



# **Study on Influence of Irrigation Belt Burial Depth and Drip Head Flow Rate on Soil Water and Nitrogen Redistribution**

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**ABSTRACT:** To investigate the effects of drip irrigation tape burial depth and nozzle flow rate on soil moisture and nitrogen redistribution, this study conducted laboratory soil tank experiments with three control factors ( $H=0\text{cm}$ ,  $H=10\text{cm}$ ,  $H=20\text{cm}$ ) for tape burial depth and two flow rate levels ( $q=2\text{L/h}$  and  $q=5.5\text{L/h}$ ). The research focused on analyzing water-nitrogen transport and redistribution patterns at 0d, 2d, and 5d post-drip irrigation. Key findings include: (1) At  $H=0\text{cm}$  burial depth, the soil moisture front exhibits a "horizontal" semi-elliptical shape; at  $H=10\text{cm}$  and  $20\text{cm}$ , it displays a "vertical" semi-elliptical configuration. Increasing tape burial depth significantly expands the moisture front area and vertical water migration distance. Notably, at  $H=20\text{cm}$ , the vertical water migration was most effectively enhanced compared to other depths. Soil moisture front areas at 0d post-drip irrigation showed greater expansion under  $q=2\text{L/h}$  flow rate than  $q=5.5\text{L/h}$ , while areas at 2d and 5d post-drip irrigation demonstrated reduced expansion under the same flow rate conditions. Increased drip head flow rate primarily enhances soil water movement in the vertical direction. Under identical redistribution time conditions, the soil moisture front area with a drip head flow rate of  $q=5.5\text{L/h}$  is relatively larger, demonstrating more pronounced horizontal water migration effects. (2) Increased burial depth of drip irrigation tapes promotes the distribution and migration of ammonium nitrogen and nitrate nitrogen in soil but fails to facilitate ammonium-to-nitrate nitrogen conversion. Higher drip head flow rates facilitate nitrogen distribution and migration in soil, particularly nitrate nitrogen. Large drip head flow rates ( $q=5.5\text{L/h}$ ) enhance the dispersion of nitrate nitrogen migration patterns, accelerate ammonium-to-nitrate nitrogen conversion, and exacerbate soil acidification trends.

**KEYWORDS:** Subsurface drip irrigation, Irrigation tape burial depth, Drip head flow rate, Moisture, Ammonium nitrogen, Nitrate nitrogen, Redistribution.

## **I. INTRODUCTION**

Water scarcity has become the primary bottleneck hindering China's rapid socioeconomic development, with agricultural water consumption accounting for 60-70% of the nation's total water usage. Enhancing agricultural water efficiency is crucial for driving economic growth[1]. Drip irrigation stands out as a water-saving technology that not only improves water utilization efficiency but also minimizes nutrient loss from crop root zones[2]. Based on the installation location of drip heads, this method can be categorized into surface drip irrigation and subsurface drip irrigation systems. Underground drip irrigation is an efficient water-saving technology developed through continuous improvements in drip irrigation systems. It involves burying capillary tubes underground to deliver water or Water and fertilizer coupling to crop root zones via water outlets for plant absorption[3]. Compared to surface drip irrigation and sprinkler irrigation, underground drip irrigation effectively reduces ineffective evaporation and deep soil seepage. It features high water distribution uniformity, multiple small-dose applications, water conservation, and yield enhancement, while significantly improving water and fertilizer utilization efficiency. With its high automation level, it reduces labor input and operational management costs, making it a crucial irrigation technology both domestically and internationally—particularly in water-scarce regions[4]- [6]. While most domestic and international scholars have focused on the impact of water migration distribution in drip irrigation systems, there is limited research on the redistribution processes of water and nitrogen in soil within subsurface drip irrigation systems. Jin Shijie et al.[7] reviewed recent advancements in soil water redistribution research. Zhang Zhigang et al.[8] investigated the variation patterns of characteristic values of wetting bodies in surface drip irrigation under different emitter flow rates in sandy loam soil. Wang Haiyu et al.[8] explored the impact of soil compaction on soil water redistribution at single-point source infiltration. Su Zhenjuan[9] examined how varying drip head flow rates, irrigation rates, and nitrogen fertilizer

concentrations (ammonium nitrate) affect nitrogen transport distribution and redistribution in surface drip irrigation systems. Sogand Arab et al.[10] evaluated the effects of different drip head flow rates and nitrogen fertilizer concentrations (urea) on nitrate redistribution in both surface and subsurface drip irrigation systems. Soil moisture redistribution determines the distribution characteristics of soil water content over time (utetheisa kong), thereby affecting the water availability in the plant root zone and the plant's water uptake[11]. The patterns of soil moisture and nitrate redistribution serve as crucial information for calculating and estimating the design parameters of drip irrigation systems[10]. This study investigates the characteristics of soil water and nitrogen transport and redistribution under different buried depths of drip irrigation tapes and emitter discharge rates through indoor soil box experiments, providing a reference basis for the irrigation scheduling of subsurface drip irrigation.

## II. MATERIALS AND METHODS

### 2.1 Experimental Design

The experiment was conducted at the Hydraulic Laboratory of the National Civil Engineering Experimental Teaching Demonstration Center at Hunan City University. The test soil was collected from a farmland in Heshan District, Yiyang City, Hunan Province, at coordinates 28°31'29" N latitude and 112°23'0" E longitude, at a depth of 10–30 cm. Its physicochemical properties are presented in Table 2-1. The drip irrigation system consisted of four components: a glass soil tank (400mm×600mm, 30°), an irrigation water source (500mg/L(NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>solution, 3L), a peristaltic pump (Tianli Pump YZ-1515 model), and a silicone dropper (Φ=10mm). A schematic diagram of the drip irrigation system is shown in Figure 2-1. Ammonium sulfate was used as the nitrogen fertilizer in the experiment, with a controlled application concentration of 500 mg/L and a controlled irrigation volume of 7.2 L. The experimental variables were the burial depth of the drip tape (H) and the emitter flow rate (q). The burial depth of the drip tape was set at three levels: 0 cm, 10 cm, and 20 cm, while the emitter flow rate was set at two levels: 2 L/h and 5.5 L/h. The redistribution time was set at three intervals: the day of irrigation completion (0 d), 2 days after irrigation, and 5 days after irrigation. A total of 18 drip irrigation tests were conducted, with the experimental level factors summarized in Table 2-2.

Table 2-1 Physicochemical Properties of Test Soil

mean soil bulk density g/m <sup>3</sup>	Mean field water retention rate	average saturated water content	Soil particle size distribution %	
1.2	0.32	0.50	sand	14.9
			Silt particle	23.1
			cosmid	62.0
Soil type: silty loam (American system)				

Table 2-2 Experimental Level Factors Table

Time after drip irrigation	Drip flow rate 2L/h			Drip flow rate 5.5L/h		
	0d	2d	5d	0d	2d	5d
Drip depth 0cm	B1	B2	B3	B10	B11	B12
Drip depth 10cm	B4	B5	B6	B13	B14	B15
Drip depth 20cm	B7	B8	B9	B16	B17	B18

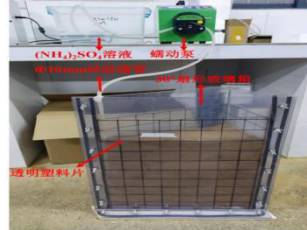


Figure 2-1 Physical diagram of drip irrigation system device

## 2.2 Research Methods

### 2.2.1 Soil Box Test Method and Soil Sample Collection

The soil box used in the experiment was a 30° sector-shaped glass box, with 8 rows and 8 columns of 5cm×5cm square grids drawn on the front and back sides. Before drip irrigation, the soil was filled into the box, with each layer consisting of 2512 g of sieved soil (2 mm diameter). After filling each layer, the soil was compacted, leveled, and roughened. A total of 8 soil layers were filled, and the corresponding depth for subsurface drip emitters was reserved in advance. After filling, the soil box was left undisturbed for 24 hours. For drip irrigation, a 500 mg/L ammonium sulfate solution was prepared. The peristaltic pump speed was set according to the emitter flow rate (2 L/h corresponding to 1.9 r/min, and 5.5 L/h corresponding to 2.2 r/min). Transparent plastic sheets were attached to the front and back sides of the soil box beforehand. The irrigation volume was 7.2 L, and the drip irrigation duration corresponded to the emitter flow rate (2 L/h corresponding to 216 min, and 5.5 L/h corresponding to 78 min). During the irrigation process, the wetting front was recorded at intervals of 1 min, 5 min, 10 min, 15 min, 30 min, 60 min, etc. For soil sampling, three types of soil samples were collected: soil inside the wetting front, mixed wet-dry soil at the wetting front edge, and undisturbed soil. These samples were placed in self-sealing bags for subsequent measurement of observation indicators. The sampling locations and procedures are illustrated in Figures 2-2 and 2-3.

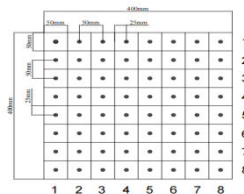


Figure 2-2 Schematic diagram of soil sampling point distribution



Soil body moistened  
by drip irrigation

Grid division of moist soil  
at 5cm×5cm intervals

Soil sampling at  
grid centers

Figure 2-3 Flowchart of soil sampling procedure

### 2.2.2 Observation indicator measurement

The paper investigates the patterns of water and nitrogen redistribution, with observed indicators including soil moisture content, ammonium nitrogen, nitrate nitrogen, and pH. Among these, soil moisture content is determined using the oven-drying method; soil ammonium nitrogen (N-NH<sub>4</sub><sup>+</sup>) and nitrate nitrogen (N-NO<sub>3</sub><sup>-</sup>) are extracted with water at a soil-to-water ratio of 10:1 and measured using the Leici water quality analyzer DGB480; soil pH is extracted with water at a soil-to-water ratio of 5:1 and measured using a pH meter.

### 2.3 Data Processing

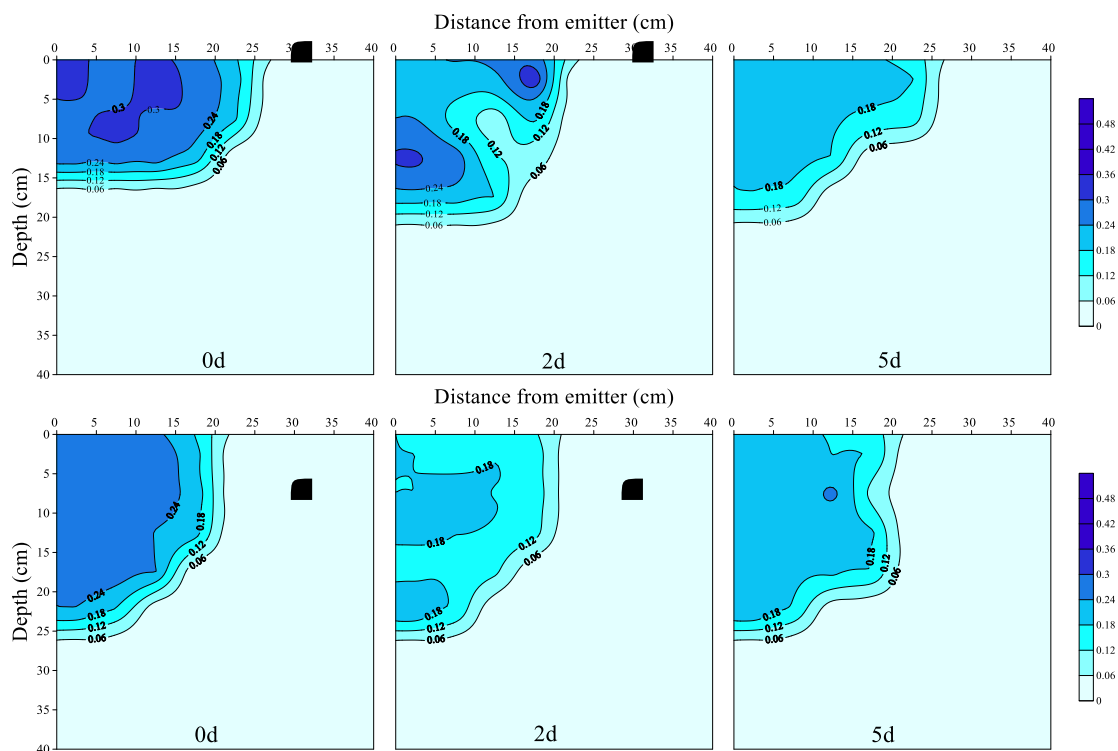
The experimental data were processed and integrated using Microsoft Excel 2019, and contour maps of soil moisture content, ammonium nitrogen, nitrate nitrogen, and pH were plotted using Surfer 13 with the Kriging interpolation method.

## III. RESULTS AND ANALYSIS

### 3.1 Moisture Redistribution

In this experiment, the effects of drip tape burial depth and emitter discharge rate on soil moisture content in a subsurface drip irrigation system were investigated. Figures 3-1 and 3-2 correspond to the soil moisture contour maps under the same emitter discharge rate with different drip tape burial depths, while Figures 3-3, 3-4, and 3-5 correspond to the soil moisture contour maps under the same drip tape burial depth with different emitter discharge rates.

#### 3.1.1 Influence of Drip Irrigation Tape Burial Depth on Water Redistribution



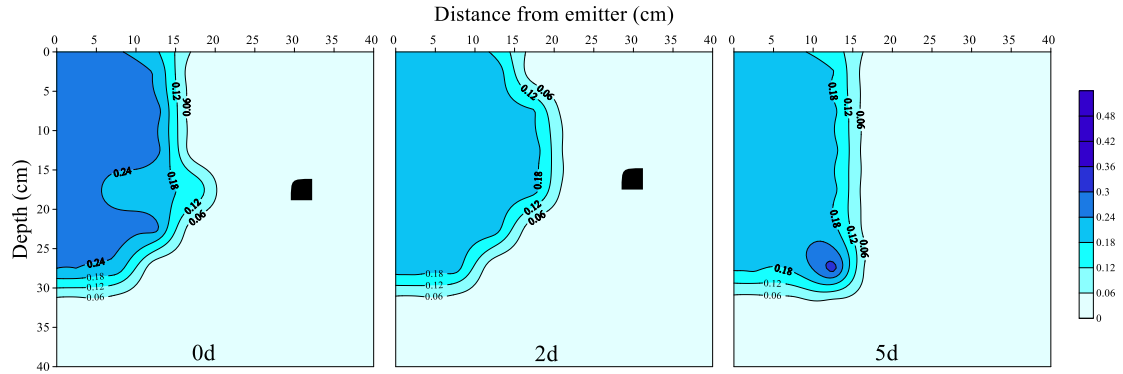


Figure 3-1 Isohyric curve of soil moisture content for drip head flow rate  $q=2L/h$

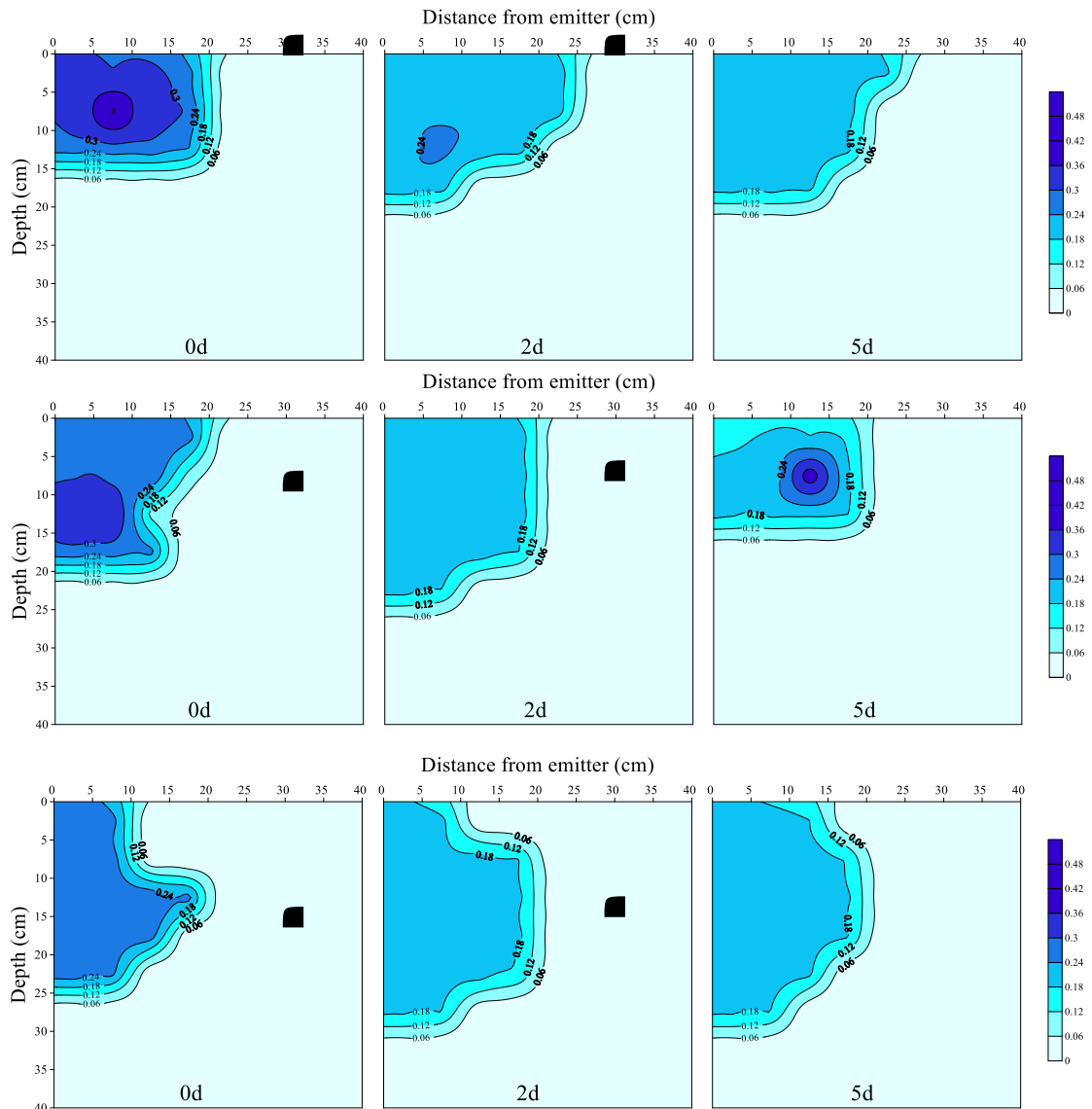


Figure 3-2 Isohyric curve of soil moisture content for drip head flow rate  $q=5.5L/h$

As can be seen from Figures 3-1 and 3-2, on the day of drip irrigation completion (0d), the maximum soil moisture content under the three different drip tape burial depths all occurred near the installation position of the drip tape. After 2d and 5d of drip irrigation completion, the soil moisture redistributed. Under different drip tape burial depths, the shape of the soil wetting front and its advancing speeds in both vertical and horizontal directions varied:

When the buried depth of the drip irrigation tape  $H = 0$  cm, the advancing speed of the soil wetting front in the horizontal direction is higher than that in the vertical direction. The migration distance of the soil wetting front in the horizontal direction is longer than that in the vertical direction, and the shape of the soil wetting front appears as a "Recumbent" semi-ellipse. The area of the soil wetting front 2 days (2d) and 5 days (5d) after the end of drip irrigation expanded compared to that on the day of drip irrigation cessation (0d). Five days after the end of drip irrigation, the area of the soil wetting front showed a "shrinking" trend compared to that 2 days after the end of drip irrigation. Overall, the area of the soil wetting front follows the order: 2 days after drip irrigation > 5 days after drip irrigation > the day of drip irrigation cessation (0d).

When the buried depth of the drip irrigation tape is  $H=10$ cm and  $H=20$ cm, the advancement speed of the soil wetting front in the vertical direction is higher than that in the horizontal direction. The migration distance of the soil wetting front in the vertical direction is longer than that in the horizontal direction, and the shape of the soil wetting front appears as a "vertical" semi-ellipse. The area of the soil wetting front follows a similar pattern to that when the buried depth of the drip irrigation tape is  $H=0$ cm, namely: 2 days after drip irrigation > 5 days after drip irrigation > 0 days after drip irrigation. When comparing drip irrigation tape burial depths of  $H=20$ cm and  $H=10$ cm, the former exhibits greater vertical advancement of soil moisture front under identical redistribution time, while showing minimal horizontal variation. From the above analysis, it can be concluded that the burial depth of drip irrigation tape has an impact on soil moisture redistribution. In subsurface drip irrigation, a greater burial depth of the drip irrigation tape promotes the advancement speed and migration distance of the soil wetting front in the vertical direction, relatively increases the area of the soil wetting front, and facilitates soil moisture redistribution.

### 3.1.2 Effect of drip flow rate on water redistribution

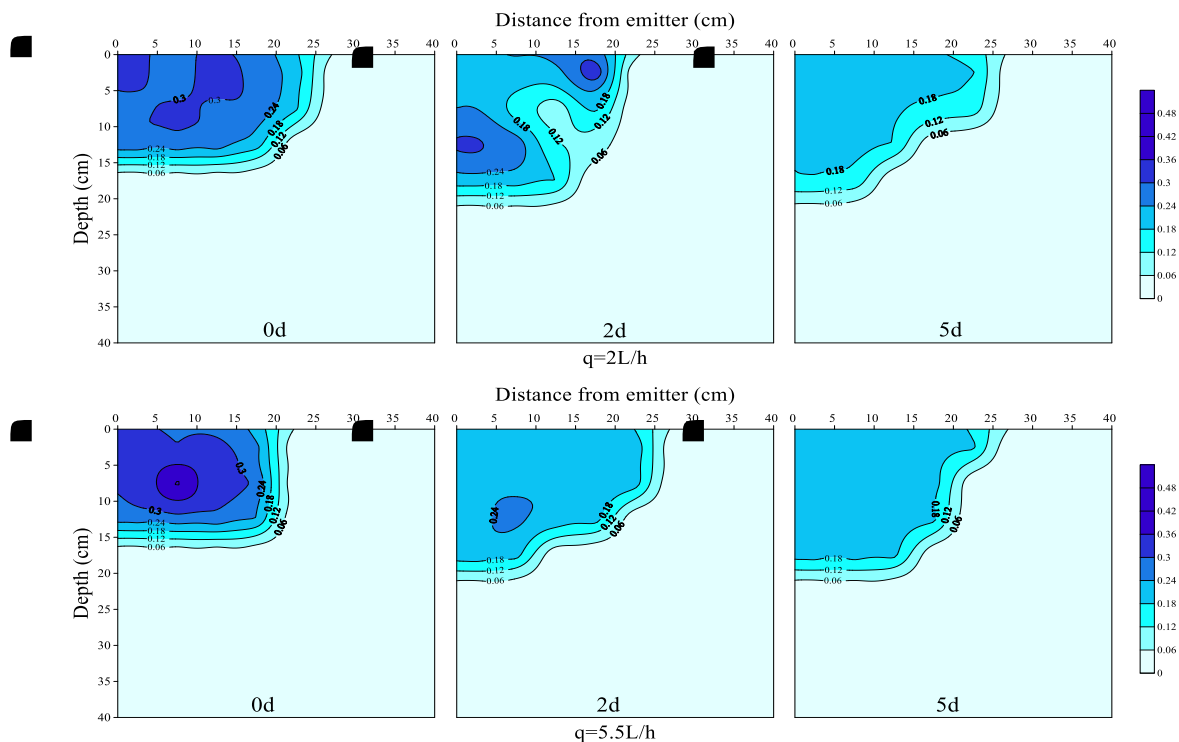


Figure 3-3 Isohydraulic contour map of soil moisture content at drip irrigation tape depth  $H=0$  cm

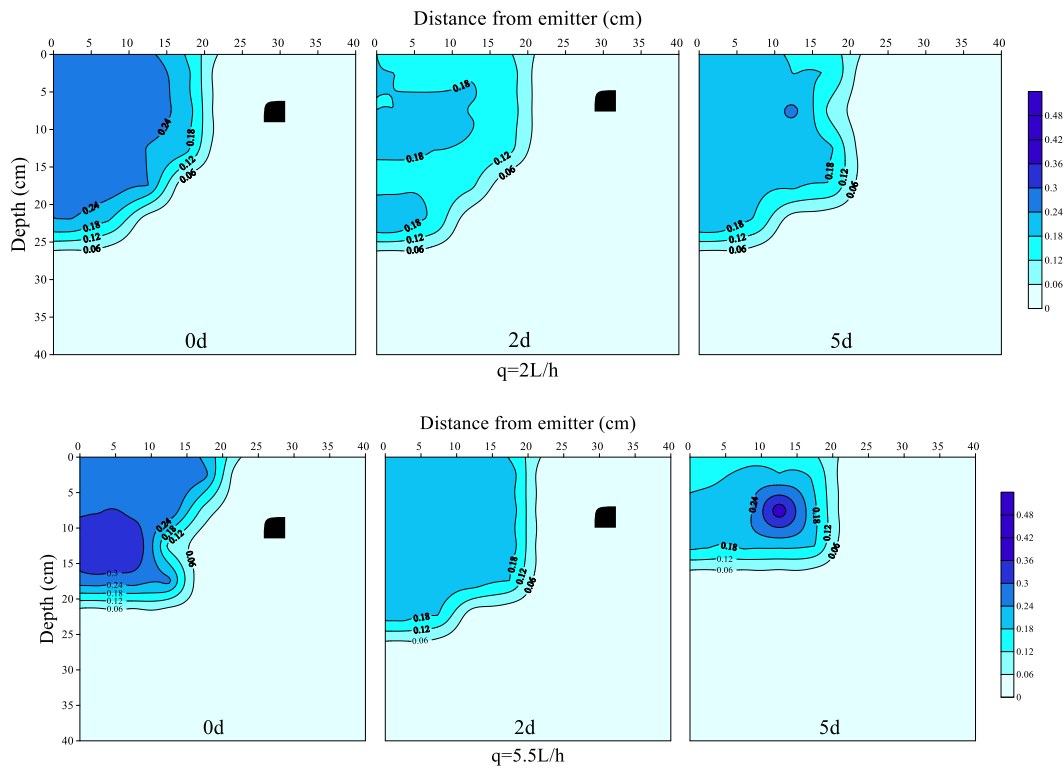


Figure 3-4 Isohydraulic contour map of soil moisture content at drip irrigation tape depth H=10 cm

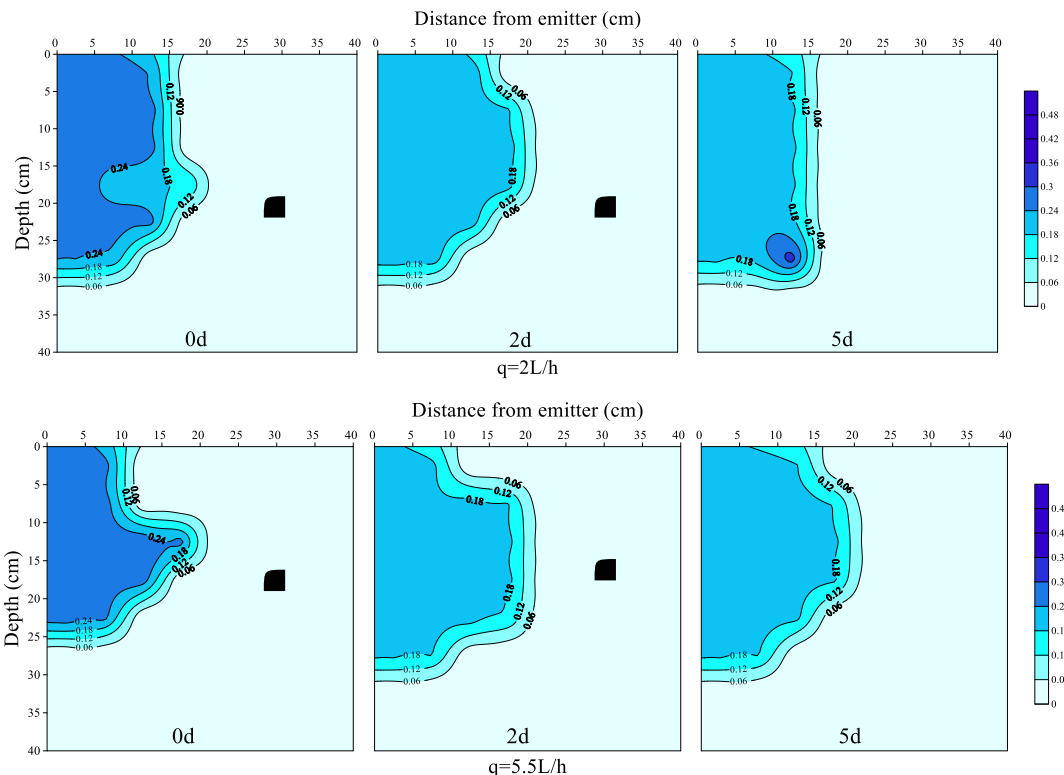
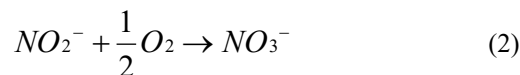
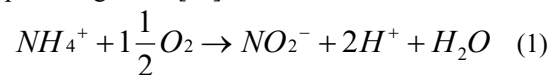


Figure 3-5 Isohydraulic contour map of soil moisture content at drip irrigation tape depth H=20 cm

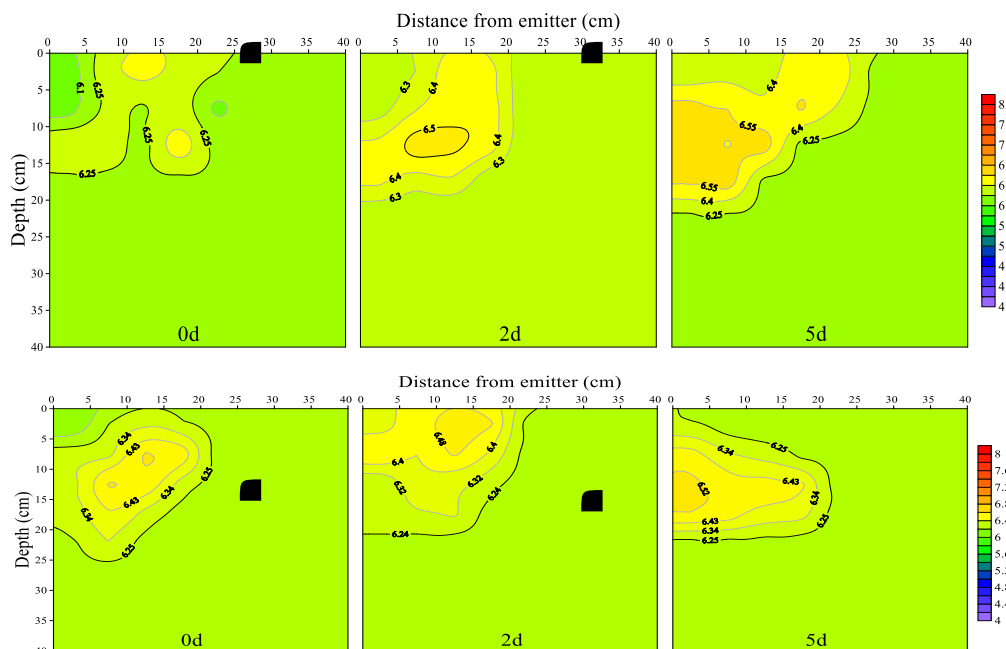
Figures 3-3, 3-4, and 3-5 demonstrate that under identical drip irrigation tape burial depths, the soil moisture front area and its horizontal/vertical variations differ between drip heads with flow rates of  $q=2L/h$  and  $q=5.5L/h$  after soil moisture redistribution. The two flow rates share similarities in soil moisture front area: 2 days post-drip irrigation > 5 days post-drip irrigation > 0 days post-drip irrigation. Their differences include: Firstly, when redistribution time is 0 days, the soil moisture front area shows that drip head flow rate  $q=2L/h > q=5.5L/h$ . At redistribution times of 2 days and 5 days, the soil moisture front area demonstrates that  $q=5.5L/h > q=2L/h$ . Secondly, compared to the soil moisture front at  $q=2L/h$  drip head flow rate,  $q=5.5L/h$  drip head flow rate exhibits increased horizontal propagation speed and migration distance of the soil moisture front, while showing negligible vertical direction changes. The analysis above indicates that drip head flow rate affects soil water redistribution. Higher drip head flow rates can increase the soil wetting front area, thereby promoting horizontal water redistribution in the soil.

### 3.2 Nitrogen Redistribution

The nitrogen fertilizer used in this study is ammonium nitrogen fertilizer  $(NH_4)_2SO_4$ , which is highly soluble in water, exhibits rapid fertilizer efficacy, and is readily absorbed and utilized by plants. However, ammonium nitrogen fertilizer can cause soil acidification and convert to nitrate nitrogen through nitrification [12]. Therefore, investigating soil nitrogen redistribution requires analyzing the distribution patterns of ammonium nitrogen ( $N-NH_4^+$ ), nitrate nitrogen ( $N-NO_3^-$ ), and soil pH. The principle of digestion [13] is as follows:



Figures 3-6 and 3-7 show soil pH contour plots corresponding to different drip irrigation tape burial depths under identical drip head flow rates. Figure 3-8, 3-9, and 3-10 show soil pH isocurve diagrams corresponding to different drip head flow rates at the same drip tape burial depth. Figure 3-11 and 3-12 show contour plots of soil ammonium nitrogen concentration at different drip irrigation tape burial depths under identical drip head flow rates. Figure 3-13 and 3-14 show contour plots of soil nitrate nitrogen concentration at different drip irrigation tape burial depths under the same drip head flow rate. Figure 3-15, 3-16, and 3-17 show contour plots of soil ammonium nitrogen concentration corresponding to different drip head flow rates at the same drip tape burial depth, and Figure 3-18, 3-19, and 3-20 show contour plots of soil nitrate nitrogen concentration corresponding to different drip head flow rates at the same drip irrigation tape burial depth.



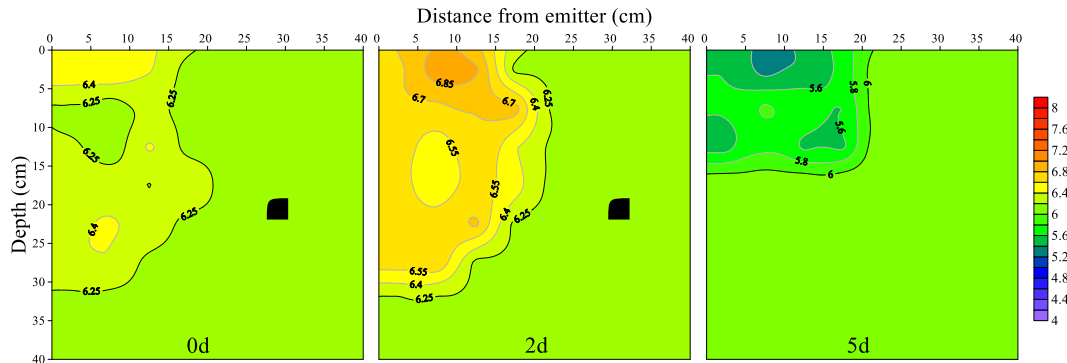


Figure 3-6 Drip head flow rate  $q=2L/h$  soil pH isocline diagram

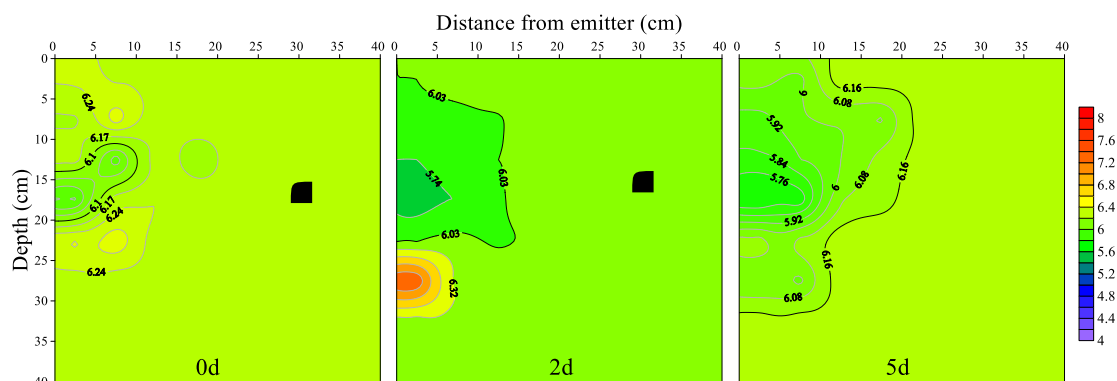
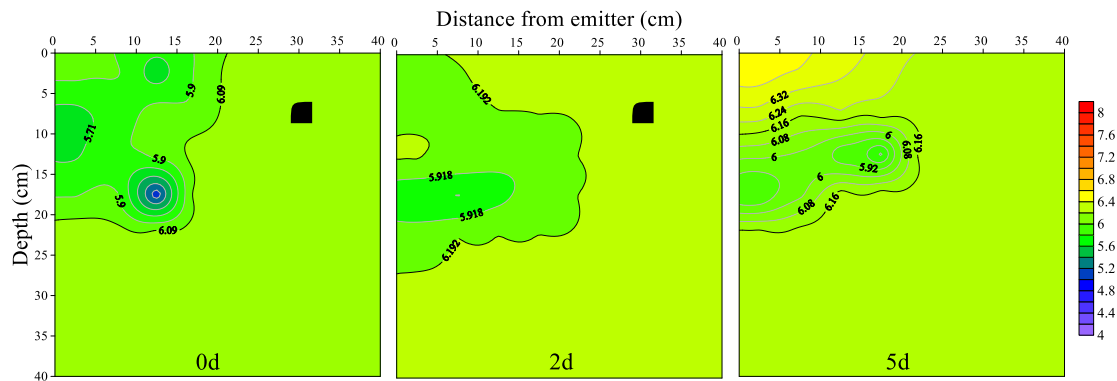
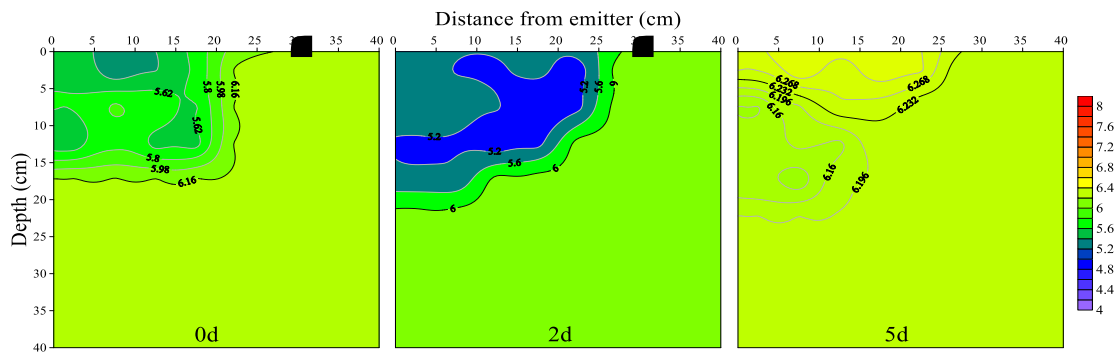


Figure 3-7 Drip head flow rate  $q=5.5L/h$  soil pH isocline diagram

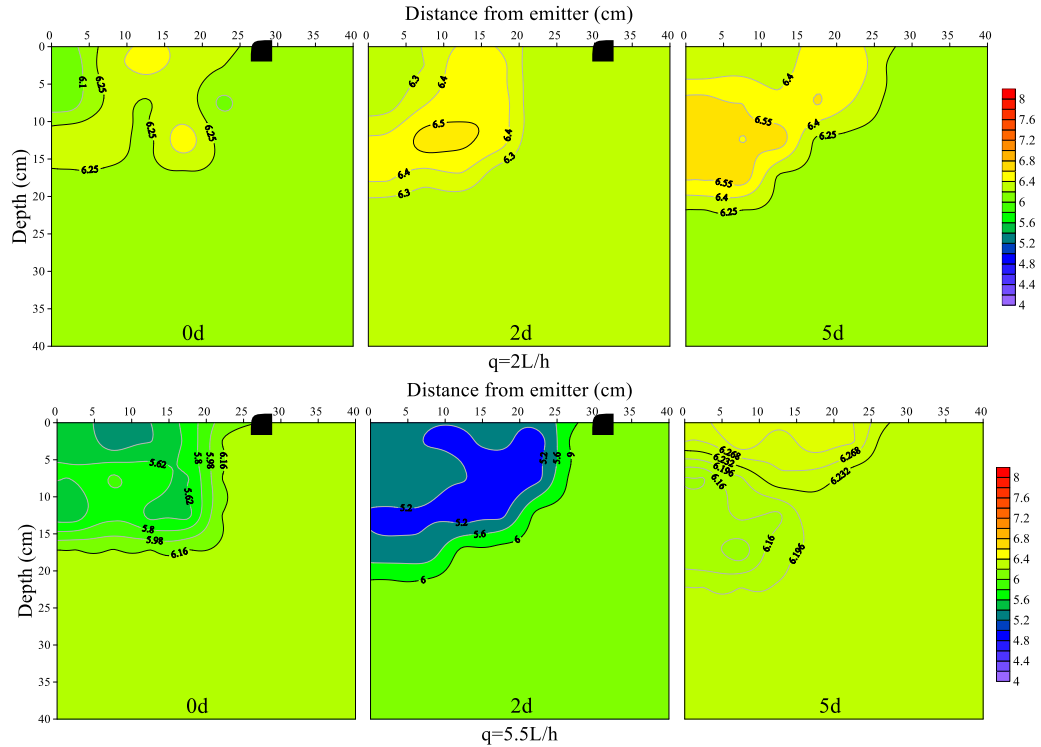


Figure 3-8 Soil pH isocline map at burial depth H=0 cm for drip irrigation tape

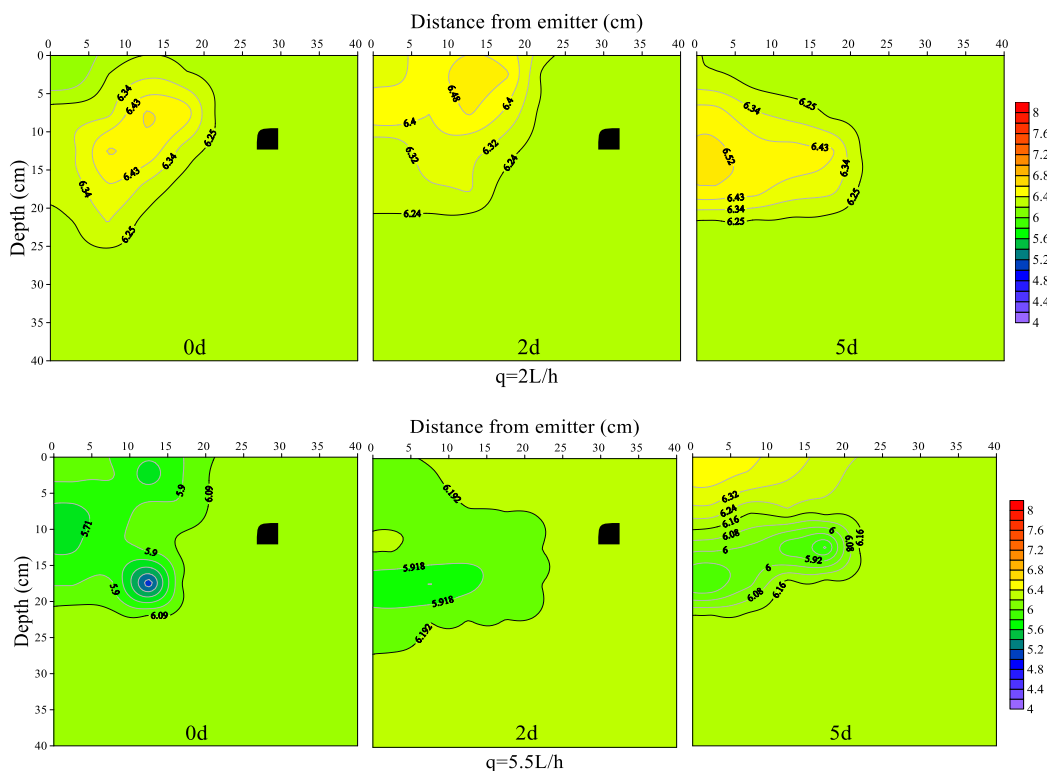


Figure 3-9 Soil pH isocline map at burial depth H=10 cm for drip irrigation tape

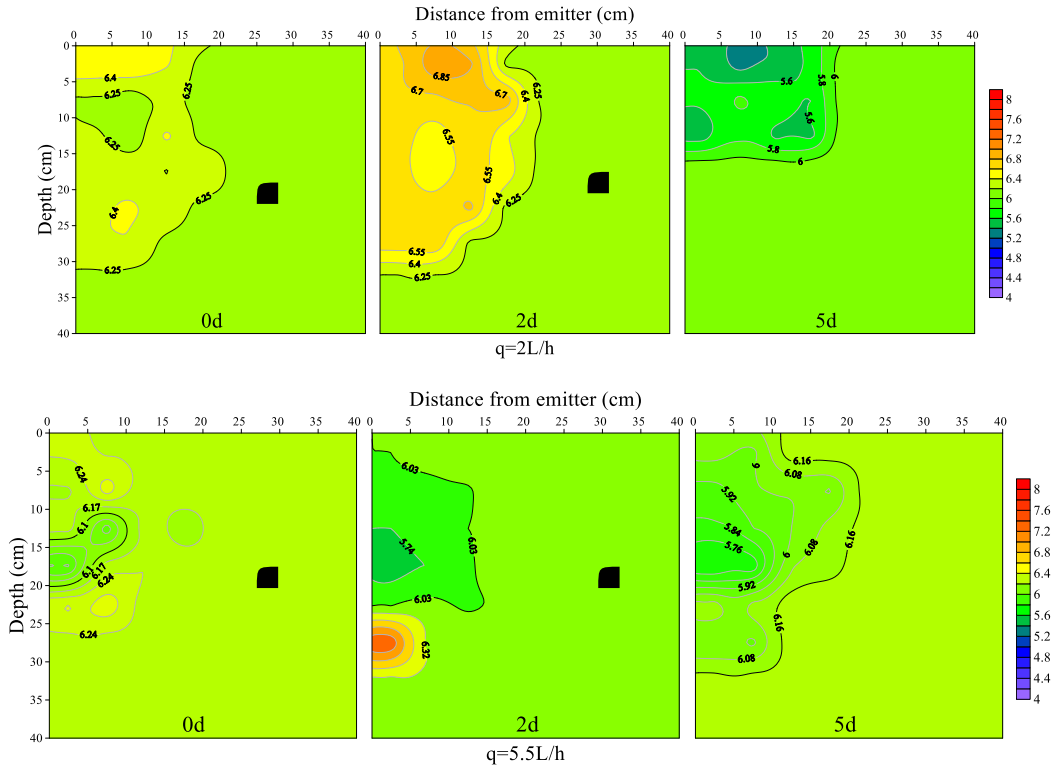
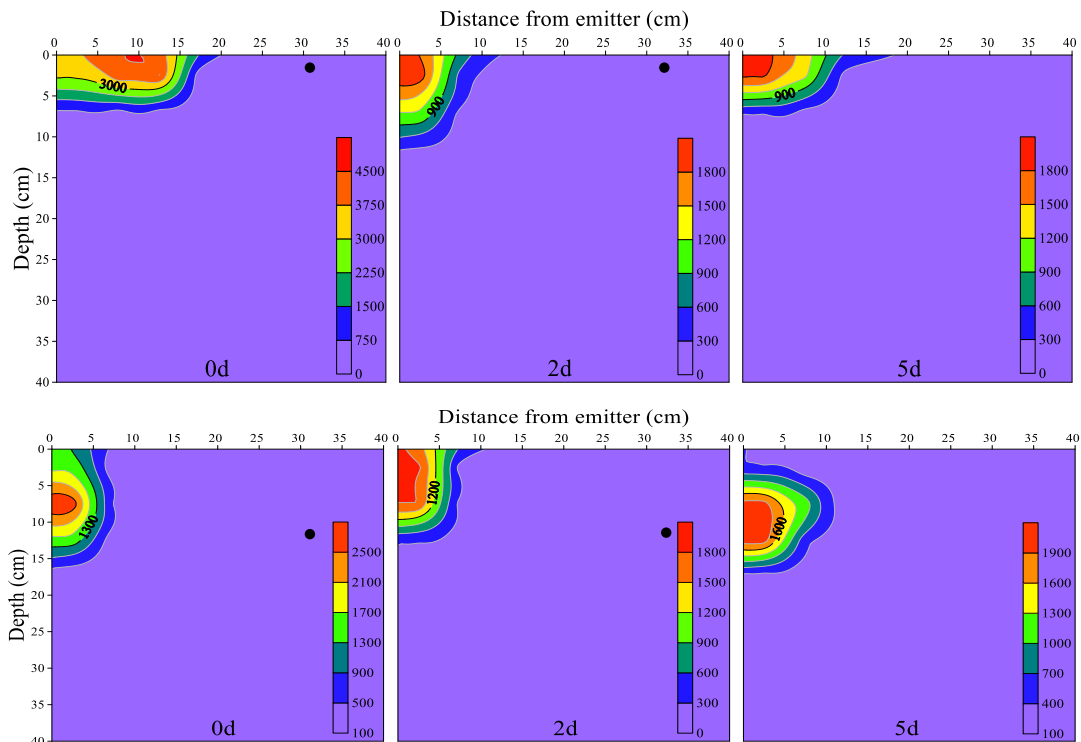


Figure 3-10 Soil pH isocline map at burial depth H=20 cm for drip irrigation tape

### 3.2.1 Effect of drip irrigation tape burial depth on soil nitrogen redistribution



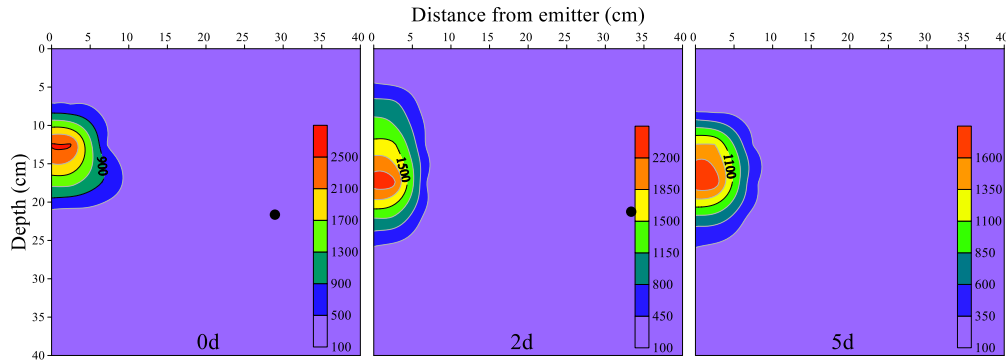


Figure 3-11 Headflow rate  $q=2L/h$  soil ammonium nitrogen isocline diagram

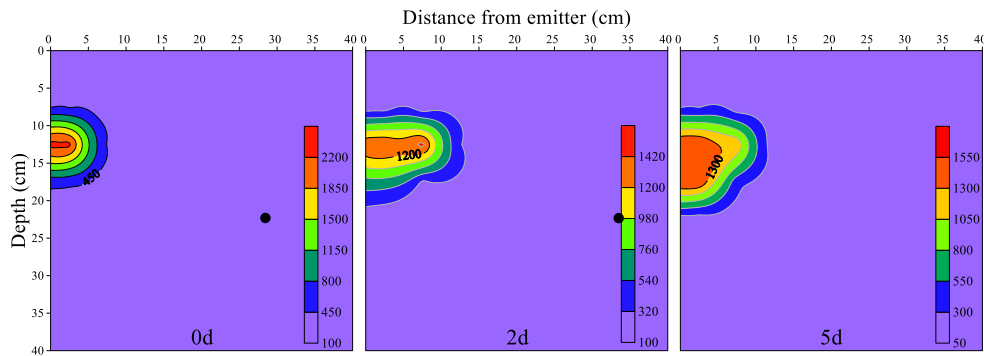
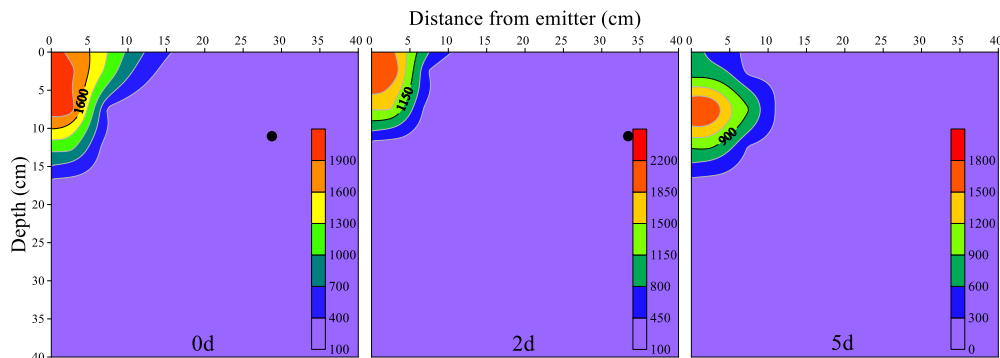
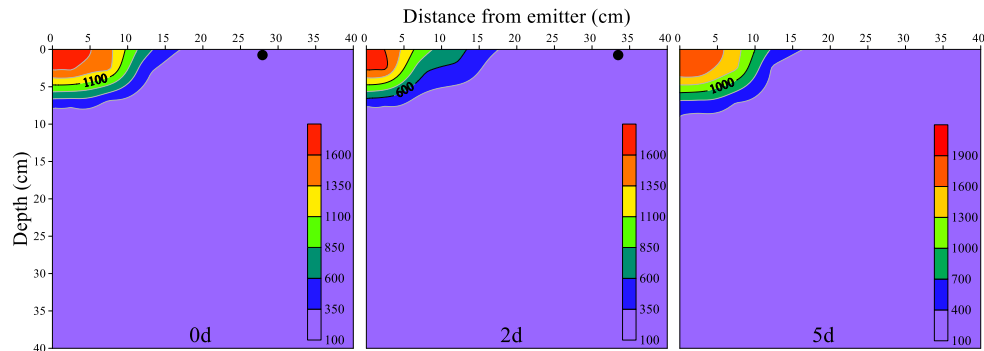


Figure 3-12 Headflow rate  $q=5.5L/h$  soil ammonium nitrogen isocline diagram

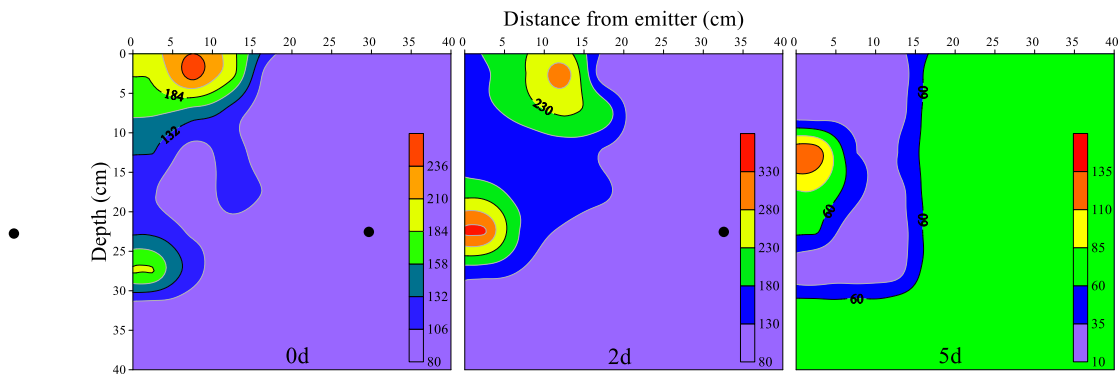
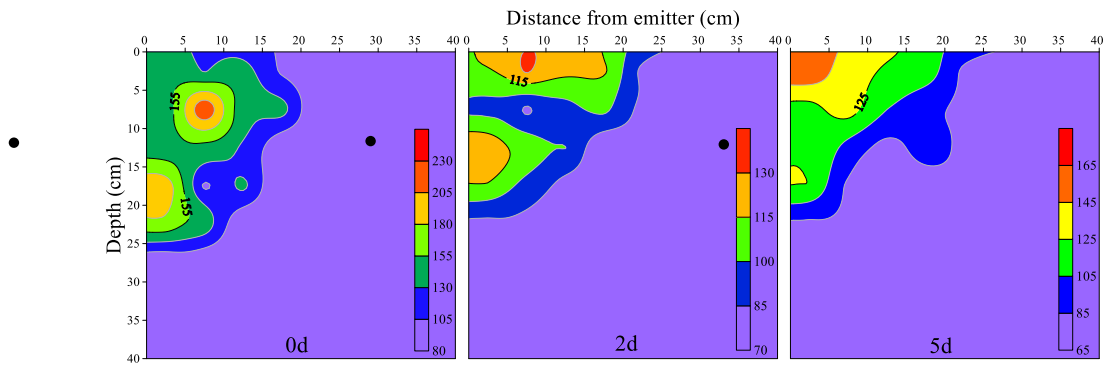
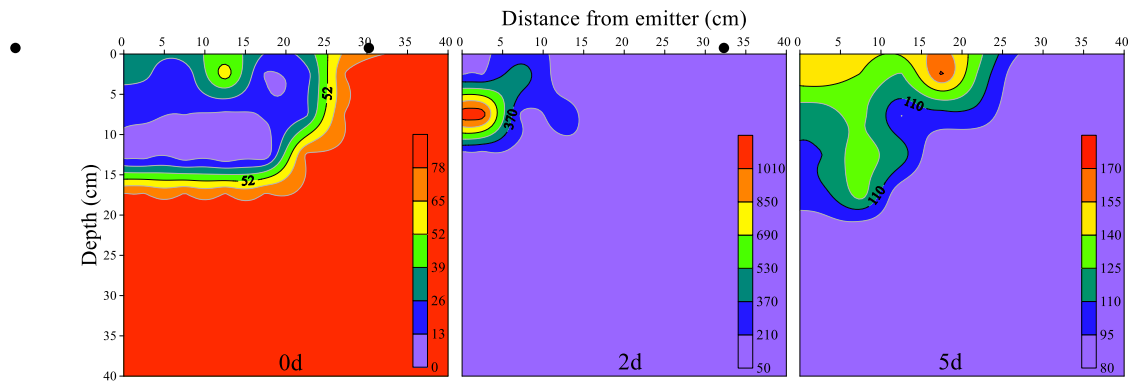
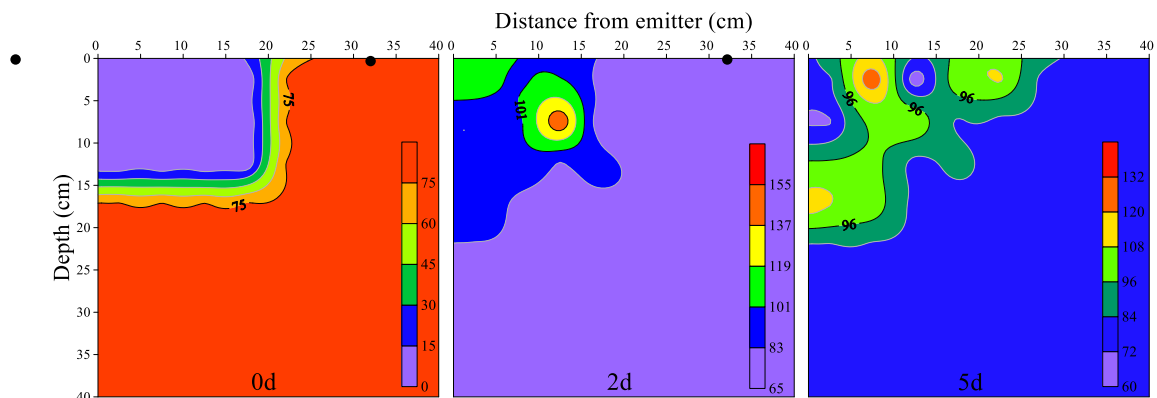


Figure 3-13 Drip flow rate  $q=2L/h$  soil nitrate nitrogen isocline map



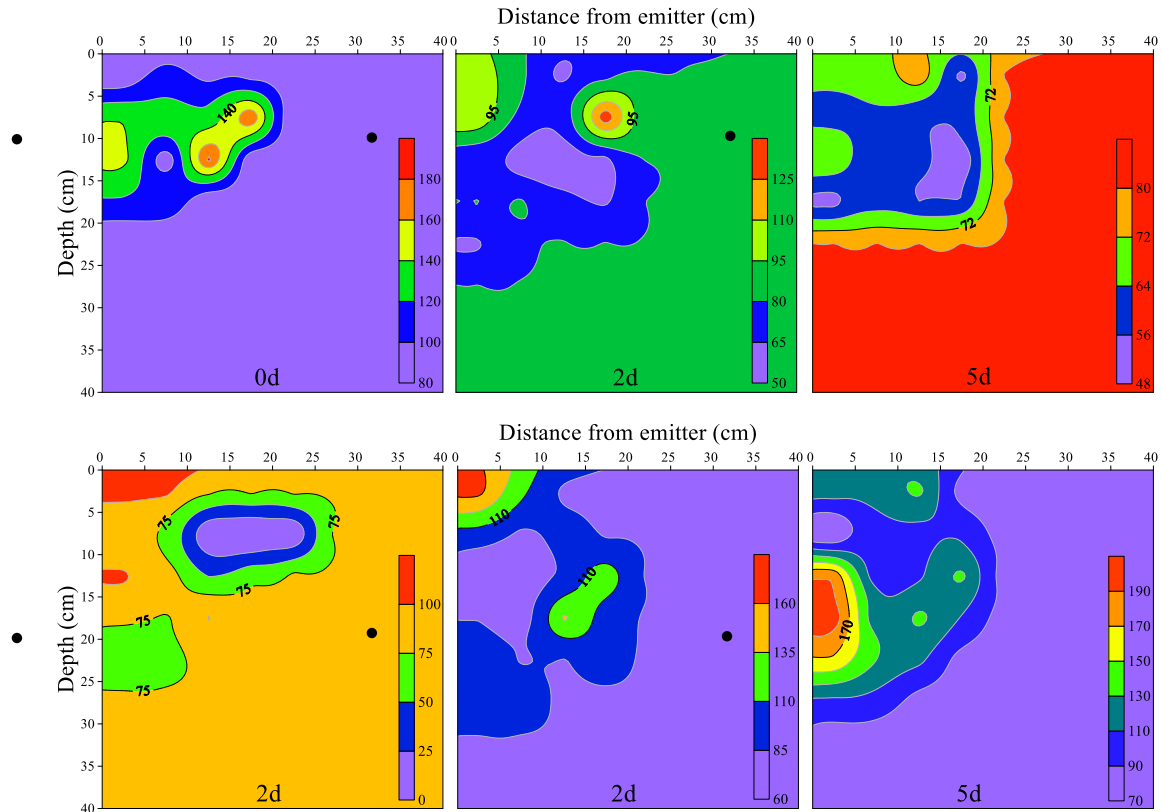


Figure 3-14 Drip flow rate  $q=5.5L/h$  soil nitrate nitrogen isocline map

Li Jiusheng et al. [14] applied nitrate nitrogen fertilizer ( $NH_4NO_3$ ) and investigated the distribution patterns of nitrate nitrogen and ammonium nitrogen under point-source fertilization and irrigation conditions. They found that ammonium nitrogen concentrations exhibited a peak near the drip head, while nitrate nitrogen formed a cumulative effect at the wetted boundary. This study applied ammonium nitrogen fertilizer ( $(NH_4)_2SO_4$ ). Comparative analysis of Figures 3-11 and 3-13 combined with Figure 3-6 reveals significant differences in the distribution patterns of soil ammonium nitrogen versus nitrate nitrogen. The former exhibits a smaller spatial distribution area with concentrated concentrations near drip heads, while the latter shows more dispersed distribution. When the drip irrigation tape was buried at 0cm depth, the peak soil ammonium nitrogen concentration exceeded 4500 mg/kg on day 0 post-drip irrigation, whereas the nitrate nitrogen concentration peaked at only 78mg/kg. During this period, soil pH values ranged between 5.6 and 6.3, indicating acidification characteristics. After 2 and 5 days post-drip irrigation, soil ammonium nitrogen concentrations declined significantly with redistribution time, while nitrate nitrogen concentrations increased accordingly, suggesting a tendency for ammonium nitrogen to convert into nitrate nitrogen in the soil. Comparative analysis of Figures 3-12 and 3-14 combined with Figure 3-7 further confirms this consistent pattern. The nitrogen distribution patterns of drip irrigation tapes buried at depths of 10cm and 20cm exhibit similarities. Under all three redistribution scenarios, soil ammonium nitrogen and nitrate nitrogen levels decrease with redistribution duration, while their distribution areas expand outward from the drip head. Concurrently, soil pH tends to increase over redistribution time. The nitrate nitrogen concentration in underground drip irrigation systems is lower than that in surface drip irrigation, indicating that increased burial depth enhances nitrogen distribution and migration within the soil but does not promote ammonium-to-nitrate conversion. This pattern is corroborated by comparative analysis of Figures 3-12 and 3-14 combined with Figure 3-7. Laher et al. [15] observed that ammonium fertilizer undergoes minimal nitrification in the water saturation zone near drip heads, with nitrification primarily occurring in unsaturated zones below this layer. These findings suggest that under soil stratification conditions in underground drip irrigation, ammonium fertilizer nitrification produces experimental phenomena distinct from those observed in surface drip irrigation systems.

3.2.2 Effect of drip head flow rate on soil nitrogen redistribution

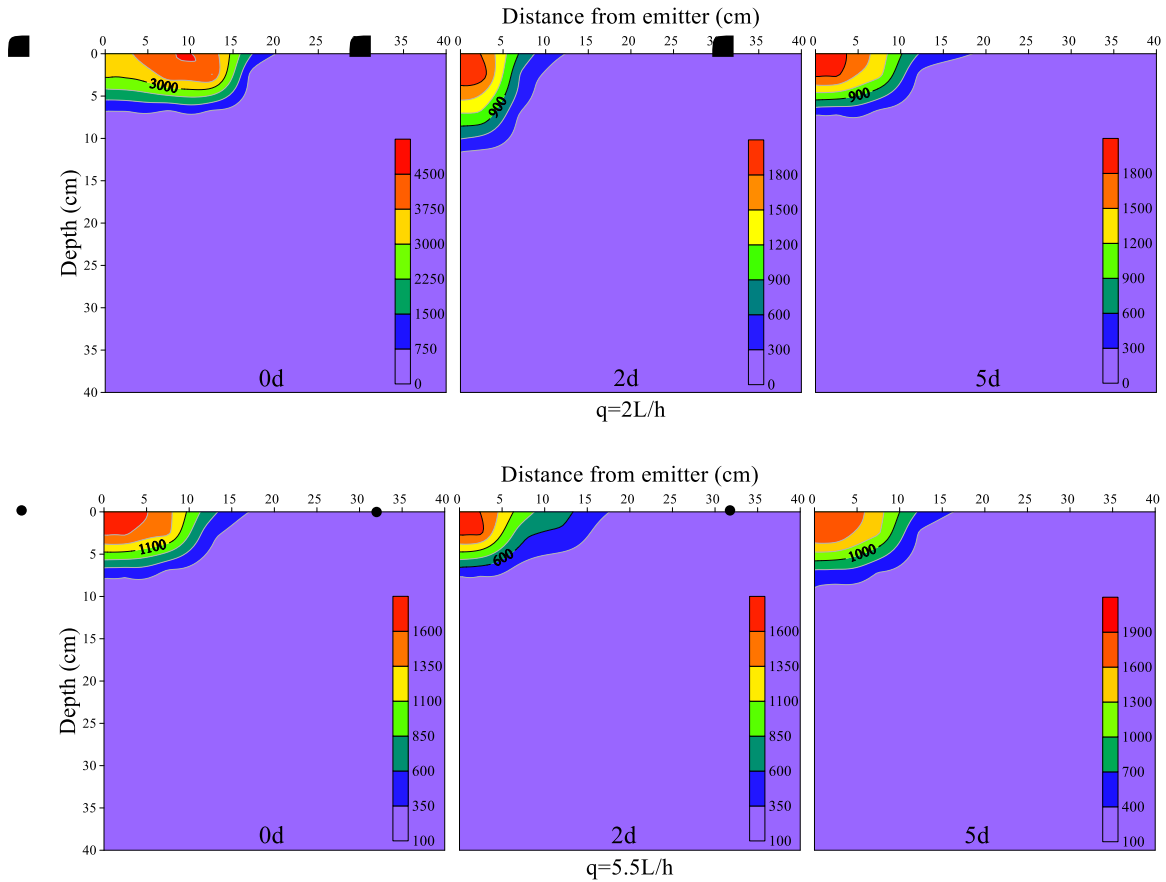
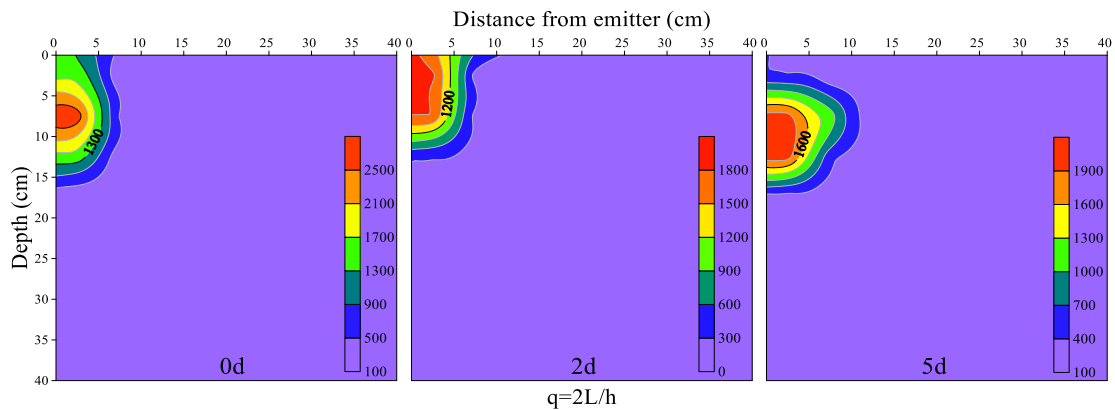


Figure 3-15 Isocline map of soil ammonium nitrogen at drip irrigation tape depth H=0cm



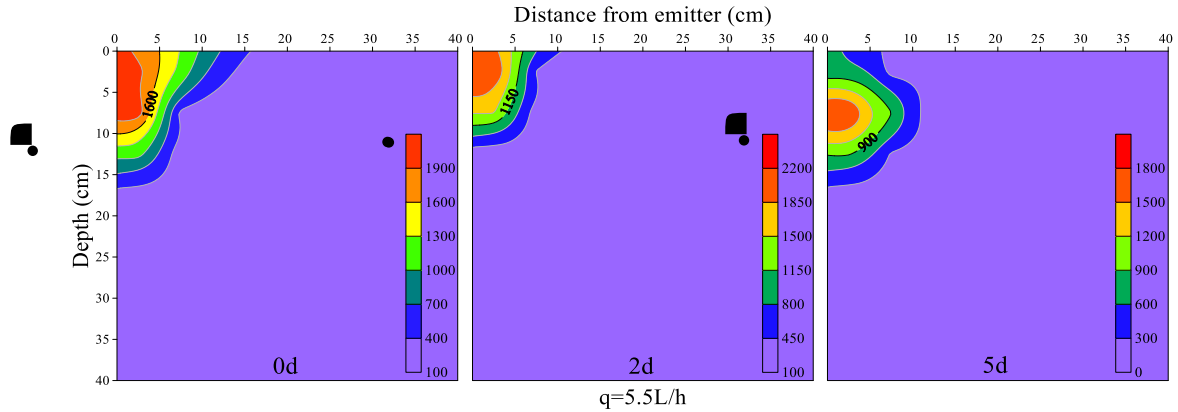


Figure 3-16 Isocline map of soil ammonium nitrogen at drip irrigation tape depth H=10cm

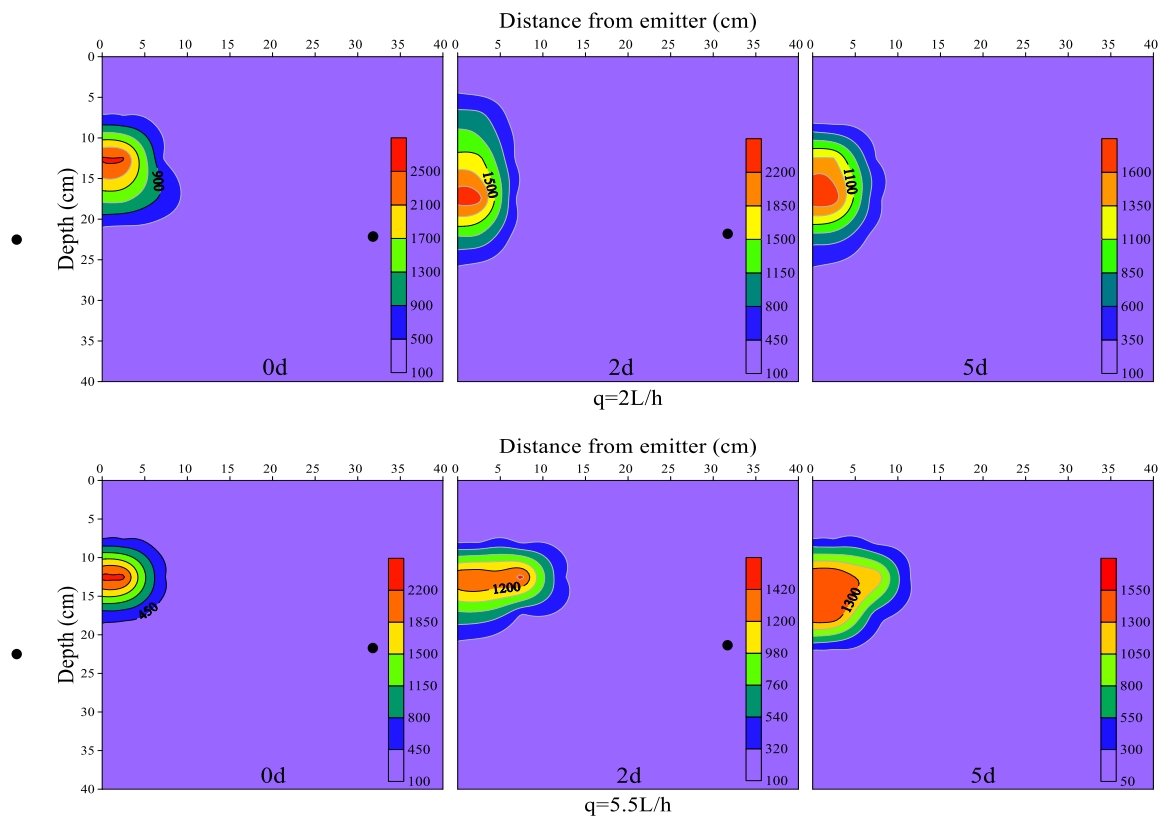


Figure 3-17 Isocline map of soil ammonium nitrogen at drip irrigation tape depth H=20cm

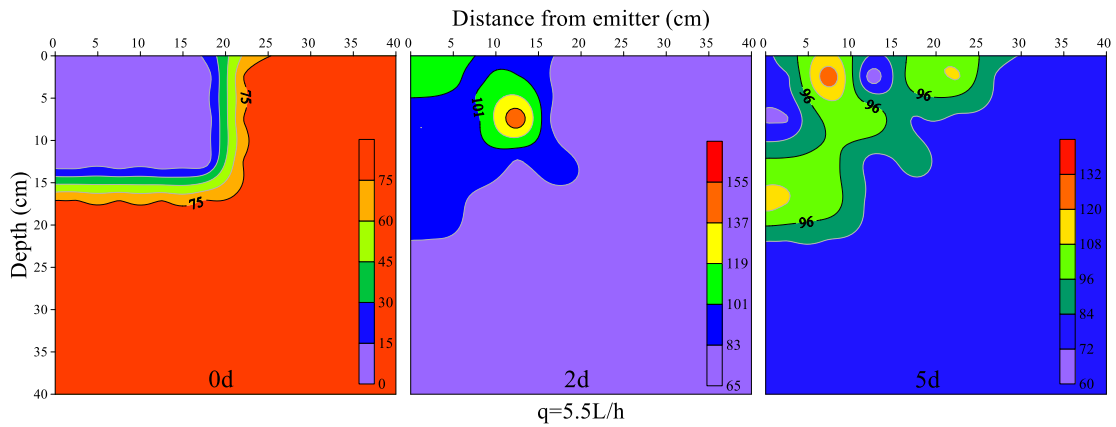
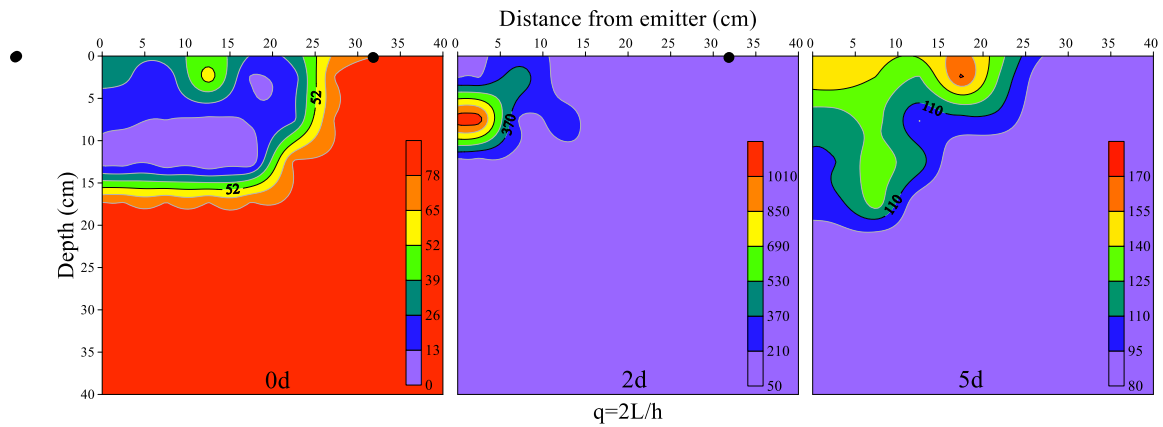
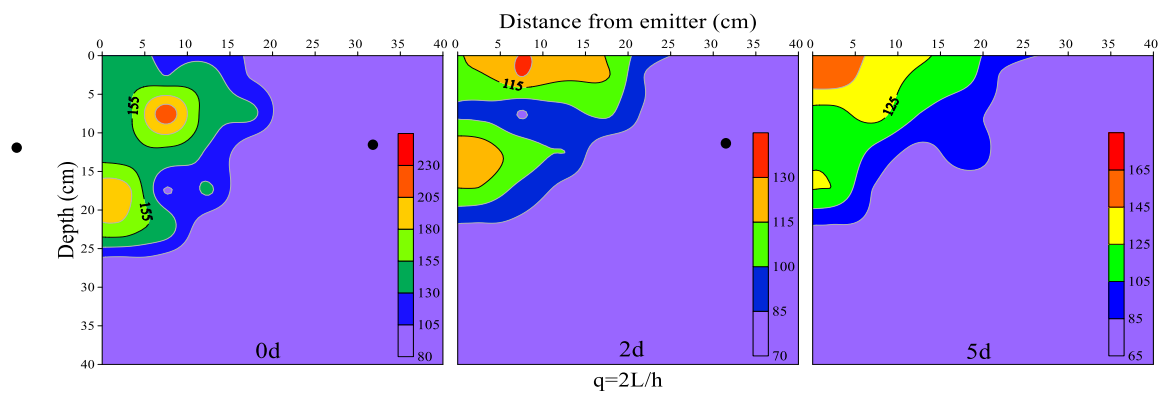


Figure 3-18 Isocline map of soil nitrate nitrogen at drip irrigation tape depth  $H=0\text{cm}$



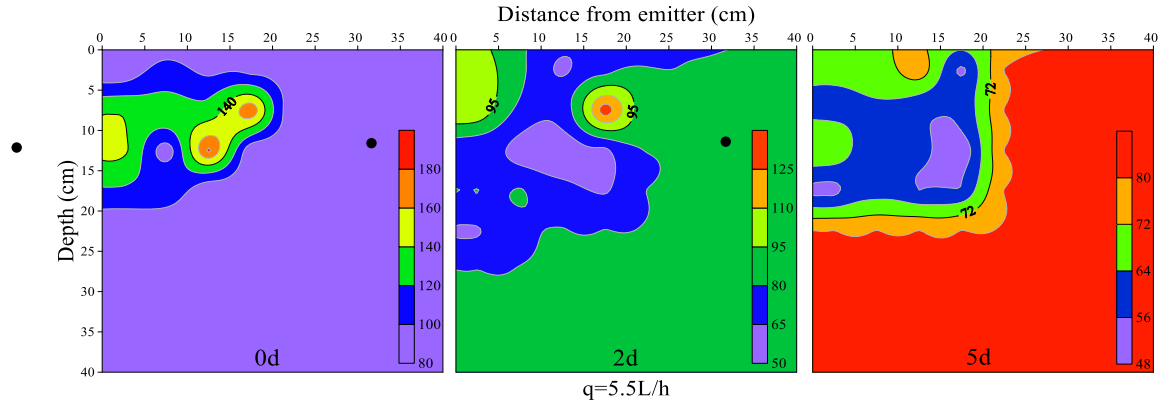


Figure 3-19 Isocline map of soil nitrate nitrogen at drip irrigation tape depth H=10cm

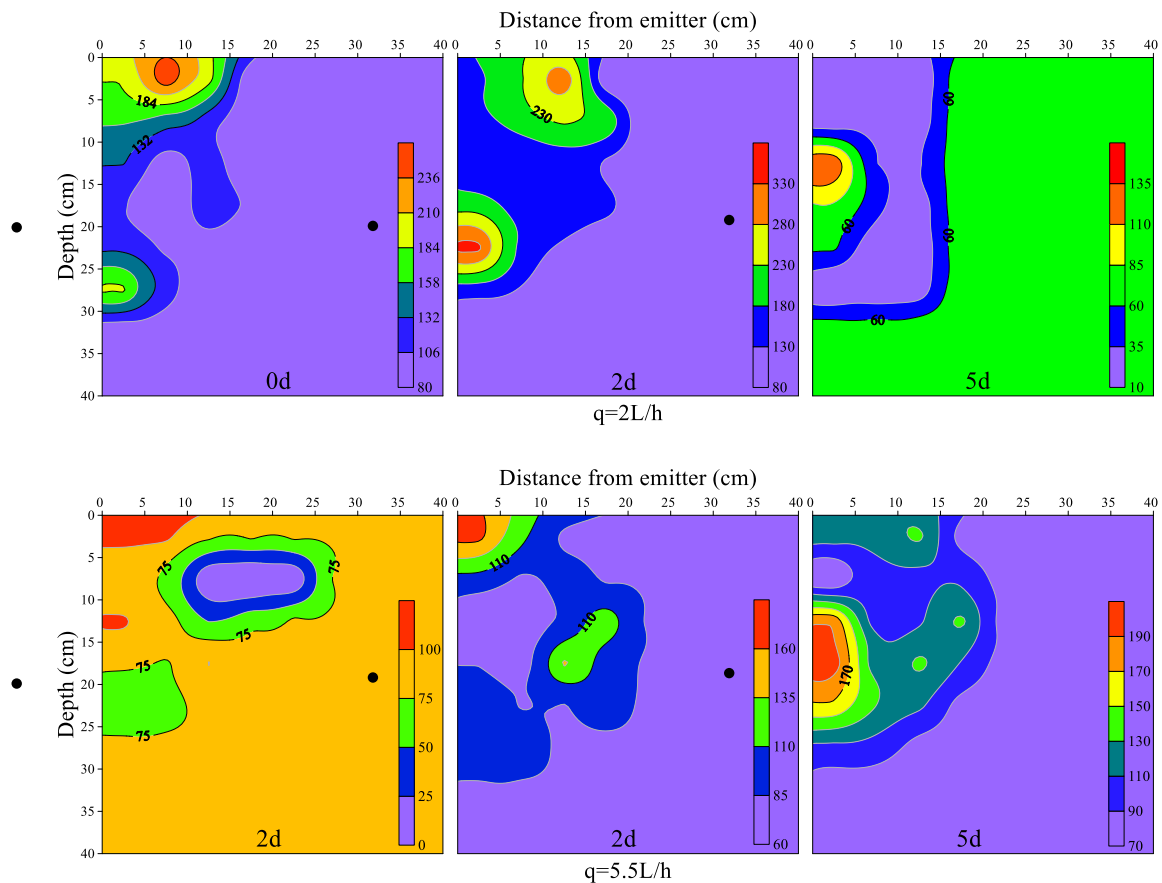


Figure 3-20 Isocline map of soil nitrate nitrogen at drip irrigation tape depth H=20cm

Figures 3-15,3-16, and 3-17 demonstrate that under identical drip irrigation tape burial depths, increasing the nozzle flow rate from  $q=2L/h$  to  $q=5.5L/h$  results in decreased soil ammonium nitrogen concentration at the same post-drip irrigation end time. When the drip irrigation tape is buried at a depth of  $H=0cm$  (surface irrigation) with small nozzles delivering a flow rate of  $q=2L/h$ , soil ammonium nitrogen concentration decreases with increasing redistribution time, showing an average reduction of 30.0%. Conversely, when using large nozzles with a flow rate of  $q=5.5L/h$ , soil ammonium nitrogen concentration increases with redistribution time, exhibiting an average rise of 9.4%. When the drip irrigation tape is buried at a depth of  $H=10$  cm, the average reduction in soil ammonium nitrogen concentration with

redistribution time is 11.2% for small drip head flow rate  $q=2$  L/h and 2.4% for large drip head flow rate  $q=5.5$  L/h. When the drip irrigation tape was buried at a depth of  $H=20$  cm, the average reduction in soil ammonium nitrogen concentration with redistribution time was 19.6% for small drip head flow rate  $q=2$  L/h and 13.1% for large drip head flow rate  $q=5.5$  L/h.

Figures 3-18, 3-19, and 3-20 demonstrate that under identical drip irrigation tape burial depths, soil nitrate nitrogen concentrations decrease as drip head flow rates increase from  $q=2$  L/h to  $q=5.5$  L/h. Specifically: At burial depth  $H=0$  cm (surface drip irrigation), soil ammonium nitrogen concentrations with small drip head flow rates ( $q=2$  L/h) show a 555.9% average increase with extended redistribution time, while those with large drip head flow rates ( $q=5.5$  L/h) exhibit a 45.9% average increase. At burial depth  $H=10$  cm, soil ammonium nitrogen concentrations with small drip head flow rates ( $q=2$  L/h) and large drip head flow rates ( $q=5.5$  L/h) demonstrate average reductions of 8.3% and 33.3% respectively with redistribution time. At burial depth  $H=20$  cm, soil ammonium nitrogen concentrations with small drip head flow rates ( $q=2$  L/h) show an average reduction of 9.6% over redistribution time, while those with large drip head flow rates ( $q=5.5$  L/h) exhibit a 55% average increase.

By analyzing Figures 3-8, 3-9, and 3-10, it is evident that at the same drip irrigation tape burial depth, increasing the drip head flow rate from  $q=2$  L/h to  $q=5.5$  L/h leads to a corresponding decrease in soil pH, demonstrating a pronounced acidification trend. Additionally, Figures 3.18 to 3.20 demonstrate that the nozzle flow rate increases from  $q=2$  L/h to  $q=5.5$  L/h, nitrate nitrogen distribution becomes more dispersed, with both horizontal and vertical transport distances expanding. These findings collectively indicate that higher drip head flow rates facilitate nitrogen transport and distribution—particularly for nitrate nitrogen—and enhance ammonium nitrogen conversion to nitrate nitrogen, thereby intensifying soil acidification processes.

#### IV. CONCLUSION

The study results demonstrate that: (1) The depth of drip irrigation tape installation and drip head flow rate significantly influence water movement patterns. When the tape depth  $H=0$  cm, the soil moisture front exhibits a "horizontal" semi-elliptical shape. At depths of  $H=10$  cm and  $H=20$  cm, the moisture front assumes a "vertical" semi-elliptical configuration. Increased tape depth primarily enhances vertical water movement with limited horizontal propagation effects. Notably, at identical redistribution intervals, the larger tape depth ( $H=20$  cm) produces a relatively larger soil moisture front area and demonstrates stronger vertical water advancement. Drip head flow rates show variable moisture front distribution patterns across different redistribution times: On the first day post-drip irrigation (0d), a flow rate of  $q=2$  L/h generates a larger moisture front area compared to  $q=5.5$  L/h. However, after 2d and 5d post-drip, the same flow rate ( $q=2$  L/h) results in a smaller moisture front area than  $q=5.5$  L/h. The increase in drip head flow rate primarily facilitates water movement of soil moisture in the horizontal direction, with minimal impact on vertical progression. Under identical redistribution time conditions, higher drip head flow rates ( $q=5.5$  L/h) result in a relatively larger soil moisture front area, thereby exhibiting more pronounced effects on horizontal water transport. (2) The burial depth of drip irrigation tapes and drip head flow rate significantly influence nitrogen transport dynamics. Increased burial depth enhances the distribution and migration of ammonium nitrogen and nitrate nitrogen in soil, but does not promote their conversion from ammonium to nitrate forms. Higher drip head flow rates facilitate nitrogen distribution, particularly nitrate nitrogen. High flow rates ( $q=5.5$  L/h) increase the dispersion of nitrate nitrogen transport patterns, accelerate ammonium-to-nitrate conversion, and exacerbate soil acidification trends.

This study also has certain limitations or areas for improvement. This experiment established an indoor point-source drip irrigation system, but lacked studies on establishing connections with the root zone of actual crops and on air isolation through mulching film covering soil boxes. However, it can still provide preliminary reference value for the determination and selection of parameters such as the burial depth of drip irrigation tape and the flow rate of drip heads in underground drip irrigation systems.

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