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Spatial and temporal variation of soil nitrogen within winter wheat growth season

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Abstract. *This study aims to explore the spatial and temporal variation characteristics of soil ammonium nitrogen and nitrate nitrogen within winter wheat growth season. A nitrogen-rich strip fertilizer experiment with eight different treatments was conducted in 2014. Soil nitrogen samples of 20-30cm depth near wheat root were collected by in-situ Macro Rhizon soil solution collector then soil ammonium nitrogen and nitrate nitrogen content determined by SEAL AutoAnalyzer3 instrument. Classical statistics were applied to explore the soil nitrogen temporal variation characteristics and geo-statistics were used to explore the spatial structure characteristics of the soil nitrogen. The study results indicated that from winter wheat up to filling stage, the ammonium nitrogen content in soil decreased obviously for all treatments. The nitrate nitrogen content in soil decreased from up to jointing stage and then increased dramatically from jointing to flowering stage. The geo-statistics analysis indicated that ammonium nitrogen existed weak spatial dependence at wheat up, flowering and filling stage. Ammonium nitrogen range decreased after jointing fertilizer and ammonium nitrogen patches were fragmented at wheat flowering and filling stage. Nitrate nitrogen showed strong spatial dependence at wheat up and jointing stage. After jointing fertilization, the nitrate nitrogen range increased, and nitrate nitrogen at flowering, filling and harvest stage distributed more continuously than that at up and jointing stage. The kriging interpolation maps revealed the soil ammonium nitrogen and nitrate nitrogen spatial distribution variation trends during the winter wheat growth season. Soil ammonium nitrogen content in the north area of experimental field was lower than that in the south area at the up and jointing stage. Then the spatial difference decreased at the flowering and filling stage. For soil nitrate nitrogen, its content in the south part of experimental field was higher than that in the north part at up and jointing stage, the spatial difference of nitrate nitrogen* *gradually decreased at flowering stage and then showed a strip distribution at wheat filling stage. High ammonium nitrogen and nitrate nitrogen co-distributed in north area with similarly strip pattern at wheat harvest stage.*

Keywords. *soil nitrate nitrogen, soil ammonium nitrogen, geo-statistics , nitrogen-rich strip fertilizer*

1. Introduction

Nitrogen (N) is the nutrient most limiting for plant growth, and agriculture soils are commonly supplemented with inorganic fertilizers mainly as nitrate (NO3−) or ammonium (NH4+). Ammonium N (NH4+N) and nitrate N (NO3−N) are major N forms taken up by plants, and their uptake amounts consist of about 70% of the total cations and anions (Caicedo, 2000). Therefore, in study of N nutrition, the two N forms become the core for concern by researchers (Kirkby, 1987). Nonetheless, an excessive nitrate application can result in its leaching or nitrogenous gas emissions into the atmosphere. In this sense, to avoid environmental problems derived from nitrate fertilization, a change in plant nutrition from NO3−- to NH4+- based fertilizers emerges as a potential alternative to be evaluated. Due to ammonium redox state, the energy consumed for direct soil ammonium assimilation is less than the needed for nitrate assimilation. In good aerative, ammonium nitrogen existing in soil, no matter whether it comes from organic matter meniralization or from N fertilization, can rapidly transformed into nitrate nitrogen through nitrification (Smiciklas and Below,1992), for this reason, ammonium nitrogen concentration in soil is low, whereas nitrate nitrogen concentration is high (Wolt,1994), and becomes the dominant mineral nitrogen resource taken by plants.

Many studies have been done on crop responses to soil nitrogen and nitrate nitrogen fertilizer treatments (Wang, et al., 2015; Jin, et al., 2007; Xu, et al., 2009, Raffaele, 2008;Cui, et al., 2013), few have focused on the variation of the two nitrogen forms in soil during the crop growth season. This study aims to explore the spatial and temporal variation characteristics of soil ammonium nitrogen and nitrate nitrogen through Soil Moisture Sampler within winter wheat growth season. Experiment was done in 2014 at National Experimental Station for Precision Agriculture, Beijing, China. A nitrogen-rich strip was set as a reference to the nitrogen nutrition management in this study. Soil nutrients data were acquired by in-situ sampling of Macro Rhizon soil solution collector at five wheat growth stages and soil solution ammonium nitrogen and nitrate nitrogen were determined by SEAL AutoAnalyzer3 instrument.

2. Methodology

This study was conducted at the National Experimental Station for Precision Agriculture (Figure 1) in the Changping district of Beijing, China (40°10.6′N, 116°26.3′E). This site has a mean annual rainfall of 550.3mm and a mean annual temperature of 11.8°C. The area of the experimental field was 0.54ha. The winter wheat was sown on October 4, 2013, with 15-cm row spacing and149.1 kg/ha sowing density. The wheat cultivar used in study was Jingdong 22, one of the most common winter wheat varieties cultivated in northern China. For fertilization, 72 kgha^{-1} UREA，60 kgha^{-1} P2O5, 75 kgha^{-1}K2O was applied for experiment field as basal before wheat seeding on October 4, 2013 according to the design.

2.1 Experimental Design and data collection

Eight different fertilizer treatments (figure 1) were used for field arrangement during the wheat growth season in 2014, each including 12 to 18 plots. Each plot had an area of 52.5 m2. A nitrogen-rich strip was set in vertical and horizontal direction of the experiment middle area, as a reference to the nitrogen nutrition management in this study. The N-rich Strip treatment (corresponding to BH treatment in figure1) was applied with 150% of the recommended N value at the wheat over-wintering stage (Nov 22, 2013) and green returned stage (Mar 14, 2014).

A conventional uniform nitrogen recommended fertilization treatment (corresponding to NM treatment in figure1), without application of nitrogen fertilizer treatment (corresponding to CK treatment in figure1) were set as the control trial in this experiment. Five variable-rate nitrogen treatments were performed at wheat jointing stage (Apr 16, 2014) based on the parameters of SPAD value (corresponding to S treatment in figure1) and NBI value (corresponding to D treatment in figure1) which acquired by(Force-A Co., Orsay Cedex, France) and DUALEX SCIENTIFIC+ (Dualex) meter (Force-A Co., Orsay Cedex, France), as well as OSAVI value (corresponding to A treatment in figure1) and REPLI value (corresponding to T treatment in figure1) acquired by ASD FieldSpec Pro FR spectroradiometer (Analytical Spectral Devices, Boulder, GO, USA), and NBI-R value (corresponding to M treatment) acquired by Multiplex 3 meter (Force-A Co., Orsay Cedex, France). As shown in figure 1, there were 12 plots in T, D, S, M, and A treatment, 13 plots in NM and CK treatment, and 18 pots in BH treatment.

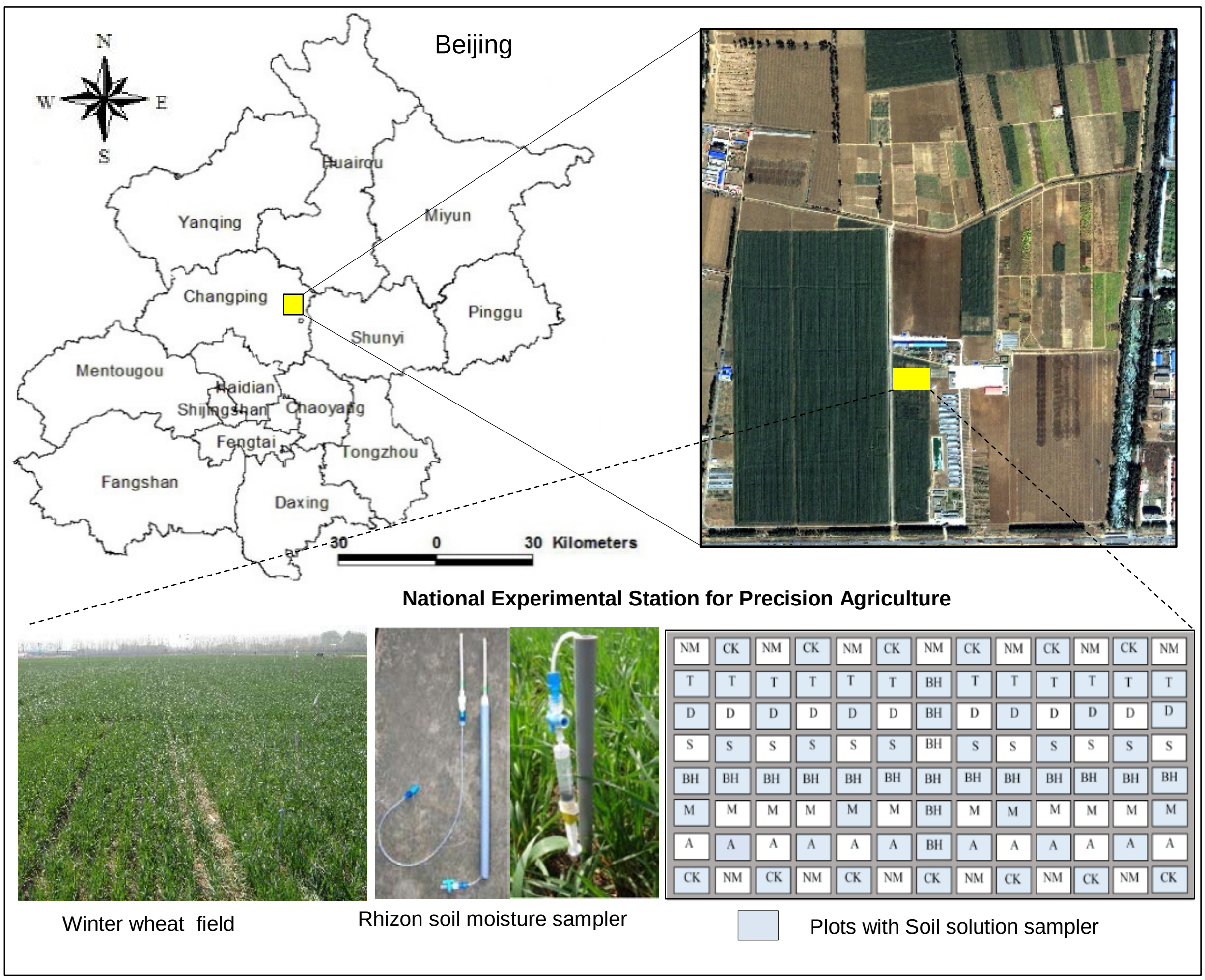


Fig 1. Study area and experiment design

Table 1 showed jointing fertilizer amount (FA) for each plot in A, M, D, S and D treatments, as well as their statistic results. It can be seen that the mean value of fertilizer amount for those five treatments were 2034 kg•hm-2. The maximum of CV value was 19.7% in T treatment while the minimum CV value was 3.4% in A treatment. Furthermore, the fertilizer amount of each BH plot was 3051 kg•hm-2 and 2034 kg•hm-2 for each CK plot (not shown in table1). While NM treatment plots were not fertilized at wheat jointing stage.

Table 1.The summary of nitrogenous fertilizer amount (FA) of each plot under variable rate fertilization (kg·hm-2)

Plot	FA	Plot	FA	Plot	FA	Plot	FA	Plot	FA
A-01	165.9	**M-01**	181.7	**D-01**	151.4	**S-01**	166.9	**T-01**	157.2
A-02	178.6	**M-02**	170.2	**D-02**	163	**S-02**	175.6	**T-02**	167.9
A-03	167.8	**M-03**	182.6	**D-03**	165.2	**S-03**	172.2	**T-03**	184.1
A-04	168.7	**M-04**	189.5	**D-04**	164.7	**S-04**	166.1	**T-04**	128.3
A-05	171.7	**M-05**	196.9	**D-05**	181.1	**S-05**	170.4	**T-05**	129.2
A-06	164.1	**M-06**	167.5	**D-06**	169.7	**S-06**	158.1	**T-06**	151.3
A-07	163.3	**M-07**	144.7	**D-07**	173.7	**S-07**	162.2	**T-07**	153.2
A-08	169.8	**M-08**	149.6	**D-08**	171	**S-08**	176.1	**T-08**	164.2
A-09	160.4	**M-09**	146.9	**D-09**	171.3	**S-09**	180	**T-09**	185.5
A-10	177.4	**M-10**	162.3	**D-10**	191.4	**S-10**	171.7	**T-10**	217.3
A-11	170.4	**M-11**	166.5	**D-11**	165.4	**S-11**	170.2	**T-11**	154.7
A-12	176.4	**M-12**	175.8	**D-12**	166.7	**S-12**	164.8	**T-12**	241.7
Sum	2034.5	**Sum**	2034.2	**Sum**	2034.6	**Sum**	2034.3	**Sum**	2034.6
Min	160.4	**Min**	144.7	**Min**	151.4	**Min**	158.1	**Min**	128.3
Max	178.6	**Max**	196.9	**Max**	191.4	**Max**	180.0	**Max**	241.7
Mean	169.5	**Mean**	169.5	**Mean**	169.6	**Mean**	169.5	**Mean**	169.6
StdV	5.8	**StdV**	16.8	**StdV**	9.9	**StdV**	6.2	**StdV**	33.4
CV %	3.4	**CV %**	9.9	**CV %**	5.8	**CV %**	3.7	**CV %**	19.7

Rhizon soil moisture sampler

The Rhizon Soil Moisture Sampler (RS) was used for repeated and reliable sampling of all dissolved ammonium nitrogen and nitrate nitrogen in the soil in this study. The Rhizon Soil Moisture Sampler (RS) is a rigid, porous plastic extraction tube that is inserted into the substrate, and solution is extracted under vacuum through a rubber cap on a collection vial (Chen, et al., 2004). As the handle of the pump is repeatedly squeezed by hand, a vacuum is created in the system that draws substrate solution into the rigid extraction tube and then on into the sample vial where it is trapped. The standard Rhizon models have a diameter of 4.5 mm and a mean pore size of 0.2 μm. They can be used for sampling pore water in pots, vessels or cylinders filled with settled soil, or directly in undisturbed cores. The Rhizons are available with a 9 cm porous part.

In this study, total 65 soil moisture samplers were installed on the root of winter wheat in depth of 20-30 cm for all plots of CK and BH treatments, as well as some plots of T, M, D, and A treatments on Apr 1, 2014. Plots installed with the Rhizon Soil Moisture Sampler were shown in figure 1 in blue color. The soil water samples were collected on Apr 9, Apr 22, May 14, June 6, after five to six days of the field spray irrigation. Then, the soil water samples were sent to lab for Ammonium N (NH4+N) and nitrate N (NO3−N) analysis by AA3 Continuous Flow Analytical System (Seal Analytical, UK).

2.2 Statistical analysis methods

Soil ammonium nitrogen (NH4+N) and soil nitrate nitrogen (NO3−N) data were then analyzed to detect their variation information between different wheat growth stages. Experiment semi-variogram was also analyzed for soil ammonium nitrogen and nitrate nitrogen data. The best-fitting model was then selected after evaluated by RMSS (root-mean-square standardized). Then, the optimal theoretical model and the corresponding semi-variogram parameters were used to generate the soil ammonium nitrogen and nitrate nitrogen spatial variability maps using ordinary Kriging method. Variowin 2.2 (Pannatier, 1996) was used to compute the variograms and Arcgis9.0 was used for kriging analysis (ESRI, 2001) in this study.

Semivariogram Modeling

Geostatistics aims to provide quantitative descriptions of natural variables distribution in space and time (Journel, et al., 1978; Isaaks, et al., 1989). Based on the regionalized variable theory, geo-statistic method assumes that variables in an area exhibit both random and spatially structured properties. (Burgess, et al., 1980).The experimental semi-variogram is a graphical representation of the mean square variability between neighboring points of distance h as show in figure 2 and Equation(1). For observations $Z_i, i = 1, \dots\dots, k$ at locations $x_i, \dots\dots x_k,$ the empirical semi-variogram is defined as (Cressie 1993):

$$\widehat{\gamma}(h) = \frac{1}{2|N(h)|}\sum_{(i,j)\in N(h)}\left|z_i - z_j\right|^2 \qquad (1)$$

Where $N(h)$ denotes the set of pairs of observation i, j such that $\left|x_i - x_j\right| = h,$ and $|N(h)|$ is the number of pairs in the set.(Generally an "approximate distance", h is used, implemented using a certain tolerance.)

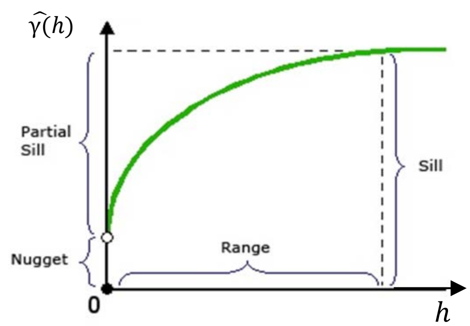


Fig 2. Parameters of semi-variogram model (Wang, 1999)

The parameters nugget, sill, range (Figure 2) are often used to describe semi-variograms. Nugget is the height of the jump of the semi-variogram at the discontinuity at the origin. Sill is the limit of the variogram tending to infinity lag distances. Range is the distance in which the difference of the variogram from the sill becomes negligible. In models with a fixed sill, it is the distance at which this is first reached; for models with an asymptotic sill, it is conventionally taken to be the distance when the semi-variance first reaches 95% of the sill.

Ordinary Kriging

Ordinary kriging was used to generate the spatial distribution of soil ammonium nitrogen and nitrate nitrogen in this study. Ordinary kriging assumes that the mean of the process is constant and invariant within the spatial domain. A linear combination of available sample values is used for ordinary kriging estimation. Weights, the coefficients of this linear combination, are dependent on two factors: the distance between the sample points and the estimated point and the spatial structure of the variable (Dash, et. al., 2010). In this study, he parameter values at the unsampled grids were established based on the values at 65 sampling plots by the ordinary kriging method, which provides the best linear unbiased estimate of regionalized variable at an un-sampled location.

3.Results and Discussion

3.1 statistical results for soil ammonium nitrogen and nitrate nitrogen

Table 2 shows the descriptive statistics of soil ammonium nitrogen and nitrate nitrogen at different growth stages. The calculated statistics include mean, standard deviation (SD), coefficient of variation (CV), minimum, maximum, skewness and kurtosis value. Figure 3 shows the variation of mean value and CV value for ammonium nitrogen and nitrate nitrogen at different wheat growth stages. From up to harvest stage, mean value of soil ammonium nitrogen content ranged from 0.542 to 0.157 mg·L-1. It decreased seriously from wheat up stage to filling stage. Mean value of nitrate nitrogen content fluctuated during the wheat growth stages. It decreased from 51.152 to 21.434 mg·L-1 from wheat up stage to jointing stage, then it increased obviously to 95.554 mg·L-1 at wheat flowering stage. At wheat filling and harvest stages, it drop to 37.331 and 21.444 mg·L-1, respectively. We can see that the ammonium nitrogen content in soil solution is obviously lower than the nitrate nitrogen content in soil solution at all five wheat growth stages, this is consistent with the conclusions of the study of Jin (Jin, et al., 2007).

Table 2. Descriptive statistics of ammonium nitrogen and nitrate nitrogen of soil solution at different growth stages

Index	Growth Stage	Minimum	Maximum	Mean	Standard deviation	Skewness	Kurtosis	CV%
Ammonium Nitrogen (mg·L-1)	Up	0.228	1.068	0.542	0.175	1.381	2.756	32.288
	Jointing	0.116	0.450	0.200	0.058	2.331	8.251	28.971
	Flowering	0.125	0.263	0.167	0.024	1.625	5.181	14.371
	Filling	0.104	0.417	0.168	0.057	2.959	10.582	33.969
	Harvest	0.080	0.425	0.157	0.096	1.733	1.660	61.146
Nitrate Nitrogen (mg·L-1)	Up	6.122	138.960	51.152	36.893	1.001	0.054	72.124
	Jointing	3.100	138.000	21.434	29.956	2.536	6.864	139.759
	Flowering	3.000	220.000	95.554	56.982	0.206	-0.470	59.633
	Filling	1.380	105.000	37.331	27.198	0.961	-0.045	72.856
	Harvest	1.900	59.100	21.444	14.158	0.990	0.358	66.023

The coefficient of variation (CV) is defined as the ratio of the standard deviation value to the mean value, the CV is often presented as the given ratio multiplied by 100. The CV for a single variable aims to describe the dispersion of the variable in a way that does not depend on the variable's measurement unit. Generally, the value of CV lower than 10% indicated low variability while CV value higher than 100% indicated great variability (Wang, et al., 2009).

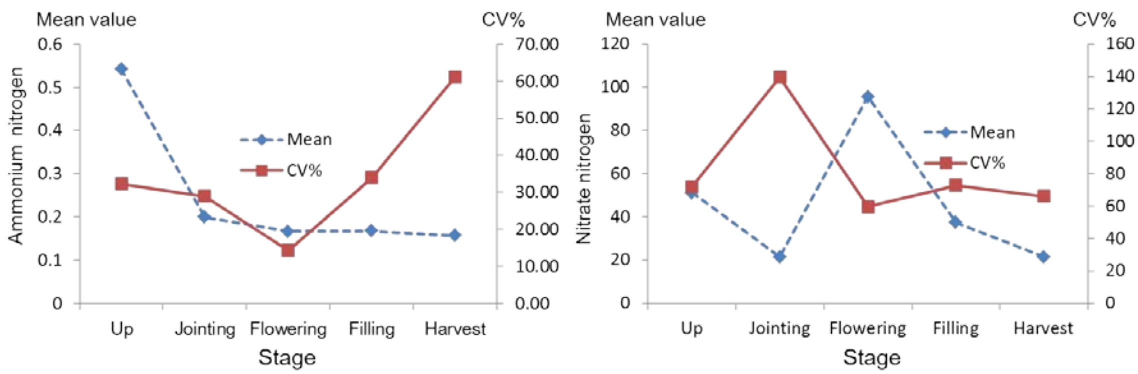


Fig 3. Mean and CV value curve for ammonium nitrogen and nitrate nitrogen at different wheat growth stages

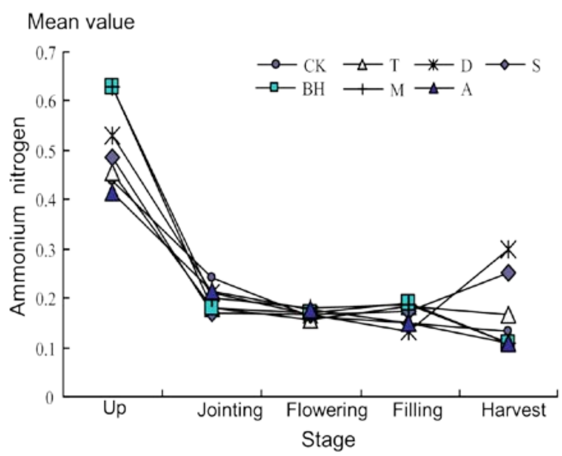
It can be seen from table 2 and figure 3 that the CV value for ammonium nitrogen ranged from 14.371% to 61.146%, which indicated a moderate variation during the winter wheat growth season. While the CV value for nitrate nitrogen ranged from 59.63% to 139.76%, which showed a moderate to great variation at the winter wheat growth season. The maximum CV appeared at wheat harvest stage (61.146%) for ammonium nitrogen and jointing stage (139.759%) for nitrate nitrogen, respectively. Nonetheless, the minimum CV for two form nitrogen co-appeared at wheat flowering stage.

3.2. Ammonium and nitrate nitrogen change comparison for different treatments

Ammonium (NH4+) and nitrate (NO3–) are predominate inorganic forms of nitrogen in soil (Yuan, et al., 2011). Crop can take up both ammonium NH4 and nitrate NO3-N from soil. Because ammonium is directly assimilated into plant metabolism and growth, the residual mineral nitrogen in the dry land soil mainly exists in the state of nitrate nitrogen (Yang, et al., 2007).

In our study, five different fertilizer treatments were arranged at the winter wheat jointing stage of 2014. For there were no soil moisture sampler installed in NM plots, the ammonium and nitrate nitrogen content samples in BH, CK, A, T, S, M, and D treatments were collected and analyzed in this study. Curves in figure 4 indicated the soil ammonium nitrogen and nitrate nitrogen content mean value variation trend for seven treatments at different wheat growth stages.

It can be seen from the figure 4, the ammonium nitrogen content mean value for seven treatments decreased obviously from wheat up stage to filling stage. And then the soil ammonium nitrogen content kept steady from wheat jointing to filling stage. There were a low level increasing for soil ammonium nitrogen in D and S treatment from filling to harvest stage, while for other treatments, soil ammonium nitrogen were still drop down weakly. The nitrate nitrogen content mean value for seven treatments, on the contrary, showed acute increasing from wheat jointing stage to flowering stage, and then it decreased dramatically from flowering stage to harvest stage. Ammonium nitrogen and nitrate nitrogen showed different change trend in this study. Urea is amide nitrogen fertilizer widely used in north of China. Urea hydrolyses into ammonium (NH4+) at first and then it will readily transform to NO3-N in dry field which with good ventilation condition (Yuan, et al., 2011). When the urea was applied at jointing stage in this study, some of the ammonium nitrogen was absorbed by the wheat while the other soil ammonium nitrogen was transformed to nitrate nitrogen. The study indicated that jointing fertilizer slow down the decreasing trend in soil ammonium nitrogen content for different treatments. While the soil nitrate nitrogen content, on the contrary, was significantly influenced by the jointing fertilization. And the soil nitrate nitrogen content in all seven treatments reached the peak at wheat flowering stage.



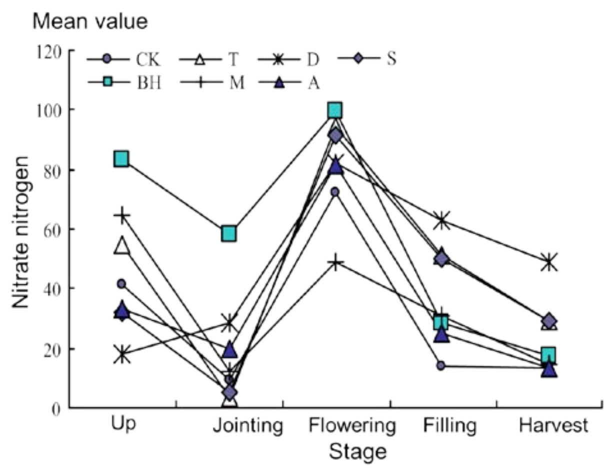


Fig 4. Ammonium nitrogen content and nitrate nitrogen content under different treatments

3.3 Spatial structure of soil ammonium and nitrate nitrogen content

The spatial structure of soil ammonium nitrogen and nitrate nitrogen at five wheat growth stages were evaluated by isotropic variogram models. The theoretical models were be fitted through the experimental semi-variogram points to quantify spatial patterns with least squares algorithm using Spherical, Gaussian and Exponential model. The optimization model was then selected after evaluated by RMSS (root-mean-square standardized).The RMSS value more close to 1, the more precision of the model. Three key terms in each model, the sill, the range, and nugget variance were then calculated from the models by Matheron's method of moments (MoM) estimator. Table 5 showed the statistical results of theoretical model fitting RMSS for ammonium nitrogen content and nitrate nitrogen content.

Table 5 Best fit theoretical semi-variogram model and parameters of soil ammonium and nitrate nitrogen

Index	Growth Stage	Best fit Model	Sill C_0	Nugget C_0+C	Range m A_0	Nugget:Sill (%)	RMSS
Ammonium Nitrogen	Up	Gaussian	0.0341	0.0243	43.4	**71.28**	1.11
	Jointing	Spherical	0.0038	0.0016	39.5	42.97	1.03
	Flowering	Spherical	0.0006	0.0004	15.8	**71.21**	2.13
	Filling	Spherical	0.0035	0.0025	9.6	**71.66**	1.02
	Harvest	Gaussian	0.0096	0.0049	20.8	50.64	0.87
Nitrate Nitrogen	Up	Exponential	1819.3067	535.3400	**13.3**	29.43	0.78
	Jointing	Spherical	886.1727	473.8887	**20.2**	53.48	1.13
	Flowering	Spherical	4129.2467	2790.4600	**19.4**	67.58	1.10
	Filling	Gaussian	1014.1157	539.7443	**29.4**	53.22	0.97
	Harvest	Gaussian	215.5067	136.1200	**21.9**	63.16	0.89

The ratio of nugget to total semi-variance, expressed as a percentage, was used to classify spatial dependence: a ratio of less than 25% indicated strong spatial dependence; between 25% and 75% indicated moderate spatial dependence; and great than 75% indicated weak spatial dependence(Cambardella，1994; Chien, et al，1997). Nugget:sill ratio values for all five stages ammonium nitrogen varied from 42.97% to 71.66%, indicating a moderate spatial autocorrelation for ammonium nitrogen (Table 5). The Gaussian semi-variogram model was found to be the best-fit model for ammonium nitrogen at wheat up and harvest stage, whereas spatial structures of ammonium nitrogen at wheat jointing, flowering and filling stage were generally fitted by the spherical model. While the Nugget:sill ratio values for nitrate nitrogen varied from 29.43% to 67.58%, also indicating a moderate spatial autocorrelation for five wheat growth stages nitrate nitrogen (Table 5). The Gaussian semi-variogram model was found to be the best-fit model for nitrate nitrogen at wheat up and harvest stage, whereas spatial structures of nitrate nitrogen at wheat jointing, flowering and filling stage were generally fitted by the spherical model. The results demonstrated that the spatial variations of soil ammonium parameters and nitrate nitrogen parameters were mainly affected by structural factors, which might include soil material, topography.

Ordinary kriging method was then applied to estimate study area soil ammonium nitrogen content and nitrate nitrogen content for five wheat growth stages based on the semi-variogram parameters listed in table5. Figure 5 were the kriging maps of ammonium nitrogen content at different wheat growth stages. It can be seen from figure 5 and table 5, the ammonium nitrogen range were 43.4m, 39.5m and 20.8m at up, jointing and harvest stage, respectively, it indicated high spatial continuous and spatial autocorrelation for ammonium nitrogen at those wheat growth stage. While the range for soil ammonium nitrogen varied from 9.6m to 15.8m at wheat flowering and filling stage, meant a strong spatial variability of ammonium nitrogen. Figure 6 showed the kriging maps of soil nitrate nitrogen content at different wheat growth stages. It can be seen from table 5 and figure 6, the nitrate nitrogen range at up and flowering stage were 13.3m and 19.4m, which indicated higher spatial variability for nitrate nitrogen than that of other stages.

The soil ammonium nitrogen content in the south area of the experiment field were higher than that in the north area at wheat up and jointing stage. While the nitrate nitrogen content in north area was also lower than that in south area at wheat up stage. But after fertilizer applied at jointing stage, the soil ammonium nitrogen and nitrate nitrogen in north area increased slowly. The high ammonium nitrogen and nitrate nitrogen area co-distributed in the middle area of the experiment field at wheat harvest stage.

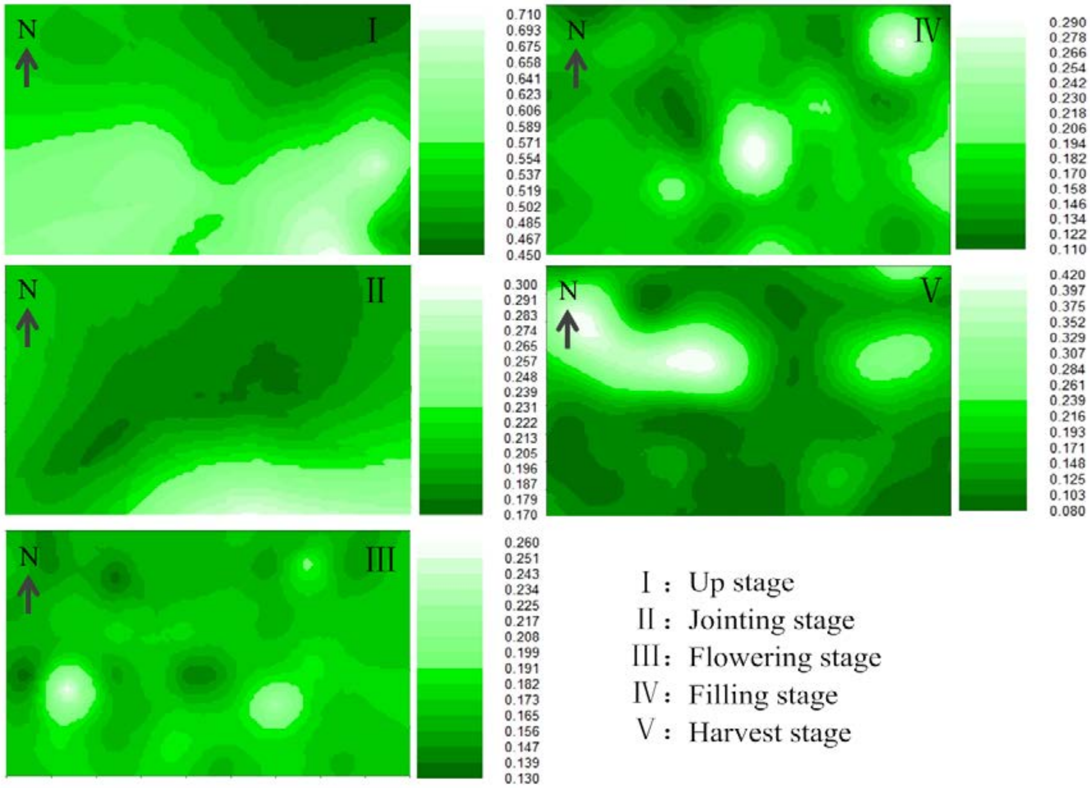


Fig 5. Maps of kriging estimation of soil ammonium nitrogen content at five wheat stages

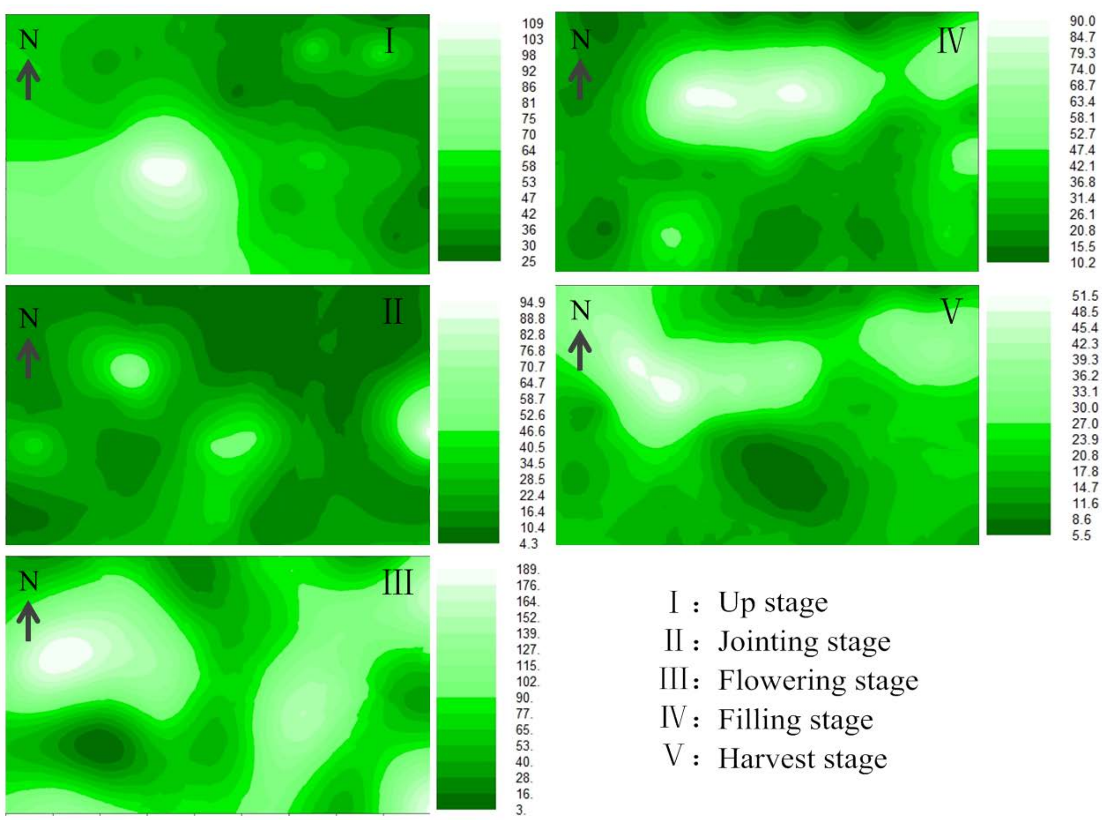


Fig 6. Maps of kriging estimation of soil nitrate nitrogen content at five wheat stages

5.Conclusion or Summary

This study focused on the spatial and temporal variation characteristics of soil ammonium nitrogen and nitrate nitrogen within winter wheat growth season. Conventional statistics and geo-statistics were applied to explore time variation characteristics and spatial structure characteristics of the soil ammonium nitrogen and nitrate nitrogen at different winter wheat growth stages. Several specific conclusions were reached by this study:

(1)Soil solution ammonium nitrogen showed acute decreasing trend from wheat up to flowering stage. The jointing fertilization had no significant effect for the drop down trend of soil ammonium nitrogen. Soil solution nitrate nitrogen for seven treatments decreased from wheat up to jointing stage and then increased dramatically from jointing to flowering stage because the jointing fertilizer. But from flowering stage to harvest stage, the soil nitrate nitrogen decreased.

(2)Ammonium nitrogen existed weak spatial dependence at wheat up, flowering and filling stage. Ammonium nitrogen range decreased after jointing fertilizer and ammonium nitrogen patches were fragmented at wheat flowering and filling stage. Nitrate nitrogen showed strong spatial dependence at wheat up and jointing stage. After jointing fertilization, the nitrate nitrogen range increased, and nitrate nitrogen at flowering, filling and harvest stage distributed more continuously than that at up and jointing stage.

(3) Soil Nitrate nitrogen and soil ammonium nitrogen in the north of experiment field were lower than that in the south area at wheat up stage. After fertilizer applied at jointing stage, the soil nitrate nitrogen and ammonium in north area increased slowly. Till wheat harvest stage, the ammonium nitrogen and nitrate nitrogen in north area were higher than that in the south area. They also showed similarly pattern at wheat harvest stage.

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