Study on the reduction and hysteresis effect of soil nitrogen pollution by Alfalfa in channel buffer bank

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Abstract. Based on the simulation experiments of solute transport in channel buffer bank and pot experiments, this study analyzed the transport of nitrogen pollution from farmland drains along the South-North Water Transfer east route project; and compared the nitrogen transport rule and purification effect of alfalfa in channel buffer bank soil under situations of bare land and alfalfa mulching. The results showed that: (1) soil nitrogen content decreased gradually with the width increase of channel buffer bank by the soil adsorption and decomposition; (2) the migration rates of nitrogen were 0.06 g·kg⁻¹ by the alfalfa mulching; (3) the removed rates of nitrogen from the soil were 0.088 g·kg⁻¹ by cutting alfalfa; (4) the residual nitrogen of soil with alfalfa was 10% of the bare land. Alfalfa in channel buffer bank had obvious reduction and hysteresis effect to soil nitrogen pollution.

1. Introduction

The South-North Water Transfer east route project is long, which is vulnerable from the human life, especially the farmland boundary. The deep accumulation of nitrogen may cause some problems such as soil pollution, nitrogen fertilizer waste and groundwater pollution. When precipitation or irrigation, the pollutants of farmland soil enter into the channel through lateral diffusion, or enter the groundwater due to leaching which may affect the conveyance water quality. Therefore, the channel buffer bank is the medium between channel and pollution source, is the occurrence area of soil water, groundwater, and seepage water of channels, is a complex and special ecotone [1-2]. It has the function of intercepting and reduction pollutants from the riparian, but also has characteristics of expressway buffer belt. It undertakes the task of reducing pollution by preventing the surface runoff and subsurface flow directly into the ditch. It is the first barrier to protect the water quality.

The reduction and hysteresis effect of pollutants in channel buffer bank is manifested in two aspects. (1) The plants in channel buffer bank control of non-point source pollution and improve the ecological environment through roots absorption, loose soil, hysteresis runoff and interflow and climate adjustment etc. (2) There are a large number of microorganisms, soil animal, organic and inorganic colloid in the soil, which can be deposited material and energy by filtering, penetration, absorption, retention. It will reduce pollutants into surface runoff and groundwater; reduce the pollution of water channels. However, the purification ability is limited. The soil will be polluted when the amount and rate of pollutants entering the soil exceed its self purification capacity or soil environmental capacity. At this time, the pollutants may enter into the groundwater or water channel system. Peterjohn’s [3] study suggests that
the riparian zone can retain 89% N and 80% P; S. Huang [4] studies the purification effect of riparian buffer on non-point source pollution, and puts forward the optimum buffer zone width calculation formula; N. Wang [5] estimate non-point source nitrogen emission load of Dapu town quantitatively through field test and field investigation, the results shows that among the five emission sources, farmland, domestic, sewage, aquaculture, waste and non-farm sediment loss, farmland pollution is most serious, accounted for 39% of the total. This study selects alfalfa as the plant of channel buffer bank, which grow quickly, cover ground densely, has strong adaptability and can effectively remove the residual soil nitrogen. This study simulated the transport of nitrogen pollution from farmland drains, analyzed reduction effect, and provided a theoretical basis for the ecological environment along the large channels.

2. Materials and Methods

2.1. Experiment Equipment

There are two sets of channel buffer bank models (CBBM) and six sets of pot experiments. The positive of CBBM is organic glass, which can observe the growth process of plant roots and water transfer. The back of CBBM is divided into 15 soil sampling hole through four layers (as shown in Figure 1).

The soil of tested simulation was from the South-to-North Water Transfer Project Jiping main section channel embankment. Backfill is loaded and irrigated. There were planted alfalfa in the farmland and embankment of CBBM 1. The sowing density was 2 kg·m². The CBBM 2 was bare land as a control. At the same time, the pot experiments were used as supplement to CBBM test. The pot was plastic buckets, high 30 cm, and filled surface soil. There were two treatments with alfalfa and bare land. Each group was treated with three replicates.

2.2. Experiment Methods

Natural subsidence for a month, alfalfa was coming on splendidly and coverage could be 99%. On October 30th, collected soil samples from different sites, cut the first crop of alfalfa, and irrigated the farmland of CBBM. Through the sampling analysis of paddy drainage ditch in South-North Water Transfer east route project, and referenced to the experimental results of Wang Ning et al., assumed that the nitrogen emission load of farmland is 80.6 kg·hm⁻²·a⁻¹, which used to simulate the input of nitrogen.

![Figure 1. Channel buffer bank models](image)
pollution in agricultural drainage ditches. Measure the water content and the soil TN content in soil sampling.

3. Result Analysis and discussion

3.1. Nitrogen absorption effect by Alfalfa

Root system is an important organ for plants to absorb nutrients, transform and store nutrients. It’s also the basis for grassland to achieve the functions of soil and water conservation. The absorb nitrogen ability of alfalfa was related to the root system, the degree development, the growth period and the biomass of root attachment. The test results showed that the root system of alfalfa was developed, the roots were more concentrated in 35cm soil layer, and the distribution density was larger. The lateral roots were mostly distributed in 45cm soil depth. There was no root growth under 85cm. The vertical distribution of roots was decreased gradually from the surface to deep soil.

Under the experimental conditions, the variation trend of soil nitrogen was increasing first and then decreasing with time on different treatments. The bare land was most sensitive to fertilization and irrigation. After irrigation with fertilizer water, the nitrogen accumulated in the soil with time under the driving of nitrogen concentration gradient. But the increasing rate decreases gradually. The clear irrigation leaded to downward movement of soil TN. The nitrogen went along with the drainage water when the soil water was saturated.

Under the condition of alfalfa planting, the soil nitrogen showed the double crest variation by the influence of irrigation and fertilization. But the overall trend was less variable than bare land. On the one hand, alfalfa had direct absorption effect on soil nitrogen, and the roots surface of alfalfa could be attached to a large number of microorganisms. On the other hand, a high density of alfalfa root distribution in surface soil, the roots were interspersed in the soil during their growth, which squeezed the soil pores to a certain extent. The soil pore became discontinuous; the root distribution blocked the transport rate of nitrogen. When the absorption and transformation of nitrogen were dominant, the content of TN decreased gradually. Therefore, the nitrogen content of potted soil was lower than that of bare soil. The initial TN content of alfalfa soil slot 1 was higher than that of bare soil slot 2, the content of soil nitrogen was higher than bare soil during the experiment, but the TN content of alfalfa soil decreased gradually, and the bare soil increased basically, so the alfalfa has a good removal effect on TN in channel buffer bank with soil.

Approximately, we assume the difference between the pot increment of alfalfa and the increment of bare soil as the alfalfa uptake, the difference between the increment of alfalfa soil slot section 1 and the alfalfa uptake in pot experiment as the horizontal migration loss of soil TN, so the nitrogen leaching, the horizontal migration quantity, the alfalfa uptake of the soil TN in different time are shown in Table 1.

| Time     | Nov.9 | Nov.17 | Nov.23 | Dec.1 |
|----------|-------|--------|--------|-------|
| the nitrogen leaching / (g·kg⁻¹) | -0.111 | -0.170 | -0.138 | -0.062 |
| the alfalfa uptake / (g·kg⁻¹) | 0.102  | 0.154  | 0.126  | 0.088  |
| the horizontal migration quantity / (g·kg⁻¹) | 0.076  | 0.122  | 0.055  | 0.060  |

The change of the leaching amount $y_1$ of bare soil with time can be expressed by the formula (1), the relation curve between the removal amount $y_2$ of TN by alfalfa and time can be fitted as the formula (2).

$$y_1 = -0.0006 t^2 + 0.0215 t - 0.0321 \quad R^2 = 0.9738$$

$$y_2 = 4e - 05 t^3 - 0.0026 t^2 + 0.0543 t - 0.2048 \quad R^2 = 1$$
3.2. The movement and accumulation of soil nitrogen under the condition of alfalfa planting

(1) The variation of TN with migration distance

On Dec.1, incremental TN concentration in different measuring points was shown in Table 2. The overall trend shows that TN increases first and then decreases with the increase of horizontal migration distance, and the TN content in root distribution area was significantly less than that in non-root area, that is, the TN content at 15cm and 30cm was less than at 65 and 85cm. Because of the border drain pollution, the TN concentration in the section 1 was higher than near the water conveyance channel, the nitrogen moves to the right under the concentration gradient, lead to the concentration of the section 2 was slightly increased than the section 1 at the same depth, the average increase rate was 15.32%, 10.34%, 9.35% and 6.62%, that is the effect of nitrogen topdressing gradually smaller with the increasing of depth. At the same depth soil, with the attenuation of nitrogen along the course (the absorption and retention of nitrogen by the channel buffer bank soil) and the absorption of plant roots, the concentration of nitrogen gradually decreases with the increase of transport distance.

Table 2. The incremental TN concentration in different measuring points (Dec, 1)

| Depth    | Horizontal 15cm | 45cm | 75cm | 105cm | 135cm |
|----------|-----------------|------|------|-------|-------|
| 15cm     | 0.144           | 0.154|       |       |       |
| 30cm     | 0.063           | 0.135| 0.048|       |       |
| 65cm     | 0.339           | 0.245| 0.302| 0.237 | 0.242 |
| 85cm     | 0.201           | 0.318| 0.238| 0.148 | 0.138 |

The relation curve of the TN concentration $y_3$ in section 2 with longitudinal migration distance could be fitted as formula (3).

$$y_3 = -2.7723x^3 + 3.6343x^2 - 1.0815x + 0.4692 \quad R^2 = 1$$

(3)

In 65cm depth, the relation curve of the TN concentration $y_4$ with horizontal migration distance could be fitted to formula (4).

$$y_4 = 0.242x^3 - 0.67x^2 + 0.5026x + 0.432 \quad R^2 = 0.9733$$

(4)

(2) The variation of TN with time

The variation of TN over time in different soil layers were shown in the table 3.

Table 3. Variation of TN concentration over time in different sections

| Depth     | Time | Nov.3 | Nov.9 | Nov.17 | Nov.23 | Dec.1 |
|-----------|------|-------|-------|--------|--------|-------|
| Horizontal (15cm) |      |       |       |        |        |       |
| 15cm      | 0.192| 0.318 | 0.269 | 0.379  | 0.336  |       |
| 30cm      | 0.297| 0.437 | 0.585 | 0.562  | 0.360  |       |
| 65cm      | 0.238| 0.476 | 0.532 | 0.501  | 0.577  |       |
| 85cm      | 0.209| 0.294 | 0.361 | 0.349  | 0.410  |       |
| 15cm      | 0.218| 0.354 | 0.230 | 0.384  | 0.372  |       |
| Horizontal (45cm) |      |       |       |        |        |       |
| 30cm      | 0.211| 0.477 | 0.594 | 0.396  | 0.346  |       |
| 65cm      | 0.266| 0.504 | 0.580 | 0.510  | 0.511  |       |
| 85cm      | 0.196| 0.176 | 0.596 | 0.461  | 0.514  |       |
The nitrogen content of surface soil (15cm) was greatly affected by the irrigation of fertilizer and water, the content of TN increased slowly after irrigation with fertilizer and reached the maximum value after 5 days; when irrigation with clear water, the topsoil could be washed and the content of TN decreased. With the extension of migration time, the TN content of the 30cm soil increased first and then decreased, the root distribution density of the region is large, in the early experiment, nitrogen was mainly transported in the soil, with the growth of alfalfa, the transformation and absorption of root system gradually increased, the increase of soil nitrogen content decreased after 10 days, in the period of nutrition vigorous growth about 18 days later, plants were able to absorb and use nitrogen quickly, plant root system plays a dominant role in the transformation and absorption of nitrogen. At this time, the nitrogen content in channel buffer bank soil decreased gradually. In the depth of 65cm, the root system distribution is approximately 0, migration was the main influencing factor. TN had little effect on irrigation, accumulation occurs in this layer during the downward movement of nitrogen, the accumulation in this layer is lagging behind in time. There was no root distribution in 85cm, nitrogen accumulated downward in the course of vertical migration during the initial stage, and gradually saturated in the bottom soil, the accumulation of nitrogen in soil layer loss from the test slot bottom hole drainage, After the accumulation of TN content to a certain extent, it began to decrease. The overall variation trend of section 2 is the same as that of section 1, and the TN content of soil is slightly larger than that of section 1.

Table 4 lists the changes of TN concentration with the time in each section at depths of 65 cm and 85 cm.

| Depth (65cm) | Time   | Nov.3 | Nov.9 | Nov.17 | Nov.23 | Dec.1 |
|-------------|--------|-------|-------|--------|--------|-------|
| 15cm        |        | 0.238 | 0.476 | 0.532  | 0.501  | 0.577 |
| 45cm        |        | 0.266 | 0.504 | 0.580  | 0.510  | 0.511 |
| 75cm        |        | 0.238 | 0.490 | 0.584  | 0.526  | 0.540 |
| 105cm       |        | 0.260 | 0.469 | 0.547  | 0.519  | 0.497 |
| 135cm       |        | 0.244 | 0.424 | 0.526  | 0.507  | 0.486 |

| Depth (85cm) | Time   | Nov.3 | Nov.9 | Nov.17 | Nov.23 | Dec.1 |
|--------------|--------|-------|-------|--------|--------|-------|
| 15cm         |        | 0.209 | 0.294 | 0.361  | 0.349  | 0.410 |
| 45cm         |        | 0.209 | 0.294 | 0.361  | 0.349  | 0.410 |
| 75cm         |        | 0.196 | 0.176 | 0.596  | 0.461  | 0.514 |
| 105cm        |        | 0.210 | 0.382 | 0.580  | 0.454  | 0.448 |
| 135cm        |        | 0.283 | 0.459 | 0.498  | 0.477  | 0.431 |

4. Conclusion
Based on the pot experiments and the channel buffer bank tests, this study analyzed the transport of nitrogen pollution in the channel bank soil under the bare land and the growth of alfalfa. The results showed that:

1. There was no vegetation cover, the channel bank could retain and degrade a small amount of soil nitrogen, but when the water content of soil reached a certain level, the nitrogen leached down and polluted groundwater; alfalfa could give full play to its root absorption and transformation of nitrogen, slowed down the transport rate of nitrogen in soil, reduced soil nitrogen content, and effectively reduced the risk of soil nitrogen leaching from bare soil.
2. Alfalfa root mainly distributed in 0-50cm, its size and the distribution density directly affects the distribution of TN in soil, the TN content of soil in root zone was higher than that in non-rhizosphere soil; with the extension of time, when the absorption and transformation of plants are dominant, the TN content of soil gradually decreases.
(3) Due to the nitrogen transport along the horizontal direction to the water diversion channel under the concentration gradient, the TN content of section 2 in the 15cm soil layer is 15.32% higher than that of section 1.

(4) Under the experimental conditions, the effect of Alfalfa on soil nitrogen removal was very obvious after the first mowing, the average removal rate of nitrogen in the upper layer of the channel buffer bank was above 70% after a month.

Tests have shown that alfalfa grown in areas contaminated by nitrogen can be used to turn waste into treasure, made full use of the nitrogen in the soil and reduced the water channel to transport and groundwater leaching, solved the effect of boundary agricultural non-point source pollution on water quality and groundwater quality. On the other hand, alfalfa was known as "the king of grass", rational use of the channel buffer bank resources to cultivate alfalfa can not only increase the income of channels, but also beautify the channel environment, realize the common development of soil, water conservation and economic development.

The experiment was carried out under the indoor simulation conditions, its results and conclusions had some particularity and limitations. In addition, there were many factors affecting soil nitrogen removal, the channel buffer bank is not a stable process in actual operation, the removal rate of the system TN will vary greatly.

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