# A Study on Dynamics and Models of N, P, K Absorption for high-yield Cotton

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### Abstract

The field experiments were carried out to investigate the dynamics and models of N,P and K absorption for the cotton plants with a lint of 3000kg/ha in Xinjiang. The main results were as follows: contents of N in leaves, squares and bolls, in particular in the leaves of fruit-bearing shoot were higher in high-yield cotton than in CK. Content of $P_2O_5$ in squares and bolls and that of $K_2O$ in stems were higher in high-yield cotton than in CK during the whole growing period. The accumulations of N, $P_2O_5$ and $K_2O$ in cotton plant could be described by a logistic curve equation. The most rapid nutrient uptake occurred at about the 90 d for N, 92 d for $P_2O_5$ and 85 d for $K_2O$ after emergence, respectively. Total nutrient accumulation of N, $P_2O_5$ and $K_2O$ were 385.8 kg/ha, 244.7 kg/ha and $K_2O$ 340.3 kg/ha, respectively. Approximately 12.5kg N, 8.0 kg $P_2O_5$ and 11.1kg $K_2O$ concentration in leaf and stem per 100 kg lint were needed to produce 3000 kg/ha in Xinjiang.

### Media summary

The cotton nutrient laws of N, P, K absorption were developed under the field condition of 3000 kg lint /ha in Xinjiang.

### Key words

Xinjiang; Cultivation of high yield; Cotton; NPK; Absorption dynamics; Model

### Introduction

A lot of research about the nutrient absorption in cotton has been reported. Pollmer (1978) considered that rate and duration of nitrogen uptake could be regarded as an indicator of high yield; Bai et al. (2002) studied nutrition traits and fertilization of cotton with lint of 2400-2600 kg/ha in southern Xinjiang. However, there has been no report about characteristics of nutrient uptake for the cotton with lint yield of higher than 2700 kg/ha. Xinjiang is located at the center of Asia-European continent, belonging to the drought desert area in terms of irrigated cotton cultivation. It has sufficient sunlight and quantity of heat, favorable for production of high-yield cotton. In 1998, planting area was 959000 hectare, with the average lint yield of 1524 kg/ha. In southern Xinjiang, planting area of cotton occupies 60% of total area and lint yield is generally over 2250 kg/ha or even as high as 3000 kg/ha. Therefore, the investigation of the nutrient absorption dynamics and model of cotton with lint yield of 3000 kg/ha in southern Xinjiang is of significance for illustrating the law of nutrient absorption in high-yield cotton and providing some valuable information on the reasonable fertilization and management of high yield cotton.

### Materials and methods

*Varieties and planting conditions*

The studies were conducted at the fortieth-five Tuan, Third Agriculture Shi Xinjiang P&C from 1997 to 1999, at the west edge of Tarkalamagan desert (39?08′N, 77?57′E). Eight fields were involved each year. The soil in these fields is umber and light. After sowing, soil was covered by mulch membrane. The planting density was 1.5?$10^5$plant/ha with 60cm row and 30cm line spacing. These fields were managed according to high yield cultivation model. The cotton varieties used were mid-maturity land cotton Jimian20, Shiyuan321 and Zhongmianshuo23. Except 1999, when the cotton yield didn't reach the expected level due to the damaging wind, in 1997 and 1998 there were six experiment spots in which lint yield reached 3000 kg/ha. The cotton yield and its composition were showed in Table 1, with the cotton yield of 2000 kg/ha in the control treatment.

**Table 1 Lint yield and its component of cotton planted in different locations and years**

| Years | Varieties | Experimental spot | Lint yield (kg/ha) | Plant no.of $10^4$ plants/ ha | No.of fruit branch | Bolls / plant | Boll weight (g) | Lint percentage (%) |
|---|---|---|---|---|---|---|---|---|
| 1997 | JM20 | 14-8-1 | 3119.7 I | 13.57 | 12.1 | 8.9 | 6.0 | 43.1 |
| | | 13-16-1 | 3092.9 I | 12.75 | 12.3 | 9.1 | 6.1 | 43.7 |
| | | 1-6 | 3072.7 I | 12.40 | 12.7 | 10.0 | 5.9 | 42.0 |
| | | 2-30-2 | 2026.3 II | 12.24 | 10.4 | 7.0 | 5.5 | 43.0 |
| | | 6-2 | 2098.9II | 12.98 | 10.8 | 7.0 | 5.5 | 42.0 |
| 199 | ZM23 | 4-160 | 3248.6 I | 14.70 | 11.0 | 9.8 | 5.5 | 41.0 |
| | | 2-30-1 | 2957.7 I | 13.05 | 12.0 | 9.4 | 5.7 | 42.3 |
| | | 2-30-2 | 2061.6II | 13.05 | 11.0 | 7.3 | 5.3 | 41.0 |
| | SY321 | 13-16-1 | 977.3 I | 13.65 | 11.3 | 9.5 | 5.6 | 41.0 |

**I, II represent yield range at 3000kg?$ha^{-1}$ and 2000kg?$ha^{-1}$ respectively.Jimian20：JM20;Zhongmianshou23：ZM23；Shiyuan321：SY321.The same as below**

The basal manual was applied before sowing at autumn or in spring, at a rate (kg/ha) of 1500deep-fry, 300urea, 300phosphoric diammonium and 75potassium sulfate. Topdressing was done just prior to the first irrigation. Urea at a rate of 300 kg/ha was applied after ditching. There were four times of irrigation in the whole growing period.

*Sampling methods, measured items and statistical analysis*

Before sowing, soil samples were taken from 0-30cm soil layers for determination of organic matter, total nitrogen, alkaline hydrolysis nitrogen, available phosphorus and potassium (Table 4). During the reproduction period, from the 40 d after emergence of seedling, 10 plants were taken from five sites in each field every 14 d interval and separated into various parts, dried at 80$^o$C until constant weight. After grinding, the nutrient analysis of plant samples was done. Organic matter was determined by potassium dichromate method, nitrogen by Kjeldahl method, phosphorous by molybdenum-stibium colorimetry method and potassium by atom absorption spectrophotometer.

## Results and analysis

### *Accumulation dynamics of nitrogen, phosphorous and potassium in cotton plants*

The results indicated that accumulation dynamics of N, $P_2O_5$ and $K_2O$ in both high-yield plants and the control could be described by equation Y=a/(1+be-cx). According to the equation, it was estimated that N, $P_2O_5$ and $K_2O$ accumulation for the cotton with lint yield of 3000 kg/ha were 385.8kg, 244.7kg and 340.3kg per hectare, respectively. The difference in absorption rate between high-yield fields and the control increased gradually from the 40 d, reached the maximum at the 90 d after emergence, then became smaller. It was indicated that nitrogen absorption capacity was obviously higher in the plants from high-yield fields than in those from the control, from budding stage to boll forming stage, and after that the difference was reduced. Compared with N absorption rate, the duration of the highest rate for $P_2O_5$ absorption lasted relatively shorter period. $K_2O$ absorption rate was higher in the plants from high-yield fields than in those from the control, just starting from emergence reached the highest absorption rate at fully flowering stage, and then decreased thereafter. It means that high-yield cotton plants had obviously higher $K_2O$ absorption capacity than the control during emergence to fully flowering stage, and moreover, reached absorption peak earlier. By analyzing dynamics of the nutrient accumulation, the highest rate and lasting duration of N, $P_2O_5$ and $K_2O$ absorption, the maximum accumulation rate (peak value) were obtained for the cotton plant with the lint yield of 3000 kg/ha. The accumulation peak of N, $P_2O_5$ and $K_2O$ in high-yield cotton occurred at the 90, 92 and 85 d after emergence, respectively, being 3, 7 and 15 d earlier than the control. The maximum absorption of N, $P_2O_5$ and $K_2O$ in the high-yield cotton was 2.20, 5.10 and 1.04 times higher than those in the control. The duration of the largest demand for N in high-yield cotton lasted 39 days, starting from 70d (first flower stage) and ending at 110d after emergence (fully boll-forming stage). During these 39 days, 88% of total N accumulated in whole growing stage, with high-yield cotton being 109.5% higher than the control.

**Table 2 The characteristics in nutrient accumulation for high-yield cotton in Xinjiang（1997，Jimian20）**

| Yield range | Nutrient | TI | | | TFNAR | VHA | VAA | PTA |
|---|---|---|---|---|---|---|---|---|
| | | D1 | D2 | D3 | | kg/ha/d | kg/ha | % |
| 1 | N | 71 | 110 | 39 | 90 | 8.63 | 336.6 | 87.3 |
| | $P_2O_5$ | 82 | 110 | 28 | 92 | 6.22 | 173.9 | 71.1 |
| | $K_2O$ | 64 | 106 | 42 | 85 | 5.72 | 240.2 | 70.6 |
| 2 | N | 72 | 110 | 41 | 93 | 3.92 | 160.6 | 69.1 |
| | $P_2O_5$ | 75 | 123 | 48 | 99 | 1.21 | 58.1 | 72.0 |
| | $K_2O$ | 77 | 123 | 48 | 100 | 5.52 | 255.3 | 70.0 |

**[1)](Days after emergence). TI: The time of inflexion, D1: The time of first inflexion, TFNAR：The time of the fastest nutrient absorption rate, D2: The time of second inflexion, D3: The time of lasting, VHA：The value of the highest absorption (kg/ha/d), VAA: The value of accelerated accumulation (kg/ha/d). PTA: Proportion to total accumulation (%)**

The duration of the highest demand for $P_2O_5$ in high-yield cotton lasted 28 days i.e. from 82 d (fully flowering stage) to 110 d after emergence. During these 28 days, the accumulated amount of $P_2O_5$ occupied 65% of the total accumulation during the whole growing stage. The accumulated amount of $P_2O_5$ was 40.7% higher in high-yield cotton than those in the control during the largest demand for $P_2O_5$. Compared with N absorption, the greater rate of $P_2O_5$ absorption appeared later and maintained a relatively shorter duration in high-yield cotton. The highest rate of $K_2O$ absorption lasted 42 days, i.e. from 64 d (initially flowering stage) to 106 d (fully boll-forming stage) after emergence. During the period, the accumulated amount of $K_2O$ occupied 67% of the total accumulation with the high-yield cotton being lower, but not significantly different from the control. It was lower than CK during the period, but no obvious difference existed if the whole growing period was considered. $K_2O$ absorption started and finished earlier than nitrogen and phosphorous absorption, and lasted longer in high-yield cotton.

*Utilization and absorption rate of fertilizer and nitrogen, phosphorous and potassium quantity drawn from the soil*

NUE was basically the same for high yield and the control (Table 3), PUE was 86.5% lower in high-yield cotton than in the control, indicating that phosphorous utilization was not economic in high-yield cotton. A possible reason might be luxury uptake occurred in high-yield field due to too much phosphorous application. KUE in high-yield cotton was 68.6% higher than the control, indicating that potassium utilization was economic in high-yield cotton. N and P recovery efficiencies in high-yield cotton were 54.7% and 180% higher than the control. On the other hand, high-yield cotton had lower K recovery efficiency than the control. Compared with N and P recovery efficiency, both of the high-yield cotton and the control showed higher K recovery efficiency. K recovery amounts were almost equal to all of applied potassium fertilizer, and together with 1.5 times potassium from the soil. Hence, the rapidly available potassium of soil declined in south Xinjiang.

**Table3 Nutrient utilization efficiency (NUE), recovery efficiency and the amount absorbed nutrient for the production of 100 kg ginned cotton （Jimian20,1997）**

| Yield Range | N | | $P_2O_5$ | | $K_2O$ | | VNAP/100kg | | |
|---|---|---|---|---|---|---|---|---|---|
| | NUE | NRE | NUE | NRE | NUE | NRE | N | $P_2O_5$ | $K_2O$ |
| | kg/ha | | kg/ha | | kg/ha | | | | |
| 1) | 8.09 | 385.8 | 12.75 | 244.7 | 9.17 | 340.3 | 12.5 | 8.0 | 11.1 |
| 2) | 8.12 | 249.4 | 23.78 | 85.2 | 5.44 | 372.6 | 12.3 | 4.2 | 18.4 |

It was estimated that around 12.5kg N, 8.0 kg $P_2O_5$ and 11.1kg $K_2O$ were required for the production of each 100 kg lint for the cotton with high-yield of 3000 kg/ha in Xinjiang. Compared with the control, high-yield cotton absorbed slightly higher N, 90% higher P and 40% lower K. For production of every 100 kg lint, the current results gave 6% lower N, 9% lower K and 36% higher P than those reported by Bai et al. (2002) on the cotton with lint yield of 2632.5 kg/ha.

## Discussion

*The basic fertility for the nutrition of high-yield cotton*

As a conclusion, by using comprehensive results of high-yield cotton fields (Table 4), the basic fertility (minimum values) may be proposed for the production of high-yield cotton over 3000kg/ha under the condition of ecosystem like the Third Agriculture Shi of Xinjiang P&C: organic matter content, 0.83%; total N, 0.05%; alkaline hydrolysis N, 50mg/kg; total P, 0.13%; available P, 8.6 mg/kg; and available K, 91 mg/kg; Based on the soil survey and ecological zone classification in Xinjiang done in 1995 and 1998, there are 80% experimental area covered by above-mentioned criteria. So, soil fertility could not be a constraining factor limiting the realization of super high-yield cotton cultivation in this area.

**Table 4 The status of soil nutrient of 3000kg/ha high yield cotton before sowing**

| Years | Varieties | Experimental spot | OM % | TN % | AHN mg/kg | WP % | RAP mg/kg | RAK mg/kg |
|---|---|---|---|---|---|---|---|---|
| 199 | JM20 | 13-16-1 | 1.10 | 0.069 | 70.8 | 0.166 | 15.8 | 129.4 |
| 1997 | JM20 | 14-8-1 | 0.87 | 0.051 | 55.4 | 0.143 | 8.6 | 104.0 |
| 1998 | ZM23 | 2-20-1 | 0.83 | 0.052 | 53.8 | 0.150 | 9.9 | 91.0 |
| 1998 | ZM23 | 4-160 | 0.87 | 0.050 | 53.8 | 0.130 | 11.7 | 96.2 |
| 1999 | ZM35 | S-3-1 | 0.89 | 0.055 | 50.4 | 0.156 | 11.8 | 187.1 |

OM: organic matter. WN: total nitrogen. AHN: alkaline hydrolysis nitrogen. RAP: rapidly available phosphorus, RAK: rapidly available potassium. ZM35: Zhongmian 35.

*Fertilization technique in high-yield cotton field*

As to nutrient uptake efficiency under the local and present fertilization, approximately all nitrogen applied was absorbed, while for phosphorous and potassium, the absorbed amount not only cover all fertilizer applied, but also consists of that originally present in soil. While in CK field, only 43% nitrogen and 34% phosphorous applied was absorbed. It indicates that the more phosphorous and potassium was absorbed with the increase of cotton yield, thus leading to higher fertilizer utilization efficiency and less environment pollution. In three years successive experiments, no consistent high yield was achieved. One possible reason is that high-yield cotton plant consumed relatively large amount of nutrients in soil, causing temporary decline in nutrient supply by soil. Therefore, for the fields producing super high-yield in the previous year, it is better to plant other crops, or fertilization should be increased. For the field as the control, present rate of fertilization seems to be too high and should be reduced according to the expected yield. Potassium content in the soil should be highly emphasized, and K fertilizer application should adjusted based on available potassium content.

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