MID-SEASON ESTIMATES OF COTTON LINT YIELD RESPONSE TO NITROGEN FERTILIZER USING IN-SEASON PLANT-BASED INDICES

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Abstract

With recent declines in acreage, a refined N-management system that has the potential to improve N use efficiency is essential to maintain productivity and environment-friendly cotton industry. Remote sensing is a precision agriculture technique for instant and non-destructive acquisition of crop spectral information, which has the potential to improve management decision making, especially N fertilizer recommendations. This sensor-based approach requires a model for an in-season estimate of the likelihood of obtaining a response to sidedress N. Therefore, it is necessary to identify what are the in-season plant indices that can be used to evaluate lint yield response to N fertilizer. The objective of this study was to determine if N requirement to maximize lint yield can be estimated using response of plant variable to N rate at mid-season. The study was initiated in three growing locations in northeast Louisiana. Linear-plateau models were used to determine optimal N rate estimates using various plant indices. Two weeks after early bloom showed the highest number of similar predictions using in-season plant indices and lint yield. The two non-destructive plant indices, NDVI readings and plant height, showed the best response with the N rate. Combining two or more plant indices as predictor variables has the potential to improve the model for in-season estimation of lint yield response to N and therefore should be further investigated.

Introduction

Nitrogen (N) has attracted concerns in cotton production systems in Louisiana over increasing cost of N fertilizers, N use efficiency (NUE), and N loss to the environment. Nitrogen management decisions remain a real challenge because vast diversity of the alluvial and upland soils that cotton is commonly grown on in Northern Louisiana. These soils are characterized by seasonal variations compounded by poor synchrony of N to crop demands (Shanahan et al., 2008). As a result, in-season evaluation of crop N status is essential to develop a more robust N fertilization scheme for cotton. The application of ground-based remote sensors as an N decision management tool to guide temporal and spatially variable N rate for cotton production has grained interest since the effective development of N fertilizer schemes for corn and wheat (Martin et al., 2007; Raun et al., 2002). The approach is to develop N management decision tools that are based on a cotton lint yield potential equation and an N response index to project lint yield level and available soil N, respectively.

Several recent sensor-based studies on cotton did not address the relationship, if any, between cotton N response and other plant-based diagnostic tools (Stamatiadis et al., 2005; Zhao et al., 2007). Tools, such as: chlorophyll content (Hawkins et al., 2007), tissue N concentration (Bronson et al., 2001), and plant height (Freeman et al., 2007), have been implemented to evaluate mid-season crop response to N fertilizers. The objectives were therefore to (1) determine if early to mid-season plant indices (height, tissue N concentration, chlorophyll content, and normalized difference vegetative index-NDVI) can be used to relate lint yield response to N fertilization, and (2) determine if N requirement to maximize lint yield can be estimated using responses of plant variables to N rate at mid-season.

Materials and Methods

The study was initiated in three locations in northeast Louisiana; these locations are on an irrigated Gigger silt loam in Winnsboro, LA, a Sharkey clay and Commerce silty clay loam in Saint Joseph, LA. The varieties used were Stoneville for Gigger silt loam and Commerce silty clay loam, and Deltapine for Sharkey clay. Cotton seeds were planted in four rows with 102 cm row spacing and the plots measured 12 m in length. Six different N rates of 0, 34, 67, 101, 134, and 168 kg ha^{-1} were applied to the plots pre-plant. Plant height, SPAD readings, tissue samples, and NDVI were collected at early square, early bloom, two weeks after early bloom (representing mid-bloom), and four weeks after early bloom (representing late bloom) and lint yield was collected at harvest. Normalized difference vegetative index reading was taken along the two middle rows using the GreenSeeker^{TM} handheld sensor (NTech Industries Inc. Ukiah, CA). Fifteen plants were randomly selected from the two middle rows for plant height, SPAD reading, and tissue samples collection. Tissue samples were digested by wet ashing with concentrated H_2SO_4 and 30% H_20_2 (Parkinson and Allen, 1975). Then the sample digests were analyzed using a salicylate colorimetric procedure by Kempers and Zweers (1986). Linear-plateau model was used to determine the optimal N rate at mid-season using tissue N, plant height, chlorophyll content, and NDVI and at harvest using lint yield.

Results and Discussion

All growth stages showed similar predictions between mid-season plant indices and cotton lint yields. However, two weeks after early bloom, "mid-bloom", show the highest number of similar predictions between mid-season plant indices and cotton lint yields (not shown). Using a linear-plateau model, optimum N rate for each site-year was established (Table 1). The values for optimum N rate ranged from no additional N need, due to not showing a response from N rate, to 206 kg N ha^{-1}.

Table 1. Nitrogen rate required to maximize yield determined using a linear-plateau model.

Variable	2008 Commerce silty clay loam	2008 Gigger silt loam	2008 Sharkey clay	2009 Commerce silty clay loam	2009 Gigger silt loam	2009 Sharkey clay
Lint Yield	113†	101	NA‡	124	101	126
NDVI	37	99	NA	118	NA	152
SPAD	75	120	51	13	207	70
Height	NA	90	NA	143	86	136
Leaf N	NA	135	69	144	168	82

† N rates are given in kg N ha^{-1}
‡ Results not given due to the effect of N rate was not significant

Most site-years have a significant N rate effect (Table 2.). However, on the Sharkey clay in 2008 there was not a significant effect of N rate on lint yield, NDVI, or height. This potentially could show the stronger similarities between the response of NDVI and height compared to the lint yield response to N rate.

Table 2. P-values for N rate effect.

Variable	2008 Commerce silty clay loam	2008 Gigger silt loam	2008 Sharkey clay	2009 Commerce silty clay loam	2009 Gigger silt loam	2009 Sharkey clay
Lint Yield	0.031	0.001	0.412	<0.001	<0.001	<0.001
NDVI	<0.001	<0.001	0.104	<0.001	0.067	0.013
SPAD	0.005	0.003	0.005	0.003	0.025	<0.001
Height	0.162	0.001	0.915	<0.001	<0.001	<0.001
Leaf N	0.562	<0.001	<0.001	<0.001	<0.001	<0.001

Plant height showed the highest correlation to N rate for the Commerce silty clay loam in 2009, Gigger silt loam in 2008 and 2009 (Table 3.). Tissue N concentration showed the highest relationship in response to N rate for the Sharkey clay in 2009; while NDVI readings showed the strongest relationship with the N rate for the Commerce silt loam in 2008.

Table 3. Coefficient of determination (r^2) values of the linear-plateau models fitted to plant indices and nitrogen rate.

	2008	2008	2008	2009	2009	2009
Variable	Commerce silty clay loam	Gigger silt loam	Sharkey clay	Commerce silty clay loam	Gigger silt loam	Sharkey clay
Lint Yield	0.140	0.217	NA	0.557	0.651	0.686
NDVI	0.319	0.340	NA	0.426	NA	0.176
SPAD	0.212	0.189	0.170	0.232	0.121	0.566
Height	NA	0.229	NA	0.610	0.450	0.463
Leaf N	NA	0.466	0.339	0.563	0.274	0.859

†Results not given due to the effect of N rate was not significant

Summary

In general, the response of plant variables to N rate, two weeks after early bloom has potential to relate to cotton lint yield response to N. However, there are a number of similar predictions on earlier growth stages, such as early square and early bloom. Our results showed that the plant indices, in this study, can be used as tools to determine the optimum N rate at mid-season based on cotton's response to N rate. More research will be needed to investigate this relationship further. Using this relationship, a model can be developed to predict lint yield response to N fertilizer using the response of plant variables to N rate at mid-season.

Development of a model that can integrate multiple mid-season plant variables needs to be further investigated. The implementation of two or more plant indices has the potential of either increasing the time frame in which these cotton variables can be measured or further improve the relationship between these plant variables and the response of lint yield to N rate. Plant height and NDVI are two plant variables that should be evaluated due to each index's non-destructive, on-the-go capabilities. With this model, cotton producers in the Mid-South region could potentially be able to more accurately determine side-dress N rates need for optimal cotton production.

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