Sodium Chloride induced salinity reduces the microbial processes in soil

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Abstract

Salts accumulation in soil may seriously affect the biological processes and N dynamics in soil. The effect of sodium chloride induced salinity on CO_2 evolution and N mineralization was assessed in a silty clay loam soil during laboratory incubations. Soil was amended with NaCl salt to increase the electrical conductivity of soil from 0.65 dSm^{-1} to 40 dS m^{-1}. Both CO_2 evolution and N mineralization decreased significantly with increasing NaCl salinity, and the reduction was proportional to the NaCl levels. The results showed that increasing NaCl salinity from 0.65 to 40 dS m^{-1} decreased cumulative CO_2 production by 56% and N mineralization by 51% during 40 days of incubation. These results demonstrated that soil microorganisms were highly sensitive to NaCl salinity indicating that salinity is a stress factor and can reduce microbial diversity and control microbial abundance, composition and functions.

Key Words: NaCl salinity, CO_2 evolution, N mineralization

Introduction

Soil salinity is a worldwide problem. More than 40% of soils in the world are faced with salinity problems. It is a serious issue and gradually increasing mostly in arid and semiarid regions of the world. Currently, out of 1.5 billion hectares of cultivated land around the world, nearly 77 million hectares is affected by various types of salinity (Evelin et al. 2009). Salts accumulation in soil may seriously affect the biological processes as well as the N dynamics in soil and exert negative influence on the establishment, growth and development of plants (Sarig and Steinberger 1994). Several studies have reported negative impact of salinity on various soil microbial attributes (e.g., Tripathi *et al*. 2006). Recently Shah and Shah (2012) found that increasing magnesium chloride salinity beyond 4 dSm^{-1} reduced N mineralization in soil by almost 80% during 40 days of incubation. This paper report the effect of NaCl induced salinity on CO_2 evolution and N mineralization in a silty clay loam soil in north Western Pakistan.

Methods

Experimental Site

Soil sample (0-20 cm) was collected from a fallow field in November, 2011 from the Research Farm of Khyber Pakhtunkhwa Agricultural University Peshawar, Pakistan. The site was situated near the eastern end of the Khyber Pass on the Iranian plateau with geographical coordinates 34° 0' 28" North, 71° 34' 24" East with an elevation of 329 meters. The area has a warm to hot, semi-arid, sub-tropical, continental climate. The average annual rainfall in the area is 360 mm with winter dominance. The soil was non-saline (EC=0.65 dS m^{-1}), alkaline (pH 8.2) and low in organic fertility (Shah and Shah 2012).

Incubation Experiments

Soil sample was amended with NaCl salt to raise the electrical conductivity (EC) of soil to 0, 4, 8, 12, 16, 20, 30 and 40 dS m^{-1}. After thorough mixing of NaCl solution with soil, two sets of same treatments were prepared. One set was run for the determination of CO_2 evolution and the other for N mineralization. The CO_2 and N mineralization in soil samples were measured at 28°C during 10, 20, 30 and 40 days of incubations.

Statistical Analysis

Analysis of variance was conducted using a Completely Randomized Design. Means significance at the 1% level were tested using LSD test. The reported values are means of three replications.

Results

Rate of Soil Respiration

The NaCl amendments significantly ($P<0.01$) reduced the rate of CO_2 evolution compared with the control treatment (Table 1). The reduction in rate of CO_2 evolution ranged from 10.1% at 4.0 dS/m to 89.3% at 40 dS/m during 10 days, from 21.6 to 89.9% during 20 days, from 20.8 to 80.4%, during 30 days and from 17.5to 83.3% during 40 days of incubation period compared with the control treatment.

Table 1. Rate of CO_2 evolution (mg/kg soil/ day) as influenced by NaCl induced salinity.

Salinity levels	Incubation period (days)							
	10		20		30		40	
EC dS/m		% Reduction		% Reduction		% Reduction		% Reduction
0	126	-	60	-	64	-	77	-
4	113	10	47	22	50	21	64	17
8	88	30	47	22	43	33	47	39
12	65	48	35	42	33	49	36	53
16	54	57	29	52	30	53	37	51
20	47	62	25	59	20	68	29	63
30	41	68	16	73	23	64	26	66
40	13	89	6	90	12	80	13	83

% Reduction in CO_2 production = [(control – treatment)/control] x 100

Cumulative CO_2 Evolution

The cumulative CO_2 evolution decreased significantly ($P<0.01$) during 40 days of incubation period (Table 2). The maximum cumulative CO_2 of 328 mg/kg soil was produced in the control treatment. However, the cumulative CO_2 production decreased gradually with increasing salt concentration. The results showed that cumulative CO_2 production decreased from 328 mg at EC of < 4 dS/m to only 45 mg/kg soil at EC 40 dS/m during 40 days of incubation period.

Table 2. Cumulative CO_2 evolution (mg/kg) during 40 days of incubation periods as influenced by NaCl induced salinity.

Salinity levels	Incubation period (days)							
	10		20		30		40	
EC dS/m		% Reduction		% Reduction		% Reduction		% Reduction
0	126	-	188	-	251	-	327	-
4	113	10	161	14	211	16	275	16
8	88	30	135	28	178	29	224	31
12	65	48	100	46	133	47	169	48
16	54	57	83	55	113	55	150	54
20	47	62	72	61	92	63	121	63
30	41	68	57	69	80	68	105	68
40	13	89	20	89	32	87	45	86

% Reduction in CO_2 production = [(control – treatment)/control] x 100

Nitrogen Mineralization

The NaCl amendments significantly ($P<0.01$) reduced the N mineralization in soil during 40 days of incubation period (Table 3). The highest reduction in N mineralization occurred in soil with NaCl at EC > 30 dS/m (Table 6). The results demonstrated that increasing salinity to 4 dS/m reduced N mineralization by 16.2% during 10 days of incubation period. The corresponding decrease in N mineralization with further NaCl salt concentration reached 55% at EC 40 dS/m compared with the control treatment during 10 days of incubation period. The extent of reduction in mineralization due to NaCl salinity during 20, 30 and 40 days of incubation was almost similar to that during the first 10 days of incubation.

Table 3. N-mineralization (mg/kgsoil) during 40 days of incubation periods as influenced by NaCl induced salinity.

Salinity level (EC Ds/m)	N mineralization during 10 days		N mineralization during 20 days		N mineralization during 30 days		N mineralization during 40 days	
	-	% reduction	-	% reduction	-	% reduction	-	% reduction
0	38	---	70	---	107	---	129	---
4	32	16	56	20	85	20	115	11
8	35	9	58	18	81	24	111	14
12	31	18	58	17	77	28	94	27
16	21	45	43	39	68	37	86	33
20	21	46	39	45	65	39	78	40
30	15	61	32	55	45	58	58	55
40	17	55	35	50	49	54	63	51

% Reduction in N mineralization = [(control – treatment)/control] x 100

Discussion

The depressive effect of NaCl salt on CO_2 evolution could be due to one or more of the several reasons. Microbial activities can be depressed due to the specific ion toxicities of Na^+ and Cl^- (Zahran, 1999), both ion toxicities and high soil pH under sodic conditions (Rietz and Hayness (2003) or deteriorated physical soil conditions (Minhas *et al*., 2007). Other reason for the reduced activity of soil microorganisms in salt affected soils could be the osmotic stress caused by high concentrations of salts in soil solution. Our results on CO_2 evolution are in line with the findings of Shah and Shah (2012) where $MgCl_2$ salinity significantly reduced the rate of CO_2 evolution under similar soil and environmental conditions and also with Tripathi *et al*. (2006). The reduction in N mineralization with NaCl salinity in our study also demonstrates the detrimental effect of NaCl salt on soil microbial activity and hence reduced rate of N mineralization could be associated with reduced microbial activity in soil caused by NaCl salt.

Conclusion

This experiment has demonstrated that NaCl induced salinity significantly reduced the microbial activity in terms of soil respiration and release of mineral N from soil organic matter during 40 days of incubation period.

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