Effects of NaCl salt on mineralization and nitrification of a silt loam soil in the North China Plain

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Abstract: Low quality water has been widely used for irrigation all over the world due to water shortage.   However, the use of low quality water may cause accumulation of salt in root-zone soils, resulting in poor nitrogen utilization by crops. The objective of the present study was to investigate the effects of sodium chloride (NaCl) on mineralization and nitrification of soils in the North China Plain (NCP).   The experiments were conducted with laboratory incubators at 30℃.   Five levels of NaCl-salt concentrations 0%, 2%, 3%, 5% and 8% in the added solutions were used in the soil samples collected from NCP.   The mineralization at NaCl-salt concentration lower than 3% was not significantly different from that of the control, whereas, significant inhibition of mineralization was found in the treatments with NaCl-salt concentration higher than 3%.   The inhibition of mineralization was attributed to the retardation of nitrification in relatively high salt content because ammonification was not depressed by the added NaCl salt.   The gas losses and nitrification were found decreasing with the increase in salinity.   It was also found that the nitrification was more sensitive to salinity than the mineralization.   Nitrification of soil samples was inhibited by 44.72%, 57.87%, and 83.64% compared with the control after 38 days of incubation at NaCl-salt concentrations of 3%, 5% and 8%, respectively.   The time dependence of both the mineralization and nitrification can be fitted into a first-order kinetic model.   The rate constant of mineralization and nitrification decreased exponentially with the salt content in the soils.   The results of the present research may provide some scientific implications for the use of saline water or treated sewage water in the farming regions of the NCP.

Keywords: mineralization, nitrification, salinity, silt loam soil

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1   Introduction

Salt accumulation in soils has become a serious problem for agriculture in the arid and semi-arid regions in the world.   The secondary salinity in soils is mainly due to improper human activities, i.e., application of more fertilizer than needed and irrigation with low quality

water[1-3].   In the southeast of the North China Plain (NCP), the shallow ground water currently used for irrigation is saline with salt concentration at 3－5 g/L[4]. While in the suburbs of large municipalities of Beijing and Tianjin, a large area of agricultural land has been irrigated with treated sewage water, which may contain a relatively large amount of salt[5].   In order to test the salinity accumulation pattern in the soils of the NCP, Qiao and Yu[6] had conducted a two-season experiment with an irrigation scheduling normally used by farmers in the area. The experimental field was irrigated with shallow ground water with a salt concentration of 3.69 g/L (equivalent to 5.50 dS/m).   They found an obvious salt accumulation in the top 40 cm of the soils, and the highest salt

concentration of saturated extracts was 10 dS/m. In the North China Plain, the normal irrigation practices still lead to an increase in soil salinity either in the coastal zone in Macun Village, Yanshan County or the middle zones at Wangsi Village, Nanpi County. The salt contents for the middle zones soils of the NCP are 2%–6%, 1%–2% and 0.8% (w/w) at the depths 0–1 cm, 1–5 cm and 5–10 cm[7], respectively.

The salt accumulation may seriously affect the physical and chemical processes as well as the nitrogen (N) dynamics in the soils, and make negatively influence on crop yields[2,8]. Many researchers have reported that the influence of salt on nitrogen dynamics in soils varies with salinity levels[9-14]. Low salinity levels can stimulate nitrogen mineralization and nitrification[9,13,15], while both processes are inhibited by high salinity levels[10-13]. Another important finding is that nitrification is more sensitive to salinity than mineralization[11,12,14,16]. However, it remains unclear in the literature at which salinity level the mineralization and nitrification for soils will be affected, and what the mathematical relationships between the salinity level and the nitrification and mineralization are. Therefore, the main purposes of this paper were: (1) to investigate the effects of salinity on nitrification and mineralization of the soils in the middle zones of the NCP with laboratory incubation method, and (2) to mathematically model the relationships between salinity and nitrification and mineralization of the soils.

2　Materials and methods

2.1　Soil sampling

The soils used in this study are Calcaric Cambisol. This type of soils is widely distributed in the North China Plain. The soil was collected from the upper 15 cm layer at the Yongledian Irrigation Experimental Station located in the suburb of Beijing Municipality with latitude 39.7°N, longitude 116.8°E, and elevation 20 m, respectively, in the NCP. The climate is classified as semi-arid. Average annual precipitation is 594 mm, and rainfall occurs mainly during the monsoon summer months. The average annual air temperature is about 12℃ and the frost-free period is about 200 days. The

surrounding area of the experimental station has a rotation cropping system with winter wheat and summer corn[17], and the crops are irrigated alternatively with secondary treated sewage water and ground water.

Soil samples were collected from the top layer (0–15 cm) and then transported to the laboratory with airtight polyethylene bags. Soil cores from the same depth were also taken by using a container with a diameter 4.7 cm and height 5.3 cm. The soil cores were used for measuring bulk density. The soil samples were air-dried, sieved (＜2 mm) and stored at 4℃ before subsequent analyses. The basic physiochemical properties of prepared soil samples are shown in Table 1.

Table 1　Physiochemical properties of the silt loam soil

Items	Values
pH value	8.55
Bulk Density/g • cm^{-3}	1.42
CaCO$_3$/g • kg^{-1} soil	0.65
Organic C/g • kg^{-1} soil	9.1
TDS/g • kg^{-1} soil	0.67
Total N/g • kg^{-1} soil	0.97
NH$_4$-N /mg • kg^{-1} soil	292
NH$_2$-N /mg • kg^{-1} soil	1.60
NH$_3$-N/mg • kg^{-1} soil	7.71
CEC/cmol kg^{-1}	13.66
Moisture content/w • w^{-1}	1.46%

2.2　Incubation experiments

2.2.1　Mineralization

A 105-day laboratory incubation experiment was performed to determine the salinity effect on nitrogen mineralization. Soil samples were air dried and sieved (＜2 mm). Four salinity levels were obtained by adding 50 g subsamples with 10 mL sodium chloride (NaCl) solutions of four different concentrations: 2%, 3%, 5% and 8% (w/w), which are corresponding to four salinity levels, respectively. The non-saline treatment, which was used as the control treatment, was prepared with 50 g subsamples and the same volume of deionized water. Each treated soil subsample has a moisture content of 21.75% (w/w), which is about 90% of the soil water holding capacity (WHC). Each prepared subsample was put into a 150 mL bottle covered with a plastic sheet with eight holes for aeration. The moisture content was kept and adjusted by weighing method at 4 to 5 days intervals.

Each treatment had 20 bottles, and all bottles were incubated at a constant temperature of 30 ℃. Four bottles of each treatment were taken at 7, 21, 42, 70 and 105 days after incubation, and all the subsamples were used for nitrogen and salinity analyses.

2.2.2   Nitrification

The laboratory incubation experiment for nitrification was conducted for 49 days. Fifty grams subsamples amended with 50 mg $(NH_4)_2SO_4$ for each were prepared for subsequent treatment. Similar to the treatments of mineralization, four saline treatments and a control were taken. The saline treatments were prepared by mixing 50 g treated soil subsamples with 6 mL NaCl-salt solutions. The NaCl-salt solutions had four concentrations: 2%, 3%, 5%, and 8% (w/w), which corresponded to four salinity levels. Whereas, the control treatment was prepared with 50 g treated soil subsamples and 6 mL deionized water. Each treated soil subsample had moisture content of 13.63% (w/w), which was about 56.8% of the soil WHC. Each prepared subsample was placed in a 150 mL bottle, and the bottle mouth was covered with a plastic sheet with eight holes for breathing. The moisture content was kept and adjusted by weighing method at 4 to 5 days intervals. Each treatment had 28 bottles, and all bottles were put into the incubator at a constant temperature of 30 ℃. Four bottles of each treatment were taken at 2, 6, 13, 20, 27, 38, and 49 days after incubation, and all the subsamples were used for nitrogen and salinity analyses.

2.3   Nitrogen and salinity analyses

Nitrogen analyses were performed on the subsamples taken just before the incubation experiments and at each sampling date. The subsamples were first extracted with 250 mL of 2 mol/L KCl solution. The extracts were then used for measuring mineral nitrogen concentration. The concentration of ammonical-N (NH_4^+-N) was determined using alkaline distillation with MgO, and nitrate-N (NH_3^--N) after reduction by Devarda's alloy[18]. Total N in the soil was determined with the Kjeldahl digestion-steam distillation method[19].

The mineralized N at each sampling date is considered as the net increase in mineral N (NH_4^+-N and NH_3^--N), which is equal to the mineral N difference from the beginning of incubation to the sampling date. Whereas, the nitrified N at each sampling date is considered as the net increase in NO_3^--N, which is equal to NH_3^--N difference from the beginning of incubation to the sampling date.

Electrical conductivity (EC_e) of the saturated extracts was measured and their Ca, Mg and Na concentrations were analyzed using atomic absorption spectrophotometry. The sodium adsorption ratio (*SAR*) was calculated as:

$$SAR = \frac{[Na^+]}{\sqrt{[Ca^{2+}]+[Mg^{2+}]}} \qquad (1)$$

where   [Na^+], [Ca^{2+}] and [Mg^{2+}] are the concentrations (in mmol/L) of Na, Ca and Mg respectively.

2.4   Mathematical and statistical analyses

Both the mineralization and nitrification were fitted into the one pool first-order kinetic model[20]

$$N_t = N_0(1-e^{-kt}) \qquad (2)$$

where N_t is the cumulative mineralized N (in mg/kg, i.e. mg-N kg^{-1}-dry-soil) or the NH_4^+-N nitrification (mg/kg) at time *t* (d), respectively; N_0 is the potentially mineralized N (mg/kg) or the potential nitrification (mg/kg); *k* is the rate constant (1/d) of mineralization or nitrification. The fitting of Eq. (2) against the measured data was performed with the non-linear least square method[21].

Statistical analyses were performed with the ANOVA and SPSS 11.5 software for Windows (SPSS Inc., Chicago, IL, USA).

3   Results

3.1   Mineralization

The cumulative mineralized N (net cumulative NH_4^+-N and NH_3^--N) at different NaCl-salt concentrations at 21, 42, 70 and 105 days of incubation is shown in Figure 1. It can be found that the mineralized N for the treatment at 2% NaCl-salt was slightly higher than that of the control before 42 days. At 42 days of incubation, the treatment with 2% NaCl-salt had the highest mineralized N, which was about 9.17% higher than that

of the control. While after 42 days of incubation, the mineralized N for the treatment with NaCl-salt concentration 2% is slightly lower than that of the control. The mineralized N for the treatments with NaCl-salt concentration larger than 3% is found lower than that of the control. With 42 days of incubation, the total amounts of mineralized N for the treatments with NaCl-salt concentrations 5% and 8% are only about 40.71% and 24.13% comparing to the control.
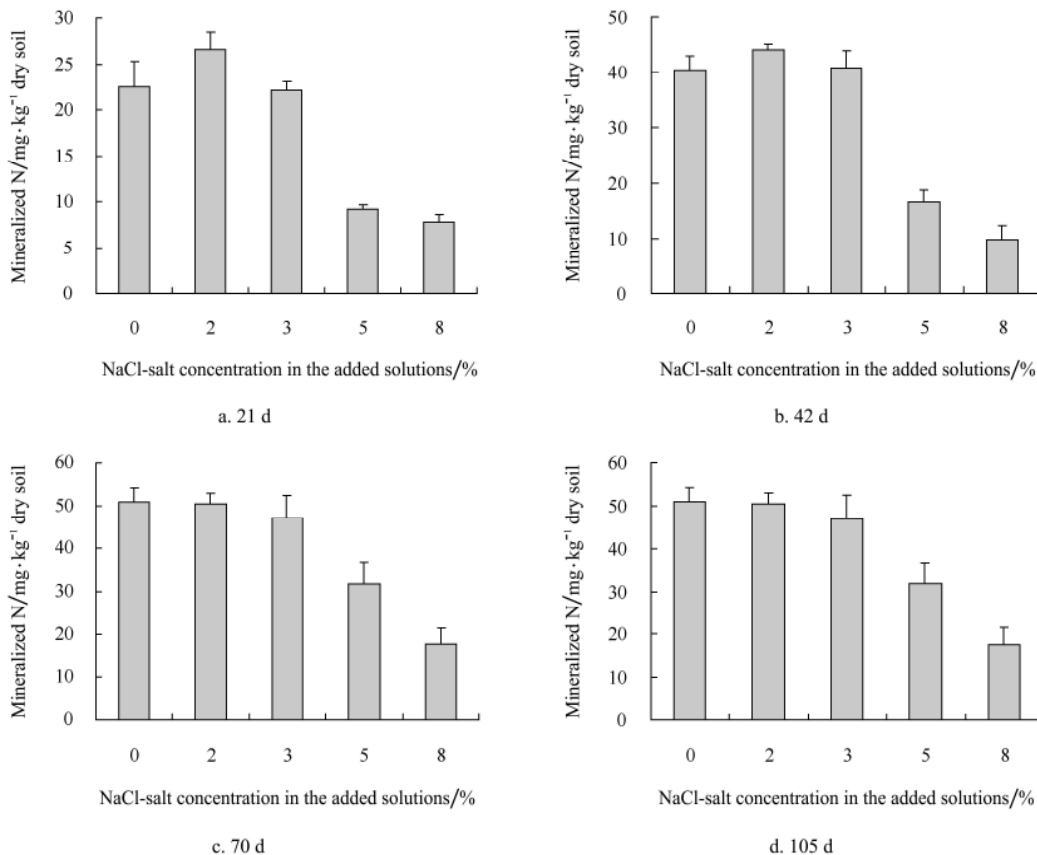

Figure 1   Mineralized N versus NaCl-salt concentration in the added solutions for different incubation time

Analyses of variance show that with the exception of 105 days of incubation, the values of mineralized N for the treatments with 2% and 3% NaCl-salt solutions are not significantly different from that of the control at P=0.05, and the values of mineralized N for the treatments with NaCl-salt concentrations 5% and 8% are significantly different (P=0.01) from that of the control.

3.2   Nitrification

The increase in NH_3^--N as the net nitrification and the reduction of NH_4^+-N was considered as the gross nitrification.   As shown in Figure 2, with the exception of long period of incubation for the cases of low NaCl-salt concentrations, the increase in NH_3^--N is approximately equal to the reduction of NH_4^+-N. The differences between the net and gross nitrification may be

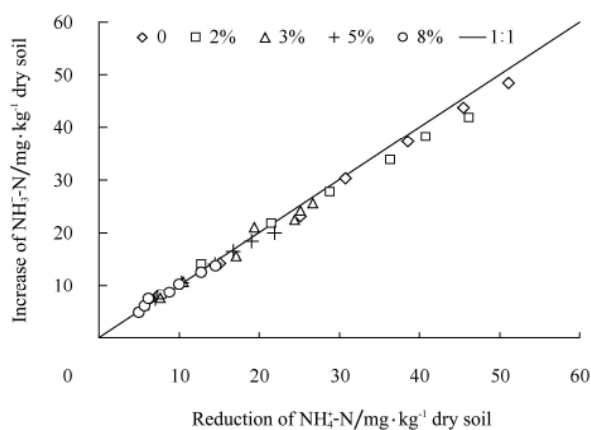due to the gas losses in nitrifying process.   In the following analyses, we focus on the net nitrification.

Figure 2   Comparison of the increase in NH_3^--N with the reduction of NH_4^+-N in the soils

The nitrification for different NaCl-salt concentrations

after 2, 6, 13, 27, 38, and 49 days of incubation is shown in Figure 3.   After two days of incubation, the nitrification for the treatment with 2% NaCl-salt is 8.25 mg/kg, which is slightly higher than that of the control (8.10 mg/kg).   While for incubation time longer than 3 days, the nitrification for the treatment with 2% NaCl-salt is lower than that of the control.

For treatments with high NaCl-salt concentrations as shown in Figure 3 (a) to (g), all the nitrification is lower than that of the control at all periods of incubation.

After 2 days of incubation, the values of nitrification for the treatments with 3%, 5% and 8% NaCl-salt respectively are 7.53, 5.26, and 4.73 mg/kg, which are 7.1%, 35.1%, and 41.6 % lower than that of the control, respectively.   While at 38 days of incubation, the values of nitrification for the treatments with 3%, 5% and 8% NaCl-salt respectively are 24.17, 18.42 and 16.36 mg/kg, which are 44.72%, 57.87%, and 83.64% lower than that of the control, respectively.

a. 2 d

b. 6 d

c. 13 d
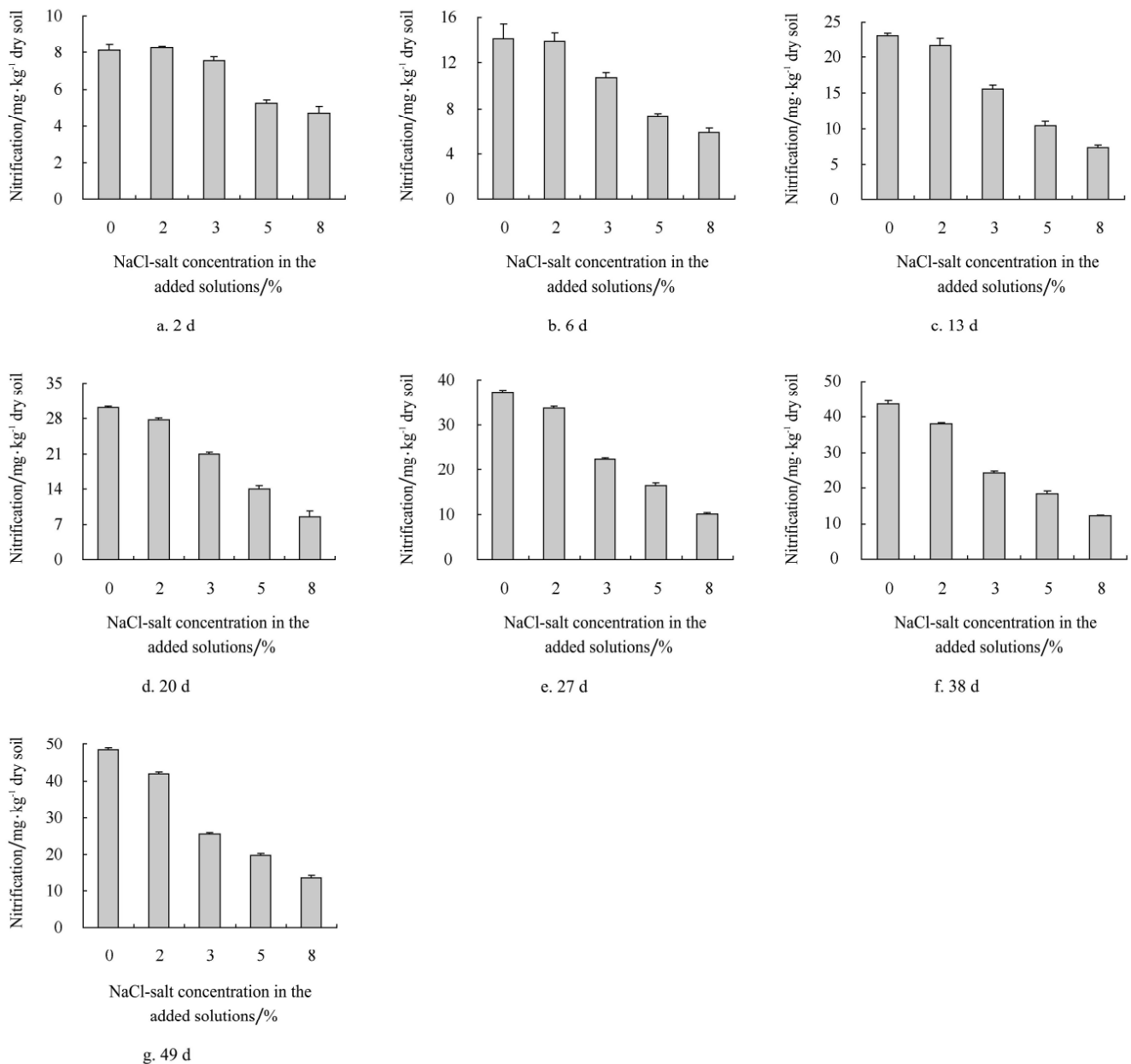
d. 20 d

e. 27 d

f. 38 d

g. 49 d

Figure 3   Net nitrification versus NaCl-salt concentration in the added solutions for different incubation time

Analyses of variance show that there is no significant difference ($P=0.05$) between the nitrification for the treatment with 2% NaCl-salt and that of the control, the values of nitrification for the treatments with higher than

2% NaCl-salt solutions are significantly different ($P=$ 0.01) from that of the control.

3.3   Salt inhibition kinetics in mineralization and nitrification

3.3.1   Salt inhibition kinetics in mineralization

The cumulative nitrogen mineralization over incubation time for different salinity levels is shown in Figure 4.   Mineral N increases at a relative high rate during the first 20 days, and then mineralization proceeds at a relatively low rate.   The first-order kinetic model (see Eq.(2)) was used to fit the measured mineralized N versus time for different NaCl-salt concentrations, and the fitted results are shown in Table 2 and Figure 4.   It can be seen that the relationship between the mineralized N and the incubation time can be well described by the first-order kinetic model with the coefficient of determination greater than 0.96.   The fitted potentially mineralized N (N_0) for the control treatment is 86.58 mg/kg, which is about three times as large as that of 8% NaCl-salt treated samples. N_0 value decreases

significantly with increasing NaCl-salt.   The fitted values of the rate constant of mineralization (k_m) for the control and the treatment with 8% NaCl-salt are much lower than those for the treatments with NaCl-salt solutions at 2%, 3% and 5%.
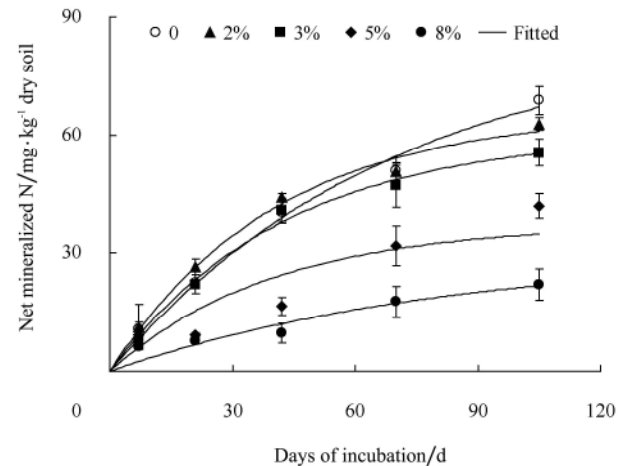

Figure 4   Comparison of the measured and fitted mineralized N versus time for different NaCl-salt concentrations 0, 2%, 3%, 5% and 8% in the added solutions

Table 2   Electrical conductivity of saturated extracts (EC_e) , sodium adsorption ratio (SAR) and the fitted parameters of N mineralization for different NaCl-salt concentrations

Treatments	EC_e /dS · m^{-1}	SAR /(mmol · L^{-1})$^{1/2}$	Without fixed potentially mineralized N			With fixed potentially mineralized N		
			N_0/mg · kg^{-1}	k_m/1 · d^{-1}	r^2	N_0/mg · kg^{-1}	k_m/1 · d^{-1}	r^2
T0	3.43	2.44	86.58	0.0142	0.9962	86.58	0.0142	0.9962
T1	26.71	68.95	65.78	0.0247	0.9959	86.58	0.0142	0.9801
T2	38.35	102.2	60.43	0.0234	0.9939	86.58	0.0118	0.9694
T3	61.63	168.71	37.47	0.0252	0.9613	86.58	0.0062	0.9653
T4	96.54	268.46	30.00	0.0123	0.9776	86.58	0.0030	0.9500

Note: N_0 is the potentially mineralized N; k is the rate constant of mineralization; r^2 is the coefficient of determination;   T0, T1, T2, T3 and T4 are the control treatment and four saline treatments with NaCl-salt concentrations of 2%, 3%, 5% and 8% respectively.

It should be pointed out that the salt effect cannot clearly be identified from the fitting results, because theoretically N_0 for the same soil will not be affected by environmental factors, e.g. soil salinity, temperature, humidity, etc.   Variations in estimates of N_0 for saline treatments precluded using the rate constant to analyze the effect of salinity.   Therefore, curve fitting was repeated by keeping N_0 as a constant with a value of 86.58 mg/kg, i.e. the potentially mineralized N without adding NaCl salt.   As shown in Table 2, the k_m value decreases with increasing NaCl-salt concentration in the

added solutions as well as the increase in EC_e value and SAR value.

The relationship between k_m and EC_e can be described by using an exponential function:

$$k_m = 0.0194e^{-0.0182EC_e} \qquad (3)$$

with a coefficient of determination $r^2 = 0.9201$, where k_m is the rate constant of mineralization (1/d) and EC_e is the electrical conductivity of saturated extracts (dS/m).   The relationship is also shown in Figure 5.   This result suggests that the salt retardation effect on mineralization follows an exponential pattern.
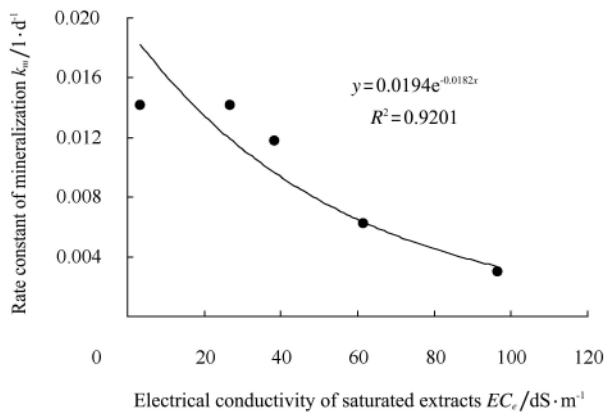
Figure 5   Relationship between the rate constant of mineralization and the electrical conductivity of saturated extracts

3.3.2   Salt inhibition kinetics in nitrification

The cumulative nitrification over incubation time for different salinity levels is shown in Figure 6. The cumulative nitrification increases at a relative high rate during the first 15 days, and then nitrification proceeds at a relatively low rate. The first-order kinetic model (see Eq.(2)) was also used to fit the measured net nitrification versus time for different NaCl-salt concentrations, the fitted results are shown in Table 3 and Figure 6. It is found that the relationship between the nitrified N and the incubation time can be well described by the first-order

kinetic model with the coefficient of determination in a range from 0.917 to 0.999. The fitted potential nitrification (N_0) is the highest with a value of 53.93 mg/kg for the control treatment, while the lowest N_0 is 12.94 mg/kg for the treatment with 8% NaCl-salt. Similar to the mineralization, the N_0 value for nitrification also decreases significantly with increasing NaCl-salt concentration. The fitted rate constant of nitrification (k_n) for the control treatment is lower than those for the treatments with added NaCl salt.
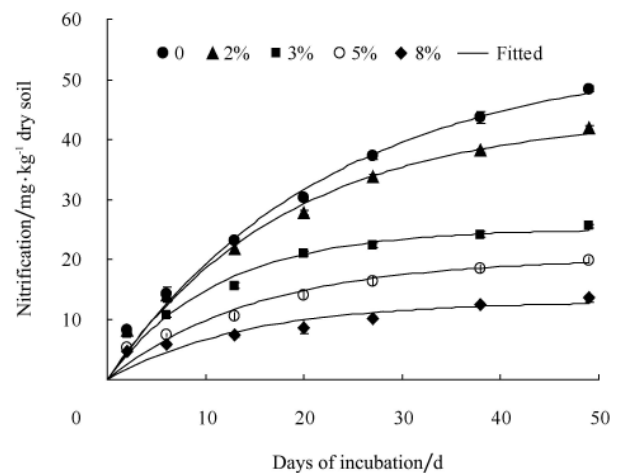

Figure 6   Comparison of the measured and fitted nitrification versus time for different NaCl-salt concentrations 0, 2%, 3%, 5% and 8% in the added solutions

Table 3   Electrical conductivity of saturated extracts (EC_e) , sodium adsorption ratio (SAR) and the fitted parameters of nitrification for different NaCl-salt concentrations

Treatments	EC_e /dS • m^{-1}	SAR /(mmol • L^{-1})$^{1/2}$	Without fixed potential nitrification			With fixed potential nitrification		
			N_0/mg • kg^{-1}	k_n/1 • d^{-1}	r^2	N_0/mg • kg^{-1}	k_n/1 • d^{-1}	r^2
T0	3.38	2.44	53.93	0.0441	0.9984	53.93	0.0441	0.9984
T1	17.15	42.34	43.88	0.0549	0.9946	53.93	0.0359	0.9885
T2	24.03	62.30	25.08	0.0892	0.9921	53.93	0.0181	0.8951
T3	37.79	102.20	20.16	0.0665	0.9889	53.93	0.0118	0.9286
T4	58.43	162.05	12.94	0.0719	0.9174	53.93	0.0072	0.8760

Note: N_0 is the potential nitrification; k is the rate constant of nitrification; r^2 is the coefficient of determination;   T0, T1, T2, T3 and T4 are the control treatment and four saline treatments with NaCl-salt concentrations of 2%, 3%, 5% and 8% respectively

Similarly, the influence of salt on nitrification cannot be drawn from the fitting results. Because non-negligible variations exist in the estimated N_0 values of saline treatments, the effect of salinity cannot be simply correlated to the rate constant. Hence, the curve fitting was repeated by keeping N_0 constant with a value of 53.93 mg/kg, i.e. the potential nitrification without added NaCl salt. As shown in Table 3, the k_n value decreases

with the increase of NaCl-salt concentration in the added solutions, consequently decreases with the increase in EC_e value and SAR value. The k_n value of the treatment with 8% NaCl-salt is 0.0072 1/d, which is smaller by one order in magnitude than that of the control.

Similarly, the relationship between k_n and EC_e can be described by using an exponential function:

$$k_n = 0.0507e^{-0.035EC_e} \qquad (4)$$

with a coefficient of determination r^2=0.9439, where k_n is the rate constant of nitrification (1/d); EC_e is the electrical conductivity of saturated extracts (dS/m). The relationship is also shown in Figure 7. This result suggests that the salt suppression effect on nitrification follows an exponential pattern.
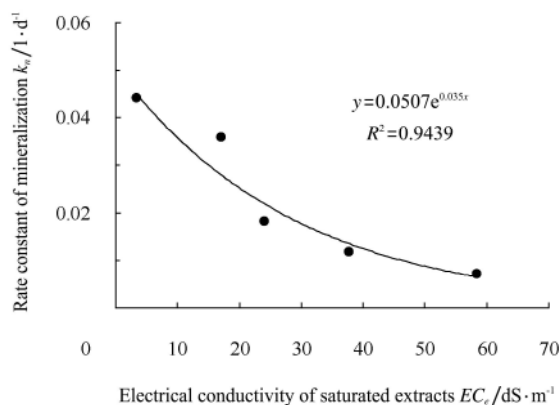

Figure 7   Relationship between the rate constant of nitrification and the electrical conductivity of saturated extracts

4   Discussion

4.1   Effect of salt on mineralization

Total mineral N decreases with increasing salinity and sodicity (Table 4). There is no significant inhibition in mineralization for EC_e<38.35 dS/m, whereas mineralization is inhibited for the cases with EC_e = 61.63 dS/m and 96.54 dS/m. As shown in Table 4, the nitrification k_n is inhibited for EC_e >38.35 dS/m, resulting in ammonical-N accumulation. The research results agree with those of

McCormick and Wolf[12], Pathak and Rao[13]. This means that ammonifiers are more tolerant to salinity than nitrifiers[11,12,14]. However, the authors did not observe any inhibited ammonification up to NaCl-salt content 1.6%, which is equivalent to EC_e 96.54 dS/m or concentration 16 mg/g. Similarly, Laura[9] found no inhibition of ammonification even up to 5.1% salt addition, and the ammonification at high salinity was considered as a chemical process. However McCormick and Wolf[12] found that a reduction of ammonification at concentrations of NaCl>25 mg/g, Pathak and Rao[13] found that the ammonification was strongly inhibited at EC_e 97 dS/m. They attributed the ammonification to a biological process.

The unaccounted N is due to the gas losses[9,13,22]. Laura[9] assumed that most of the N lost at high salinity is through NH_3 volatilization, while Pathak and Rao[13] reported that most of the N lost in saline and alkali soils is presumably due to denitrification. As shown in Table 4, there is no significant difference in unaccounted N as EC_e ≤38.35 dS/m, whereas a significant reduction of unaccounted N is found for EC_e >38.35 dS/m. This means that gas losses decrease with increasing salinity, consistent with the response of nitrification to salinity in section 3.1. Decrease in nitrification with increasing salinity will result in a decrease in denitrification. Our results confirm the works of Pathak and Rao[13].

Table 4   Changes in mineral and total nitrogen content of soils incubated for 105 days

Treatments	EC_e /dS・m^{-1}	SAR /(mmol・L^{-1})$^{1/2}$	Inorganic N		Organic N /mg・kg^{-1}	Total N /mg・kg^{-1}	Unaccounted N /mg・kg^{-1}
			NH_4-N/mg・kg^{-1}	NO_3-N/mg・kg^{-1}			
T0	3.43	2.44	2.603	122.970	702.349	827.922	112.622
T1	26.71	68.95	2.563	116.886	726.736	846.185	94.359
T2	38.35	102.2	2.583	109.593	717.437	829.613	110.931
T3	61.63	168.71	4.021	94.645	784.383	883.049	57.495
T4	96.54	268.46	12.724	66.078	781.588	860.390	80.154

Note: T0, T1, T2, T3 and T4 are the control treatment and four saline treatments with NaCl-salt concentrations of 2%, 3%, 5% and 8% respectively.

4.2   Effect of salt on nitrification

An increase in ammonical-N and a decrease in nitrate-N can be found with an increase in salinity (Table 5), which then implies nitrification is inhibited by NaCl salt. The reduction of nitrification especially in high salt

concentration is due to that high NaCl-salt concentration may become toxic to organisms and the microbial activity will be retarded. Similar results were also found by McClung and Frankenberger[11], McCormick and Wolf[12], Pathak and Rao[13].

Table 5   Changes in mineral nitrogen content of soils incubated for 49 days

Treatments	EC_e/dS $\cdot$ m^{-1}	SAR/(mmol $\cdot$ L^{-1})$^{1/2}$	NH$_4$-N/mg $\cdot$ kg^{-1}	NO$_3$-N/mg $\cdot$ kg^{-1}	Total mineral N/mg $\cdot$ kg^{-1}
T0	3.38	2.44	187.51	81.69	269.20
T1	17.15	42.34	192.47	75.15	267.61
T2	24.03	62.30	211.91	58.85	270.75
T3	37.79	102.20	216.71	53.14	269.85
T4	58.43	162.05	224.08	46.90	270.98

Note: T0, T1, T2, T3 and T4 are the control treatment and four saline treatments with NaCl-salt concentrations of 2%, 3%, 5% and 8% respectively.

As shown in Table 5, unlike the mineralization, significant inhibition of nitrification happens at relatively low NaCl-salt concentration, i.e. EC_e=17.15 dS/m. This results support those works of Martikainen[16], McCormick and Wolf[12], McClung and Frankenberger[11], Westerman and Tucker[14], who reported that nitrification is more sensitive to salt than mineralization

However, it should be pointed that the indices for microbial activity, i.e. microbial biomass C and N in both the mineralization and the nitrification processes have not been measured. Therefore further investigation of the microbial mechanisms as evident by Rietz and Hayes[23], Wichern et al.[24] within the two processes are needed .

5   Conclusions

The effects of NaCl salt on mineralization and nitrification of a silt loam soil in the NCP were investigated with aerobic incubation experiments at a constant temperature 30℃ and five NaCl-salt solutions with concentrations of 0, 2%, 3%, 5% and 8%. The datasets of both the mineralization and the nitrification versus time for different salinity levels were fitted into a first-order kinetic model. Results indicate that total mineralization shows no significant difference for EC_e <38.35 dS/m (equivalent to NaCl-salt concentration 3% in the added solutions), and is strongly inhibited for EC_e >38.35 dS/m. The reduction in mineralization in relatively high salt concentrations is mainly due to the inhibition of nitrification because ammonification is not depressed by the added NaCl salt. Gas losses are found decreasing with increasing salinity. Nitrification is inhibited by the added NaCl salt. The nitrification is more sensitive to salinity than the mineralization. The rate constant of mineralization and nitrification decreases exponentially with increasing salt content in the soils.

However, the results obtained for Calcaric Cambisol at given soil moisture content and environmental temperature may provide some scientific implications for the use of saline water or treated sewage water in the agricultural area of the NCP. Further investigations under different environmental conditions either for this type of soils or other types of soils are needed.

Acknowledgements

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