A Dynamic Knowledge Models of Nitrogen Fertilizer and Computer System for Cotton

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College of Information Engineering, Tarim University, Xinjiang 843300, China
smallx1002@sina.com

Abstract: Through analyzing the newest research results about nitrogen management of cotton and experimental results, and on the basis of the different effects of cotton yield, plant height and leaf area, a dynamic knowledge model for decision making on total nitrogen and their distribution among main growth stages of cotton under different environments and yield targets was developed with the principles of nitrogen balance and by integrating the factors of climate, soil, yield and so on. A comprehensive and intelligent computer system for cotton management was established using VC++6.0 and SQL Server 2003.

Key words: nitrogen management, influence factors, dynamic knowledge models, decision support system

1 Introduction

As nitrogen is one of the important components of protein, which is also the important element making up of cellular plasm, so to speak, life activities cannot be formed without nitrogen. The nutrition level of nitrogen fertilizer has a very essential influence on cottons' growth and development, which not only limits the height of cotton leaves, but also cotton yields. In the case of lacking the nitrogen fertilizer, cottons take on a slow and weak growth, with undersized and thin stems, cotton buds and bolls with a high expulsion rate and rare bolls; in the case of using too much or improperly fertilizing in different growth periods of cottons, sugars formed by organic nutrition consume too much with little accumulation, excessive vegetative growth and increasing expulsion. Fertilization of abundant nitrogen fertilizers will not only decrease the utilization rate of fertilizer and increase its cost, but also cause adverse effects to the environment. Different treatments of nitrogen fertilizer have certain influence on the growth of cotton organs and the yields. So, it will be of much importance for guiding the agricultural production to create accurate and effective nitrogen management models and design and develop them into systems.

2 Materials and methods

2.1 Experiment design

The experiment is conducted in agricultural experiment station (with latitude of 40°32' N and longitude of 81°18' E) of Tarim University in Xinjiang Province in

April, 2011. With a height above the sea level of 900-950 meters and of warm temperate desert climate, the experimental zone locates in the upper and middle reaches of Tarim River, graced with rich resources of water and soil, dry weather, abundant sunlight and four distinctive seasons. For nearly 30 years, the area has an average annual precipitation of 40.1-82.5 mm, with little rain in summer and little snow in winter, an average annual temperature of 10.7℃ and a total annual sunshine duration of 2900 hours, suitable for the growth of long-staple cotton. The cottons are planted by means of plot, with a planting density of 12200 plants per mu. The experimental soil is loam, with 14g/kg organic content, 0.5g/kg total nitrogen, 85mg/kg effective nitrogen, 14mg/kg available phosphorus and 75mg/kg rapidly available potassium. The experimental variety is the New Sea 21 of long-staple cotton, with a plot area of $132m^2$.

This experiment designs five nitrogen fertilization treatments, namely, 0, 180, 240, 300, $360kg/hm^2$, with the amount of base fertilizer holding 45% of the total fertilization amount, and the remainder being top dressing/nitrogen application, respectively in the periods from the bud period to the flower and boll stage and 3 fertilization proportions with water of 15%, 25% and 15%. Besides, the phosphorus and potassium fertilizers in the base fertilizer separately are P_2O_5 138 kg/hm^2 and K_2O 72 kg/ hm^2. The experiment is arranged in random groups, with 3 repeated treatments in each group. The samples make up of the following table 1:

Table 1. Schemes of every fertilization treatment in the experiment

Treatment	Total amount			Base fertilizer			Topdressing nitrogen fertilizer		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	1^{st}(6.10)	2^{nd}(7.15)	3^{rd}(8.20)
N0	0	138	72	0	138	72	0	0	0
N1	180	138	72	81	138	72	27	45	27
N2	240	138	72	108	138	72	36	60	36
N3	300	138	72	135	138	72	45	75	45
N4	360	138	72	162	138	72	54	90	54

2.2 Experimental method

In the main growth period, seedling stage, bud stage, flower and boll stage and boll period, samples are respectively taken in the time between 10:00-12:00 am on the corresponding dates. Each nitrogen fertilizer treatment area randomly selects 3 representative cotton plants (5 plants in the bud period), and measures related data from the selected plant samples.

The plant height of cotton: the plant heights of cotton are measured with rulers on June 9^{th}, June 17^{th}, July 2^{nd}, July 17^{th} and September 15^{th}.

The length and width of cotton leaves: the length and width of the largest leaves in representative plants are measured with rulers on June 9^{th}, June 17^{th}, July 2^{nd}, July 17^{th} and September 15^{th}.

The leaf area: according to the quantitative functional relationship between pulse length and leaf area in cotton leaves applied in Literature [2], the leaf area is solved.

With the pulse length x as the independent variable and the leaf area y as the dependent variable, the quadratic regression equation of one variable $y=2.4337-0.4328x+0.8265x^2$ is established.

3 The influence of nitrogen fertilizer on the growth of long-staple cotton

3.1 The influence of nitrogen fertilizer on the yield of long-staple cotton

The research literature [3-5] show there is certain quantitative relationship existing between nitrogen fertilizer NR and the target of yield TY (kg/ha), which can be expressed in the following linear function:

$$NR = 0.1062 \times TY + 17.181 \qquad R = 0.8313^{**} \qquad (1)$$

The literature [6] proves that under the condition of border irrigation in southern Xinjiang area, different amounts of nitrogen fertilization have influences on the boll number of each cotton plant, the weight of each boll and the yield of seed cottons. This research suggests that under different nitrogen treatments, there is certain difference in the boll number of each cotton plant, the weight of each boll and the yield of seed cotton. Thereinto, the relationship of the boll number of each cotton plant and nitrogen treatments accords with quadratic curve equation. At first, the yield of seed cotton increases with the increasing amount of nitrogen fertilization, but when the nitrogen level reaches N3, the yield takes on downtrend. By simulating and matching the nitrogen fertilizer effect of cottons with quadratic equation of one variable, the experimenter concludes the correlation between the amount of nitrogen fertilization and the cotton yield as follows:

$$y = -0.0039x^2 + 2.6895x + 1962.9 \qquad R^2 = 0.9576^{**} \qquad (2)$$

In the equation, y refers to the yield and x the amount of nitrogen fertilization.

Table 2. The influence of different amounts of nitrogen fertilizer on cotton yields

Treatment	Boll numbers of each plant(No./plant)	Weight of each plant(g)	Yield of seed cotton(kg./hm^2)
N0	7.6	2.9	4562.2
N1	8.3	2.8	4810.7
N2	8.4	2.9	5042.5
N3	8.5	3.1	5454.5
N4	8.4	3.0	5216.4

3.2 The influence of nitrogen fertilizer on plant height and leaf area of the long-staple cotton

The experimental result (seen in Chart 3) shows that with the advancement of long-staple cotton’s growth process, there is no difference in different nitrogen fertilizer treatments in periods of seedling and bud, that the growth processes of cotton in the beginning of flowering and at full-blossom stage are both a little delayed and that in the full-blossom stage, the heights of front plants rapidly increase and after that, the difference in plant height with different nitrogen treatments gradually increases with the growth process.

Table 3. The influence of different nitrogen levels on plant height, leaf number and leaf area

Treatment	Plant height(cm)	True leaf number(leaf number/plant)	Leaf area (cm^2/plant)	Plant height(cm)	True leaf number(leaf number/plant)	Leaf area (cm^2/plant)
	(Stage of 4 leaves) May 21th			(Stage of 5 leaves) May 21th		
N0	4.0	3.5	61.2	5.1	4.8	109.8
N1	4.1	3.6	64.3	5.6	5.0	118.5
N2	4.3	3.8	84.5	6.1	5.0	133.0
N3	3.1	3.5	59.8	5.7	5.1	122.3
N4	3.6	3.5	55.7	5.4	5.0	114.5

4 The dynamic knowledge model of nitrogen management

4.1 The establishment of the model/the modeling

Based on the widely collecting and consulting the latest literatures about the cultivation, the soil science and plant nutrition of the long-staple cotton, by means of the principle of system analysis and mathematical modeling method, the experiment builds the relevant quantitative mathematical model of nitrogen management and develops the cotton nitrogen management system based on dynamic knowledge model, and finally tests the correctness of this model with practical applications and optimizes the model with understanding and analyzing the feedback information from the system.

4.2 Descriptions of model algorithm

4.2.1 The amount of soil nitrogen supply in season

The amount of soil nitrogen supply in season: $SN = ON + ION$

In the equation, ON refers to the supply amount of reducible N element in season and ION the supply amount of irreducible N element in season.

(1). the supply amount of reducible N element in season

$$ON = \frac{0.08 \times TSN \times SPD \times SBW \times N(t) \times SNUE}{365} \times 1000 \quad (3)$$

In the equation, TSN refers to the real total amount of N element in the soil (g ·kg^{-1}); SPD the thickness of the top layer (cm); SBW the volume (g ·kg^{-1}). The utilization rate of the fertilizer in season is affected by the fertilizer variety, fertilizing method, weather conditions and soil environment and so on. Under the conventional fertilizing technique, the utilization rate of fertilizer in season is generally 32. 5%±2. 5%. Recently, as a new fertilizing technique, drip fertigation has obtained/achieved much development. Because the fertilizer is quantitatively applied with water, the solubleness of the fertilizer and the close fertilization are increased, thus improving the fertilizer efficiency and the utilization rate of nitrogen fertilizer reaches 50. 5%±3. 5%. According to the fertilization pattern and past experience, users can determine the utilization rate of corresponding fertilizers in season.

N (t) refers to the total number of standardized days under water temperature effect:

$$N(t) = N(t)'_1 + N(t)'_2 + \cdots + N(t)'_{365}$$

N (t) I refers to the number of standardized days under the effect of water and the temperature of Number i, whose value is:

If the value of PDT_i (psychological development time the variety accumulates gradually under actual sowing dates) is taken and fixed from 0 to 144, then

$$N(t)'_i = F_T(t) \times F_w(\qquad (4)$$

Otherwise, its value is 0.

FT (t) is the influence function of temperature to nitrogen fertilization, whose value is $F_T(t) = \left(8 \times e^{-0.058 \times STA_{20}}\right)^{\frac{STA_{20}-30}{10}}$. Thereinto, STA20 is the soil temperature when the plough layer is 20 cm thick.

Fw (t) is the influence function of moisture to nitrogen fertilization.

$$F_w(t) = \begin{cases} 0.2 & W(t) \le W_D \\ 0.2 + 0.8 \times \dfrac{W(t) - W_D}{W_O - W_D} & W(t) \le W_O \\ 1 - 0.6 \times \dfrac{W(t) - W_O}{W_S - W_O} & W(t) \le W_S \\ 0 & W(t) > W_S \end{cases} \qquad (5)$$

WD is the wilting moisture content; WO the optimum soil moisture content under mineralization; Ws saturated moisture content of soil; W(t) the actual moisture content of soil.

(2). The supply amount of irreducible N element in season

$$ION = AOVN \times SPD \times SBW \times 10$$

In the equation, AOVN is the content of irreducible N element and effective nitrogen in the top layer of soil; SPD the thickness of the topsoil (cm); SBW soil capacity (g $\cdot$kg^{-1}).

4.2.2 The necessary/needed amount of N under specific yields

The necessary amount of N under specific yields URN (kg $\cdot$hm^{-2})

$$UR_N = \frac{418.5966}{1 + e^{-0.0014 \times (TY - 415)}} \qquad (6)$$

In the equation, TY（kg/hm^2）is used to calculate the realizable yield potential of users.

$$TY = \begin{cases} TY_{max} & YM \times \left(1 + \dfrac{YLPP - YM}{4 \times YLPP}\right) \ge TY_{m} \\ YM \times \left(1 + \dfrac{YLPP - YM}{4 \times YLPP}\right) & YM \times \left(1 + \dfrac{YLPP - YM}{4 \times YLPP}\right) < TY_{max} \end{cases} \qquad (7)$$

In the equation, TYmax is the yield potential under the earliest time of suitable sowing period; YM the average yield in the first three years; YLPP the production potential of production technology.

4.2.3. The fertilizing ratio of organic N to inorganic N OINR1：OINR2

(1) The fertilization amount of organic N

$$OINR_1 = \begin{cases} 5-\left(1-2.5/LA'\right)-\left(1-1.5\times TY/TY_{\max}\right) & OMC<8 \\ 4-\left(1-2.5/LA'\right)-\left(1-1.5\times TY/TY_{\max}\right) & 8\le OMC<14 \\ 3-\left(1-2.5/LA'\right)-\left(1-1.5\times TY/TY_{\max}\right) & OMC\ge 14 \end{cases} \tag{8}$$

In the equation, TY（kg/hm^2）is used to calculate the realizable yield potential of users; TYmax is the yield potential under the earliest time of suitable sowing period; OMC the organic material content in the soil (g/kg).

LA is the age of transplanted leaves after PS correcting the seeding method, whose value is:

$$LA' = \begin{cases} 2.5 & \text{direct seeding} \\ LA & \text{Otherwise} \end{cases}$$

，LA refers to the age of transplanted leaves (9)

(2) The fertilization amount of inorganic N $OINR_2$

$$OINR_2 10-OINR_1 \tag{10}$$

4.2.4. The drip fertigation

In different growth stages of cotton, the ratio of base fertilizer to top-dressing; the drip fertigation ratio in base fertilizer, bud stage, the beginning of flowering, the full-blossom stage, boll stage and early flocculant stage, namely, BTRND1：BTRND2：BTRND3：BTRND4：BTRND5：BTRND6.

(1) The base fertilizer

$$BTRN_{D1} = \begin{cases} 4.5-\left(1-2.5/LA'\right)+CLAYC/100+\left(1-1.5\times TY/TY_{\max}\right) & TY\le 0.4\times TY_{\max} \\ 3.5-\left(1-2.5/LA'\right)+CLAYC/100+\left(1-1.5\times TY/TY_{\max}\right) & 0.4\times TY_{\max}<TY\le 0.7\times TY_{\max} \\ 2.5-\left(1-2.5/LA'\right)+CLAYC/100+\left(1-1.5\times TY/TY_{\max}\right) & TY>0.7\times TY_{\max} \end{cases} \tag{11}$$

In the equation, LA is the age of transplanted leaves after PS correcting the seeding method; TY（kg/hm^2）is used to calculate the realizable yield potential of users; TYmax is the yield potential under the earliest time of suitable sowing period.

CLAYC is the content of the physical clay (%), whose value is listed in Chart 4 as follows:

Table 4. The soil texture and the corresponding values of CLAYC

Soil texture	CLAYC value
Sandy soil	7.5
Sandy loam	15
Light loam	25
Middle loam	37.5
Heavy loam	52.5
Clay	65

(2) The bud stage

$$BTRN_{D2}=\begin{cases}1 & TY\le 0.4\times TY_{\max}\\ 0.9 & TY>0.4\times TY_{\max}\end{cases}\tag{12}$$

TY（kg/hm^2）is used to calculate the realizable yield potential of users; TYmax is the yield potential under the earliest time of suitable sowing period.

(3). The beginning of flowering stage

$$BTRN_{D3}=\begin{cases}2.2+\left(1-2.5/LA^{'}\right)-CLAYC/100-\left(1-1.5\times TY/TY_{\max}\right) & TY\le 0.4\times TY_{\max}\\ 2+\left(1-2.5/LA^{'}\right)-CLAYC/100-\left(1-1.5\times TY/TY_{\max}\right) & 0.4\times TY_{\max}<TY\le 0.7\times TY_{\max}\\ 1.8+\left(1-2.5/LA^{'}\right)-CLAYC/100-\left(1-1.5\times TY/TY_{\max}\right) & TY>0.7\times TY_{\max}\end{cases}\tag{13}$$

(4). The full-blossom stage

$$BTRN_{D4}=\begin{cases}2-\left(1-2.5/LA^{'}\right)+CLAYC/100-\left(1-1.5\times TY/TY_{\max}\right) & TY\le 0.4\times TY_{\max}\\ 2.5-\left(1-2.5/LA^{'}\right)+CLAYC/100-\left(1-1.5\times TY/TY_{\max}\right) & 0.4\times TY_{\max}<TY\le 0.7\times TY_{\max}\\ 3-\left(1-2.5/LA^{'}\right)+CLAYC/100-\left(1-1.5\times TY/TY_{\max}\right) & TY>0.7\times TY_{\max}\end{cases}\tag{14}$$

(5). The boll stage

$$BTRN_{D5}=\begin{cases}0.3+\left(1-2.5/LA^{'}\right)-CLAYC/100+\left(1-1.5\times TY/TY_{\max}\right) & TY\le 0.4\times TY_{\max}\\ 0.8+\left(1-2.5/LA^{'}\right)-CLAYC/100+\left(1-1.5\times TY/TY_{\max}\right) & 0.4\times TY_{\max}<TY\le 0.7\times TY_{\max}\\ 1.4+\left(1-2.5/LA^{'}\right)-CLAYC/100+\left(1-1.5\times TY/TY_{\max}\right) & TY>0.7\times TY_{\max}\end{cases}\tag{15}$$

(6). The early flocculant stage

$$BTRN_{D6}=\begin{cases}0 & TY\le 0.4\times TY_{\max}\\ 0.3 & 0.4\times TY_{\max}<TY\le 0.7\times TY_{\max}\\ 0.4 & TY>0.7\times TY_{\max}\end{cases}\tag{16}$$

4.3 Verification of the model

By systemically using the meteorological data, soil bank, commercial variety, perennial production data of 5 areas with different latitudes like Alear City, Bachu, Bytown, and Shihezi, the experimenter designs management schemes of cotton nitrogen in normal years for these areas and then compares with the cotton cultivation mode in local use to find that they are basically consistent, which suggests this system is of good practicality and accuracy.

5 The design and development of nitrogen management system

By understanding and refining document literatures and expert knowledge, combining with field trials and dynamic knowledge model of nitrogen management, with the help of programming language VC++6.0 and data platform SQL 2000, the experiment designs and develops nitrogen management system based on dynamic knowledge model, which mainly covers 4 modules.

The first three modules simulate the influences of different nitrogen treatments on such parameters as the yield of long-staple cotton, the plant height and leaves. Thereinto, the module of production estimation realizes the influences of 5 nitrogen treatments on the number of bolls in each cotton plant, the weight of each boll and the seed cotton yield, further realizing the estimation of long-staple cotton yield; by analyzing the influences of 5 nitrogen treatments on long-staple plants, the module of plant height prediction concludes to predict the plant height by the fertilization amount of nitrogen fertilizer; by the influences of 5 nitrogen treatments on leaf number and leaf area, the leaf parameter estimation module concludes to estimate related parameters of leaves according to the fertilization amount of nitrogen fertilizer.

According to input parameters by users, nitrogen management module can help users calculate the amount of soil nitrogen supply in season, the necessary amount of nitrogen under specific yields, and the fertilization proportion of long-staple cotton in different growth stages under drip fertigation.

6 Conclusion

By understanding and refining document literatures and expert knowledge, combining with field trials, the study analyzes the influences of nitrogen fertilizer on relevant parameters such as the cotton yield, plant height and leaves, further giving out the dynamic knowledge model of nitrogen management and designs and develops the cotton nitrogen management system based on dynamic knowledge model. Proved by practical applications, dynamic knowledge model is of good practicality and accuracy, and the system is characterized by fast and convenient uses, practicality and universality. In the future studies, the system will strengthen the study on the influence of nitrogen fertilizer on other cotton organs and be able to make better service for production.

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