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Effect of Drip Irrigation Under Mulch on Nitrogen Transport in Deep Soil Layers in an Agricultural Region of the Xiliao River Plain, China

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ABSTRACT

In the agricultural region of the Xiliao River Plain, drip irrigation under mulch has been widely implemented. It not only saves irrigation water, but also changes the structure of the underlying surface of agricultural land, which affects the local hydrological cycle to a certain extent, and makes the process of nitrogen transportation in soil with new characteristics. This study analyzed the distribution of NH_4-N, NO_3-N, and NO_2-N in different soil depths during the whole growth period under three underlying surface conditions, including drip irrigation under mulch, border irrigation, and bare area through field in-situ observation experiment, and analyzed the influence of drip irrigation under mulch on nitrogen transport in deep soil layers. The results showed that under the soil properties of the experimental area, drip irrigation under mulch creates more water to enter the deep soil layers, which was beneficial to alleviate the downward trend of local groundwater level to a certain extent. The average content of NH_4-N and NO_3-N under drip irrigation under mulch was higher than that under border irrigation. The average content of NH_4-N under drip irrigation under mulch was 1.24 $mg.kg^{-1}$ in soil depths of 80-300 cm, and 0.97 $mg.kg^{-1}$ under border irrigation. The average content of NO_3-N under drip irrigation under mulch was 2.73 $mg.kg^{-1}$ in soil depths of 80-300 cm, and 1.99 $mg.kg^{-1}$ under border irrigation. The increment of NH_4-N and NO_3-N distribution in deep soil layers under drip irrigation under mulch was greater than that under border irrigation, and the increment of NO_3-N content is significantly greater than that under border irrigation. Soil water content has a significant impact on the contents of NH_4-N and NO_3-N. It indicated that compared with traditional border irrigation, drip irrigation under mulch was beneficial to alleviate the downward trend of local groundwater, but it would increase the risk of nitrogen pollution in local groundwater.

INTRODUCTION

The Xiliao River Plain is located in the western part of northeast China, most of which is in the semi-arid area, with low annual rainfall and high evaporation, relatively poor surface water, and abundant groundwater which is easy to exploit and utilize. With the development of agriculture, industry, and economy in the region, the lack of surface water can hardly meet the needs of normal production and life, and the rich local groundwater resources become the main source of water supply in the region (Zhong et al. 2018). Long-term sustainable utilization of groundwater is the basis of economic development and agricultural production in this region. Therefore, ascertaining the characteristics of groundwater recharge and the safety of groundwater quality is critical to the effective management of local water resources and the ecosystem that depends on groundwater. (Macdonald & Edmunds 2014, Zhang & Wang 2021)

Research shows that groundwater nitrogen pollution is a common environmental problem in China, and the concentration of NO_3-N in shallow groundwater is close to 10 $mg.L^{-1}$ (the maximum pollution scale of EPA in the United States). Excessive use of nitrogen and phosphorus in agricultural production in an irrigated farming area will cause groundwater pollution through eluviating. (Hansen et al. 2017, Soldatova et al. 2021) Compared with non-point source pollution of surface water, the pollution of groundwater by nitrogen and phosphorus is more serious to human health in the Xiliao River Plain, where groundwater is the main source of water supply. At present, the Xiliao River Plain is faced with many water resources problems, such as river drying up, surface water pollution, groundwater overexploitation, etc. (Zhong et al. 2018). Groundwater quality in some areas of the basin has been polluted to different degrees, especially nitrogen pollution, the detection rate, and the variation trend both show an upward trend, and three kinds of nitrogen (NH_4-N, NO_3-N,

NO_2-N) are often detected at the same time. The potential threat of nitrogen pollution to groundwater security is more serious in an irrigated farming area of the Xiliao River Plain where groundwater is the main source of water.

Eluviation is considered to be one of the main ways of nitrogen loss in agricultural production, especially in irrigation systems of farmland. The results showed that precipitation and irrigation amount influenced the eluviation process of nitrogen and phosphorus (Williams et al. 2021, Hao et al. 2015), nitrogen eluviation is easy to occur in places with high nitrogen application rate and shallow rooting depth (Halvorson et al. 2008, Fan et al. 2010). The transport process of NO_3-N is related to soil properties (Liu et al. 2021, Iqbal et al. 2019). The clay layer in the soil profile tends to form saturated soil, which is conducive to delaying and attenuating the process of water infiltration, to reduce the amount of NO_3-N leaching into groundwater (Li et al. 2018). In addition, the time point of fertilization and type of fertilizer, the type of land use, and the thickness of the percolation zone also significantly affected the storage of soil nitrogen salts and the concentration of groundwater nitrogen salts (Robertson. et al. 2017, Suchy et al. 2018). With the increasing demands for water in irrigation areas and the development of irrigation technology, under the background of "Water-saving and grain-increasing", drip irrigation under mulch has been widely promoted in the Xiliao River Plain (Wang et al 2014). Drip irrigation under mulch is a technology combining film mulching and drip irrigation, which makes the limited water cycle between soil and mulching, and changes the original hydrological cycle (Wang et al. 2014, Jia et al. 2021). The large-scale promotion of drip irrigation under mulch has also changed the underlying surface conditions in an irrigated farming area of Xiliao River to a certain extent, and new characteristics of water transport and solute transport have emerged. Therefore, the study on the characteristics of solute transport under drip irrigation under mulch is helpful to more comprehensively evaluate the comprehensive effect of drip irrigation under mulch as a water-saving measure.

At present, the research on drip irrigation under mulch mainly focuses on crop yield, effective water utilization coefficient, and salt and water utilization above the root length of crops, while less attention is paid to the storage, movement, and attenuation process of inorganic nitrogen in deep soil layers (Mil et al 2018, Chen et al 2015). Because of the difficulty of sampling, the potential reserves and retention time of inorganic nitrogen in deep soil layers have not been determined, posing a potential threat to the quality of future groundwater in some areas (Ascott et al. 2017). At present, numerous methods have been applied to monitor the characteristics of water and solutes, such as field in-situ experiments, monitoring equipment (time domain reflectometry, etc.) (Aharoni et al 2017), and tracer experiments and stable isotopes (Xiang et al. 2019). Field in-situ experiment is widely used because of their authenticity and accuracy.

The experimental area of this study is located in the Jianping Irrigation Experimental Station, Chaoyang City, Liaoning Province, China. Through field, in-situ observation experiments, the soil water content, and nitrogen content in different soil depths under three kinds of soil surface conditions, including drip irrigation under mulch, border irrigation, and bare area were observed during the whole crop growth period. The main objectives of this study were to (1) describe, analyze the effects of drip irrigation under mulch on different distribution characteristics of soil water and nitrogen content, and (2) analyze the effect of drip irrigation under mulch on nitrogen migration. From the perspective of hydrology and water resources, this paper reflects a more comprehensive evaluation of the performance of drip irrigation under mulch in the hydrologic cycle and provides more references for making water resource development strategies in similar areas.

MATERIALS AND METHODS

Site Description

The experimental area is located in the Jianping Irrigation Experimental Station, Chaoyang City, Liaoning Province, China (E119°18', N 41°47'), on the east bank of the Lao-Ha River and has an elevation of 461m. It is located in the transitional zone of oceanographic monsoon climate to a continental climate, which belongs to the semi-arid monsoon continental climate. This area is a typical semi-arid area with the characteristics of a vertical hydrological cycle. Rainfall rarely forms surface runoff, and the infiltration is intense. Rainfall is the main source of groundwater recharge. The average annual rainfall is 440mm, 80% of the rainfall is concentrated from June to August. The average annual evapotranspiration is 1800-2100mm, and the evaporation is the largest in April-June, accounting for 45%-50% of the total annual evaporation. The sunshine duration is long, and the annual average sunshine duration is 2868-3111h. The average temperature for many years is 5-6°C. The hydrologic cycle and climate-related characteristics of the experimental area are representatives, which can represent the Xiliao River basin.

Field irrigation methods in the experimental area are mainly border irrigation and drip irrigation under mulch. The soil is dominated by loamy sandy soil and sandy with some sandy loam interbedded between layers. The concentrations of inorganic nitrogen (NH_4-N, NO_3-N, NO_2-N) in groundwater were 0.590 mg.L^{-1}, 12.889 mg.L^{-1}, and 0.004 mg.L^{-1}, respectively. Among them, the NO_3-N concentration exceeds the maximum pollution scale of THE US EPA. According to the actual local planting situation, maize (Liaodan 1211) was selected as the research object in this experiment.

Design of Experiments

In the planting area of the experimental area, two irrigation methods were set, one was drip irrigation under mulch and the other was border irrigation. At the same time, the bare area (non-planted crops) was set as blank control, and there were three kinds of underlying surface forms. To exclude the error caused by soil spatial variability and experimental contingency, the experiment was repeated several times. Due to the impermeability of drip irrigation and mulching under the plastic film and the rain-catching effect of furrows, water will move sideways (Zhang & Wang 202). In the drip irrigation area under mulch, two monitoring sections were set up, namely, the middle position of plastic film (MPF) and the middle position of furrow (MF). Water infiltration under drip irrigation was changed from one-dimensional infiltration to two-dimensional infiltration. To eliminate errors, the moisture and solute contents were calculated using MBF and MF. A separate monitoring section, called MBI, MBA, is set up in border irrigation and flat bare areas, respectively, as shown in Fig. 1.

The experiment began on April 29, 2019, and ended on October 22, 2019. Border irrigation was carried out irrigation before sowing on May 9, with the irrigation amount of 600 m³.hm^{-2}, sowing on May 15, and seedling on May 25. Drip irrigation under mulch was carried out irrigation before sowing on May 9, with the irrigation amount of 300 m³.hm^{-2}, sowing on May 9, and seedling on May 21. Border irrigation was applied with DAP (diammonium phosphate) (N 18%) 187.5 kg.hm^{-2} on May 15 and urea (N 46%) 375.0 kg.hm^{-2} on June 28. Drip irrigation under mulch was applied with DAP (N 18%) 187.5 kg.hm^{-2} and slow-release fertilizer (N 20%) 450.0 kg.hm^{-2} on May 9. To explore the characteristics of soil water and inorganic nitrogen migration in different growth periods of crops, typical time points of crop growth were selected for measurement, namely, April 29 (Initial state), June 5 (Early stage of crop growth), July 9 (Rapid growth stage of crop growth), August 23 (Middle stage of crop growth) and October 10 (Late stage of crop growth). The rainfall, irrigation, and sampling time points during the test are shown in Fig. 2.

Design and Measurement

During the experiment, the groundwater level in the experimental area was maintained at about 320 cm. To better explore the characteristics of water and solute transport between crop roots and groundwater levels in deep soil layers, the research depth was set at 300 cm. Soil samples at different depths were sampled with a soil sampler, and soil samples were taken every 20 cm To eliminate the errors caused by soil spatial variability and experiment contingency, repeated tests and multiple selection sites were carried out.

The soil mass moisture content was measured by oven drying method and converted to soil volume water content, the formula is shown below.

$$\theta_m = \frac{M_w}{M_s} \quad \ldots(1)$$

$$\theta_v = \theta_m \cdot \frac{\rho_b}{\rho_w} \quad \ldots(2)$$

Where θ_m is the soil mass moisture content (g·g^{-1}), θ_v is the soil volume water content (cm^3·cm^{-3}), M_w is the mass of water in the sample (g), M_s is the mass of soil in the sample (g). ρ_b is soil bulk density (g·cm^{-3}), ρ_w is the bulk density of water, ρ_w =1.0 g· cm^{-3}.

The soil samples were extracted with KCL solution and analyzed with Auto Discrete Analyzers (CleverChem380) for NH_4-N (lower detection limit 0.005 mg.L^{-1}), NO_3-N (lower

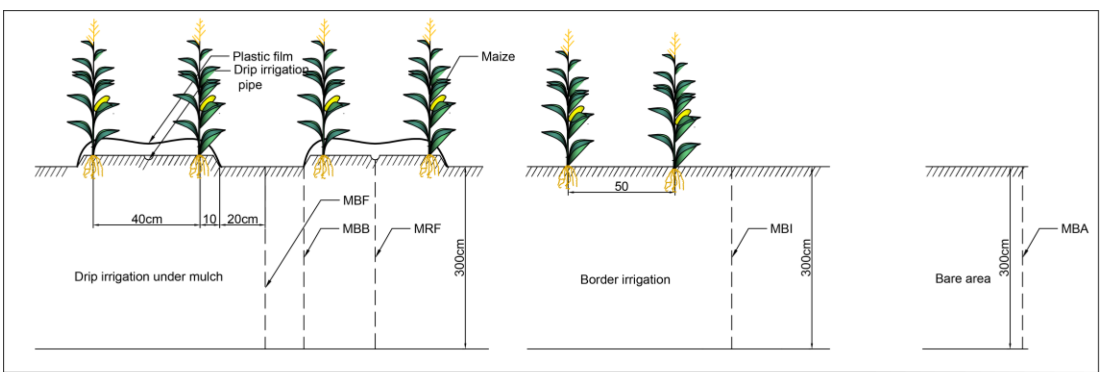

Fig. 1: Soil water content and solute observation profile.

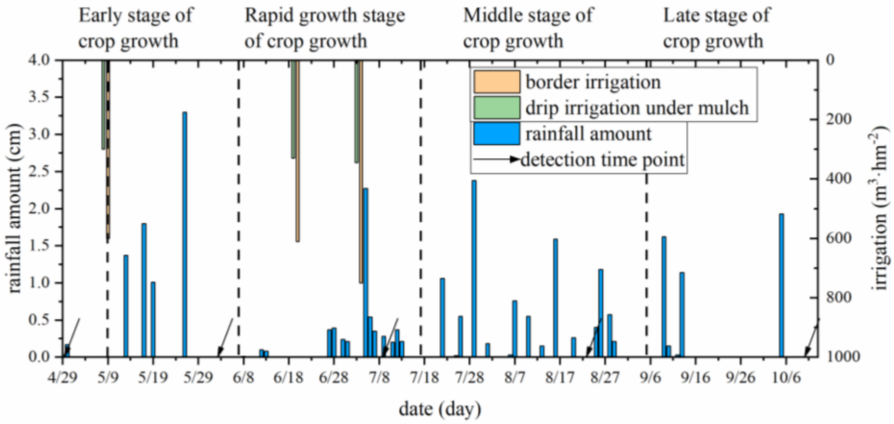

Fig. 2 Rainfall and irrigation records in 2019.

detection limit 0.003 mg.L^{-1}), and NO_2-N (lower detection limit 0.002 mg.L^{-1}). Use the following formula to make the conversion.

$$\theta_m = \frac{M_w}{M_s} \quad \ldots(3)$$

Where C is soil solute concentration (mg.kg^{-1}), C_T is the concentration of sample solution (mg.L^{-1}), v is the volume of KCL solution (mL), M_s is the mass of soil in the sample (g).

RESULTS

Soil Property

Undisturbed soil was taken from 0-40cm, 40-70 cm, 70-110 cm, 110-250 cm, and 250-300 cm in the test area, and the basic physical properties of soil (bulk density, field capacity, and saturated soil water content) were obtained through experiments. Soil particle analysis was carried out to determine the soil type according to the American soil classification standard. The test results are shown in Table 1. The soil texture in the test region is mainly loamy sandy soil and sandy, with some sandy loam interbedded between layers. From the results of soil particle analysis, it can be seen that the sand content in the experimental area is large and the infiltration capacity is strong. Previous studies have also proved that the soil in the experimental area has a strong infiltration capacity.

Soil Water Content

The distribution of soil water content with soil depth in border irrigation, drip irrigation under mulch, and the bare area are shown in Fig. 3.

Since the roots of maize are mainly distributed in 0-80cm soil, the ability of root water uptake in the region below 80 cm was relatively weak, the soil was divided into two parts with a limit of 80 cm. Above 0-80 cm, the water content of drip irrigation under film was high. At 40 cm, the maximum water content of drip irrigation under mulch was 24.54%, which was greater than that of bare area (22.39%) and far greater than that of border irrigation (17.91%). At 80cm-300 cm, the average water content of drip irrigation under mulch was 7.94%, which was close to that of bare area (7.68%) and greater than that of border irrigation (6.35%). Soil water content firstly increases and then decreases. The reason for this phenomenon is related to soil properties at different depths. The soil at the depth of 40 cm had better water preservation, while the soil below 80 cm had better infiltration capacity.

The results showed that the water content of drip irrigation under mulch was higher than border irrigation in the soil about 40 cm and below 80 cm. The reason for this phenomenon was that under the influence of the local hydrological cycle, the film mulching did not reduce the infiltration amount

Table 1: Physical properties of soil in the test area.

Soil depth (cm)	Volume weight [g·cm^{-3}]	Field capacity [cm^3·cm^{-3}]	Saturated soil water content [cm^3·cm^{-3}]	Soil type
0-40	1.54	0.21	0.44	Loamy sand
40-70	1.65	0.35	0.44	Sandy loam
70-110	1.59	0.24	0.43	Sand
110-250	1.62	0.14	0.41	Sand
250-300	1.51	0.10	0.36	Sand

of rainfall and made the water vapor circulation under the film, which reduced the evaporation of soil water to a certain extent. Due to the rain-catching effect of ridging, more water is absorbed into the deep soil Under the comprehensive influence of the strong infiltration capacity of the local soil. Compared with border irrigation, drip irrigation under mulch could save about 50% of irrigation water and get more water into deep soil, which was beneficial to the process of groundwater infiltration and recharge, and alleviated the downward trend of local groundwater level to a certain extent.

The Content of NH_4-N

The distribution of NH_4 -N content with soil depth in border irrigation, drip irrigation under mulch, and bare area during the whole growth period is shown in Fig. 4.

As can be seen from Fig. 4, the contents of NH_4-N in the soil under the three underlying surface conditions all decreased gradually with the increase of soil depth. Under drip irrigation under mulch, the average content of NH_4-N was 2.85 $mg.kg^{-1}$ at 0-80 cm depth and 1.24 $mg.kg^{-1}$ at 80 cm-300 cm depth during the crop growth period. Under border irrigation, the average content of NH_4-N was 1.90 $mg.kg^{-1}$ at 0-80 cm and 0.97 mg.kg at 80 cm -300 cm. Under bare area the average content of NH_4-N was 1.44 $mg.kg^{-1}$ at 0-80cm and 0.55 $mg.kg^{-1}$ at 80-300 cm. This was because the solute transport was easily affected by soil properties, the shallow soil layers in the experimental area contained much more clay and silt than the deep soil layers. The negatively charged colloids in the shallow soil layers tended to adsorb the positively charged NH_4-N ions, thus hindering the further downward movement of NH_4-N, resulting in a higher content of NH_4-N in the shallow soil layers. Only when the soil water content was close to the saturated water content or reached the upper limit of the adsorption capacity of colloidal particles, NH_4-N would be driven by infiltration to the deep soil layers.

During the whole growth period, the average content of NH_4-N in 0-300cm under drip irrigation under mulch was 1.63 $mg.kg^{-1}$, which was higher than that under border irrigation (1.20 $mg.kg^{-}$). However, due to the lack of nitrogen fertilizer supplement, the content of NH4-N in flat bare land was low and hardly changed over time, with the average content maintained at about 0.77$mg.kg^{-}$. The reason for this phenomenon was that the film mulching reduced the ammonia volatilization from the surface soil, and at the same time, drip irrigation under mulch got more water into the soil due to the rain-catching effect and impermeability of plastic film. The leaching effect was increased. This caused more NH4-N to migrate from the surface to the deep soil layers.

The Content of NO_3-N

The distribution of NO_3-N content with soil depth in border irrigation, drip irrigation under mulch, and bare area during the whole growth period are shown in Fig. 5.

As can be seen from Fig. 5, the contents of NO_3-N in the soil under the three underlying surface conditions all increased with the increase of soil depth, and there was an obvious increase process at 60cm-120cm. Under drip irrigation under mulch, the average content of NO_3-N was 0.37 $mg.kg^{-1}$ in 0-80 cm and 2.73 $mg.kg^{-1}$ in 80 cm – 300 cm during the crop growth period. Under border irrigation, the average content of NO_3-N was 0.16 $mg.kg^{-1}$ in 0-80 cm and

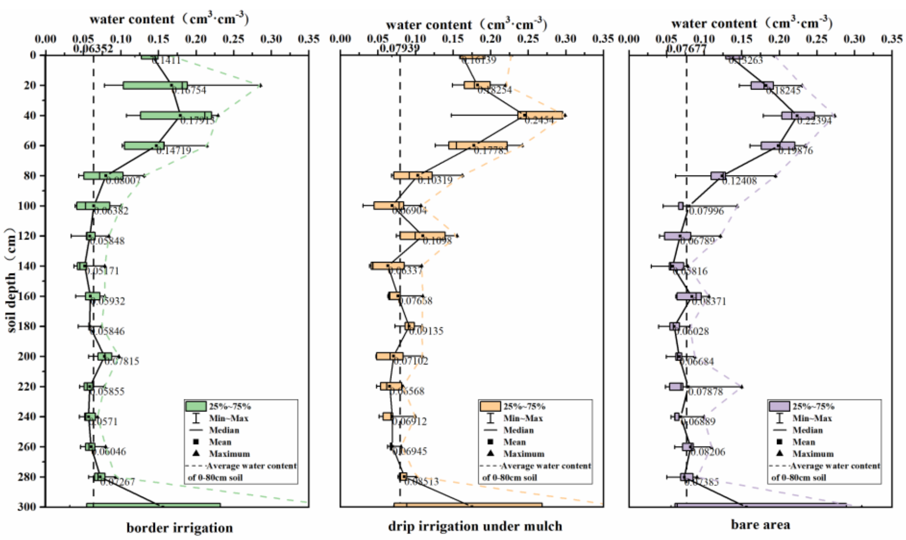

Fig. 3: Distribution of water content.

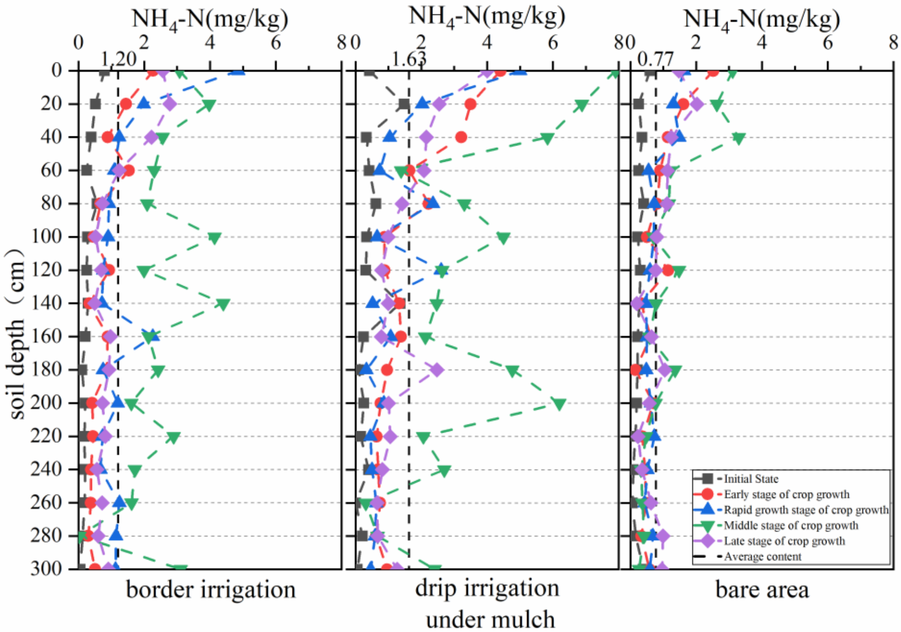

Fig. 4: Distribution of NH_4-N content.

1.99 mg.kg^{-1} in 80 cm-300c m. Under border irrigation, the average content of NO_3-N was 0.08 mg.kg^{-1} at 0-80cm and 0.86 mg.kg^{-} at 80-300cm. This was because the soil property in the experimental area was relatively sandy, with a strong ability for infiltration. The leaching effect of rainfall and irrigation was strong, which made a large amount of NO_3-N in the shallow soil layers migrate to the deep soil layers. At the same time, considering the absorption and utilization of crops, the NO_3-N content in shallow soil layers was less, while the NO_3-N content in deep soil layers was more.

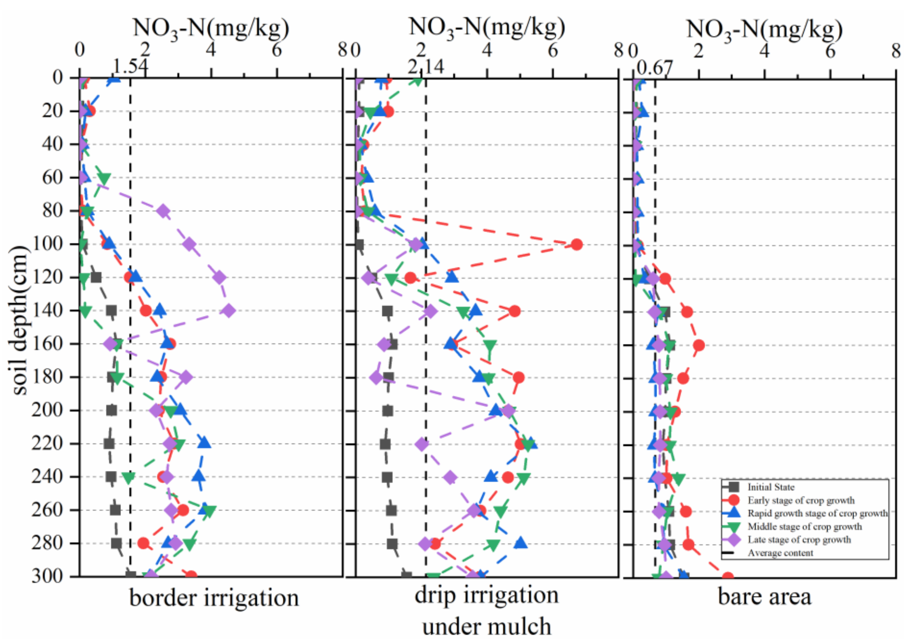

Fig. 5: Distribution of NO_3-N content.

During the whole growth period, the average content of NO_3-N in 0-300cm under drip irrigation under mulch was 2.14 mg.kg^{-}, which was higher than that under border irrigation (1.54 mg.kg^{-1}). However, due to the lack of nitrogen fertilizer supplement, the content of NO_3-N in flat bare land was low, and changed little over time, with the average content maintained at about 0.67 mg.kg^{-1}. This was because drip irrigation under mulch made more water enter the soil, enhanced the leaching effect, and made more NO_3-N migrate to the deep soil layers.

The Content of NO_2-N

The distribution of NO_2-N content with soil depth in border irrigation, drip irrigation under mulch, and bare area during the whole growth period are shown in Fig. 6.

As can be seen from Fig. 6, the contents of NO_2-N under the three underlying surface conditions hardly changed with the increase of soil depth, and the contents of NO_2-N fluctuated only in the surface soil above 40cm at different growth stages. The content of NO_2-N in the soil below 40cm was unchanged and low.

In drip irrigation under mulch, border irrigation, and bare land, the NO_2-N content was 0.040 mg.kg^{-}, 0.035 mg.kg^{-1} and 0.031 mg.kg^{-1}, respectively. As the content of NO_2-N in soil was low, and as an intermediate product of nitrification and denitrification, it was unstable in soil, so no further discussion would be made.

DISCUSSION

Relationship Between Inorganic Nitrogen Content and Water Content

"Salt with water" is the basic law of solute transport. Drip irrigation under mulch changed the underlying surface of farmland. Under the comprehensive effects of local soil properties and the characteristics of the hydrological cycle in a semi-arid area, new characteristics appeared in the process of water infiltration, that was, more water entered deep soil under drip irrigation under mulch. Therefore, exploring the relationship between inorganic nitrogen and water content is crucial to understand the process of nitrogen transport in the experimental area.

The relationship between the average content of NH_4-N and NO_3-N and the average water content was obtained by weighting the content of NH_4-N and NO_3-N and water content. The results are shown in Fig. 7 and Fig. 8.

As can be seen from Fig. 7, there was no clear correlation between NH_4-N content and water content in the soil above 60cm. In the soil below 60cm, the content of NH_4-N and water fluctuated in some areas, but the overall change trend with soil depth was the same. This was because there were many factors affecting the content of NH_4-N in shallow soil layers, including the application of nitrogen fertilizer and ineffective volatilization, the effects of root absorption and utilization, rainfall, irrigation, and the negatively charged

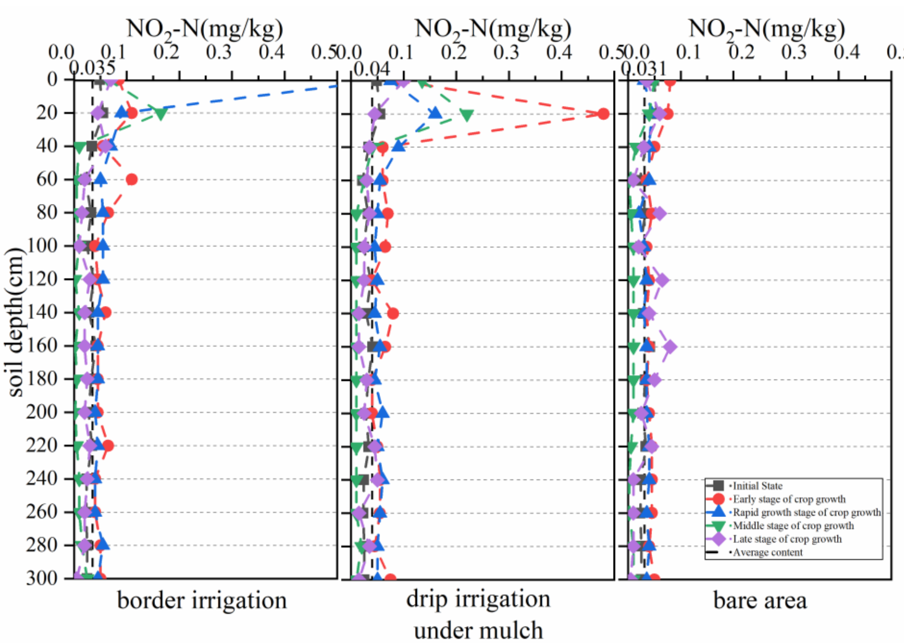

Fig. 6: Distribution of NO_2-N content.

colloidal adsorption in shallow soils, which all affected the migration of NH_4-N. Therefore, there was no clear correlation between the content of NH_4-N in the shallow soil layers and water content. However, for the deep soil layers, the soil properties of each layer were the same, which were mainly sand particles, and the colloidal adsorption is weak. The infiltration of soil water becomes the main factor affecting the migration of NH_4-N. Therefore, the variation trend of NH_4-N content with soil depth was consistent with the variation trend of water content with soil depth.

As can be seen from Fig. 8, there was no clear correlation between NO_3-N content and water content in the soil above 80 cm. The variation trend of NO_3-N content and water content in the soil below 80cm was the same as the soil depth. The reason for this result was the same as that for NH4-N, except that the soil in the experimental area was sandy and there was no clay layer with a certain thickness in the shallow soil layers. During irrigation or rainfall, saturated soil could not be formed in the shallow layer to delay and attenuate water infiltration, so NO_3-N in the shallow layer

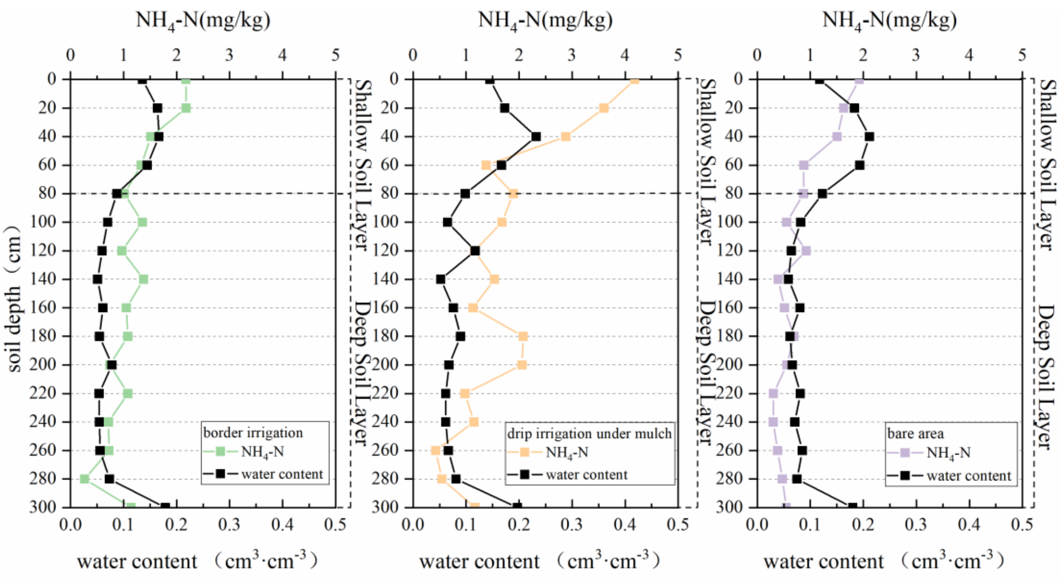

Fig. 7: Distribution of NH_4-N content and water content.

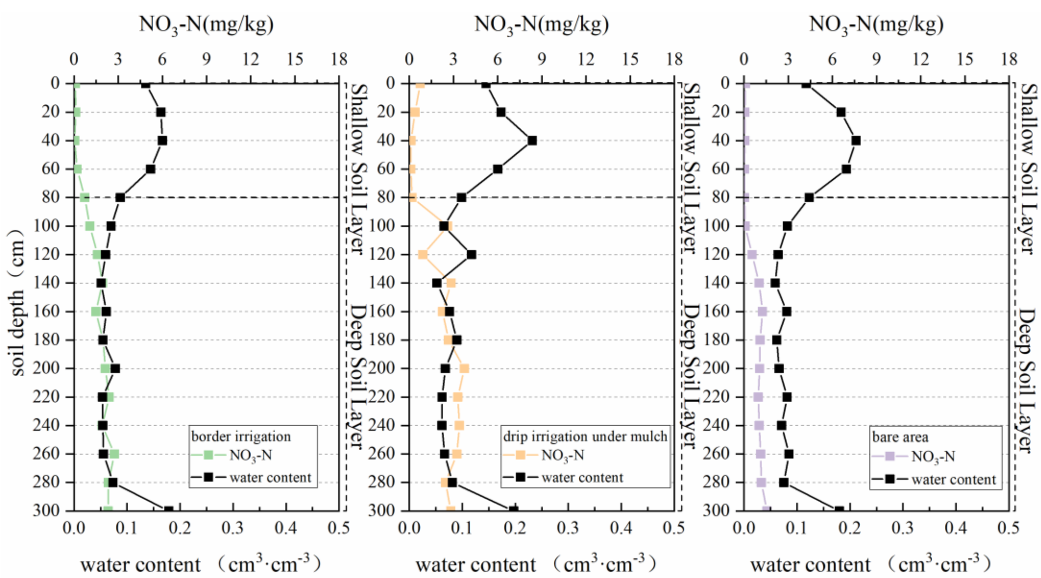

Fig. 8: Distribution of NO_3-N content and water content.

rapidly migrated to the deep layer, and the content of NO_3-N increased with the increase of soil depth.

The Change of NH_4-N and NO_3-N Content at Different Depths

The content of NH_4-N and NO_3-N in each growth period was weighted, and the initial state content value was subtracted to obtain the change of NH_4-N and NO3-N content in each growth period. The vertical migration of soil inorganic nitrogen could be reflected by the changes of NH_4-N and NO_3-N contents at different depths. The content changes of NH_4-N and NO_3-N at different depths under drip irrigation under mulch and border irrigation are shown in Fig. 9. Due to the lack of nitrogen fertilizer application, the change value of soil NH_4-N and NO_3-N content was small, so it was not further discussed.

As can be seen from Fig. 9, in the soil above 80cm, the change of NO_3-N content under drip irrigation under mulch and border irrigation was small, but the increased value of NH_4-N content under drip irrigation under mulch was significantly greater than that under border irrigation.

In the soil below 80cm, the change value of NH_4-N content under drip irrigation under mulch and border irrigation decreased with the increase of soil depth. Although the increase of NH_4-N content under drip irrigation under mulch was slightly greater than that under border irrigation, the increase of NH_4-N content under two conditions below 220 cm was almost the same. It can be seen that with the increase of groundwater depth, the amount of NH_4-N entered into groundwater will gradually decrease. When the depth of groundwater is more than 220cm, the amount of NH_4-N entered into groundwater under the two conditions is almost the same.

In the soil depth range of 80cm-220 cm, the change value of NO_3-N content under drip irrigation under mulch and border irrigation increased with the increase of soil depth and decreased with the increase of depth below 220 cm. However, in the whole interval below 80cm, the increment of NO_3-N content under drip irrigation under mulch was significantly greater than that under border irrigation. It can be seen that when the local groundwater depth is less than 220 cm, the amount of NO_3-N entered into the groundwater will gradually decrease. When the depth of groundwater is more than 220cm, the amount of NO_3-N entered into groundwater decreases with the increase of groundwater depth. The amount of NO_3-N entered into groundwater under drip irrigation under mulch was significantly greater than that under border irrigation.

It is worth noting that the NO_3-N and NH_4-N distributed in the area between the soil level below 80cm and the groundwater level above cannot be effectively utilized by crops, and will move further to the groundwater under the leaching effect of rainfall and irrigation. In this area, the contents of NH_4-N and $N0_3$-N in drip irrigation under mulch were higher than those in border irrigation. The promotion of drip irrigation under the mulch will increase the risk of nitrogen pollution in local groundwater.

CONCLUSION

Compared with traditional border irrigation, drip irrigation under mulch not only saved irrigation water but also made more water infiltrate into deep soil layers, which increased

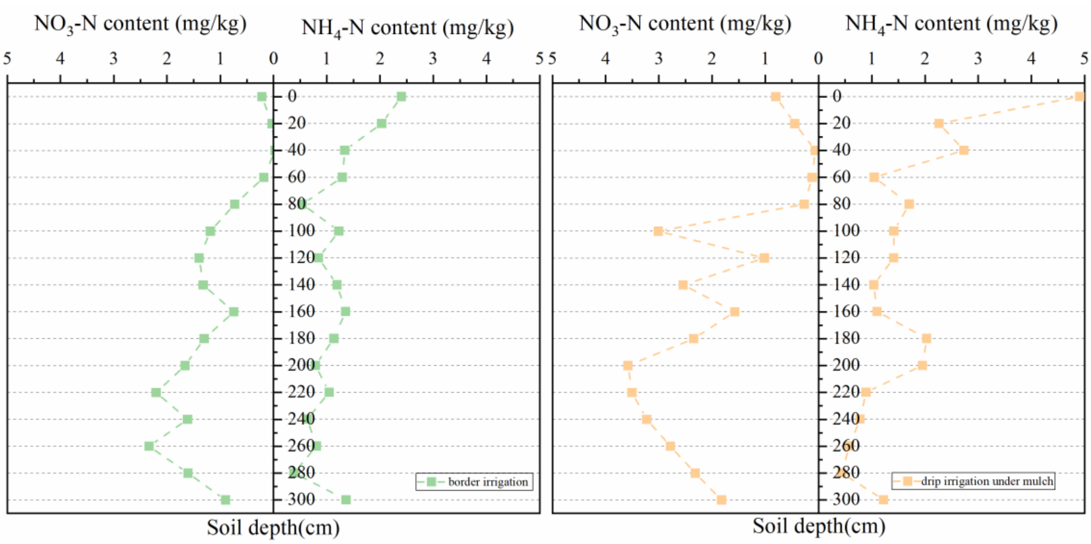

Fig. 9: Distribution of changes in NH_4-N and NO_3-N contents.

the infiltration recharge of groundwater and had a positive effect on alleviating the decrease of local groundwater level.

The average content of NH_4-N and NO_3-N under drip irrigation under mulch was higher than that under border irrigation because drip irrigation under mulch increased the infiltration of water into the deep soil, it intensified the leaching effect of irrigation and rainfall on inorganic nitrogen. This phenomenon was especially obvious in deep soil layers. The average content of NH_4-N was 1.24 $mg.kg^{-1}$ at 80 cm-300 cm under drip irrigation under mulch and 0.97 $mg.kg^{-1}$ under border irrigation. The average content of NO_3-N was 2.73 $mg.kg^{-1}$ at 80 cm-300 cm under drip irrigation under mulch and 1.99 $mg.kg^{-1}$ under border irrigation.

According to the analysis of the relationship between soil NH_4-N, NO_3-N contents, and water content, the deep soil layers' water content has been significantly impacted by the contents of NH_4-N and NO_3-N. The change value of NH_4-N content in deep soil layers decreased with the increase of soil depth. The change value of NO_3-N content increased with the increase of soil depth above 220cm and decreases with the increase of soil depth below 220 cm. The increment of NH_4-N and NO_3-N contents in deep soil layers under drip irrigation under mulch was greater than that under border irrigation, and the increment of NO_3-N content was significantly greater than that under border irrigation.

This study analyzed the distribution of NH_4-N, NO_3-N, and NO_2-N in different soil depths during the whole growth period under three underlying surface conditions, including drip irrigation under mulch, border irrigation, and bare area through field in-situ observation experiment, and analyzed the influence of drip irrigation under mulch on inorganic nitrogen transport in deep soil layers. The results showed that drip irrigation under mulch saved the amount of irrigation water and increased the amount of groundwater recharge, but increased the risk of nitrogen pollution in local groundwater. From the perspective of hydrology and water resources, this paper provides a more comprehensive evaluation of the performance of drip irrigation under mulch in the hydrological cycle and also provides more basis for similar areas to formulate water resources development strategies.

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