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Effect of Irrigation with Dairy Factory Effluent on the Content of Soluble Cation in Soil of Winter Wheat

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Abstract. With rapid development of large-scale dairy farming in China, unreasonable emissions of the dairy slurry have caused eutrophication of surface water and pollution of the groundwater. Through carrying out field experiment in wheat-maize rotation farmland from 2012 to 2016 in Xushui county of Heibei province, the effect of utilizing ways of dairy slurry on soluble cation in different soil layers of wheat field was studied in order to determine the degree of the soil salinization and guide the reasonable utilization of the dairy slurry. The soluble cations in the soil increased with the application of the dairy slurry to some degree. The content of Na^+ was significantly higher than that in the control soil, but the content of K^+ showed no significant difference. The contents of Ca^{2+} and Mg^{2+} in the soil were negatively correlated with soil pH. Under the treatments with application of the dairy slurry, the content of soluble cations in soil was positively correlated with the dairy slurry concentration. Under the influence of rainfall and irrigation, the content of soluble cations in the 0 to 200cm soil showed the top soil >the subsoil.

Introduction

The large amount of manure issued from the large-scale aquaculture production is difficult to handle. According to the 2007 national first census of pollution sources bulletin, annual output of livestock and poultry industry manure was 243 million tons, urine and other sewage production was 163 million tons, nitrogen and phosphorus emissions reached 1.028 million tons and 1.604 million tons, accounting for about 21.7 % and 37.9 % of the total national emissions; COD 12.682 million tons, accounting for about 41.9 % of the total national pollutant COD emissions [1]. Livestock and poultry waste water, production workshop flushing water, indoor sewage, runoff and livestock and poultry manure fermentation of biogas slurry and other aquaculture wastewater are likely to cause the eutrophication of surface water bodies and contamination of groundwater nitrate excess [2]. In addition, the harmful substances in sewage such as heavy metals and salt residues in the farmland will cause soil degradation thus inhibiting crop growth [3].

Dairy slurry after anaerobic fermentation contains amount of N, P, K and a variety of amino acids, proteases and other physiologically active substances and beneficial bacteria, and can be used as an organic fertilizer. The application of livestock and poultry waste water can increase crop yield, improve crop quality and physic-chemical properties of soil, enhance the resistance of crop that inhibit the growth of pathogenic bacteria and prevent the occurrence of pests and diseases [4-8].

While, some results showed that the irrigation with high salinity water caused the loss of Ca and Mg in the soil, destroyed the balance of the Ca ions in the soil, and affected the availability of Ca and Mg in the soil. The application of dairy factory effluent can increase soil exchangeable K, Na, Ca content in soil [9-12]. Compared with short-term irrigation with wastewater and river water irrigation, the conductivity of soil with long-term irrigation increased significantly, the exchangeable Na and K contents in soil increased, while the exchangeable Ca and Mg decreased[13].

In this study, in winter wheat-summer maize rotation field, the effect of irrigation with different concentration dairy factory effluent and different application time on soluble cation content in different soil layers was researched. These results would provide technical support and basis for irrigation with dairy factory effluent.

Experimental materials and methods

Experimental site

The experiment was conducted at the Agriculture Experimental Station (38° 56′ N, 115° 32′ E) in Xushui, Hebei province, China from October 2012 to October 2016. The mean annual temperature and total precipitation are 12.3℃ and 575 mm, respectively. Approximately 80% of the total precipitation occurs from July to September, and the groundwater level is 30 m. The main cropping system is a rotation of wheat and maize (>80% of agricultural fields). Irrigation is needed for the growth of winter wheat. Wheat is often planted at the beginning of October and harvested in the middle of June, whereas maize is planted after the wheat harvest and harvested at the end of September. The soil belong to meadow cinnamon soil, with pH (0-20 cm soil) 8.28, Na^+ 26.85mg/kg，K^+ 3.62mg/kg，Mg^{2+} 10.17mg/kg, Ca^{2+} 43.99mg/kg.

Experiment design

Five treatments was designed in the experiment: namely the control(CK), no fertilization, irrigation with groundwater at different growth stages of winter wheat and after summer maize sowing; usual fertilization(CF), the application rate of N, P_2O_5 and K_2O as a basal fertilizer was 150kg·hm^{-2}, 120 kg·hm^{-2} and 75 kg·hm^{-2}, respectively, and dressing 150kg·hm^{-2} N at jointing stage in the wheat season, the application rate of N, P_2O_5 and K_2O when sowing maize was 120kg·hm^{-2}, 60 kg·hm^{-2} and 60 kg·hm^{-2} respectively, irrigating with fresh water at the growth period of wheat and after maize planting; low concentration of slurry (C1), 3 times irrigation with a mix of 20% dairy effluent and 80% groundwater at winter wheat overwintering and jointing stage and after summer maize sowing; medium concentration of slurry (C2), 3 times irrigation with a mix of 33% dairy effluent and 67% groundwater at winter wheat overwintering and jointing stage and after summer maize sowing; high concentration of slurry (C3), 3 times irrigation with a mix of 50% dairy effluent and 50% groundwater at winter wheat overwintering and jointing stage and after summer maize sowing. 4 times irrigation in the wheat growth period and one time in the corn growth period were set in all treatments. Randomized block design with 3 replicates was used in this experiment. Each plot of 51m^2 (8.5×6) was separated by 190cm deep plastic film with 1m protection zone. The border irrigation quota was 830m^3·hm^{-2}. The wheat cultivar was Jimai 22.

The mixtures of dairy factory effluent (collected from a biogas pond) and groundwater were applied via 10 cm diameter PVC plastic pipe; the application rate was recorded using a pipeline ultrasonic flowmeter (UF10). The application rate of groundwater was recorded using an open channel ultrasonic flowmeter (HQMQ-8000). The pH of dairy factory effluent for the irrigation was 7.9, the content of Na^+, K^+, Ca^{2+}, Mg^{2+} was 2.0-3.3 g/mL, 2.5-3.3 g/mL, 0.31-0.49 g/mL and 0.71-1.33 g/mL, respectively.

Determination of indicators

After wheat harvesting in 2016, 0-20cm, 20-40cm, 40-60cm, 60-80cm, 80-100cm, 100-120cm, 120-140cm, 140-160cm, 160-180cm and 180-200cm soil samples at each plot were collected, air dried and sieved with 20 mesh sieve. The content of soluble Na, K, Ca and Mg in the supernatant was determined by flame atomic absorption spectrophotometer.

Data analysis

The single factor variance analysis was performed with SPSS17.0 software, and Duncan method was used in multiple comparisons ($p<0.05$).

Results and analysis

Soluble Na^+ content in 0-200 cm soil under different fertilizer and water treatments

The content of soluble Na^+ at 0-200cm soil layers in winter wheat field was shown in Fig.1. The soluble Na in soil increased at 0-40 cm layer, decreased at 40-160 cm later, and then increased again at 160-200 cm. The soil soluble Na content in CF treatment increased slowly with the increase of soil depth.

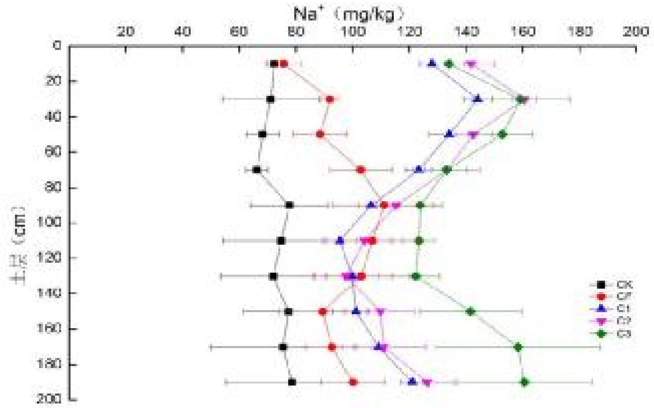

Fig. 1 The soluble Na in 0-200 cm soil in winter wheat field under different treatments

Soluble K^+ content in 0-200 cm soil under different fertilizer and water treatments

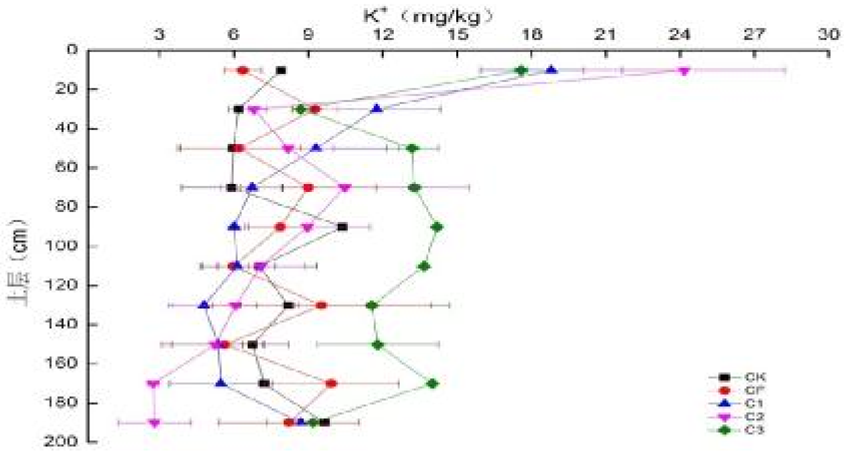

Fig. 2 The soluble K in 0-200cm soil in winter wheat field under different treatments

The content of soluble K^+ at 0-200cm soil layers in winter wheat field was shown in Fig.2. At 20-200cm soil layer, no significant difference was observed in the soluble K content. The K content at 0-20cm soil layer was significantly higher than those in other soil layers.

Soluble Ca^{2+} content in 0-200 cm soil under different fertilizer and water treatments

The content of soluble Ca^{2+} at 0-200cm soil layers in winter wheat field was shown in Fig.3. At 0-200cm soil layer, the content of soluble Ca^{2+} in C2 and C3 treatments increased slowly with the increase of soil depth, while, which increased only at 0-60cm soil layer in C1 treatment. The content of soluble Ca was highest at 20-40cm soil layer in CF treatment, and decreased with the increase of soil depth.

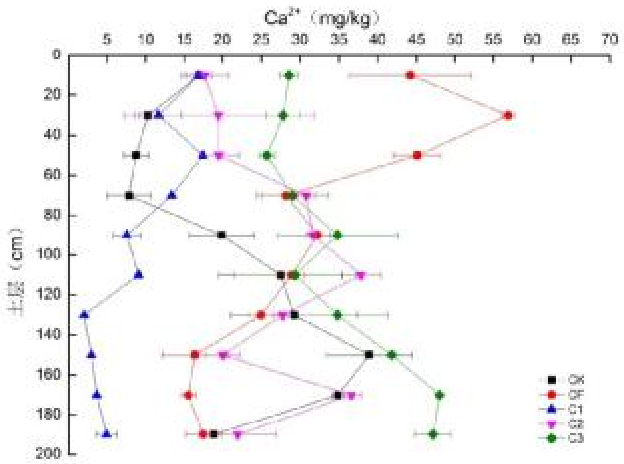

Fig. 3 The soluble Ca in 0-200cm soil in winter wheat field under different treatments

Soluble Mg^{2+} content in 0-200 cm soil under different fertilizer and water treatments

The content of soluble Mg^{2+} at 0-200cm soil layers in winter wheat field was shown in Fig.4. The soluble Mg content decreased with the increase of soil depth, which indicated that soluble Mg in the soil mainly accumulated in the surface soil (0-40 cm).

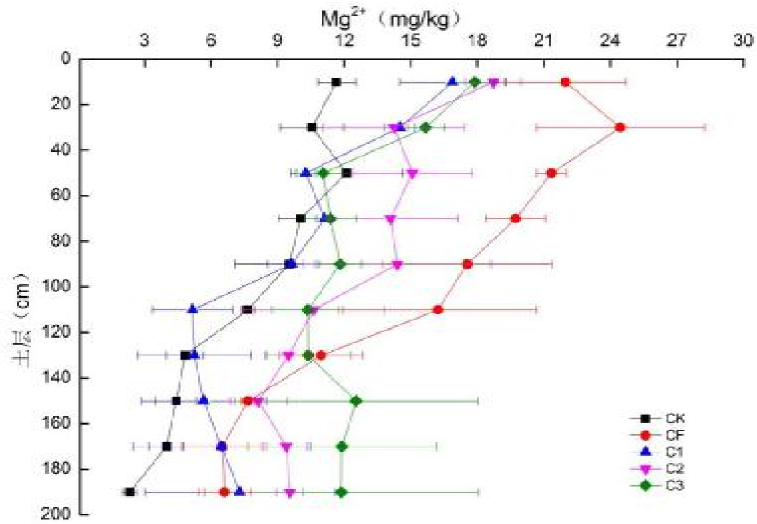

Fig. 4 The soluble Mg in 0-200cm soil in winter wheat field under different treatments

Conclusion and discussion

Na^+ is the main element leading to soil degradation among the soluble cation in soil, so controlling the soluble Na content in soil is an important measure to ensure the utilization of farmland soil. In this experiment, the soluble Na in soil increased with the increase of soil depth under the application of dairy slurry, indicating that soluble Na migrated to the lower layer since rainfall and irrigation, resulting in a little accumulation of Na in surface soil. Therefore, in order to ensure the soluble Na in soil within a reasonable range, the application concentration and times of dairy slurry should be controlled. The soluble K content in soil did not change obviously with the increase of soil depth (20-200cm), maybe due to less residual K in soil because of the crop uptake. More soluble K in top soil (0-20cm) may come from the decomposition of straw which remained in the soil after harvesting. The content of Ca and Mg in soil changed in accordance with soil pH[14], the higher the pH of soil, the more soluble Ca and Mg content in soil. The content of soluble Ca and Mg at 20-60cm soil was lower than those in other soil layers. Ca^{2+} and Mg^{2+} in alkaline conditions easily formed a precipitate, thus reduced the soluble Ca^{2+} and Mg^{2+} content, while, the dissolution of Ca and Mg increased to some extent in soil with low pH, therefore, to ensure the availability of Ca and Mg in soil and prevent over-alkalization of the soil, the soil pH should be considered when using the dairy slurry.

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