An Experimental Study on the Variation Regularity of Soil Nitrate Nitrogen in Yehe Irrigation Area

Huiyan GAO[*1], Luhua YANG[2]

1. College of Urban &Rural Construction, Agricultural University of Hebei, Baoding, Hebei 071000, China
2. Tianjiang Agricultural University, Tianjin 300384, China

***Abstract* — Soil moisture and nitrate nitrogen experiment were conducted in wheat-maize field in Yehe irrigation area from 2012 to 2013 in order to analyze the effect on agricultural ecosystem and groundwater environment by agricultural products. Groundwater level and quality were observed in the same time. The experiment results show that nitrate nitrogen content shows in "X" shape in 0~300cm soil profile during the wheat-maize rotation period. When adding identical irrigation quota, Soil depths which soil moisture changes significantly are different by the initial soil moisture and soil spatial heterogeneity. Nitrate nitrogen content varies in monotone decline curve in 0~300cm soil profile during the wheat-maize rotation period. The cumulative amount and leaching amount of nitrate nitrogen are maximum value in March and May respectively. When groundwater depth is about 8~9m and irrigation quota is 900~1200m^3/hm^2, nitrate nitrogen transport occurs in tilth soil. Fertilization and precipitation are the main factors influencing the groundwater quality and soil nitrate leaching.**

Keywords - soil moisture; nitrate nitrogen; transport rule; field experiment; Yehe irrigation area

I. INTRODUCTION

China has only 7% of the land to feed successfully 22% of the world's population, grain self-sufficiency for many years. Fertilizer accounted for more than 50% on the grain production in China, especially nitrogen fertilizer was the most obvious, fertilizer consumption accounted for more than 60%. But in recent years, due to excessive application of nitrogen fertilizer, the soil appeared lump, caking phenomenon, grain yield and crop quality decline, water pollution, nitrate in water lead to "blue baby" syndrome and cancer incidence increased, seriously affect human health [1-3]. Therefore, it plays an important role to study distribution of soil nitrogen and movement law of farmland, in order to protect agricultural ecosystem, water environment and human health.

It can be concluded that the residual nitrogen in soil mainly exists in the nitrate form by Pan Jiarong [4]. Related research indicates [5-7] that the residual nitrate in the soil moves downwards with the infiltration water and becomes a potential source of contamination. Zhang Yun [8] studied on the accumulation of nitrogen on the condition of excessive fertilization and irrigation. The results show that nitrogen mainly accumulates in shallow soil layer during early stage, and then fluctuates with the soil depth and infiltration water. Guo Zipeng [9-12] studied on the distribution of soil nitrogen in well irrigation area and came to the conclusion that the soil nitrate content shows an "S" shape in shallow soil and a "W" shape in deep soil. In paper, Soil moisture and soil nitrate were dynamic measured in Yehe irrigation area and groundwater level and water quality were observed in the same time. Based on experimental data, the cumulative variation of nitrate nitrogen in soil and effect on groundwater were analyzed. It is theoretical foundation to improve the utilization efficiency of nitrogen fertilizer and protect the groundwater environment.

II. EXPERIMENTAND METHOD

A. Experiment Field

The field experiment was conducted in Yehe irrigation area, which is located in the Taihang Mountain piedmont plain and is the main grain production base in North China. Gangnan Reservoir and river water is the source of irrigation water. The design irrigation area is 28360 hm^2; design diversion discharge is 22m^3/s. It belongs to the continental monsoon semi-arid climate; the average annual precipitation is 565.2mm, and precipitation concentrates in 6~9 months, accounting for 70%~80% of the annual precipitation; the average temperature is 13.3 ℃ .The soil is sandy loam; soil volume weight is 1.35g/cm^3. It is suitable for the growth of crops, mainly wheat, maize other crops.

B. Materials and Methods

The field experiment was conducted in the fifth branch canal of Yehe irrigation area from 2012 to 2013. Soil moisture and nitrate nitrogen were dynamic measured. Measurement time depends on crop growth, irrigation, fertilization, etc.. Soil moisture is measured by drying method, measured depth is 300cm and interval is 20cm. Determination of soil nitrate with PXSJ-226 ion meter, determination of soil bulk density with ring knife. The methods of irrigation and fertilization are the same of local farmers. Fertilizer was applied on October 9, 2012 and March 25, 2013 during the experiment. The amount of fertilizer was 450kg/hm^2 and 600kg/hm^2 respectively. There were 3 eyes well-log at the right side of the second lateral canal of the fifth branch for monitoring groundwater level and water quality. The detail layout as follow figure 1.

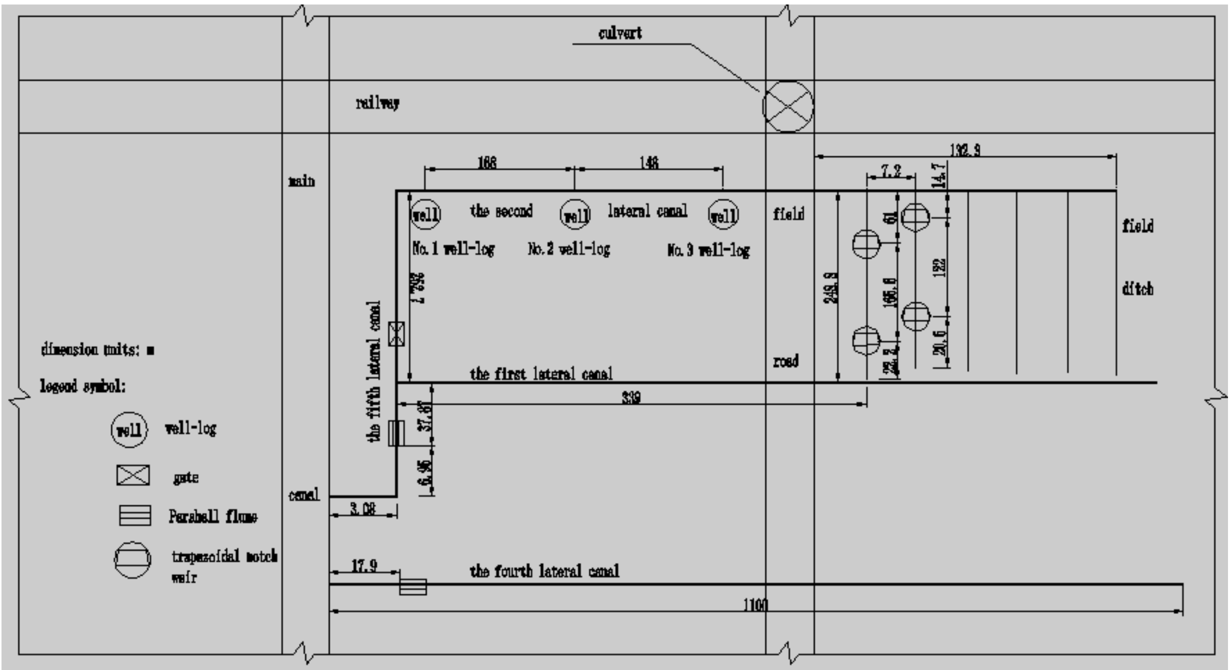


Fig.1 Location of the experimental area in the Yehe irrigation area.

III. RESULTS AND DISCUSSION

A. The distribution of soil moisture

1) Variation of soil moisture in wheat-maize rotation period

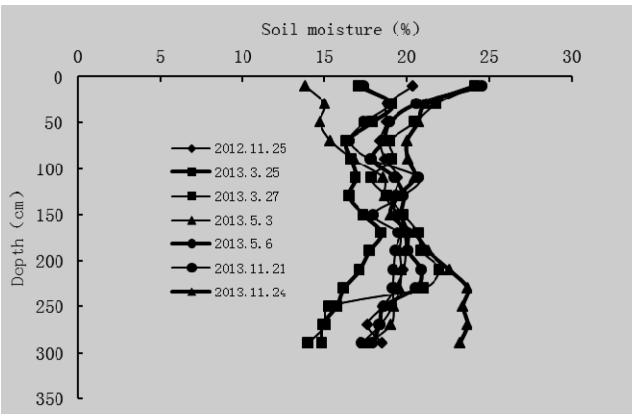
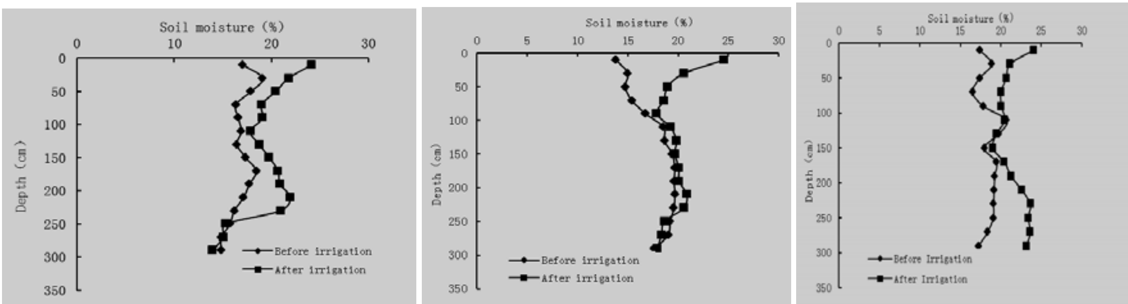


Fig.2 Soil moisture distribution in field

Figure 2 shows that soil moisture is in "X" shape at 0~300cm soil profile in the wheat-maize rotation period. The soil moisture varies from 13.82% to 24.57%. The soil moisture content varies greatly in 0~150cm soil profile, its value is 13.82%~24.57%. Precipitation, irrigation evaporation, transpiration are the main influencing factors. The soil moisture is 13.96%~23.18% below 150cm soil profile. The spatial heterogeneity of soil plays an important role. The minimum value of soil moisture occurs on May 3, 2013 in 0~100cm soil profile and emerges on March 25, 2013 in 100~300cm soil profile. The reason is mainly related to climate and precipitation. It is cold and less snow in winter, dry and windy in spring in Yehe Irrigation Area. After winter and spring, which is scarce rainfall, the soil moisture is in a state of water shortage. Especially, the soil moisture content in 100~300cm soil profile is the lowest in a year. The soil moisture content increases after irrigation at returning green stage. The soil moisture decreases with the growth and development of wheat, and the minimum value of soil moisture emerges on May 3 in 0~100cm soil profile. And then, the soil moisture content increases continually because of the irrigation and the arrival of the rainy season.

2) Variation of soil moisture before and after irrigation

The soil moisture was measured before and after irrigation in late March 2013, early May and late November. The results were shown in Figure 3.



（a）Late March （b）Early May （c）Late November

Fig.3 the change curve of soil moisture before and after irrigation.

When adding identical irrigation quota in late March, early May and late November, Soil depths which soil moisture changes significantly are different and Soil depths are 250cm, 100cm and above 300cm respectively shown in Figure 3. The main influence factors are the soil moisture content and its distribution before irrigation in late March and early May. The distribution of soil moisture is uniform in 0~300cm soil profile in late March, and Soil moisture increases evidently in 0~250cm soil profile after irrigation. Soil moisture is in a state of shortage within 0~100cm soil profile and is full below 100cm soil profile in early May. After irrigation, soil moisture content increases significantly within 0~100cm and irrigation water is mainly concentrated in the surface soil. Soil depth which soil moisture changes significantly is maximum value after irrigation in late November by the initial soil water content and soil spatial heterogeneity. It is more sand at sampling locations, irrigation water rapidly infiltrates, and soil moisture content increased obviously after irrigation 0~300cm soil profile.

The actual irrigation amount in the soil can be calculated by the following formula:

$$m = 10000\sum_{i=1}^{15} H_i \gamma_i \left(\theta_{i1} - \theta_{i0}\right) \qquad (1)$$

Where, m is the actual amount of irrigation, m^3/hm^2; H_i is the soil depth of the layer i, m; γ_i is the soil bulk density of the layer i, g/cm^3; θ_{i0} and θ_{i1} is soil moisture of the layer i before irrigation and after irrigation respectively, %; i is the number of the sampling and equal to 15.

According to the experimental data, the actual amount of irrigation is calculated by using (1) in late March, early May and late November, its value is 1025, 980 and 1230 m^3/hm^2 respectively. The actual amount of irrigation is near in late March and early May. The actual amount of irrigation is larger in late November, which further proves that deep percolation is larger and irrigation water waste serious for sand soil. Therefore, in a large irrigation area, the spatial heterogeneity of soil is an important factor affecting leaching amount of water during irrigation, leakage cannot be avoided.

B. The distribution of nitrate nitrogen in soil profile

1) The variation of nitrate nitrogen in wheat-maize rotation period

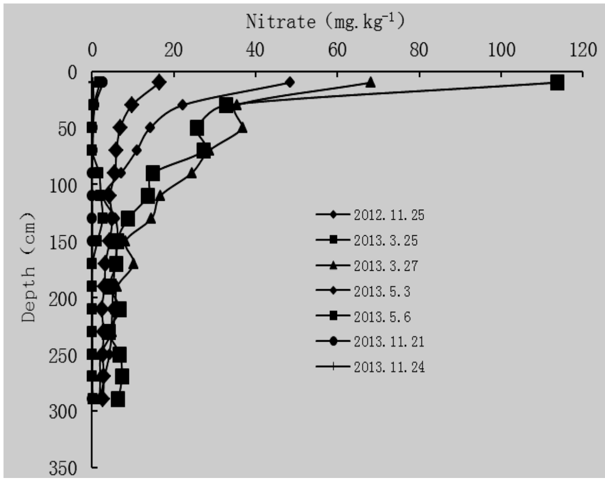


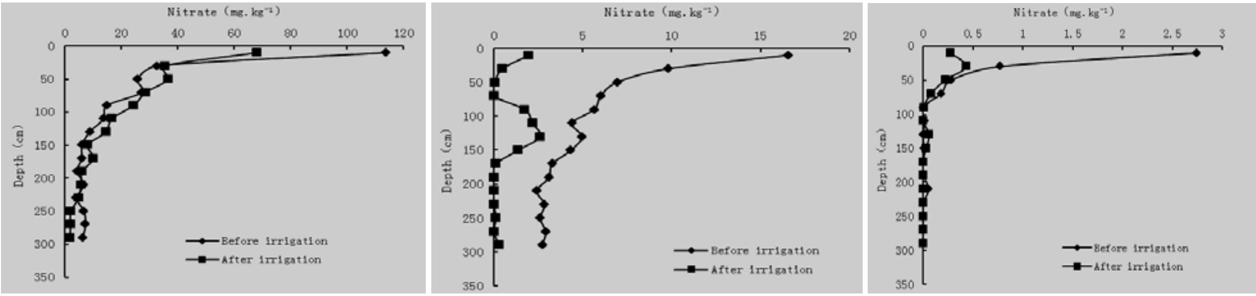
Fig.4 the distribution of soil nitrate nitrogen in field

It can be concluded from Figure 4 that nitrate nitrogen content varies in monotone decline curve in 0~300cm soil profile during the wheat-maize rotation period. Soil nitrate nitrogen content changes greatly in 0~150cm soil profile, and its value is 0~113.65mg/kg. Soil nitrate nitrogen content tends to be stable below 150cm soil profile. The maximum nitrate content exists on March 25, 2013 and its value is 113.65mg/kg. Fertilization habits and the distribution of precipitation are reasons for causing these phenomena. Before winter wheat sowing, nitrogen fertilizer is in basal application in order to ensure the crop yield and soil fertility, nitrogen fertilizer application combine with irrigation on turning green stage. The local fertilizing habitation is not consistent with the regularity of nitrogen requirement in crop. As result of conventional nitrogen application, nitrate nitrogen is mainly accumulated in 0~100cm soil profile in the wheat growth period.

2) The variation of nitrate nitrogen before and after irrigation

a) The distribution of nitrate nitrogen in soil profile

The nitrate nitrogen content were measured before and after irrigation in late March, early May and late November, 2013. The results were shown in Figure 5.



（a）Late March （b）Early May （c）Late November

Fig.5 the change curve of soil nitrate nitrogen before and after irrigation

Figure 5 shows that the distribution of soil nitrate nitrogen varies evidently before and after irrigation in late March, early May and late November. Soil nitrate content before irrigation is a main factor affecting the distribution of soil nitrate after irrigation. Fertilization is before irrigation in late March, soil nitrate content is larger and soil nitrate content reaches the maximum value in shallow layer, its value is 113.65mg/kg. After irrigation, soil nitrate content decrease rapidly, its value is 68.2 mg/kg in 0~20cm soil profile; soil nitrate content increase continually in 20~180cm, and increasing extent decreases with the increase of soil depth. Soil nitrate content is low before irrigation in early May. After irrigation, soil nitrate content decreases in 0~300cm soil profile and decreases significantly at shallow layer, its value is from 16.55 mg/kg before irrigation to 1.98 mg/kg after irrigation. Soil nitrate content is the lowest before irrigation in late November. After irrigation, soil nitrate content decreases rapidly in 0~40cm soil profile, and the variation of the soil nitrate content is not obvious below 40cm soil profile.

b) The accumulation and leaching of soil nitrate nitrogen

Nitrate accumulation formula is as follows:

$$N_{acc} = 0.1\sum z\rho_d c \quad (2)$$

Where, N_{acc} is the accumulation of nitrate nitrogen, kg /hm^2; z is the depth of soil, cm; ρ_d is the soil bulk density, g/ cm^3; c is the soil nitrate content, mg/ kg.

The calculation results are shown in Table I.

Table I shows that in late March the maximum accumulation amount of soil nitrate is 769.54 kg/hm^2; In early may take second place, the value of 212.10 kg/hm^2; In late November, the value of 11.01 kg/hm^2. It is down that soil nitrate accumulation in 0~100cm soil profile accounts for the proportion of 0~300cm soil profile before and after irrigation in late March, early May and late November, drop-out values are 2.54%, 18.24% and 5.99% respectively. It increases that soil nitrate accumulation in 100~200cm soil profile accounts for the proportion of 0~300cm soil profile before and after irrigation in late March, early May and late November, its values are 4.76%, 13.26% and 1.55%.

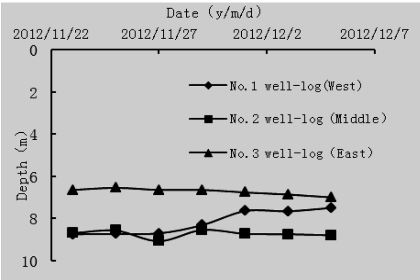
The leaching amount of soil nitrate in 0~100cm soil profile are 56.54kg/hm^2, 109.82kg/hm^2, 7.98 kg/hm^2 respectively before and after irrigation in late March, early May and late November; the leaching amount of soil nitrate in 0~200cm soil profile are 11.00kg/ hm^2, 147.14kg/hm^2, 7.83 kg/hm^2 before and after irrigation; the leaching amount of soil nitrate in 0~300cm soil profile are 50.84kg/hm^2, 182.47kg/hm^2, 8.00kg/hm^2 before and after irrigation. It can be concluded that soil nitrate leaching occurs mainly in 0~100cm soil profile in late March and late November and emerges significantly in 0~300cm soil profile in early May. The maximum leaching amount occurs in early May. In addition to water infiltration, soil factors, soil moisture before irrigation is the main influencing factor for the accumulation and leaching of soil nitrate.

TABLE I. AMOUNT OF ACCUMULATED NITRATE NITROGEN BEFORE AND AFTER IRRIGATION

Date			**Late March**	**Early May**	**Late November**
Before irrigation	0~100cm	Accumulation（kg/hm^2）	579.04	121.37	10.74
		Percent（%）	75.24	57.22	97.53
	0~200cm	Accumulation（kg/hm^2）	684.50	175.60	10.84
		Percent（%）	88.95	82.79	98.45
	0~300cm	Accumulation（kg/hm^2）	769.54	212.10	11.01
After irrigation	0~100cm	Accumulation（kg/hm^2）	522.5	11.55	2.76
		Percent（%）	72.7	38.98	91.54
	0~200cm	Accumulation（kg/hm^2）	673.5	28.46	3.01
		Percent（%）	93.71	96.05	100.00
	0~300cm	Accumulation（kg/hm^2）	718.7	29.63	3.01

C. variation regularity of groundwater level and quality

The groundwater level and quality of the No. 1, No. 2, No. 3 well-log, which were located on the second lateral canal of the fifth branch, were dynamic measured in wheat-maize rotation area from 2012 to 2013.The results are shown in Figures 6 and 7.



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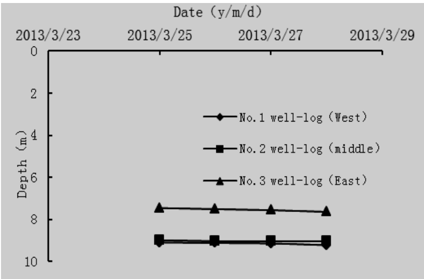

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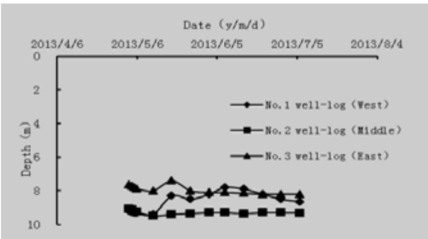

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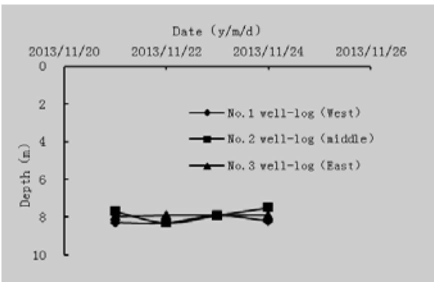
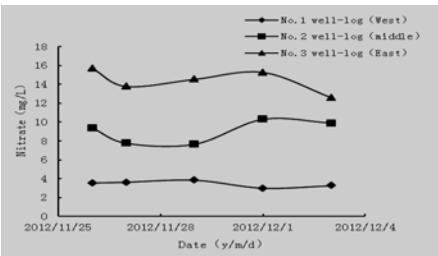


(d)

Fig.6 the change curve of underground depth



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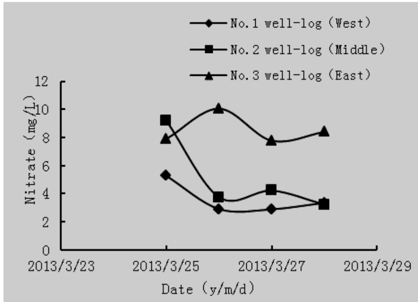

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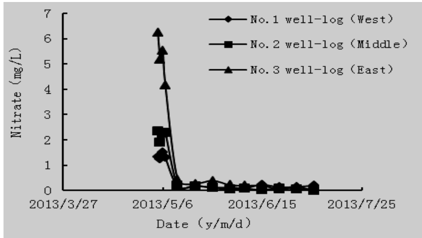

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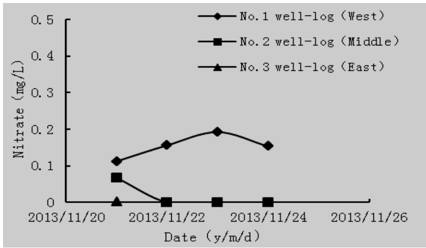

(d)

Fig.7 the change curve of groundwater quality

It can be concluded from Figure 6 that the groundwater depth is shallow (Fig. 6a) in November and December 2012. The reason is the recharge of precipitation after the rainy season, and then groundwater level rises. Groundwater depth reaches the maximum value on May 12, 2013; its values are 9.40m, 9.50m and 8.00m for No.1 well-log, No.2 well-long and No.3 well-log respectively. Then, the groundwater level is in picking up state. After a large rainfall in May 12, 2013, the range of picking up is 1.1m, 0.1m, 0.6m (Fig.6b, c) for No.1 well-log, No.2 well-log and No.3 well-log respectively in May 19, 2013. The local climate and precipitation are reasons for causing these phenomena. With the arrival of the rainy season, precipitation recharges groundwater, groundwater level gradually increases, as shown in Figure 6d. Therefore, the precipitation is the main source of groundwater recharge in the area.

Figure 7 shows that nitrate content in groundwater is higher and tends to be relatively stable (Fig.7a, b) in November, December 2012 and March 2013. Nitrate content in groundwater is lower and varies evidently (Fig.7c) in May to July 2013. Nitrate content in groundwater is lower and tends to be stable (Fig.7d) in November 2013. Irrigation, precipitation and fertilization are the main influencing factors for the leaching of soil nitrate. When groundwater depth is about 8m and the amount of irrigation is 900~1200m^3/hm^2, soil nitrate transport in tilth soil and fertilization and precipitation are the main factors affecting the content of nitrate nitrogen in groundwater.

IV. CONCLUSIONS

Field experiment was performed and soil moisture, soil nitrate, groundwater level and quality were dynamic measured in Yehe irrigation area from 2012 to 2013. The following conclusions can be drawn by the analysis of the experimental data:

(1) Soil moisture content is in "X" shape at 0~300cm soil profile in the wheat-maize rotation period. Precipitation, irrigation, evaporation, transpiration are the main influencing factors for soil moisture in 0~150cm soil profile. The variation of the soil moisture in 150~300cm soil profile are relation to soil spatial heterogeneity. When adding identical irrigation quota, Soil depths which soil moisture changes significantly are different by the initial soil water content and soil spatial heterogeneity.

(2) Nitrate nitrogen content varies in monotone decline curve in 0~300cm soil profile during the wheat-maize rotation period. Soil nitrate content varies greatly in 0~150cm soil profile, its value is between 0~113.65mg/kg. Soil nitrate content tends to be stable below 150cm soil profile. The cumulative amount and leaching amount of nitrate nitrogen are maximum value in March and May respectively. The distribution of soil nitrate after irrigation varies with the distribution of soil nitrate before irrigation and emerges the different regularity. In addition to accumulation amount of soil nitrate, infiltrating water, soil texture and so on, the initial soil moisture before irrigation has an important influence on the leaching of soil nitrate.

(3) Precipitation is the main recharge sources of groundwater in the area. Groundwater level varies combined action of precipitation, evaporation and transpiration. Groundwater depth reaches the maximum value in March, and with the arrival of the rainy season, the groundwater level gradually rebounds. When groundwater depth is about 8m and irrigation quota is 900~1200m^3/hm^2, soil nitrate transports in tilth soil. Fertilization and precipitation are the main factors affecting the content of nitrate nitrogen in groundwater.

ACKNOWLEDGEMENTS

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