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Research Article

The Impact of Different Fertigation Practices and Initial Soil Salinity on Soil N and Salinity Transport

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Abstract: For studying the impact of different fertigation practices and initial soil salinity on soil N and salinity transport, large Plexi-glass columns (18.2 cm in diameter and 100 cm long) assembled from sandy loam (Inner Mongolia) and saturation optimum design were employed to simulate a range of initial soil salinity conditions in soil profile and fertigation practices. (4~8 L) solution with 20 g urea dissolved was applied evenly and slowly to the surface of each column. Nitrate and ammonium nitrogen in soil and discharge from the outlet were sampled and the electrical conductivity of soil and the chloride ion concentration of discharges were also measured. Findings from this study include: (1) high initial salinity in soil had a certain impact on the changes of water content of vertical soil section with the time being after large amount of water irrigation and it might increase the rate of infiltration; (2) the amount of irrigation water significantly affected the transport of soil salinity; (3) high soil salinity content was likely to promote the conversion of urea nitrogen to ammonium nitrogen and it might also play an active role in ammonium nitrogen accumulation in drainage; (4) There is a sound linear relation between the cumulative content of chloride ion and that of nitrate nitrogen in the drainage and soil profile ($r^2 = 0.8221$ and 0.7442).

Keywords: Dispersion, irrigation, leaching, nitrogen, salinity

INTRODUCTION

In arid and semiarid areas of China, agricultural development is critically subject to water, salt, nutrient and the interactions of them. For a long time, plant growth relies on using fresh water to leach the salt in the soil and promote nutrient uptake. But the abuse of NPK (Nitrogen, Phosphorus and Potassium) and pesticides might lead to agricultural non-point pollution, which exert negative impact on soil, environment and agricultural ecosystem , in spite of the fact that large-scale fresh water irrigation improves the yield (Gabriella *et al*., 2010; Bi *et al*., 2004; Feng *et al*., 2003a). In China, about 20% of the farmland has been affected by agricultural non-point pollution and the amount of nitrogen leaching from farmland to the environment is about 1.3×10^7 t/year. Leaching is one of the main reasons for nitrogen loss in farmland. While some portion of nitrogen in the field is absorbed by plants and some fixed in the soil, the other is prone to be lost through different channels. And 30~50% of the nitrogen applied to the field leaches to the groundwater, causing eutrophication and groundwater pollution (Zhang, 1987).

A large number of researches have been conducted to promote high yield and reduce agricultural non-point pollution (Zhang and Han, 2012; Hosen and Yagi, 2011). Hydrus-1D has been used to simulate the nitrogen transport at different fertigation levels and the results indicate that, at the same level of fertilizing, more nitrate nitrogen is lost under fertigation than that under top application (Alon *et al*., 2008; Meng *et al*., 2004). Salinity in the soil decreases when irrigation starts and the time of the salinity elution to the bottom varies in light of the depth of the soil layers and varied irrigation approach (Moreno *et al*., 1995). Besides, high water table can effectively reduce the leach of chemicals in the field and research indicates that the yield of soybeans can be increased by 42% when water table is controlled below the depth of 0.6 m from the surface of the soil (Sarwar and Kanwar, 1996). Nevertheless, much of current research concentrates on the interactions between water and fertilizer or between water and salinity, without any in-depth study of the interactions among water, fertilizer and salinity, which is the key to the development of highly productive and effective agriculture as well as to the reduction of agricultural non-point pollution.

The objective of the study is to find out the nitrogen transform and transport discipline under different irrigation and initial soil salinity levels in the soil columns.

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Table 1: Soil properties of the Yonglian experimental station

Soil texture	Particle size distribution (%) <2 um	 2~20 um	 >20 um	Organic carbon g/kg	pH*	Saturated moisture content cm^3/cm^3
Sandy loam	6.61	20.13	73.26	5.513	8.43	43.4

*: Soil ratio water = 1:1

MATERIALS AND METHODS

Site description: The Hetao irrigation district (40º19'-41°18'N, 106°20'-109°19'E), located in the western arid areas of the Inner Mongolia Autonomous Region, is one of the three largest irrigation districts in China, covering a total area of 1.12×10^6 ha with 5.7×10^5 ha under irrigation, 92.1% of which is cropland. The irrigation water is mainly drawn from the Yellow River and about half of the irrigated cropland is saline-alkali soil (Feng *et al*., 2003b).

The region is featured with an arid continental climate. Annual average temperature is 8.1°C with monthly average ranging from 23.76°C in July to-10.08°C in January. The average annual precipitation totals 150 mm, with about 60% falling in July and in August. The annual potential evaporation is about 2200-2400 mm. The soil in this area is usually frozen for about 180 days/year from late November to the middle of May (Lei *et al*., 2001).

Column preparation: Soil samples were taken from Yonglian Experimental Station, Wuyuan County, Hetao irrigation district, China and they were pretreated by crushing, smoothing and air-drying. Then the pretreated samples are put through 1 mm sieve for future application. Both sieving and hydrometer method were used to analyze soil particles while the sodium hexametaphosphate (AR) was selected as dispersant. According to the international soil texture triangle, the soil samples were classified as sandy loam. Table 1 shows the basic physical and chemical properties of the soil samples.

The factors included irrigation Water (W) and the initial soil Salt content (S) and the experimental programs were adopted in accordance with the saturation optimum design (Table 2). Taking into account that water content in the soil (m^3/m^3) was about 20~30% before sowing and chloride is the major content of the local soil salinity, we designed the initial soil water content as a rate of 25% and adjusted the initial soil salt content by applying sodium chloride. To be more specific, Electrical Conductivity (EC) of the soil was determined in an extract (1:5) after shaking for 3 min and total dissolved salt of the soil was estimated from a linear regression equation between sodium chloride and the measured EC values (ms/cm). The regression equation was calculated as salt (%) = $0.2066EC_{1:5}$ (R = 0.9985) or salt (g/cm^3) = $0.0004EC_{1:5}$ (R = 0.9985). Distilled water and sodium chloride were added to the soil samples after pre-treatment on the basis of the regression equation and then these samples were set-aside for a day to ensure that water and salt were evenly mixed so as to meet the requirements of the design in the experiment.

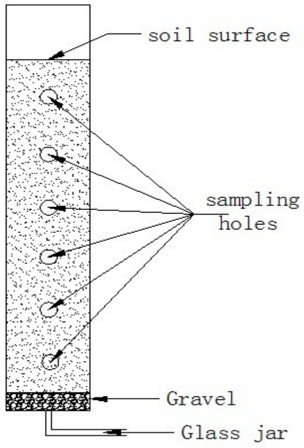

Fig. 1: Experimental column

The experimental devices using 18.2 cm inner diameter by 100 cm long cylindrical organic glass columns were assembled from the prepared soil with the designed soil dry bulk density (1.5 g/cm^3). There were totally 6 columns and each of them contained a 60 cm long soil core which was divided into 12 layers to pack and special Treatment was engaged to make the layers become rough to gain well connection between soil layers. In addition, an organic glass end cap containing a 2 cm thick layer of washed pea gravel sandwiched in fiberglass cloth was fitted in each column. For facilitating soil sampling during the experiment, four 2 cm diameter sampling holes were set up around each soil column at intervals of 10 cm on the vertical column profile (Fig. 1).

Column experiment: As shown in Table 2, 4~8 L solution with 20 g urea dissolved was applied evenly and slowly to the surface of each column. Soil samples of the 6 columns were taken from the sampling holes when filling the soil column every 2, 5 and 10 days after irrigation, respectively. The entire discharge from the outlet pipe for each column was collected once a day for the first 5 days, once every 2 days for the next 4 days and once every 3 days thereafter, for a total of 12 days. The nitrate and ammonium nitrogen in soil and water samples were analyzed by using a Cleverchem200 auto analyzer (Dechem-Tect Germany) respectively. In addition, the electrical conductivity of soil and the chloride ion concentration of discharge

Table 2: Design of experiment

Treatment		Soil height cm	Salinity content %	Irrigation volume L	Urea content g
1	S_1W_1	60	0.40	4	20
2	S_4W_1	60	0.70	4	20
3	S_1W_4	60	0.40	8	20
4	S_2W_2	60	0.54	5.7	20
5	S_4W_3	60	0.70	6.8	20
6	S_3W_4	60	0.62	8	20

were measured by a conductivity meter and a chloride selective-ion electrode respectively.

Statistical analysis: Changes in soil water content, soil salinity, soil nitrate nitrogen and ammonium nitrogen content and the cumulative mass of nitrogen in discharge of water were analyzed. In addition, the cumulative masses of nitrate nitrogen and chloride ion in discharge of water were compared and their relations were obtained through regression analysis by SAS software (SAS/SSAT, 1989).

Water balance methods: According to the measured soil water content, we can obtain the total amount of water in soil columns at specified moment by formula 1:

$$W_i = \sum_{j=0}^{n} \theta(j,t_i)\Delta Z_j \tag{1}$$

where,

W_i = The total water content at t_i moment, cm

ΔZ_j = The depth of the j layer of soil, cm

n = The total number of soil layers

θ (j, t_i) = The soil volumetric moisture content of the j layer of soil at t_i moment, cm^3/cm^3

For one specified soil column, we get formula 2 by the theory of water balance:

$$\Delta W = I - D - E \tag{2}$$

where,

ΔW = The change of soil water content during the period, cm

I = The decreased water depth, cm

D = The amount of discharged water, cm

E = The amount of evaporation or moisture loss by other ways, cm

Solute distribution: By measuring the solute concentration in soil profile, we can get the total amount of solute in soil columns:

$$m_i = \sum_{j=0}^{n} [\theta(j,t_i)c(j,t_i)\Delta V_j] \tag{3}$$

where,

m_i : The total mass of solute in soil column at t_i moment, g

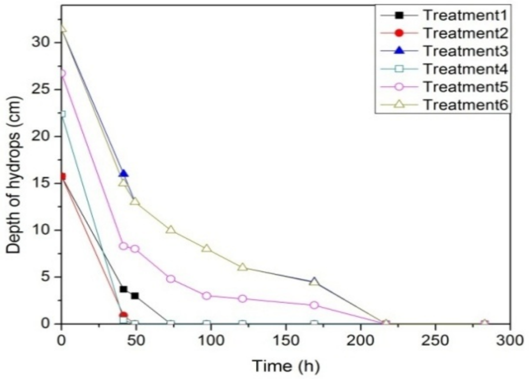

Fig. 2: Depth of hydrops

c (j, t_i): The solute concentration of j layer of soil solution at t_i moment, g/cm^3

ΔV_j : The volume of the j layer of soil, cm^3

Nachabe *et al.* (1999) recommended that we could calculate and describe the distribution of solute in soil using the following formulas:

$$X_i = \frac{1}{m_i}\sum_{j=0}^{n} [\theta(j,t_i)c(j,t_i)\Delta V_j z_j] \tag{4}$$

$$\sigma_i^2 = \frac{1}{m_i}\sum_{j=0}^{n} [\theta(j,t_i)c(j,t_i)\Delta V_j (z_j - X_i)^2] \tag{5}$$

where,

z_j : The average depth of j layer of soil, cm

X_i : The center of solute mass to describe the average depth of solute, cm

σ_i : The dispersion of soil solute, cm

RESULTS

Infiltration and outflow of water: Figure 2 shows the changes of water depth on the top of soil. We found that increasing initial soil salt content might promote the rate of water infiltration. To be more specific, the rate of infiltration of Treatment 2 (S_4W_1) and Treatment 6 (S_3W_4) were higher than that of Treatment 1 (S_1W_1) and Treatment 3 (S_1W_4) respectively. This phenomenon might be caused by the electric double layer structure of the soil colloids, which compressed to the surface of soil clay and reduced repulsion between the soil particles when the initial soil salt content increased. Therefore, higher soil salt content could play a role in enhancing flocculation of soil colloids, promoting the formation of soil aggregate structure and strengthening the soil hydraulic conductivity ability.

Figure 3 shows the cumulative displacement line at the bottom of each soil column. Every Treatment began to drain off water 41.5 h after irrigation and the drainage rate of Treatment 1 (S_1W_1), Treatment 2 (S_4W_1) and Treatment 4 (S_2W_2) was faster than other

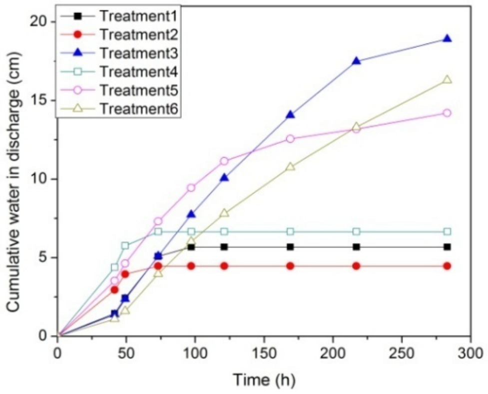

Fig. 3: Cumulative discharge water

Treatments. Furthermore, the drainage rate (0.05~0.12 cm/h) of the early drainage process (41.5~73 h) was higher than the rate (0.02~0.04 cm/h) of the final drainage process (217~283 h) in this experiment. We believed that drainage rate was largely determined by its filtration rate in each Treatment. In terms of cumulative water discharge, the values of Treatment 3 (S_1W_4) and Treatment 6 (S_3W_4) (18.91 and 16.30 cm, respectively) were significantly higher than other Treatments. So the effect of irrigation water amount on cumulative water discharge was far greater than the initial soil salt content, which was consistent of our common sense.

Changes of soil water content: Before irrigation, the initial water content of each column was designed value (0.25 cm^3/cm^3). Soil vertical profiles of water content changed over time after irrigation, as is shown in Fig. 4, indicated that, although the amount of irrigation of each Treatment was different, an general rule was observed, that was, the water content declined with the increase of soil depth; and the average water content was maintained between 0.40 and 0.44 cm^3/cm^3 at the soil depth of 50~60 cm. This phenomenon indicates that the long-term variation of the vertical distribution of water content of soil profile is consistent in conditions of good drainage. Meanwhile, there was no significant difference of the soil water content at the surface layer (0~10 cm) of each Treatment and the value was generally found to be in the range of 0.50-0.57 cm^3/cm^3 the day after irrigation. The possible reason for this case is that hydrops was still above the soil surface the day after irrigation, even though the amount of irrigation and initial salt content varied from each Treatment.

Treatment 1 (S_1W_1) and Treatment 2 (S_4W_1) showed that at 0~20 cm depth, soil water content decreased gradually over time at a low level of irrigation amount. However, the water content of 2>10>5 days was found below the depth of 20 cm

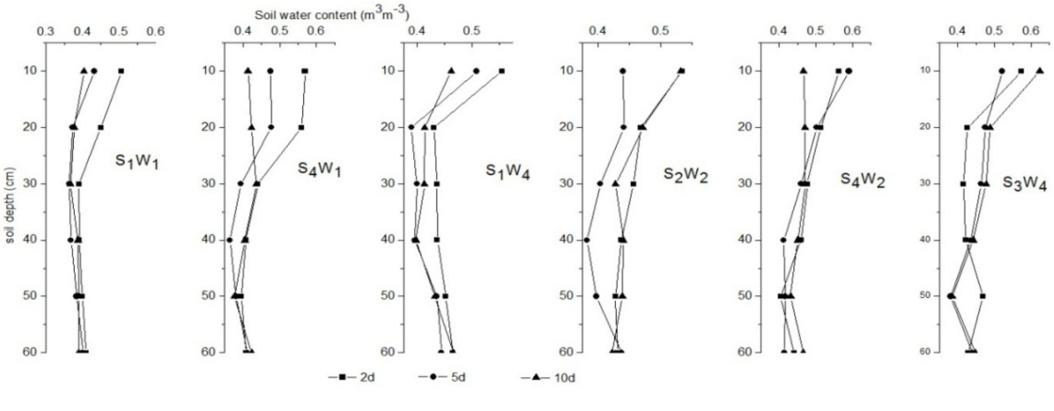

Fig. 4: Changes of soil water content in different treatments

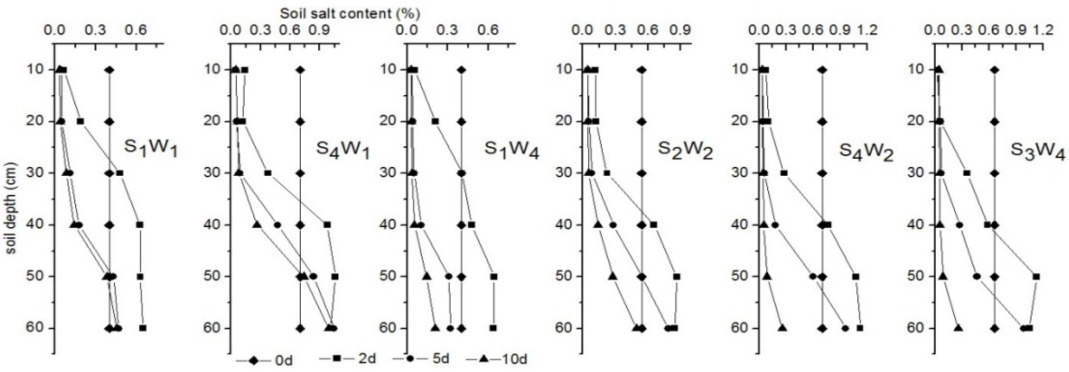

Fig. 5: Changes of soil salt content in different treatments

because infiltration of irrigation water and the discharge process were relatively rapid in condition of low amount of irrigation; furthermore, the impact of soil salinity on the water content was not obvious in this situation. Comparison between Treatment 3 and Treatment 6 illustrated that the soil water content changed differently over time at 10~40 cm depth; more specifically, at 10~40 depth, the value of soil water content was 5<10<2 days in Treatment 3 (S_1W_4) while 2<5<10 days was observed in Treatment 6 (S_3W_4). This case might be attributed to the soil salt content which possibly affected the soil aggregate structure and thus played a part in soil water retention capacity. What's more, this effect of salt might reflect only in condition of large amount of irrigation and high initial soil salt content.

Changes of soil salinity: Before irrigation, the salinity distribution in the soil profiles ranged between 0.4 and 0.7% as shown in Table 2 while it was found to have changed after irrigation (Fig. 5). The soil salt content of each Treatment had emerged in accordance with the law of decreasing over time (2>5>10 days) and increasing with depth. Except for Treatment 1 (S_1W_1), the salinity in the upper layers (0~30 cm) of all the Treatments was significantly lower than that before irrigation. In contrast to the initial salt content, larger value was found in Treatment 1 (S_1W_1) the day after irrigation and this might be a result of the low level of irrigation amount and initial salt content of Treatment 1 (S_1W_1), so the speed of salt leaching was slower than that of the other Treatments.

In addition, soil salt content at the days after irrigation was less than the initial value of all Treatments except Treatment 1 (S_1W_1) and Treatment 2 (S_4W_1), which suggested that the amount of irrigation water was the main factor affecting the transport of soil salinity, that is to say, the more irrigation water applied, the more obvious salt would be leaching.

Soil ammonium nitrogen content: The distribution of ammonium nitrogen in the soil was shown in Table 3. Before irrigation, the ammonium nitrogen content of each Treatment was so low that might be ignored in the analysis process except Treatment 4 (S_2W_2). Two days after irrigation, soil ammonium nitrogen content was significantly increased, indicating that the urea applied in irrigation water had been partly transformed into ammonium. Studies have shown that the proportion of urea transforming into ammonium is 28.9% in 3~7 h after urea applied to soil and 63.85~76.50% in 24 h, 79.99~85.02% in 48 h (Nkrumah *et al*., 1989), illustrating that urea can be rapidly decomposed in soil. We found a gradual uptrend of ammonium nitrogen content over time except Treatment 1 (S_1W_1) and the main reason is that, after irrigation for some time, soil microbial activity was enhanced with the improvement of soil aeration, which promoted the conversion of urea nitrogen into ammonium nitrogen. However, 5 to 10 days later after irrigation, for Treatment 1 (S_1W_1) the soil ammonium content decreased at 0~40 cm depth and then increased a little bit at 40~60 cm depth. The possible explanation is that the amount of irrigation was comparatively small, so it discharged quickly from soil column, which greatly strengthened the activity of soil nitrifications and thus the ammonium nitrogen content presented a low-high-low change over the time.

The increase of ammonium nitrogen in experimental columns should mainly come from the transformation of the urea applied with irrigation water. Therefore, the changes of ammonium nitrogen could reveal the impact of different water and salt combinations on the transport and transformation of urea nitrogen fertilizer in the soil. Overall, the distribution of ammonium nitrogen in the soil profile decreased from top to bottom and this situation indicated that the amount of irrigation water had relatively weak influence on the leaching of urea nitrogen. So the application of urea mostly remained in the upper layer of soil and gradually transformed into ammonium in the role of urease, which resulted in the enrichment of ammonium nitrogen in soil.

The increase of ammonium nitrogen content of Treatment 2 (S_4W_1) was significantly more than that of Treatment 1 (S_1W_1) and a similar result was observed between Treatment 6 (S_3W_4) and Treatment 3 (S_1W_4) in 2 days after irrigation (Table 3). In addition, the average content of ammonium nitrogen of Treatment 2 (S_4W_1, 1.732) was more than that of Treatment 1 (S_1W_1, 1.334) and this phenomenon was also found between Treatment 6 (S_3W_4, 2.531) and Treatment 3 (S_1W_4, 1.335). As a result, we supposed that increasing the soil salt content could be conducive to the conversion of ammonium nitrogen from urea and the accumulation of ammonium nitrogen. Nonetheless, comparison of Treatment 4 (S_2W_2) and Treatment 5 (S_4W_2) did not match the above results. This might be caused by the following two reasons: firstly, the amount of irrigation water between Treatment 4 (S_2W_2) and Treatment 5 (S_4W_2) was different; secondly, the initial ammonium nitrogen content of Treatment 4 (S_2W_2) was relatively high, which obviously had effect on the distribution of ammonium nitrogen after irrigation.

Soil nitrate nitrogen content: Before irrigation, there had been certain amount of nitrate nitrogen in the soil profile. After irrigation, lower nitrate nitrogen content of soil profile was observed in upper layers than lower ones of all Treatments (Table 3). Previous studies indicated that no nitrate nitrogen was generated after urea being applied to soil for 8 h and only after 96 h significant accumulation of nitrate nitrogen occurred (Nkrumah *et al*., 1989). Therefore, we believe that the changes of nitrate nitrogen in the soil 2 days after irrigation were mainly due to the transport of the initial nitration nitrogen with irrigation water.

Furthermore, salt content had no obvious impact on the transformation of nitrate nitrogen in soil columns no matter with large or small amount of irrigation water amount when comparing Treatment 1 (S_1W_1) with

Table 3: Ammonium and nitrate nitrogen content in soil profile under different treatments

		NH_4^+-N (mg/kg)				NO_3^--N (mg/kg)			
Treatment	Layer (cm)	0 days	2 days	5 days	10 days	0 days	2 days	5 days	10 days
S_1W_1	0~10	0.104	1.046	2.427	1.614	0.950	0.743	0.668	0.483
	10~20	0.031	1.010	1.952	1.742	1.280	1.088	0.938	0.715
	20~30	0.026	0.199	1.544	1.423	1.595	1.925	1.865	1.308
	30~40	0.187	0.178	1.315	1.247	1.175	1.865	2.395	2.285
	40~50	0.010	0.126	0.964	1.025	1.398	1.800	2.563	2.603
	50~60	0.010	0.097	0.769	0.955	1.443	1.825	2.968	2.938
S_4W_1	0~10	0.052	1.526	2.222	2.491	0.793	0.713	0.678	0.520
	10~20	0.026	1.280	2.536	2.659	1.253	0.818	1.295	0.605
	20~30	0.016	0.859	1.687	2.241	0.753	1.423	1.315	1.755
	30~40	0.109	0.339	1.427	1.719	0.940	1.693	2.330	2.263
	40~50	0.047	0.147	0.660	0.823	1.410	1.688	2.635	2.990
	50~60	0.016	0.136	0.429	0.405	1.105	1.865	2.870	3.168
S_1W_4	0~10	0.042	0.682	1.546	1.661	1.705	0.540	0.725	1.295
	10~20	0.042	0.558	1.294	1.957	1.490	1.523	0.650	1.403
	20~30	0.016	0.374	1.120	1.501	1.483	1.660	0.855	1.630
	30~40	0.042	0.338	1.034	1.251	1.158	1.743	2.308	1.700
	40~50	0.031	0.261	0.813	0.830	1.218	1.933	2.343	2.318
	50~60	0.047	0.253	0.619	0.811	0.853	1.953	2.655	2.970
S_2W_2	0~10	0.312	2.071	3.371	3.847	2.093	0.778	0.510	1.580
	10~20	0.431	1.926	2.399	3.949	1.938	0.803	0.960	1.095
	20~30	0.364	1.615	2.357	3.185	2.100	0.998	1.540	1.210
	30~40	0.385	0.680	2.069	2.701	2.028	1.658	2.088	3.265
	40~50	0.416	0.353	1.453	2.405	2.080	1.713	2.210	3.850
	50~60	0.036	0.326	0.455	2.343	1.875	1.785	2.543	5.653
S_4W_3	0~10	0.036	1.018	1.208	2.545	1.895	0.443	0.550	1.030
	10~20	0.021	0.981	1.292	2.584	2.165	0.850	0.633	1.055
	20~30	0.047	0.742	1.008	1.871	1.958	1.095	0.823	1.200
	30~40	0.026	0.522	0.899	1.703	2.298	1.670	1.335	1.315
	40~50	0.042	0.348	0.769	1.415	1.913	1.735	2.200	2.553
	50~60	0.047	0.317	0.515	1.337	1.940	1.933	2.323	3.168
S_3W_4	0~10	0.031	1.550	3.451	3.189	2.150	0.635	0.725	1.400
	10~20	0.062	1.377	1.879	3.403	2.418	1.245	1.155	1.725
	20~30	0.036	0.858	1.401	3.056	2.050	1.273	1.370	1.250
	30~40	0.021	0.293	1.123	2.740	1.895	1.358	2.030	1.418
	40~50	0.031	0.231	0.988	1.676	1.873	1.590	2.293	1.883
	50~60	0.036	0.207	0.569	1.119	1.888	1.648	2.463	2.533

Treatment 2 (S_4W_1) and Treatment 3 (S_1W_4) with Treatment 6 (S_3W_4) respectively.

In addition, at 30~60 cm depth, for all Treatments, the content of nitrate nitrogen on the fifth day and on the tenth day after irrigation was higher than that on the second day after irrigation, but a similar result could not be found at 0~30 cm depth. The possible reason was the accumulated irrigation water in part of the soil columns making soil nitrification not obvious at 0~30 cm depth. What's more, by comparing Treatment 1 (S_1W_1) and Treatment 3 (S_1W_4), the change of nitrate nitrogen with soil depth of low water application was more obvious than that of high water application. It is likely that the larger amount of irrigation water led to more nitrate leaching from the soil column.

Table 3 also indicates that there was a downward trend of the soil mineral nitrogen (sum of ammonium and nitrate nitrogen) in some Treatments when the amount on the fifth day and that on the tenth day after irrigation were compared. There are two possible reasons, for one thing, the conversion of urea nitrogen by soil caused the fixation of ammonium the soil played a role in fixating the conversion of urea nitrogen into ammonium; the phenomenon was caused by ammonia volatilization. Nevertheless, further study is required to explore the specific reasons. In addition, in this study, only soil experimental columns in the room were used to simulate the transformation of irrigation, fertilization and soil salinity; however, in the field where crops grow, these rules should be further investigated.

Cumulative salinity mass in discharge water: Figure 6 indicates the change of salt concentration in discharge water. In general, the salt concentration was low in initial phase of discharge and gradually increased with the discharge process. However, this rule was not obviously in Treatment 2 (S_4W_1) and Treatment 5 (S_4W_3). This might because the initial soil contents were high in these 2 Treatments. We could calculate the cumulative discharge of salt as formula 6:

$$L_s = \sum_{i=1}^{n} D_i c_i \tag{6}$$

where,

L_s = The cumulative discharge of salt, g
n = The total number of the observation session
D_i = The discharge water of i session, L/h
c_i = The salt concentration of discharge in i session, g/L

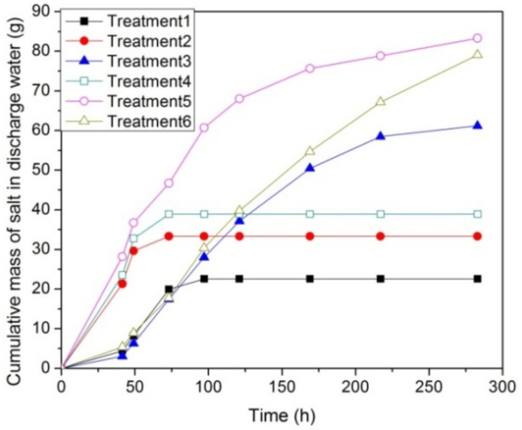

Fig. 6: Cumulative mass of salt in discharge water

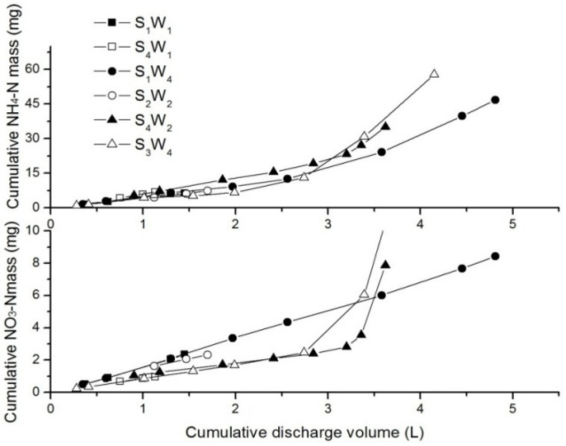

Fig. 7: Cumulative nitrogen mass in discharge

In this way, we got the process of cumulative discharge of salt (Fig. 6), the total mass of salt in 6 Treatments was 22.58, 33.34, 61.18, 38.88, 83.29, 79.06 g, respectively and if irrigation was same, the more initial soil salt content, the more salt discharge while the more irrigation, the more salt discharge if the initial soil salt content was same in each Treatment. This was because the discharge process prolonged and the rate of solute discharge kept relatively stable to cause more cumulative salt discharge when irrigation water increased.

Cumulative nitrogen mass in discharge water: The entire experimental process of the leaching of nitrate and ammonium nitrogen was shown in Fig. 7. Overall, with the increase of irrigation water, the amount of water discharged from the soil columns gradually increased as well as the accumulated loss of nitrate and ammonium nitrogen, which were consistent with the findings of nitrogen loss in subsurface drainage areas by Kanwar *et al*. (1983).

What's more, comparing Treatment 1 (S_1W_1) with Treatment 2 (S_4W_1) and Treatment 3 (S_1W_4) with Treatment 6 (S_3W_4) respectively revealed that initial salt content in soil had a vital impact on the accumulated loss of ammonium nitrogen in the drainage. To be more specific, increasing the initial soil salt content could add the leaching of the ammonium nitrogen and this was in accordance with the analysis of the distribution of ammonium nitrogen in soil mentioned herein before. But in nitrate nitrogen, the similar law was not reflected. Furthermore, comparison between Treatment 4 (S_2W_2) and Treatment 5 (S_4W_3) illustrated that the impact of irrigation water on accumulated loss of nitrogen in the drainage was greater than the initial salt content in the soil.

DISCUSSION

Soil water balance: Using the formula 1 and 2 to do water balance analysis of 6 Treatments in initial moment and the 3 time sessions which were divided by 3 sampling time (2, 5 and 10 days) respectively. The calculation results showed that the water loss of the 6 Treatments of each time session were 0.5±1.18, -0.43±1.92, -0.56±1.78, -0.49±1.08 and -0.61±1.27 cm, respectively. Obviously, we could deem that the water loss of each Treatment in every time session was 0 cm. that is to say, we could ignore the effect of evaporation and other forms of water loss on water balance in our experiments.

Rule of soil salt transport: We could see from Fig. 5 that the distribution of soil salt content in the 6 Treatments were significantly different in every moment. Furthermore, we used formula 3 to 5 to calculate parameters of soil salt distribution of each Treatment to describe the differences and the results were shown in Table 4 to 6. Since the reduction of total amount of salt in the soil column is equal to the discharge salt amount at the bottom of soil column, the law of variation shown in Fig. 5 was consistent with the total salt content of Table 4.

The center of mass can reflect the orthocenter of salinity distribution in soil profile (Table 5). Before irrigation, soil salinity profile was uniform; therefore the center of mass was in the center of the soil column. It can be predicted that, if there was a sufficient amount of leaching to get a uniform distribution of soil salt content after leaching, the center of mass would return to the center of the soil column. However, between these two states, soil salt gathered to lower soil and discharged from the bottom of columns would make the mass of center transport downward and upward respectively. What's more, the changes of the center of mass in soil profile of each Treatment were due to the interaction of these two processes. Treatment 1 (S_1W_1) and Treatment 2 (S_4W_1) mainly experienced the process of salt gathering to lower soil layer from 0 to 10 days and thus the center of mass decreased; however, for other Treatments, the center of mass decreased from 0 to 5 days, then in the subsequent periods, the salt

Table 4: Total mass of salt

	Total salt mass (cm)					
Time (days)	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Treatment 5	Treatment 6
0	100.81	160.23	100.81	123.61	160.23	151.08
2	91.56	140.53	92.53	107.83	130.45	121.62
5	49.26	97.09	32.86	68.57	72.20	72.04
10	43.35	83.31	19.23	40.12	20.34	20.73

Table 5: Depth of center of mass

	Depth of center of mass (cm)					
Time (days)	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Treatment 5	Treatment 6
0	30	30	30	30	30	30
2	38.31	40.51	38.84	41.18	42.57	43.41
5	42.87	45.09	43.37	44.99	46.89	46.33
10	44.09	45.86	42.05	44.47	41.90	40.74

Table 6: Dispersion of soil salt

	Dispersion of soil salt (cm)					
Time (days)	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Treatment 5	Treatment 6
0	17.08	17.08	17.08	17.08	17.08	17.08
2	13.44	12.90	13.73	13.18	12.10	10.98
5	13.23	11.16	13.24	12.06	11.20	11.71
10	13.64	11.50	15.32	13.56	16.38	17.16

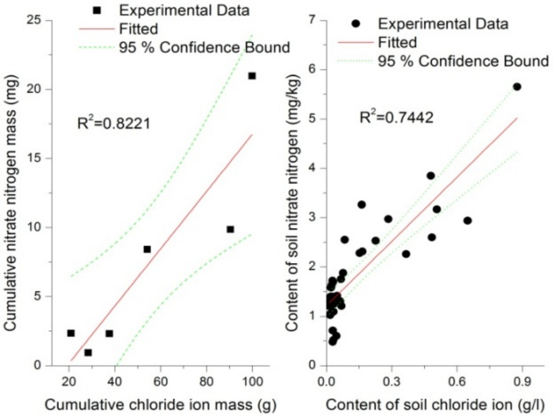

Fig.8: Regression analysis between cumulative loss of chloride ion and nitrate nitrogen

gathering to subsoil became weak and the salt discharging gradually increased, as a result of the superposition of these two effects, the center of mass become stable and had a moving up trend. There were mainly two reasons for this, for one thing, the irrigation amount was relatively small (15.73 cm) in Treatment 1 (S_1W_1) and Treatment 2 (S_4W_1) and the leaching of soil salinity was insufficient; for another, the rate of water movement in Treatment 1 (S_1W_1) and Treatment 2 (S_4W_1) was rapid and the rapid water movement was mostly macro-pore flow, furthermore, the faster the rate of flow, the more difficult thoroughly mixed with all the solute in soil pores, which reduced the ability of carrying solute (Cote *et al*., 2000; Walton *et al*., 2000) and thus the rate of salinity transport downward in Treatment 1 (S_1W_1) and Treatment 2 (S_4W_1) was behind the other Treatments.

In addition, soil salt gathering in lower soil layers and discharging from the bottom of soil columns were also affected its dispersion in soil profile. To be more exact, the stronger of aggregation, the smaller of the dispersion. However, sooner discharging from the bottom of soil columns would reduce the aggregation and increased the dispersion of soil salt. The changes of dispersion of soil salt shown in Table 6 were overall the same, decreasing firstly and then increasing, reaching a minimum value at 5 days. What's more, we found that the soil salt dispersion in Treatment 1 (S_1W_1), Treatment 2 (S_4W_1) and Treatment 4 (S_2W_2) was small than other Treatments in the end of discharge process. This might because the discharge amount of these three Treatments was less than other Treatments and there was more salt gathering in the lower soil layers in the end of discharge process, which reduced the dispersion of soil salt.

Relationship between salinity and nitrate nitrogen: It is well known that nitrate nitrogen content in soil and soil salinity are two major factors affecting the crop growth. Table 3 and Fig. 5 illustrate that the nitrate nitrogen and salinity content of the soil profile progressively become larger from top to bottom of the soil columns. Considering the major constituent in Hetao Irrigation District is chloride and both chloride ion and nitrate nitrogen are negatively charged ions of high solubility and are non-reactive chemicals, they should move similarly with water flow in the soil columns.

Therefore, regression analysis was done for the cumulative loss of chloride ion and nitrate nitrogen and content of chloride ion and nitrate nitrogen at 10 days in soil profile of all experimental columns by SAS software. Figure 8 shows a clear linear relationship between them and the correlation coefficients were approximately 0.82 and 0.74, respectively.

CONCLUSION

Conclusions from this study are summarized as follows:

- The high initial salinity in soil had a certain impact on the changes of water content of the vertical soil section with the time being after large amount of water irrigation. Furthermore, high soil salt content might increase the rate of infiltration.
- The amount of irrigation water significantly affected the transport of soil salinity; to be more specific, the more irrigation water applied, the more obvious the salt leaching was.
- The high soil salinity content was likely to promote the conversion of urea nitrogen to ammonium nitrogen and it may also have an active role in ammonium nitrogen accumulation in drainage. However, no similar law could be applied on nitrate nitrogen.
- Regression analysis showed that there existed a sound correlation between the content of chloride ion and nitrate nitrogen both in the drainage and soil profile ($r^2 = 0.8221$ and 0.7442, respectively).

Results from this research have shown that different fertigation practices and initial soil salinity are important factors affecting soil N and salinity transport. It is therefore possible to reduce nitrogen leaching and prevent salt from accumulating in soil profile by carefully managing the irrigation and fertilizer application methods. In addition, irrigation and fertilization managements should be integrated with other management plans, such as tillage practice, to minimize nitrogen leaching and salinity accumulating.

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