Analysis on soil ammonia volatilization characteristics of summer maize in northern China

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Abstract. Summer maize is the main grain crop in northern China, which is of great significance to food security and farmers' income generation. Due to the arid climate, high wind speed and relatively poor natural conditions in northern China, the application amount of nitrogen fertilizer in farmland is large but the utilization rate is low, and ammonia volatilization causes serious environmental pollution. This study analyzed and summarized the literature on ammonia volatilization of summer maize from 2000 to 2019, and analyzed the influence of different fertilizer application amount and fertilization period on ammonia volatilization of summer maize by means of regression equation. The results showed that the total amount of ammonia volatilization, the amount of net ammonia volatilization, the amount of ammonia volatilization and the amount of fertilizer applied in summer maize showed a quadratic function. To control the ammonia volatilization of summer maize, the use of nitrogen fertilizer should be reduced, especially the amount of nitrogen fertilizer in topdressing period.

Keywords: Summer maize; Ammonia volatilization; Ventilation method; Fertilization period; Fertilizer rate.

1. Preface
Nitrogen is one of the essential elements in the process of plant growth and development. The main source of nitrogen in China's farmland ecosystem is synthetic nitrogen fertilizer. In general, the application of nitrogen fertilizer in China presents the characteristics of high dosage and low utilization efficiency. Since the 1990s, with the improvement of the economic level and the increase of the population, the amount of nitrogen fertilizer used in China has increased from 16.385 million tons in 1990 to 20.654 million tons in 2018, an increase of 26%. China is one of the countries with high nitrogen input in the world [1]. With the improvement of the level of science and technology, the
efficiency of nitrogen utilization has been improved, and the amount of nitrogen used per unit area has been reduced from 765.60 kg/hm² in 1990 to 490.25 kg/hm² in 2018. Although the intensity of nitrogen used per unit area is decreasing, the utilization efficiency is still not high. Compared with the 60%–80% nitrogen fertilizer utilization efficiency of developed countries, the utilization efficiency of China is only about 30% [2]. In 2018, the sown area of main crops in China was 165,902.38 thousand hectares, and the sown area of corn was as high as 42130.05 thousand hectares. The potential for saving and using nitrogen fertilizer is huge.

The use of nitrogen fertilizer has greatly promoted China's grain production and played an important role in ensuring China's food security. However, the low utilization rate of nitrogen fertilizer has not only caused a waste of material and energy, but also affected the agricultural ecological environment. The part of synthetic nitrogen fertilizer that is not absorbed and utilized by plant roots enters the environment through dissolution infiltration and ammonia volatilization. Ammonia volatilization is an important way for the gaseous loss of nitrogen fertilizer, and the loss rate has reached more than 20% of the fertilization amount [3]. Ammonia in the atmosphere can return to the ground with precipitation, but most of it enters rivers, lakes, oceans, and forests, leading to increasing nitrogen content and eutrophication in these areas, leading to the extinction or replacement of plant species. Ammonia volatilization also causes air pollution and contributes to the formation of smog. Ammonia volatilization is closely related to factors such as temperature, soil pH, fertilization period, and fertilization mode. The higher the temperature, the stronger the soil enzyme activity, the faster the hydrolysis rate of urea, and the greater the ammonia volatilization. [4]. The increase in soil temperature also reduces the solubility of ammonia in the aqueous solution and promotes its diffusion in the atmosphere. That is to say, ammonia volatilization loss mainly occurs in the summer when the temperature is higher-the summer corn growing period. Cultivated land in northern China accounts for more than 60% of the country's cultivated land. The soil is mainly neutral and slightly alkaline. At the same time, calcareous alkaline soil is widely distributed, which provides convenient conditions for ammonia volatilization. In this paper, we searched the field trials of ammonia volatilization in summer corn in northern China from 2000 to the present through HowNet literature, collected, sorted, processed and analyzed the data involved, and studied the amount of fertilizer application and the total amount of ammonia volatilization during summer corn growth The aim is to provide a scientific theoretical basis for the rational application of nitrogen fertilizer and reduction of nitrogen loss in summer maize in northern China.

2. Data sources and research methods

2.1. Data collection

The data of this study comes from the CNKI database, and the literature mainly comes from the journal literature and doctoral and master's thesis of Chinese core journals. Through searching the literature on ammonia volatilization of summer corn in the past 20 years, the subject terms are "summer corn" and "ammonia volatilization". Search, select, sort, and extract the data needed for this research. The documents selected in this research should meet the following conditions: ① The crop is summer corn; ② The experiment took place in northern China; ③ The nitrogen fertilizer used in the field experiment is chemical synthetic nitrogen fertilizer. Exclude other types of fertilizers such as farmyard manure and straw return; ④ Select conventional treatment data, exclude different irrigation modes, deep fertilizer application and other measures; ⑤ For a long time, there have been many studies on ammonia volatilization in northern China. There are few micrometeorological methods and wind tunnel methods that interfere with natural meteorological conditions, and most of them use simpler ventilation methods, so this time only the ventilation method is considered, and other methods are not considered temporarily; ⑥ The experiment was repeated more than 3 times. A total of 20 documents were collected and used this time, and a total of 50 ammonia volatilization observation data were collected.
2.2. Study area
This time I mainly study northern China. The regions covered in the literature mainly include Shandong, Hebei, Shaanxi, Gansu, Henan, Shanxi and other provinces. The output of summer corn in these regions accounts for about 50% of the national corn output. These regions are located in the mainland and have relatively small differences in annual average temperature, sunshine, precipitation, and planting systems in the temperate monsoon climate zone and the warm temperate monsoon climate zone. The soil types in these areas mainly include brown soil, cinnamon soil, fluvo-aquic soil, aeolian sand soil, etc., and cultivating conditions. Relatively similar and rich in mineral nutrients, the ammonia volatilization of summer corn in these areas is relatively consistent [5].

2.3. Data analysis
Extract the amount of non-fertilized ammonia volatilization, fertilization amount and ammonia volatilization amount, net ammonia volatilization amount, base and top dressing fertilizer amount and ammonia volatilization amount in relevant literature, and use Excel to perform fitting and statistical analysis. In the process of processing data, if there is no data on ammonia volatilization without fertilizer application in the literature, the average value of ammonia volatilization without fertilizer treatment in other literature shall be calculated first, which is 4 times higher than the average value or lower than 1/4 of the average value. The data should be eliminated, and then the average value should be calculated as the ammonia volatilization value of the soil without fertilizer. [6].

3. Results and analysis

3.1. The effect of different fertilizer rates on ammonia volatilization
The amount of ammonia volatilization in the treatment without fertilization in northern China is 0.13~11.00kg/hm², the average is 4.05kg/hm², the application rate of agricultural chemical fertilizer is about 270kg/hm², the conventional application rate in the experiment is 20~360 kg/hm², the average 207.35kg/hm², the average total ammonia volatilization is 18.42kg/hm². Figure 1 is the relationship between the total ammonia volatilization of summer corn and the amount of fertilizer. It can be clearly seen from the figure that with the increase of fertilizer application, ammonia volatilization amount is gradually increasing, and the total amount of ammonia volatilized during the entire growth period of summer corn and the amount of fertilizer applied show a quadratic function relationship.

![Fig.1 The relationship between total ammonia volatilization amount and fertilizer application amount of summer maize](image)

In the northern regions, most of the wheat-corn rotation planting mode is adopted. The application of chemical fertilizers during the wheat growth period may have a certain effect on the ammonia volatilization of summer corn. This time, the net ammonia volatilization of summer corn is used as the ammonia volatilization caused by chemical fertilizers. The ammonia volatilization of the nitrogen fertilizer treatment is deducted from the ammonia volatilization of the soil without nitrogen fertilizer treatment. For the missing ammonia volatilization data without chemical fertilizer, the average value is...
deducted. The net ammonia volatilization of conventional experimental fertilization is 2.15~36.85 kg/hm², and the average is 11.29 kg/hm², which accounts for about 5.5% of the fertilizer application. Figure 2 shows the relationship between summer corn net ammonia volatilization and fertilizer application. It can also be seen from the figure that with the increase in the amount of fertilizer application, the net ammonia volatilization is gradually increasing, and the two show a quadratic function relationship, which is basically the same as the relationship between the total ammonia volatilization of summer corn and the amount of fertilizer.

![Figure 2](image)

**Fig. 2** The relationship between net ammonia volatilization and fertilizer application of summer maize

3.2. The effect of different fertilization periods on ammonia volatilization

Ammonia volatilization presents a trend of increasing first and then decreasing. With the passage of time, there is a certain range of fluctuations, which may have a lot to do with the method of fertilization or the type of fertilizer [7]. Under normal circumstances, the ammonia volatilization cycle in the basal fertilizer period is about 14 days, showing a bimodal fluctuation, with a peak in 1 to 4 days and a peak in 10 to 14 days; the ammonia volatilization in the top dressing period continues to increase, generally around 6 days. Slow down, strong ammonia volatilization during top dressing, and longer duration. Comparing the basal fertilizer and top dressing periods, there is a significant difference in the field soil ammonia volatilization. The ammonia volatilization in the basal fertilizer period accounts for an average of 4.25% of the fertilizer amount, and the ammonia volatilization in the top dressing period accounts for 6.75%. The volatilization rate of ammonia is highest at noon (12:00~14:00) in 24 hours a day, and the volatilization rate is the lowest in the early morning (0:00~2:00) [8]. In the process of summer corn production, the ratio of base fertilizer and topdressing is generally 1:1, and the conventional fertilizer rate is 0~300 kg/hm². Figure 3 and Figure 4 show the relationship between ammonia volatilization and fertilization during the basal and top dressing periods of summer corn. It can be seen from the figure that as the amount of fertilizer increases, the ammonia volatilization increases linearly. The amount showed a quadratic function relationship, which was basically consistent with the relationship between the total amount of ammonia volatilization of summer corn, the amount of net ammonia volatilization and the amount of fertilizer.
Figure 3 is a comparison diagram of ammonia volatilization during summer corn basal fertilizer and top dressing periods. Analyzing the literature samples of 26 pairs of summer corn basal fertilizer and top dressing period, it can be found that the average ammonia volatilization of summer corn in the top dressing period is higher than the average ammonia volatilization in the basal fertilizer period. The average value of the top dressing period is 13.81 kg/hm², which accounts for ammonia. About 75% of the total volatilization, the average base fertilizer period is 6.42 kg/hm², and the base fertilizer period accounts for about 35%.
4. Discussion

4.1. The effect of different fertilizer rates on ammonia volatilization

The main factor affecting soil ammonia volatilization is the amount of fertilization. The higher the level of nitrogen application, the greater the total ammonia volatilization emissions from the soil, and the higher the corresponding net ammonia emissions. Reducing the amount of nitrogen application can effectively reduce soil ammonia emissions [9]. The data collected this time also supports this view. The study found that the ammonia volatilization amount and its proportion in the fertilization amount of summer corn in each fertilization period increased with the increase of the fertilization amount.

Under the conventional fertilization treatment, the ammonia Both the total volatilization amount and the net ammonia volatilization amount have a quadratic function relationship with the fertilization amount. At present, China is still in an era of excessive use of fertilizers. Under the premise of ensuring the normal growth of crops, appropriately reducing the amount of nitrogen fertilizer applied can reduce soil ammonia emissions and alleviate the environmental problems it brings. Studies have also found that the fertilizer application rate is within the range of 112.3~205kg/hm², which can ensure the normal growth of crops, and excessive application of nitrogen fertilizer is not conducive to the increase of crop yield [10].

4.2. The effect of different fertilization periods on ammonia volatilization

In this study, the ammonia volatilization of summer corn in the top dressing stage was significantly higher than that in the base fertilizer period. The ammonia volatilization during the top dressing period accounted for 75% of the ammonia volatilization during the growth period on average, accounting for 6.6% of the fertilization amount, and the ammonia volatilization during the base fertilizer period accounted for 35% of the total volatilization. 35% of fertilization, accounting for 3.3% of fertilization, which is basically consistent with the results of previous studies. The main reason for the low ammonia volatilization of the base fertilizer is that the fertilizer is mixed with the surface layer of 0-20cm soil, and the ammonia volatilization intensity is affected by the depth of the soil, and it will decrease with the increase of the fertilization depth. After the chemical fertilizer is applied, it is fully mixed with the soil. After deep application of urea, it can be fully mixed with the soil. NH₄⁺ is adsorbed by the soil, and the range of activities is limited, so the volatilization is not strong [11]; The reason for the higher ammonia volatilization during the top dressing period is: On the one hand, the environmental temperature during the top dressing period is higher, and the high soil temperature can promote the conversion of NH₄⁺ into NH₃. Generally, after top dressing, water will be irrigated, and the soil moisture will quickly evaporate, and NH₃ will diffuse into the atmosphere. Which accelerates the rate of soil ammonia volatilization, which also shows that soil moisture content promotes ammonia volatilization; on the other hand, soil moisture content is high, and urease activity is enhanced, which promotes the decomposition of urea into inorganic nitrogen, which is conducive to the escape of ammonia from the soil [12].

5. Conclusion

In the growth of summer corn in northern China, the total amount of ammonia volatilization, the net ammonia volatilization, the ammonia volatilization during the basal and top dressing period and the amount of fertilizer all present a quadratic function relationship, which increases with the increase of the amount of fertilizer, and the ammonia in the top dressing period The volatilization amount is higher than the base fertilizer period. Reducing the use of nitrogen fertilizer, especially in the top dressing period, can effectively reduce ammonia volatilization. At present, many scholars have conducted research on different fertilization methods, and proposed many methods that can reduce ammonia volatilization, which need to be further studied and practiced.

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