IOP Conf. Series: Materials Science and Engineering **730** (2020) 012064 doi:10.1088/1757-899X/730/1/012064

Drainage and Total Nitrogen Loss of Cropland under Drip Irrigation and Subsurface Pipe Drainage

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Abstract. Water saving irrigation as an effective measure to improve the utilization rate of water resources and alleviate water deficit has been widely practiced in arid and semi-arid regions. In this study, an integrated drip irrigation and subsurface pipe drainage system was developed to study the total nitrogen emission concentration of sunflowers during the whole growth period. The test and results show that total nitrogen concentration of farmland drainage in the spring irrigation period exceeded the standard V of "Surface Water Quality Standard". In addition, prolonging the leaching time or reducing the irrigation quota can effectively reduce the concentration of total nitrogen in farmland drainage.

1. Introduction

Water scarcity and non-point source pollution have been a serious issue for crop production in arid and semi-arid regions in China (*1*, *2*). Poor natural water endowment and mismanagement of water resources are the main contributor to water shortage as well as water pollution (*3*, *4*). Water saving irrigation, especially drip irrigation, as an effective water resources management measure, greatly improved the utilization rate of water resources and effectively alleviated water deficit. It has been widely practiced in arid and semi-arid regions in China. Therefore, it is significant to research the influence of drip irrigation system on pollutant emission concentrations.

Nitrogen is not only an important nutrient in crop growth but also one of the main components of eutrophication. Over the last a few decades, there have been a number of studies have considered the change rule of TN concentration based on drip irrigation system. For instance, Peng et al. (*5*) developed an integrated water-saving irrigation and controlled drainage system to monitor the TN and TP load in South China and confirmed the system's desirable function of water saving and pollutant reduction. Sepaskhah and Tafteh (*6*) revealed the effect of different N application rates on rapeseed yield, drainage water and N leaching. Ye et al. (*7*) found that the main water pollution including TN, TP and COD of paddy filed could decrease at least 22% by using water saving irrigation. Many years researches have shown that water saving irrigation is one of the effective tools to achieve good results of water saving and pollution decreasing.

However, major challenges still remained for controlling non-point source pollution by water saving irrigation technology. Because the farmland drainage is too small in arid region, most of the previous work focus on paddy field, few studies consider the change of pollutant concentration in farmland drainage letting alone incorporation into water saving irrigation. Therefore, this study will take Hetao irrigation region of Inner Mongolia province as an example, and combine drip irrigation with subsurface pipe drainage to monitor the TN emission concentration of sunflower, a local

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characteristic crop, during the whole growth period. The objective of this research is to reveal the change rule of TN emission concentration of crops in arid region under water saving irrigation and provide reasonable suggestions for local water saving and pollution control according to the research results.

2. Materials and Methods

Experiments were conducted in the single sunflower-growing region (May to August) in 2019 at Heji Experiment Station (40°44′N-107°16′E), Hetao Irrigation District (Figure 1), one of the main grain production regions in the west of the Inner Mongolia Autonomous Region, China. The experimental site has an area of approximate 7.84 ha. The study site has a typical continental desert climate with a mean annual precipitation of 130mm to 250mm and evaporation of 2,100mm to 2,300mm. Therefore, irrigation is very important for crop growth in Hetao Irrigation District, which will consume [4.35, 5.19] billion m^3 water resources from Yellow River every year. In order to reduce soil salinity, salt-leaching was fixed to May and October each year and consumed [1.34, 1.84] billion m^3 of the irrigation water. Eutrophication of Lake Wuliang Suhai has become severer and severer because of the release of various pollutants of farmland wastewater.

This experiment makes sunflowers as research object where the plant spacing was 60 cm and planting density was 37,000 plant/hm^2. This experiment used the ARIES TM drip irrigation tape produced by Netafim. The dripper spacing is 30cm and the dripper discharge is 1.0L / h. The drainage pipe consists of 8 suction pipes and 1 collector pipe. The row spacing of drip irrigation tape is 40cm. The suction pipe is PE bellows with diameter 4 inches, distance 30m, buried depth 1.5m and slope 0.5%. The collector pipe is PE bellows with diameter 6 inches. One collecting well is installed at the end of the intersection of the suction pipe and the collecting pipe, which is a concrete culvert with diameter 2m and depth 4.5m. The water of collecting well was discharged into the main drain by pump. In addition, the collecting well could monitor drainage through electromagnetic flowmeter.

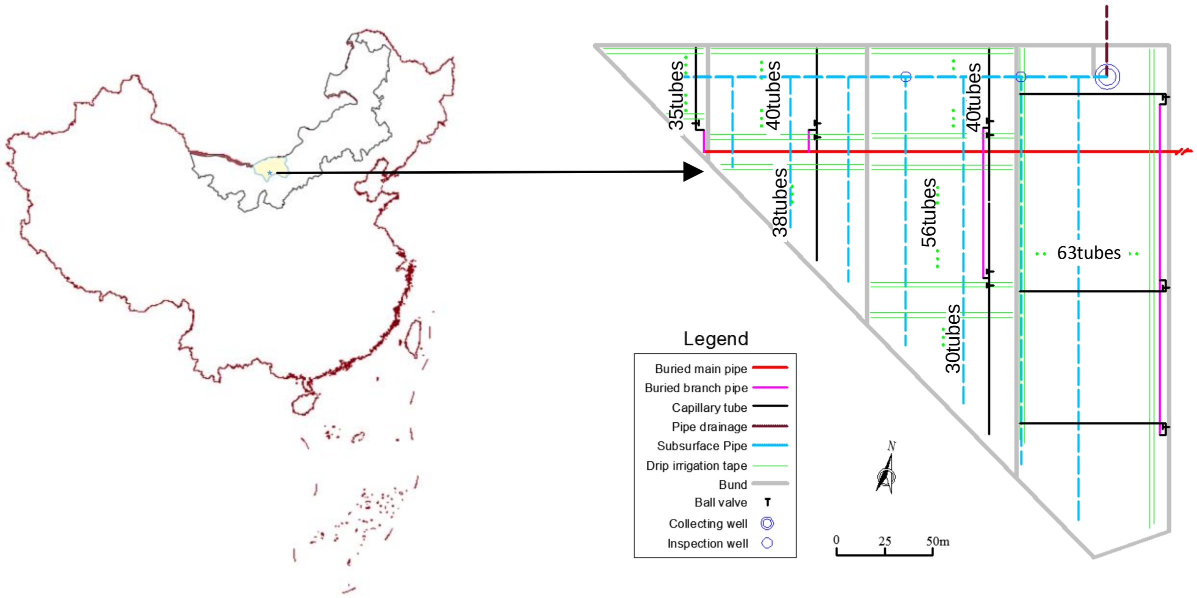


Figure 1. Location of experiment site and layout of pipe layout

3. Results and Discussion

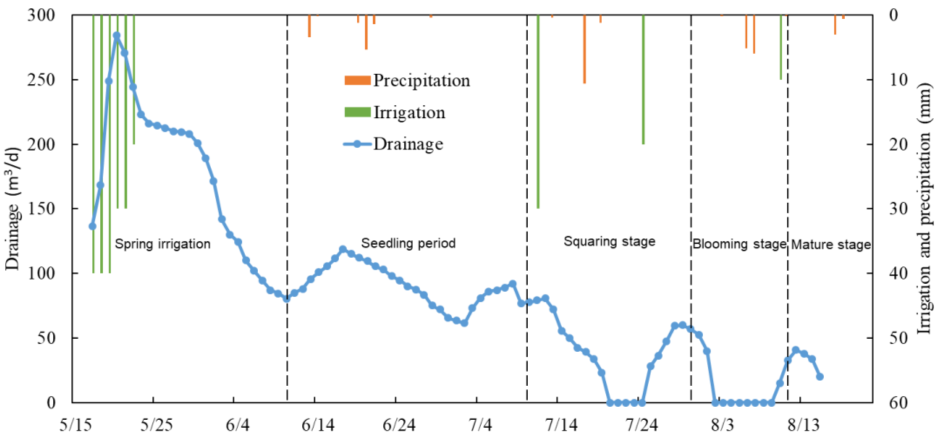
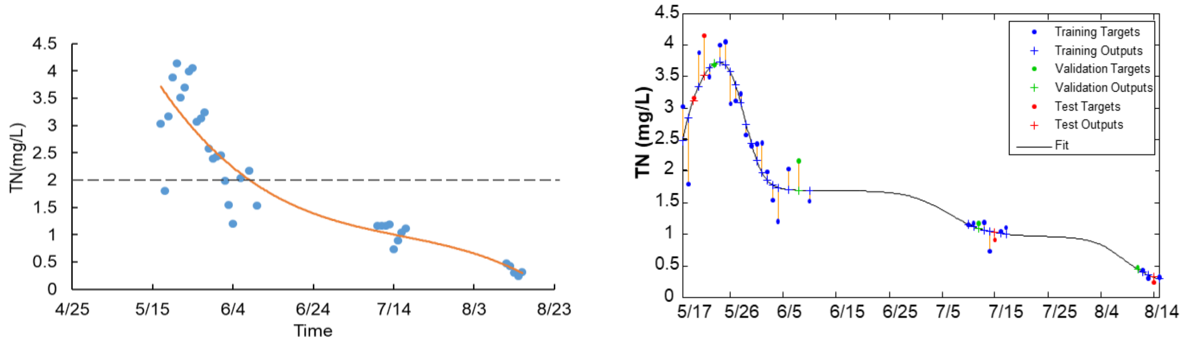


Figure 2. Drainage, irrigation and precipitation during the experimental period

There are four times of irrigation, one is before sowing (spring irrigation period), and the remaining three times are distributed in the growth period. The irrigation before sowing lasts a long time and the irrigation amount is large. But the irrigation amount in the growth period is relatively small and the duration is short. Most of the rainfall is from June to August, and most of the rainfall is less than 10mm. in the aspect of water output, the daily water drainage first increased rapidly and then decreases tortuously. In detail, the discharge was 284.5m^3 on May 20, which is the maximum for the whole year and more than double of the drainage, 135m^3, on May 17. Then, the drainage continued to drop from May 21 until sowing was completed. After entering the seedling period, there was a short-term recovery of drainage. This may be because the Yellow River had entered into the high flow period, raising the groundwater table of Hetao Irrigation district. But as crops grow, the demanded for water increases, so the drainage decreased again.

Figure 2 also shows that irrigation is usually arranged when drainage is zero. This means that the natural water resources had been unable to fully meet the growth needs of crops, after entering the squaring stage. Irrigation is necessary for crops growth. However, it is worth noting that the drainage has increased significantly a few days before irrigation. Through field investigation and analysis, it can be inferred that this may be because the experimental field is close to the canal, and the water level of canal will rise significantly before irrigation, which will lead to the rise of groundwater table in the nearby field. In addition, there was no significant change in the drainage before and after precipitation, which means that precipitation would not supply groundwater in Hetao Irrigation district.

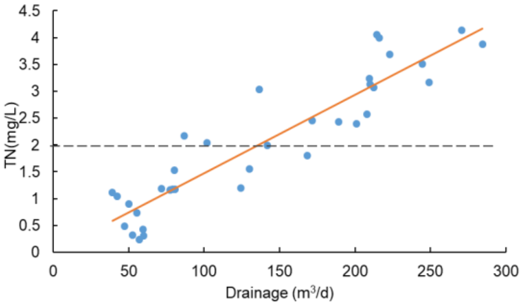


(a) Polynomial (b) BP Neural network

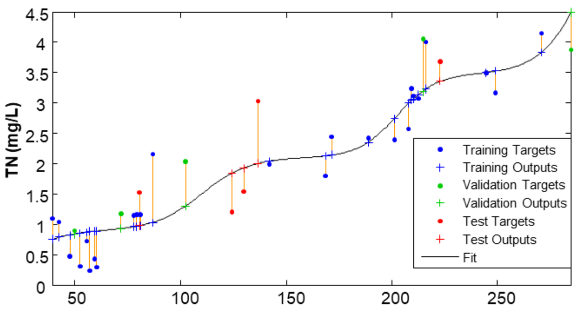
Figure 3. Simulation for concentration of TN in agricultural drain

Figure 3 shows the relationship between time and emission concentrations of TN based on polynomial and BP neural network. In particular, the structure of BP neural network is designed as three-layer feed forward neural networks, including 3 neurons in input layer, 5 neurons in hidden layer and 1 neuron in output layer. Among the samples, 80% points would be selected as training set, 10% points would be singled out for validation set and the rest 10% points would be chosen as test set. The Determination Coefficients R^2 are 0.8040 and 0.9146, respectively, that is to say, as time passed by, the TN emission concentrations would be significantly reduced, which agreed well with the finding of earlier related studies(*8-10*). K-Folder-Cross Validation Further (K-CV, where K=10) would be chosen to calculate the Predicted Determination Coefficient (predR^2) of fitting curve of polynomial and BP neural network, which are 0.7670 and 0.8014, respectively. Because of the non-linear mapping ability and adaptation and other such characteristics BP neural network, it is feasible for TN emission concentrations fitting, with higher precision than polynomial fitting.

The fitting result of BP neural network indicated that TN emission concentrations would increase firstly and then decrease. The concentration of TN of agriculture drain changed dramatically during the spring irrigation stage, rising from 2mg/L to 4mg/L in ten days, and then decreasing rapidly to about 2mg/L. This may be related to the application of nitrogen before sowing. In addition, the change of TN concentration was relatively slow and the concentration stable at 1.5-2mg/L during seeding stage. In mature stage the TN concentration of drainage was lower than 0.5mg/L, and the possibility via runoff was very little.



(a) Polynomial



(b) BP Neural network

Figure 4. The relationship between drainage and the concentration of TN in agricultural drain

The relationship between drainage and emission concentration of TN based on polynomial and BP neural network as indicated in Figure 4. The statistical parameters were R^2 and PredR^2 for polynomial (0.8494 and 0.8342) and BP neural network (0.9126 and 0.7041) respectively. It can be seen that the fitting precision of BP neural network is better than using polynomial, but the latter one shows more stable. That is to say that there is a positive linear relationship between the agricultural drainage and the emission concentration of TN. Combined with Figure 3, a large amount of drainage during the spring irrigation period is also the main factor leading to the rapid loss of nitrogen.

4. Conclusion

This study take Hetao irrigation region of Inner Mongolia province as an example and combine drip irrigation with subsurface pipe drainage to monitor the TN emission concentration of sunflower during the whole growth period. The test and results show that the largest amount of drainage was produced in spring irrigation stage, while irrigation and rainfall did not promote the drainage in crops' growth period. Therefore, further study could pay more attention to the water movement before sowing. In addition, the experimental results also showed that TN concentration of farmland drainage exceeded the standard V of "Surface Water Quality Standard" during the spring irrigation period. This means that the salt leaching would easily lead to nitrogen loss and water pollution at this time. However, after a growth period, most of the nitrogen in the soil has been absorbed by the crops. Salt leaching after harvest can effectively prevent nitrogen loss and water pollution. It is well known that the purpose of spring irrigation and autumn irrigation is to leach excess salt from the soil. Therefore, the management department can alleviate the local water pollution by regulating the leaching scheme, such as reducing the water cost of autumn irrigation to encourage local farmers to discharge salt in autumn. Moreover, due to the direct ratio between the drainage and the loss of nitrogen, prolonging the leaching time or reducing the irrigation quota can also effectively reduce the concentration of TN in farmland drainage.

5. Acknowledgement

This research was supported by the National Natural Science Foundation of China (No. 51822905; 51779255; 51639009; and 51621061).

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