Effects of nitrogen application on growth and yield of maize

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Abstract. The effects of different nitrogen application levels on growth, dry matter accumulation, SPAD value, leaf area index and yield of maize were studied to provide theoretical basis for rational and efficient nitrogen application management of crops. In the field experiment, 225, 337.5, 450, and 675 kg·hm$^{-2}$ nitrogen application levels were set, respectively expressed by $N_1$, $N_2$, $N_3$, and $N_4$. Without nitrogen fertilizer was used for the control experiment. During the growing period, plant height, leaf area index and SPAD were observed, and dry matter accumulation, yield and yield components were counted. The growth index, dry matter accumulation, yield and yield components of maize were influenced by different fertilization levels. When the nitrogen application amount is greater than 225 kg·hm$^{-2}$, it could significantly promote the growth and development of corn and increase the yield. Through comparative analysis, it was concluded that when the nitrogen application amount was 280 kg·hm$^{-2}$, it was the optimal nitrogen application amount for the efficient production of corn in the experimental area.

1. Introduction
Corn is an important feed crop and cash crop, which is widely planted in China. At the same time, fertilizer application, especially nitrogen fertilizer, is one of the main measures to increase agricultural production[1]. Rational application of nitrogen fertilizer is a key link to ensure the normal growth and development of maize, realize efficient cultivation and management, and improve the yield quality of maize. Therefore, a large number of studies have been carried out on the effects of growth and yield formation of maize, as well as the absorption and utilization of fertilizer nitrogen by maize [2-5]. A series of achievements have been made in studies on the effects of different nitrogen application conditions on the growth and development of corn under different overall conditions [6-7].

In this paper, the growth and yield of maize at different growth stages were analyzed and studied with different amount of fertilizer applied in northern China, which could provide theoretical basis for the accurate management of nitrogen application amount of maize.

2. Materials and Methods

2.1. Experimental Site
Testbed affiliated to the national engineering research center for water saving irrigation daxing test base, township is located in Beijing's daxing district Wei Shanzhuang town east to grind it (39 DHS north latitude 39˚, east longitude 116 DHS 15˚). The region has a semi-arid temperate continental monsoon climate. The annual average water surface evaporation is more than 1800 mm, and the
average annual rainfall is 540 mm, mainly concentrated in June and September of flood season, accounting for more than 80% of the annual rainfall, the annual change of precipitation is large and the distribution is uneven. The test field is flat and has good fertility, so it is suitable for the comparative experiment of corn with different nitrogen content.

2.2 Experimental Design
Four nitrogen application levels (225, 337.5, 450, 675 kg·hm$^{-2}$) were set in the experiment, and expressed as N$_1$, N$_2$, N$_3$ and N$_4$, and compared with N$_0$ which is without nitrogen fertilizer. Each nitrogen application level corresponds to a different plot, and each treatment plot is randomly arranged. The growth indexes of corn are observed and repeated for 3 times in each plot. The yield of corn and its components are measured and repeated for 3 times in each plot in the mature stage. 2 m protective belts are placed around the test area, and double-row ears were selected for each time, threshing and weighing.

In this experiment, base fertilizer (compound fertilizer) and top fertilizer (urea) were applied once and the corn variety tested was era 168. It was sown on June 15, 2018 and harvested on September 24, 2018. There were no obvious diseases and insect pests during the growth period and the growth condition was good.

2.3 Experimental Observation Items and Methods

2.3.1 Plant Growth Index
Plant height and leaf area were measured at the jointing stage, tasseling stage, grouting stage and mature stage, and 3 maize plants with a certain growth were selected in each plot for measurement and calculation. Plant height was measured by a tape measure, leaf area was measured by its leaf length and leaf width and leaf area index by $LAI = S_L \times K / S_p$, $S_L$ leaf was the leaf area of a per plant, $K$ was the conversion coefficient, and $S_p$ was the area per plant.

2.3.2 Plant SPAD Values
SPAD value was determined by SPAD-502 chlorophyll meter as the relative chlorophyll content value. The SPAD value was determined by sampling samples in the plot, and was measured twice for each sample. The arithmetic mean value was the chlorophyll content value at the sample point. As the measuring position has great influence on the reading, the measuring position should be consistent and avoid the vein as far as possible.

2.3.3 Dry Matter Accumulation in Plants
At the mature stage of corn, three points were selected for each plot, and each point was harvested with double rows of ears, threshed, dried and weighed. In this treatment, the plants were divided into four parts: upper leaf, middle leaf, lower leaf and stem. And the dry weight is gained after drying.

2.3.4 Production
The yield and its components were 6 plants randomly selected from each plot in the mature stage of corn, and 18 plants were repeated for 3 times in total. Then air-drying separation to determine the total weight and its components.

3. Results and Analysis

3.1 Variation of Maize Plant Height
Plant height is an important indicator of crop growth. As shown in figure 1, the growth rate of maize plant height was higher from jointing stage to tasseling stage, while it was lower from filling stage to maturity stage and remained basically unchanged. Different nitrogen application rates had obvious
promoting effect on maize plant height. Through data analysis, the plant height of nitrogen-fertilized maize was 10.42% higher than that of non-nitrogen-fertilized maize on average. Plant height first increased and then decreased with the increase of fertilization level. Therefore, plant height growth was best when nitrogen application was controlled between 225-450 kg·hm\(^{-2}\). When nitrogen application was controlled between 225-450 kg·hm\(^{-2}\), plant height had the best growth, otherwise the plant height would be reduced and economic losses would be caused.

![Figure 1. Variation Pattern of Maize Plant Height.](image1)

3.2 Variation of Leaf Area Index of Maize
The size of the corn leaf area is one of the main factors which influence the production of corn biology. As can be seen from figure 2, with the advance of growth period, the leaf area index of maize shows a trend of increasing first and then decreasing, and reaches the maximum value in tasseling period. At different levels of N\(_0\), N\(_1\), N\(_2\), N\(_3\) and N\(_4\), the maximum LAI values are 3.67, 4.00, 4.13, 3.96 and 4.49, respectively. With the increase of nitrogen application level, leaf area index also increased correspondingly. Under the nitrogen application level of 225-337.5 kg·hm\(^{-2}\), the leaf area index of the whole corn changed stably.

It can be seen from the figure analysis that the leaf area growth varies in different periods. In the process from jointing stage to tasseling stage, the leaf area index growth rate of maize is obvious. From tasseling to filling stage, the leaf area index will show a downward trend with the growth period. Comparing the leaf area index of maize under different nitrogen application rates, when the nitrogen application level was 225 kg·hm\(^{-2}\), the decrease rate of leaf area index of maize during the whole growth period was the minimum of 0.071, and the overall change was stable and well developed.

![Figure 2. Variation of Leaf Area Index of Maize.](image2)
3.3 Variation of Dry Matter Weight Per Plant in Maize

3.3.1 Variation of Dry Matter Weight of Maize Leaves Per Plant
It can be observed from figure 3 that the dry matter weight of maize can reflect the growth situation of maize in a certain change. In different growth stages, the dry matter weight of the upper, middle and lower leaves of a single maize plant presents an increase. During the process from tasseling stage to grouting stage, the dry matter weight of the leaves reaches the maximum, and then presents a downward trend. It can be observed from the figure that, in the whole growth period, the dry matter weight of the leaves of a single plant of maize with nitrogen application level of 225 kg·hm⁻² was 29.45 g at the highest, while the maximum dry weight of the upper leaf corresponding to 675 kg·hm⁻² was 31.59 g. The maximum value of dry matter weight in the middle period of the whole growth period was 31.15 g for 675 kg·hm⁻². At the nitrogen application level of 450 kg·hm⁻², the dry matter weight in the lower leaf of a single plant reached the maximum value of 23.73 g at the filling stage. Under different nitrogen application levels in different growth periods of the whole leaves, the dry matter weight of the upper leaves of the single maize plant with nitrogen application was significantly increased compared with that of the non-nitrogen application. By comprehensive comparison, at the level of 337.5 kg·hm⁻², it was the optimal nitrogen application amount for the dry matter weight of the single maize plant.

![Figure 3. Variation of Leaf Dry Matter in Maize.](image)

3.3.2 Variation of Dry Matter Weight of Maize Stem Per Plant
As can be seen from figure 4, the dry matter weight of single plant stem of maize showed a linear upward trend during the process from jointing stage to grouting stage. And the growth rate slowed down obviously after grouting stage, but still showed an upward trend. At the jointing stage, nitrogen application was more important than that of stem dry matter without nitrogen application. But the difference was not obvious. The dry matter weight of maize stem per plant showed an upward trend with the same change, and the overall increase and change of nitrogen application level at 337.5-675 kg·hm⁻² was more obvious.
3.4 The Change of SPAD Value in Maize

It can be observed from figure 5 that SPAD value of corn presents a slow growth trend from jointing stage to grouting stage. It can reach a maximum value of 62.12 in tasseling stage or grouting stage, and presents a downward trend after grouting stage. Under different nitrogen application levels, the SPAD value of maize increased significantly compared with that of non-nitrogen application. When nitrogen application levels were 337.5 and 675 kg · hm$^{-2}$, the SPAD value changed in the same way and was more stable than other nitrogen application levels. Considering economic factors, the SPAD value of maize increased significantly and effectively when nitrogen application levels were 337.5 kg · hm$^{-2}$.

3.5 Effects of Different Treatments on Maize Yield Were Analyzed

Row number per ear, grain number per row and hundred-grain weight are important factors of maize yield composition. It can be seen from the statistical results in table 1, with the increase of nitrogen application, the ear length, spike length and hundred-grain weight of corn all show an increasing trend within a certain range. And when the nitrogen application exceeds 225 kg · hm$^{-2}$, the hundred-grain weight has an appropriate reduction. According to the analysis in figure 6, when the nitrogen application level is 225-337.5 kg · hm$^{-2}$, the maize yield is relatively high.

Table 1. Yield Analysis under Different Nitrogen Application Levels.

| Nitrogen levels | Mean spike length(cm) | average tip length(cm) | Average ear weight(g) | Hundred grain weight(g) | production (kg · hm$^{-2}$) |
|-----------------|------------------------|-------------------------|-----------------------|--------------------------|-----------------------------|
| $N_0$           | 18.33                  | 1.00                    | 837.90                | 33.01                    | 72.01                       |
| $N_1$           | 20.80                  | 1.23                    | 1120.07               | 40.01                    | 87.28                       |
4. Conclusion
From what has been discussed above, the fertilization level of corn is related to the physiological growth characteristics of aboveground parts of corn and the yield of chlorophyll accumulation. To a certain extent, the increase of nitrogen application can increase the yield of corn, while in this experiment, when the nitrogen application level exceeds 450 kg·hm$^{-2}$, the yield increases slowly. The results showed that the yield and dry matter weight of maize increased with the increase of nitrogen application amount between 225 and 337.5 kg·hm$^{-2}$. Through comparative analysis, when nitrogen application amount was 280 kg·hm$^{-2}$, it was the best nitrogen fertilizer application amount for efficient production of maize in the experimental area. Therefore, it is necessary to apply fertilizer rationally at different stages of maize planting and at different growth conditions at the same time. In this experimental field, when the nitrogen level is 280 kg·hm$^{-2}$, the growth and development of maize can be better promoted, and the yield of maize can be improved.

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