–	100	17	50	17	–
A. versicolor	50	–	–	–	–	–	–	–	–	–
Cladosporium herbarum	–	100	33	–	–	–	–	–	–	–
Chaetomium globosum	17	100	50	17	17	–	–	–	–	–
Curvularia lunata	–	17	–	–	–	50	100	–	–	–
Drechslera australiencsis	–	50	50	100	–	–	–	–	–	–
Fusarium solani	50	50	–	–	–	–	17	–	17	–
Rhizopus arrhizus	100	50	100	17	–	50	83	50	–	50
Stachybotrys atra	–	100	–	–	–	–	–	–	–	–
Trichoderma varide	–	–	–	–	–	17	17	50	–	–
2. *No. Of species:*	11	12	7	5	3	9	9	3	4	2
3. *Fungal counts x 10^3/g soil:*	32	36	26	23	22	35	42	28	23	34
4. *Bacterial counts x 10^5/g soil:*	627	297	365	136	83	677	496	295	167	104

and *Drechslera australiensis* were commonly isolated from the soil amended with *D. fusca*, whereas *Aspergillus niger, A. parasiticus* and *Fusarium solani* were relatively common fungi isolated from soil amended with *S. aculeata.*

Discussion

The results of this study relate primarily to the saline sodic soils. Previously such studies have been carried out either under the influence of salinity (Johnson & Guenzi, 1963; Laura, 1973; Laura, 1974; El-Shakweer *et al,* 1976) or sodicity (Laura, 1976). Since major portion of salt-affected soils in Pakistan is saline-sodic in nature, therefore, this parameter was taken into account in the present investigation. A general decrease in the biological activity was observed which resulted in slow rate of carbon mineralization. Similar results were obtained previously (Malik & Haider, 1977) where ^{14}C labelled *S. aculeata* and barley straw were added to various naturally occurring severe to moderately saline-sodic soils. The decrease in CO_2 evolution has been attributed to the poor microflora of highly saline-sodic soils. During present investigation, both bacterial and fungal counts decreased with the increase in salinity which resulted in the slowing down of carbon mineralization. A similar effect of salinity on the transformation of carbon to humic acid fraction was observed. The humic acid carbon decreased as the salinity increased showing an inverse proportionality in both the organic amendments. However, in *D. fusca* amendment more carbon was transformed into humic acid fraction as compared to *S. aculeata* amendment, apparently due to the difference in lignin content of the two organic materials used. When the results are expressed in terms of humification productivity as the ratio between humic acid carbon produced to the soil carbon lost, *D. fusca* amendment had a better productivity than *S. aculeata* (Table 5). All these values showed slight decrease with the increase in salinity. This decrease in humification productivity at higher salinity levels is probably due to the production of proportionately less humic acid carbon as compared to carbon dioxide evolved.

The overall depression of biological activity also influenced nitrogen mineralization. Ammonium and nitrate nitrogen showed gradual decrease with the increase in salinity but there was no inhibition of nitrification at the salinity levels tested. Sindhu & Cornfield (1967) reported inhibition of nitrification at higher salinity levels and Laura (1974) observed complete inhibition of nitrification at 0.9% salt concentration (ca. 3.6 Sm^{-1}) after 6 months of incubation, whereas Gandhi & Paliwal (1976) did not observe complete inhibition of nitrification at 5.0 Sm^{-1} after an incubation of 6 weeks, though nitrification decreased with the increase in salinity. Similar results have been observed during present investigation.

The nitrogen losses have been found wholly due to ammonia volatilization. Previously (Johnson & Guenzi, 1963; Broadbent, 1965; Sindhu & Cornfield, 1967; Singh *et al,* 1969; Agarval *et al,* 1971; Broadbent & Nakashima, 1971) have reported nitrogen losses by measuring the accumulated nitrogen in the soil. In the present investigation actual ammonia volatilization was measured which accounted for total nitrogen losses. As the soil was kept under aerobic conditions, possibility of nitrogen losses due to denitrification is over ruled. The increase in ammonia volatilization with increase in salinity has also been observed by Ghandhi & Paliwal (1976). This increase inspite of the decrease in biological activity may be attributed to some physicochemical processes which are responsible for ammonium formation (Laura, 1974).

Comparison of the rate of carbon and nitrogen mineralization from *D. fusca* and *S. aculeata* plant material added to saline soils and its transformation to soil organic matter fraction has been made. Both CO_2 and NH_3 evolution was more in the case of *S. aculeata* which is due to high nitrogen content and low lignin content of this plant material whereas *D. fusca* has low nitrogen content and relatively higher lignin which is not readily decomposed.

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