# Study on Monitoring Methods of Nitrogen Nutrition in Cotton Leaves Based on Android Platform

Yanqun Wang[1, 2], Guoliang Li[1]*, Zhenqi Fan[2], Xianqiang Gao[2]

[1] School of Information, Huazhong Agricultural University, Wuhan ,430070, China.
[2] College of Information Engineering, Tarim University, Alaer, Xinjiang, 843300, China.

*Corresponding author. Tel.: +86-27- 87282027; email: Guoliang.li@ mail.hzau.edu.cn
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**Abstract:** In view of the cumbersome, time-consuming and high-cost detection methods of nitrogen content in cotton leaves, the research of Monitoring Methods of Nitrogen Nutrition in Cotton Leaves Based on Android Platform was puts forward. Taking flowering period as an example, Android mobile phone was used to obtain images, then image denoising, color correction and image segmentation were carried out. Then sensitive color eigenvalues of nitrogen content in cotton leaf were extracted and analyzed, and monitoring model of nitrogen content based on improved BP algorithm was established. Finally, the detection system based on Android platform for nitrogen contents in cotton leaves was developed. This study not only provides a simple, rapid and accurate method for nitrogen nutrition diagnosis, but also provides a scientific basis for rational application of nitrogen fertilizer in the future.

**Keywords:** Android, improved BP model, image technology, monitoring model, Nitrogen content.

## 1. Introduction

Nitrogen nutrition status of cotton can be diagnosed by nitrogen content of canopy leaves. There was a significant correlation between nitrogen contents of canopy leaves and chlorophyll contents, and chlorophyll content was related to canopy green [1]. Therefore, the change of crop nitrogen nutrition directly affects the crop canopy color. The change of leaf color indicates whether the nitrogen is sufficient. In recent years, based on a suitable color model, diagnosis of crop nutrition by image processing technology has become a hot topic of machine vision in agricultural applications.

Machine vision technology is a technology that includes image acquisition and image processing through image acquisition equipment. Image processing is the core, including image acquisition, image preprocessing, image segmentation and feature extraction, image feature analysis and processing, etc [2]. With the continuous development of digital image technology, more and more researchers began to use machine vision technology for nitrogen nutrition diagnosis.

The images were acquired by near infrared spectrometer [2], digital camera [3], smart phone [4], scanner [5] and so on, and then the characteristic information of the shape, area and color of the leaves was extracted by using the image analysis and processing technology to establish the features Information and nitrogen nutrition model in order to achieve the use of machine vision technology for diagnosis of nitrogen nutrition. Nitrogen detection based on machine vision has been applied to crops such as wheat, rice, sugar beet, cotton and so on. However, the research on cotton nitrogen needs to be further studied.

The existing problems in the research are as follows: The method of obtaining the image of cotton nitrogen is not best, and the detection means is not the most convenient. The detection of cotton nitrogen is basically through remote sensing [6] or digital camera [7], [8] to obtain images, easy to be affected by external

environment, and follow-up steps are more cumbersome. The image acquisition process of the scanner is less affected, and the scanning conditions remain constant, but the steps are not so convenient.

In this study, Android mobile phone was used to capture the top four leaf images of cotton canopy, and machine vision technology was used to extract cotton leaf color eigenvalues (R-means, G-means, B-means, red standardized mean $R_S = R/(R + G + B)$, green standardized mean $G_S = G/(R + G + B)$ and blue standardized mean $B_S = B/(R + G + B)$, hue H, saturation S, brightness V), then the relationship between the eigenvalues and the nitrogen nutrition status of cotton was analyzed. Next, the appropriate color eigenvalues were selected and the improved BP neural network was used to establish the diagnosis model of Cotton Nitrogen nutrition. Finally, the detection system of nitrogen contents in cotton leaves based on Android platform was established.

## 2. Materials and Methods

### 2.1. Experimental Design

The experiment was carried out at the experimental station of the College of Botanical Sciences, Tarim University, Xinjiang Uygur Autonomous Region,China. The tested variety was Xinluzhong 48. The tested soil was loam, containing 14 g/kg of organic matter, 0.5 g/kg of total nitrogen, 85 mg/kg of alkali-hydrolyzed nitrogen, 14 mg/kg of available phosphorus and 75 mg/kg of available potassium.

The recommended level of nitrogen fertilization in this area is 260 kg/hm$^2$, in which the basic fertilizer amount accounts for 45%,and the topdressing rate is 55%. Three times of topdressing with water from bud stage to flowering and boll stage of cotton, the proportion was 15%、25% and 15% respectively.At the same time, the amount of phosphorus and potassium in the base fertilizer was 138 kg/hm$^2$ for $P_2O_5$ and 72 kg/hm$^2$ for $K_2O$.

The plot area of the experimental area was 500 square meters, about 0.75 mu, which was divided into 4 blocks. In order to cultivate cotton leaves with different nitrogen content, the gradient fertilization schemes of the four plots were as follows: ①no nitrogen fertilizer application,②Half of normal nitrogen application, ③Normal nitrogen rate,④1.5 times of normal nitrogen application.

### 2.2. Image Acquisition

Android mobile phone with effective pixels up to 20 million was used to acquire images and images were uniformly stored in JPG format. The images were collected at about 14:00 on July 4, 2017 under the natural light conditions in the field. Five plants were randomly selected from each experimental plot. The fully expanded canopy inverted four-leaf of full-bloom cotton was selected , numbered and photographed. In order to reduce the workload of post-processing, the vertical shooting was made at the vertical height of 0.2m from the sample blade to ensure that the light intensity of each shot was basically the same. Before shooting, the position of photographers, branches and leaves was adjusted, so as not to cause shadows. In addition, in order to facilitate the manual removal of complex background in the later image processing, whiteboard was placed under the blade to keep horizontal.

### 2.3. Determination of Nitrogen Contents in Cotton Leaves

After image acquisition, the cotton leaves were quickly picked up and packed in self-sealed plastic bags. The cotton leaves were put into kraft paper bags. Then the cotton leaves were put into WG-71 electric blast drying box. The samples were killed at 105℃ for 30 minutes and then dried at 80℃ for constant weight. The dried cotton leaves were grinded into powder by a crusher, and 0.2±0.01g powdery samples were weighed by FA2104N electronic analysis balance and put into test tubes. Then the nitrogen contents of cotton leaves were measured by FOSS-2300 automatic Kjeldahl nitrogen analyzer of the testing center of the Food

Science Institute.

## 2.4. Image Preprocessing

The median algorism filter was used to reduce the noise of the image during the collection and transmission. And the white balance algorithm [9], [10] was used to correct the color of the image in order to reduce the influence of the photographic light on the color of the image. Through the threshold of the color feature information of the image (G > R &G > B), the leaf region of cotton could be segmented by image segmentation, which was a simple, fast and effective method according to the specific situation.

## 2.5. Color Feature Extraction

After the image preprocessing was completed, the leaf area would be segmented. Through acquisition of the R, G, B information of each pixel in the blade region, the color feature information of the whole blade region was counted. In this study, R mean, G mean and B mean of leaf area were extracted, and H, S, V values, $R_S = R/(R + G + B)$, $G_S = G/(R + G + B)$ and $B_S = B/(R + G + B)$ were calculated as color characteristic values of leaf area.

## 2.6. Establishment of Monitoring Model of Nitrogen Contents in Cotton Leaves

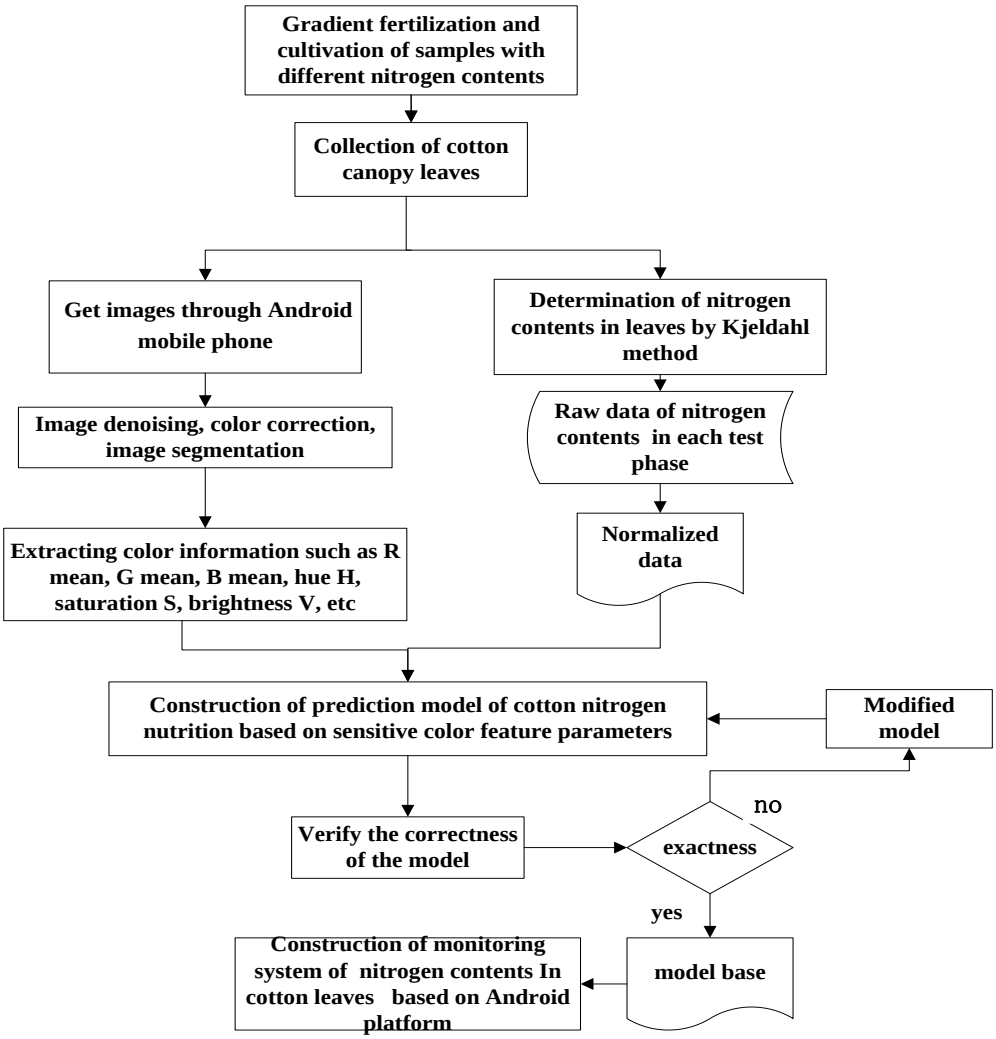


Fig. 1. Technology roadmap.

After the sensitive color characteristic values of nitrogen contents in cotton leaves were analyzed, a

monitoring model of nitrogen contents in cotton leaves would be established. Linear regression analysis, basic BP neural network and improved BP neural network based on Levenberg-Marquardtmann algorithm [11] can be used to establish prediction model of nitrogen contents in cotton leaves. After comparison and analysis, finally, the optimal model was implemented on Android mobile platform. To sum up, the methods are shown in Fig. 1.

## 3. Results and Analysis

### 3.1. Data Analysis

Twenty groups of cotton leaf samples were collected for analyzation. The nitrogen contents and color characteristic parameters are shown in Table 1. Among the table, Ncontent means nitrogen content.

Table 1. Nitrogen Contents and Color Characteristic Parameters of Cotton Leaves

| NO. | Ncontent(%) | R | G | B | $R_S$ | $G_S$ | $B_S$ | H | S | V |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.25 | 90.51 | 163.99 | 156.67 | 0.2201 | 0.3989 | 0.3810 | 174.02 | 0.4481 | 0.6431 |
| 2 | 2.09 | 109.5 | 153.77 | 140.15 | 0.2714 | 0.3812 | 0.3474 | 161.54 | 0.2879 | 0.6030 |
| 3 | 2.71 | 129.3 | 163.35 | 109.07 | 0.3219 | 0.4066 | 0.2715 | 97.65 | 0.3323 | 0.6406 |
| 4 | 1.73 | 160.9 | 160.70 | 168.45 | 0.3283 | 0.3279 | 0.3438 | 178.68 | 0.0460 | 0.6606 |
| 5 | 2.64 | 108.7 | 167.76 | 134.88 | 0.2642 | 0.4079 | 0.3279 | 146.61 | 0.3522 | 0.6579 |
| 6 | 2.80 | 84.4 | 160.82 | 132.12 | 0.2236 | 0.4263 | 0.3502 | 157.48 | 0.4755 | 0.6307 |
| 7 | 2.74 | 113.6 | 160.35 | 116.65 | 0.2908 | 0.4105 | 0.2986 | 123.90 | 0.2915 | 0.6288 |
| 8 | 2.88 | 99.1 | 148.56 | 122.93 | 0.2675 | 0.4009 | 0.3317 | 148.89 | 0.3327 | 0.5826 |
| 9 | 2.31 | 90.1 | 138.33 | 110.28 | 0.2659 | 0.4085 | 0.3256 | 145.14 | 0.3490 | 0.5425 |
| 10 | 2.78 | 108.8 | 150.96 | 118.88 | 0.2873 | 0.3987 | 0.3140 | 134.38 | 0.2795 | 0.5920 |
| 11 | 1.96 | 158.5 | 172.71 | 145.30 | 0.3327 | 0.3624 | 0.3049 | 91.04 | 0.1587 | 0.6773 |
| 12 | 2.39 | 109.3 | 155.27 | 124.58 | 0.2808 | 0.3990 | 0.3202 | 139.98 | 0.2963 | 0.6089 |
| 13 | 1.79 | 169.9 | 180.84 | 187.60 | 0.3157 | 0.3359 | 0.3484 | 157.03 | 0.0941 | 0.7357 |
| 14 | 2.22 | 117.0 | 146.36 | 125.30 | 0.3011 | 0.3765 | 0.3224 | 136.92 | 0.2004 | 0.5740 |
| 15 | 1.41 | 184.1 | 183.93 | 189.19 | 0.3303 | 0.3301 | 0.3395 | 118.52 | 0.0278 | 0.7419 |
| 16 | 2.93 | 110.3 | 172.01 | 117.82 | 0.2757 | 0.4299 | 0.2945 | 127.31 | 0.3588 | 0.6745 |
| 17 | 2.83 | 113.3 | 163.73 | 129.14 | 0.2789 | 0.4031 | 0.3180 | 138.86 | 0.3081 | 0.6421 |
| 18 | 2.55 | 78.7 | 141.02 | 116.67 | 0.2338 | 0.4193 | 0.3469 | 156.58 | 0.4423 | 0.5530 |
| 19 | 2.50 | 106.8 | 157.47 | 134.11 | 0.2681 | 0.3953 | 0.3367 | 152.35 | 0.3219 | 0.6175 |
| 20 | 2.80 | 113.7 | 162.41 | 120.55 | 0.2866 | 0.4905 | 0.3039 | 128.45 | 0.3000 | 0.6369 |

The function corrcoef In MATLAB was used to analyze the correlation between the extracted color features and nitrogen contents, and the significant color features related to nitrogen contents were selected. Correlation analysis between nitrogen contents in cotton leaves and color characteristics of images is shown in Table 2.

Table 2. Correlation Analysis between Nitrogen Contents in Cotton Leaves and Color Characteristics of Images

| Color feature | meaning | Correlation coefficient |
|---|---|---|
| R | The red light mean in the image | -0.7330 |
| G | The green light mean in the image | -0.4208 |
| B | The blue light mean in the image | -0.8260 |
| $R_S$ | Standard mean of red light | -0.5081 |
| $G_S$ | Standard mean of green light | 0.8157 |
| $B_S$ | Standard mean of blue light | -0.3481 |
| H | hue | -0.1155 |
| S | saturation | 0.7634 |
| V | lightness | -0.3481 |

It can be seen from Table 2 that there is a weak negative correlation between the nitrogen contents of cotton leaves and G、$R_S$、$B_S$、H、V, and a strong negative correlation between the nitrogen contents and R、B.There is a positive correlation between the nitrogen contents and $G_S$、S, but the significant level of S is slightly weaker than that of $G_S$. Based on the above analysis, $G_S$ and S are selected as the sensitive color characteristic values to characterize the nitrogen contents in cotton leaves, which can be used to construct a monitoring model of nitrogen contents in cotton leaves.

### 3.2. Comparisons of Several Prediction Models

The regression model was established by using linear regression analysis to predict the nitrogen contents of cotton leaves at the full-flowering stage: $N = -0.63128 + 6.792259G_S + 1.238653S$, $R^2 = 0.6653$, indicating that the regression equation was not very significant.

Then the basic BP neural network and the improved BP neural network based on the Levenberg-Marquardt (L-M) algorithm were used to establish the forecast models of nitrogen content in cotton leaves respectively. The samples with nitrogen contents of 1.79% and 2.88% were selected as the test samples respectively. The prediction results under different models are shown in Table 3.

Table 3. Predictions under Different Models

| Model name | predicted value of Sample one | Absolute error | predicted value of Sample two | Absolute error |
|---|---|---|---|---|
| Linear regression model | 1.852 | 0.062 | 2.504 | -0.376 |
| BP neural network model | 1.623 | -0.167 | 2.64 | -0.240 |
| Improved BP model | 1.732 | -0.058 | 2.743 | -0.137 |

It can be seen that the improved BP model is superior to the other two prediction models in predicting accuracy and can be used to construct a prediction model of nitrogen content in cotton leaves.

## 4. Development of the Detection System Based on Android Platform for Nitrogen Contents in Cotton Leaves


Fig. 2. Select and trim the image.

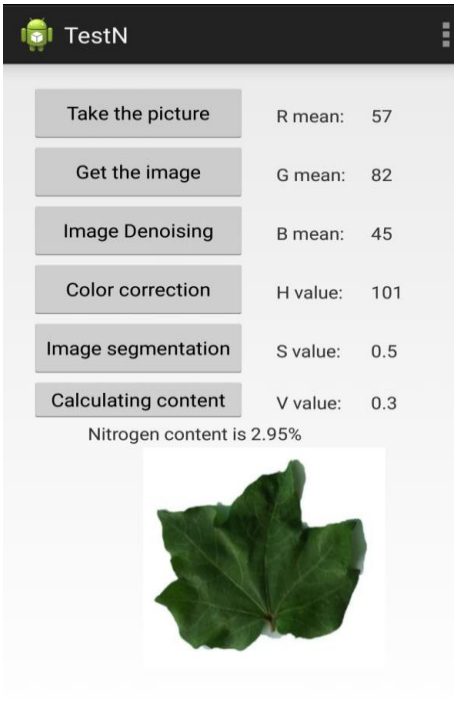


Fig. 3. Calculation of nitrogen content.

Android mobile phone is very popular smart phones at present. In view of this, detection model for nitrogen content in cotton leaves was implemented on Android mobile phone. Through the Eclipse development environment, Android application project was established. With the aid of OpenCV computer vision library, the method of image processing of cotton leaves was implemented in Java, including image denoising, color correction, image segmentation, extraction of color feature information of leaf area, and the prediction model of nitrogen content in cotton leaves based on improved BP algorithm. The whole system includes the modules of taking images, selecting images, image denoising, color correction, image segmentation and calculation of nitrogen content. Some of the interfaces are as follows in Fig. 2 and Fig. 3.

## 5. Conclusion

Based on the extraction and analysis of image color characteristics of cotton leaves, the correlation between image color characteristics and nitrogen content was analyzed. $G_S$ and S were selected as sensitive color characteristics to characterize nitrogen content in cotton leaves. The monitoring model of nitrogen content in cotton leaves at flowering stage was established based on improved BP neural network. Furthermore,a monitoring system for nitrogen content in cotton leaves based on Android platform has been established. The absolute error between predicted value and real value is between -0.19% and 0.01%. It shows that the detection method has good applicability. The future direction of improvement is to establish more accurate monitoring model through intelligent algorithm such as support vector machine or deep learning to improve the accuracy of the result.

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**Yanqun Wang** is the lecturer of Information Engineering College, Tarim University, Alaer, Xinjiang, China. He obtained the bachelor degree of computer application technology profession at Xinyang Normal University in 2005 and completed his master degree of education technology profession at Huazhong Normal University. Now, he is a Ph.D. student at School of Information, Huazhong Agricultural University. His research interests include agricultural information engineering.

**Guoliang Li** is the director of the Department of Biological Information, Department of Information Institute of Huazhong Agricultural University. He obtained the bachelor degree of automatic control profession at Xi'an Jiaotong University in 1994, completed his master degree of automatic control profession at Chinese Academy of Sciences in 2001 and completed his postdoctoral degree at Genome Research Institute, Singapore in 2012. His major research interests include bioinformatics and agricultural information engineering.

**Zhenqi Fan** received his master's degree in control theory and control engineering from Institute of Information Engineering, Inner Mongolia Science and Technology University. From 2005 to 2013, He was a lecturer, and from 2014 until now, he is an associate professor in the Department of Computer Engineering, Tarim University, China. His interests include agricultural informatization and digitalization technology.

**Xianqiang Gao** received his master's degree in computer application technology from College of Computer Science & Technology, Xi`an University Of Science and Technology. From 2009 to 2014, he was a lecturer, and from 2015 until now, he is an associate professor in the Department of Computer Engineering, Tarim University, China. His interests include data mining and computer application research.