Effects of Slow-release Nitrogen Fertilizer on Yield and Nitrogen Accumulation of Summer Maize in Shajiang Black Soil Area

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Abstract [**Objectives**] This study was conducted to verify the field application effect of slow-release nitrogen fertilizer on summer maize in Shajiang black soil area by simultaneous sowing and fertilization, and explore the application scope and nitrogen metabolism mechanism, so as to lay a foundation for fertilizer reduction and efficiency improvement. [**Methods**] With maize variety Beiqing 340 and sulfur-coated urea as experimental materials, five nitrogen application levels were set, namely, control (C0), slow-release nitrogen 70 kg/hm^2 (C70), slow-release nitrogen 140 kg/hm^2 (C140), slow-release nitrogen 210 kg/hm^2 (C210) and slow-release nitrogen 280 kg/hm^2 (C280). The phosphorus and potassium fertilizers were all in accordance with the unified standard. [**Results**] With the application rate of slow-release nitrogen increasing, the nitrogen accumulation in organs increased first and then decreased after tasseling stage of maize. In order to reduce the fertilizing amount and increase efficiency, 210 kg/hm^2 of slow-release nitrogen fertilizer was the best fertilizing amount for summer maize in Shajiang black soil area. [**Conclusions**] This study provides reference for fertilizer reduction, efficiency improvement and sustainable development of summer maize in Shajiang black soil area.

Key words Slow-release nitrogen fertilizer; Shajiang black soil; Summer maize; Nitrogen metabolism; Yield

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Shajiang black soil is one of the main soil types in the summer maize area of Henan Province, accounting for 37.14% of the total cultivated land area in the province[1]. It is characterized by poor soil structure, heavy soil texture and low organic matter content[2-3]. In maize production, one-time basal application of common nitrogen fertilizer is prone to the phenomenon of overgrowth and even seedling burning in the early stage, and the phenomenon of fertilizer exhaustion and premature aging in the later stage of growth[4]. However, the nutrient release of slow-release nitrogen fertilizer is synchronized with crop absorption and growth, and the fertilizer efficiency is long and stable. It can realize one-time fertilization and meet the nutrient demand of crops throughout the growth period, and reduce the loss of nitrogen leaching and volatile nitrogen and its impact on farmland ecological environment to varying degrees, thus improving the use efficiency of nitrogen fertilizer and playing a good role in fertilizer reduction and efficiency improvement[5-6]. In this study, sulfur-coated urea was used as the test fertilizer, and the field application effect on summer maize in Shajiang black soil area and its effects on the accumulation of slow-release nitrogen fertilizer and yield were discussed under the condition of simultaneous sowing and fertilization. This study aimed to explore a slow-release nitrogen fertilizer for summer maize in Shajiang black soil area, determine the nitrogen accumulation under the condition of simultaneous sowing and fertilization, clarify the field application effect of slow-release fertilizer, and investigate the application scope and fertilizer-reducing and efficiency-increasing mechanism.

Materials and Methods

Basic information of experimental field

The experiment was conducted in June 2019 in the contracted responsibility field of Bo Keqin in Xuwan Township, Huaiyang District, Zhoukou City (33°37′39″ N 114°47′40″ E). The soil type was Shajiang black soil. The 0 – 30 cm soil layer contained organic matter 18.59 g/kg, available nitrogen 37.32 mg/kg, available phosphorus 6.82 mg/kg and available potassium 196.89 mg/kg, and the experimental irrigation and drainage conditions were good.

Experimental design

The experimental material, Beiqing 340, was planted with 60 000 plants/hm^2 in equal row spacing. Each plot had an area of 24 m^2. The experiment adopted completely random arrangement, and was done in three replicates. Five fertilization levels were set up: no fertilization (C0), slow-release urea 70 kg/hm^2 (C70), slow-release urea 140 kg/hm^2 (C140), slow-release urea 210 kg/hm^2 (C210), and slow-release urea 280 kg/hm^2 (C280).

Determination items and methods

At jointing stage, tasseling stage (VT), filling stage (R3) and maturation stage (R6), five representative plants were selected from each plot, and the stem sheath (stem, leaf sheath, tassel), leaf, ear (corn cob, corn bract, ear stalk) and seeds were

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separated, and subjected to deactivation of enzymes at 105 ℃ for 4 h. Finally, the materials were dried at 60 ℃ to a constant weight.

Data processing and analysis

The test data were plotted by Microsoft Excel 2013 and statistically analyzed by dps 8.5 software.

Results and Analysis

Effect on population nitrogen accumulation

Table 1 shows that the nitrogen accumulation in the aboveground part of maize increased gradually from jointing stage to maturation stage, and the nitrogen accumulation speed was faster from jointing stage to tasseling and flowering stage, and the nitrogen accumulation increased slowly after tasseling and flowering stage. The total nitrogen accumulation in organs at jointing stage increased by 10.68%, 17.65%, 24.28% and 32.82%, respectively compared with the control. The total nitrogen accumulation in organs at tasseling stage increased by 21.35%, 36.85%, 46.49% and 39.84% respectively compared with the control. During grain filling, it increased by 14.6%, 24.63%, 34.68% and 28.39% respectively compared with the control. In mature organs, it increased by 21.13%, 37.20%, 41.19% and 36.85% respectively compared with the control. At the same growth stage, with different nitrogen treatments, the nitrogen accumulation of the population increased with the increase of nitrogen application rate before tasseling, and subsequently, it showed a changing law of increasing first and then decreasing with the nitrogen application rate increasing. The relationship was C0 < C70 < C140 < C280 < C210, among which C210 showed largest nitrogen accumulation.

Table 1 Nitrogen accumulation of population at different growth stages kg/hm²

Treatment	Jointing stage V6	Tasseling stage VT	Filling stage R3	Maturation stage R6
C0	39.97 ±1.11 e	107.59 ±0.28 e	152.57 ±2.53 e	165.50 ±2.23 e
C70	44.27 ±1.06 d	130.56 ±0.68 d	174.01 ±1.56 d	202.54 ±1.72 d
C140	47.06 ±1.16 c	147.31 ±1.53 c	192.33 ±1.36 c	229.56 ±1.36 c
C210	49.65 ±0.98 b	157.63 ±1.15 a	210.82 ±2.78 a	243.88 ±2.11 a
C280	53.09 ±0.56 a	150.53 ±1.21 b	199.25 ±1.13 b	234.56 ±1.21 b

Effect on nitrogen accumulation in vegetative organs

As can be seen from Table 2, with the development of the growth process, the nitrogen accumulation showed a changing law of first increasing and then decreasing in maize leaves and stem sheaths, and was the largest at tasseling stage. Under different nitrogen levels at the same growth stage, the nitrogen accumulation in leaves and stem sheaths increased with the increase of nitrogen application rate in the growth stages before tasseling stage, and after tasseling stage, the nitrogen accumulation in leaves and stem sheaths first increased and then decreased with the slow-release nitrogen application rate increasing. Among various treatments, C210 showed the largest value.

Table 2 Nitrogen accumulation in organs at different growth stages kg/hm²

Growth stages	Organ	C0	C70	C140	C210	C280
Jointing stage	Leaf	39.97 ±1.11 e	44.27 ±1.06 d	47.06 ±1.16 c	49.65 ±0.98 b	53.09 ±0.56 a
V6	Stem-sheath	22.11 ±0.57 e	25.57 ±0.77 d	27.54 ±0.41 c	29.68 ±0.85 b	31.88 ±0.52 a
Tasseling stage	Leaf	42.82 ±0.29 e	55.45 ±0.36 d	59.44 ±0.19 c	63.08 ±0.47 a	61.65 ±0.91 b
VT	Stem-sheath	58.78 ±0.39 e	77.11 ±0.43 d	84.54 ±0.55 c	95.88 ±0.56 a	88.88 ±0.94 b
Filling stage	Leaf	34.49 ±0.41 d	47.12 ±0.94 c	50.81 ±0.56 b	55.80 ±1.13 a	50.89 ±1.02 b
	Stem-sheath	54.17 ±0.71 d	64.93 ±0.07 c	66.70 ±0.36 b	71.75 ±0.41 a	71.88 ±0.30 a
R3	Corn cob + corn bract (BCW)	19.62 ±0.59 c	20.08 ±0.46 b	21.26 ±0.52 ab	23.25 ±0.70 a	21.40 ±0.43 ab
	Grain	34.63 ±0.28 e	47.22 ±0.76 d	52.98 ±0.26 c	59.38 ±0.19 a	54.47 ±0.84 b
Maturation stage	Leaf	23.58 ±0.28 d	27.58 ±0.27 c	30.74 ±0.49 b	33.45 ±0.89 a	33.28 ±0.86 a
	Stem-sheath	37.64 ±1.50 e	47.80 ±0.88 d	49.92 ±0.15 c	54.59 ±0.37 a	52.63 ±0.44 b
R6	BCW	16.31 ±0.29 d	19.22 ±0.19 c	20.95 ±0.53 b	22.56 ±0.59 a	21.11 ±0.67 ab
	Grain	87.97 ±1.34 e	105.61 ±0.32 d	121.96 ±0.35 c	137.00 ±1.97 a	124.75 ±0.47 b

Effects of slow-release nitrogen on yield and components of summer maize in Shajiang black soil area

It can be seen from Table 3 that there were differences in rows per ear of summer maize under different slow-release nitrogen fertilizer conditions, among which treatment C210 had the longest ear, reaching 15.6 rows, and the order of size was C210 > C280 > C140 > C70 > C0. C210 had no significant differences from C140 and C280, but it was significantly different from other treatments. The number of grains per row was the largest in C210, reaching 31.55 grains, which was significantly different from other treatments. C210 showed the largest yield of 10.13 t/hm², which was 22.5% – 68.3% higher than those of other treatments, and the differences were significant. The results showed that appropriate slow-release nitrogen fertilizer supply was the material basis for high yield of summer maize, which promoted the coordinated growth of yield traits and was beneficial to high yield.

Table 3 Effect of yield characteristics of maize under slow-release fertilizer

Treatment	Row number	Grain number per row // grains	1 000-grain weight // g	Actual yield // t · hm^2
C0	12.73 ± 0.46 b	22.97 ± 1.04 c	307.61 ± 1.91 c	5.59 ± 0.21 d
C70	13.16 ± 0.29 b	29.17 ± 0.94 b	307.86 ± 3.14 c	7.63 ± 0.18 c
C140	14.99 ± 0.79 a	28.58 ± 0.74 b	313.63 ± 2.04 b	8.68 ± 0.23 b
C210	15.62 ± 0.26 a	31.55 ± 0.31 a	318.53 ± 1.83 a	10.13 ± 0.21 a
C280	14.86 ± 0.84 a	29.03 ± 1.00 b	309.53 ± 2.28 bc	8.62 ± 0.22 b

Discussion

Effect on nitrogen accumulation

A large number of experimental studies show that one-time basal application of common nitrogen fertilizer is likely to lead to insufficient nitrogen supply and decreased use efficiency of light energy in late growth stages of crops, which will limit crop growth and development[7], while one-time basic application of slow-release nitrogen fertilizer can ensure the demand for nitrogen in the early, middle and late stages of crops, effectively reduce volatilization loss and improve the nitrogen nutrition status of plants through slow and controlled release of nitrogen fertilizer. One-time basal application of slow-release nitrogen in Shajiang black soil area can significantly improve the nitrogen assimilation amount of maize in late growth stages, which was 16.6% – 38.8% higher than other treatments. Maintaining the nitrogen content in leaves at late growth stages is beneficial to increasing the nitrogen assimilation amount of plants.

Effect on yield

The yield of maize is mainly determined by the number of rows per ear, the number of grains per row and 1 000-grain weight[8], and the key periods determining the yield components of maize are the vegetative growth and reproductive growth period of female ear differentiation and the reproductive growth period of grain filling[9]. During the grain filling stage of maize, the energy sources of material accumulation mainly include the part accumulated in vegetative organs before flowering and the part transported from organs to grains after flowering, and the part of photosynthetic products transported from leaves and bracts to grains after flowering[10]. One-time basal application of slow-release nitrogen fertilizer in Shajiang black soil area could well coordinate the supply of nitrogen in different growth stages of maize, and improve the absorption, accumulation, transport and assimilation of nitrogen in organs, which not only met the demand of nitrogen for vegetative growth and development of maize in early growth stages, but also well coordinated the supply of nitrogen for the increase of rows per ear, grains per row and 1 000-grain weight in later reproductive growth stages.

Conclusions

To sum up, one-time basal application of slow-release nitrogen fertilizer at 210 kg/hm^2 in Shajiang black soil area could well coordinate the demand for nitrogen in the early vegetative growth and late reproductive growth of maize, improve the absorption, accumulation, transport and assimilation of nitrogen in organs, promote the increase of rows per ear, grains per row and 1 000-grain weight, and effectively reduce the volatilization loss of fertilizer efficiency and environmental pollution. This study provides reference for fertilizer reduction, efficiency improvement and sustainable development of summer maize in Shajiang black soil area.

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