Utilization of the Dark Green Color Index to Determine Cotton Nitrogen Status

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RESEARCH PROBLEM

Inadequate or excessive applications of fertilizer N in cotton are financially and environmentally costly. Timely in-season determination of the N nutritional status of cotton can help producers combat these negative effects; however, current methods of N determination are often time consuming and/or expensive. More instantaneous, accurate methods of determining N status, which utilize equipment already in the possession of the producer, are needed.

BACKGROUND INFORMATION

Recent work utilizing an inexpensive digital camera and image processing software to calculate the dark green color index (DGCI) has resulted in successful determination of corn and turf N status (Karcher, 2003; Rorie et al., 2011). The objective of this research was to examine the effectiveness of the DGCI derived from standard digital photographs and image-analysis software to determine the N status of cotton and to compare sensitivities of calculated DGCI from laboratory, field nadir, and field off-nadir photographs to measurements of leaf N concentrations from laboratory and chlorophyll meter determinations.

RESEARCH DESCRIPTION

The trial was planted with cotton (Gossypium hirsutum L.) cultivar Stoneville 4288 B2RF on 27 May 2011 at the Lon Mann Cotton Research Station near Marianna, Ark. Fertilizer N rates included 0, 30, 60, 90, 120, and 150 lb N/acre applied as urea applied in a single preplant application and incorporated to create a wide range of plant N status. Leaf sampling, chlorophyll meter readings and digital pictures were taken at the third week of flowering. Field nadir and field off-nadir (approximately 60° from nadir) pictures were taken of the canopy with an inexpensive digital camera (Canon PowerShot SD450, Lake Success, N.Y.)
against a neutral pink color board that included yellow and green disks which served as interval color standards (Fig. 1). Two most recently matured, fully expanded leaves 4-6 nodes from the terminal were sampled and placed on ice. Chlorophyll meter (Minolta SPAD-502, Konica Minolta Sensing, Inc., Tokyo, Japan) measurements and pictures of the leaf samples were taken indoors under fluorescent lighting against a standardized color board (referred to as laboratory DGCI) within 2 hours of sampling (Fig. 2). Leaf samples were then dried and leaf N concentration of sample was determined by the Agricultural Diagnostic Laboratory at the University of Arkansas in Fayetteville, Arkansas.

Images were processed using SigmaScan Pro v. 5.0 (Systat Software, Inc., San Jose, Calif.). This software normalized each image using internal color standards prior to the calculation of DGCI. A full description of the DGCI calculation used can be found by Rorie et al. (2011). Images were manually cropped and cleaned to eliminate noise in analysis. Linear regressions of the replicate data examining the relationships between DGCI measurements (field nadir, field off-nadir, and laboratory), SPAD readings, and leaf N concentrations were performed in JMP 9 (SAS Institute Inc., Cary, N.C.).

RESULTS AND DISCUSSION

Visible differences in N status due to treatment were noted at sampling; cotton receiving 0 lb N/acre appeared stunted and yellow in color, while cotton receiving 150 lb N/acre appeared much larger and dark green in color (Fig. 1). The regressed replicate data indicated the response of leaf N concentration to fertilizer N rate was significant, positive and linear ($r^2 = 0.55$, data not shown) and measured leaf N values reached and exceeded published critical values (Bell et al., 2003).

Field nadir and off-nadir DGCI readings did not correlate as strongly to leaf N as laboratory DGCI readings (Fig. 2). The laboratory DGCI readings were also slightly more sensitive to leaf N ($r^2 = 0.603$) than SPAD readings were to leaf N ($r^2 = 0.561$, not shown). Coefficients of determination with leaf N ranged from 0.44 for the nadir DGCI readings to 0.603 for the laboratory DGCI readings. Stronger relationships between laboratory DGCI readings and leaf N than between all other methods may be due to the laboratory method’s inclusion of all plant material used to determine leaf N concentration. In contrast, the SPAD meter measured only a portion of each leaf and the field nadir and off-nadir methods included upper canopy plant material which was not in the leaf N measurement.

The relationship between nadir laboratory DGCI readings and SPAD readings was strong (Fig. 2). This strong relationship is logical, as both measurements are conducted on the same tissue. Failure of the field nadir and off-nadir DGCI readings to correlate as strongly with SPAD readings is again most likely due to the inclusion of tissue in the field images that was not actually sampled by the SPAD meter. However, the relationship between SPAD readings and field off-nadir DGCI readings was also quite strong ($r^2 = 0.818$). These results suggest that field off-nadir images may be the most practical method for in-field determination
of cotton N status since the relationship between laboratory DGCI readings and SPAD readings was only slightly higher but consisted of leaf sampling, storing, transportation, and more required time than other methods. The full article can be found in Raper et al. (2012).

PRACTICAL APPLICATION

Initial results indicate digital image analysis as a practical and inexpensive method sensitive to cotton N status which could possibly replace chlorophyll meters. Although laboratory images are the most sensitive to changes in leaf N and SPAD readings, field off-nadir images seem to be the most practical method of cotton N status determination for the producer since it requires no destructive sampling and much less time. Further research across years and sites is necessary to establish critical DGCI values for cotton and streamline the image processing. An effective extension program could be easily set up to allow producers to email or picture message off-nadir images of the crop of interest with a standardized color board for instantaneous determination of cotton N status.

LITERATURE CITED

Fig. 1. Field off-nadir images of plots receiving 150 lb N/acre (left) and 0 lb N/acre (right) with standardized color board in the background. Standardized color board consists of a dark green and yellow color chip on a neutral pink background to allow the normalization of each image during analysis. The high N rate treatment was taller and visibly darker green than the 0 lb N/acre treatment.
Fig. 2. Simple linear regression and coefficients of determination between laboratory DGCI, field nadir DGCI, field off-nadir DGCI and leaf N or SPAD readings during 2011 at the third week of flowering near Marianna, Arkansas.