Nitrogen Deficiency alters Cotton Reproductive Performance and Fiber Quality

Suresh B. Lokhande and K. Raja Reddy

Department of Plant and Soil Sciences
Mississippi State University, Mississippi State, MS, USA

Introduction and Rationale

- Growth, reproductive performance, yield, and fiber quality of upland cotton (*Gossypium hirsutum* L.) will be influenced by genetics, nutrients supplied and other environmental conditions (Reddy 2004) .
- Plants respond continuously to changes in nutrient supply and other abiotic factors. Nitrogen is a major element for plant vegetative and reproductive growth and development.
- Nitrogen deficiency affects several aspects of cotton growth and development including fiber quantity and quality (Read *et al.*, 2006).
- A comprehensive database on nitrogen stress effects on several aspects of cotton growth and development has been established and incorporated into cotton simulation model, GOSSYM. But model is still doesn't have fiber properties due to lack of quantitative fiber quality functional data as a function of nitrogen.
- The process-specific functional algorithms developed in this study may improve the predictive capability of the cotton models including fiber quality for natural resource management in the field and in assisting policy decisions under variable climatic conditions.

Objectives

- To study the effects of nitrogen stress on cotton growth, reproductive performance, and fiber properties.
- To develop the functional algorithms for nitrogen deficiency-dependent growth, physiological processes and fiber quality parameters.

Materials and Methods

The experiment was conducted in sunlit controlled environment chambers known as SPAR (Soil-Plant-Atmosphere-Research; Plate 1) at the Mississippi State University's Plant Science Research Center, Mississippi State, MS, during the 2009 growing season. Cotton cultivar TM-1 was grown with fine sand as growing medium. Plants were irrigated with automated drip irrigation system.

Treatments

Two nitrogen treatments of 100 and 0 % of Nitrogen (N) concentration were imposed from flowering to maturity stage of the crop. The plants were grown at optimum temperature (30/22°C) and 400 ppm CO_2 throughout the study. Prior to treatment conditions, all plants received full-strength Hoagland nutrient solution and during the treatment period, plants were well-watered with respective nutrient solutions with all other nutrients.

Measurements

- Stem lengths and node numbers were recorded once a week after emergence to few days after flowering stage.
- Leaf photosynthesis, chlorophyll content, and chlorophyll stability were measured every alternate week over time from 0 to 56 days after treatment.
- Total as well as various plant biomass components along with boll numbers per plant were recorded at the end of experiment.
- Individual boll components such as boll, seed cotton, lint, and, seed weight per boll were recorded at end of experiment.
- Fiber properties were estimated by HVI (High Volume Instrument).

Data analysis

- To test the significance of different nitrogen stress regimes on growth and development and fiber parameters, ANOVA was performed using general linear model "PROC GLM" procedure in SAS.
- Sigma Plot 11.0 was used to fit the curves and regression analysis.

Plate 1. Soil-Plant-Atmosphere-Research (SPAR) Facility

Results

I. Leaf nitrogen concentration

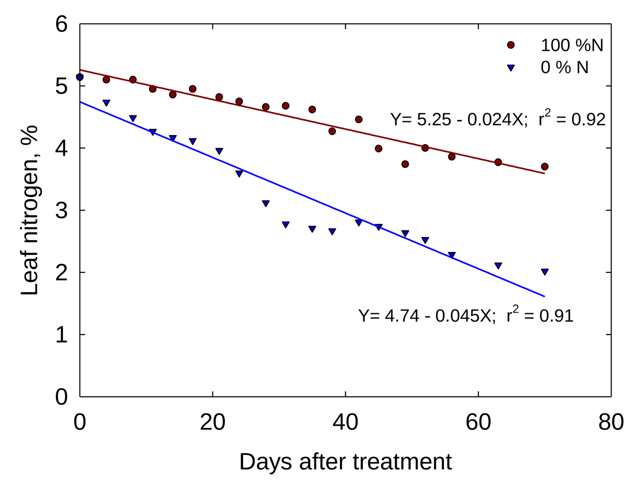


Fig. 1. Temporal trends in cotton leaf N concentrations as influenced by nitrogen treatments.

- The strategy of growing plants until flowering with 100%N and imposing N treatments during the fiber development period worked well for the purpose of achieving variability in leaf N and fiber and to derive functional relationships between various processes and leaf N. (Fig. 1)
- Leaf N declined in both the treatments, with steeper decline at 0% N (slope: -0.045) than at 100% N (slope: -0.024) treatments.

II. Gas exchange parameters

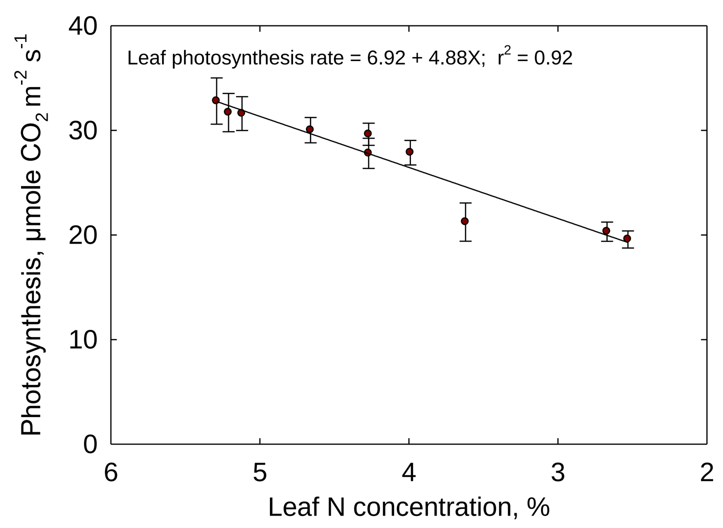


Fig. 2. Relationships between photosynthesis rate as a function of leaf nitrogen content.

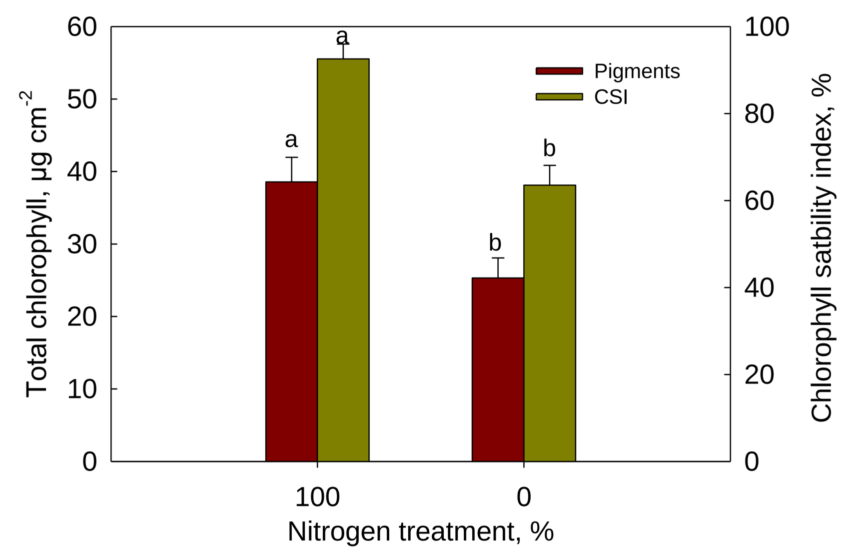


Fig. 3 Influence of nitrogen treatments on total leaf chlorophyll and chlorophyll stability index, 56 DAT.

- Leaf photosynthesis rate measured at 1500 PAR substantially declined with nutrient deficient condition (r^2 = 0.92, Fig. 2). Total chlorophyll content and chlorophyll stability indices measured at 56 days after treatment showed significant difference (P = 0.014 and P = 0.001, respectively) between sufficient and deficient nitrogen treatments (Fig. 3).

III. Reproductive parameters

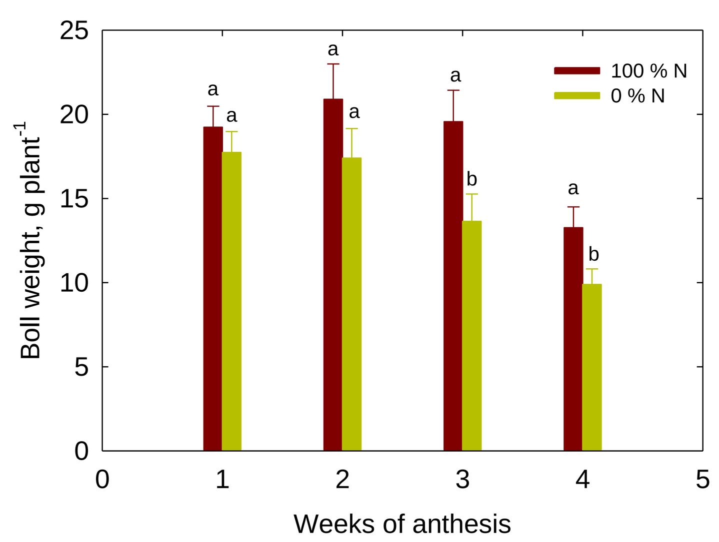


Fig. 4. Nitrogen stress effect on total boll weight.

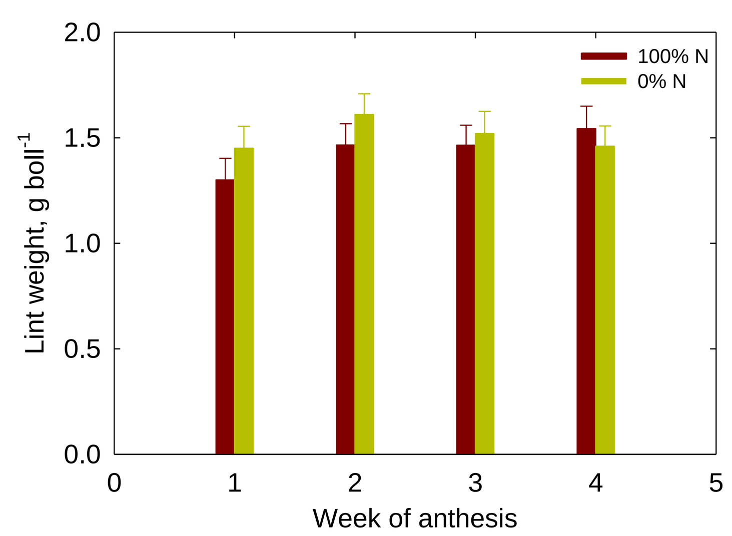


Fig. 5. Influence of nitrogen stress on lint weight per boll

- Total boll weight per plant was significantly declined (P = 0.013) in N-deficient treatment in later part of flowering because of fewer number of bolls produced and retained (Fig. 4). N-deficient plants did not show significant reduction in lint weight as compared to optimum N-level (Fig. 5). Decrease in weights under N stress was more related to reduction in total boll number than bolls that were retained.

IV. Fiber properties

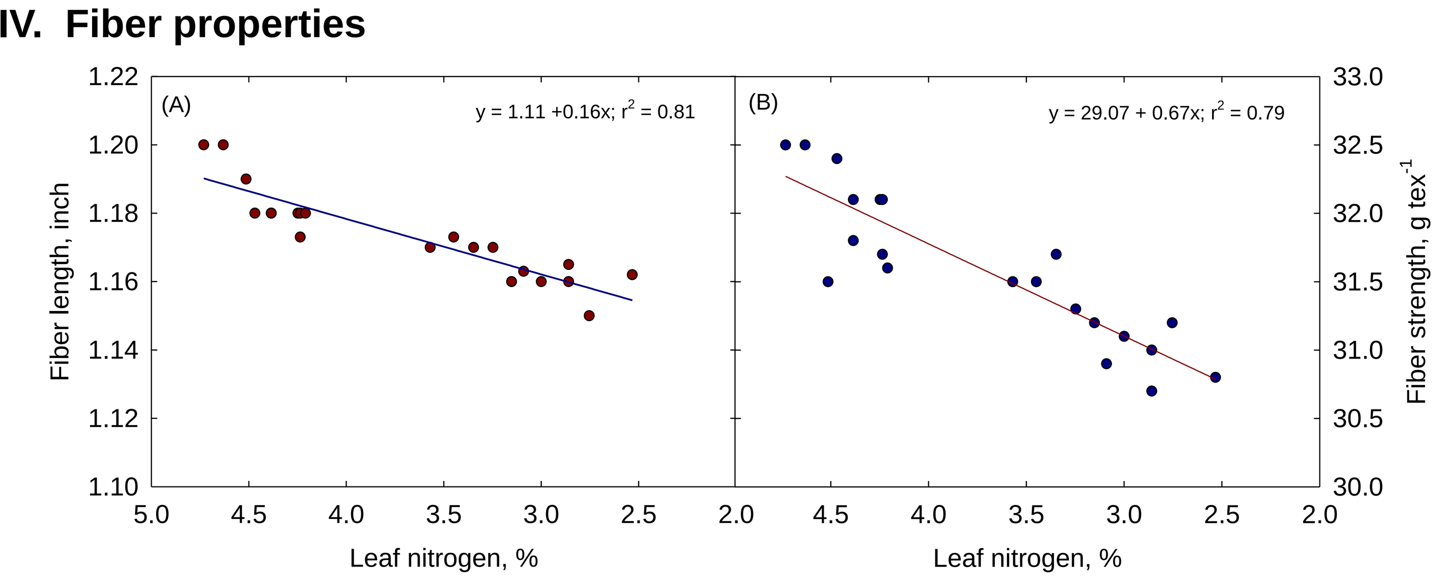


Fig. 6. Relationships between fiber length (A) and fiber strength (B) as a function of leaf nitrogen content.

- Fiber length showed a linear decrease with reduction in leaf nitrogen concentration (r^2 = 0.81, Fig. 6A), indicating positive association with leaf N during boll maturation period.
- Fiber strength increased with increase in leaf N (r^2 = 0.79, Fig. 6B).

Results cont.…

IV. Fiber Properties cont..

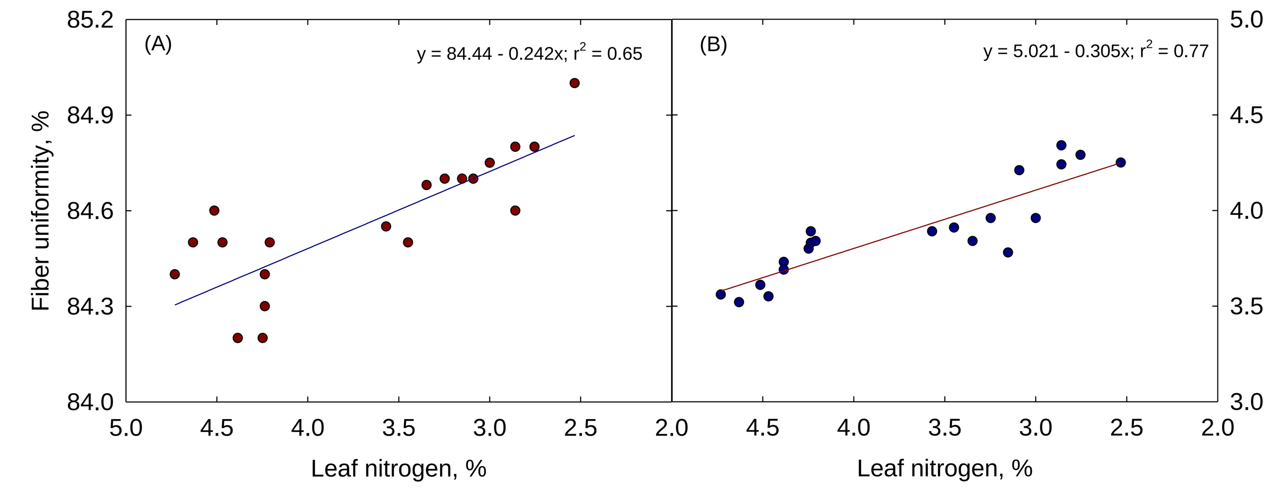
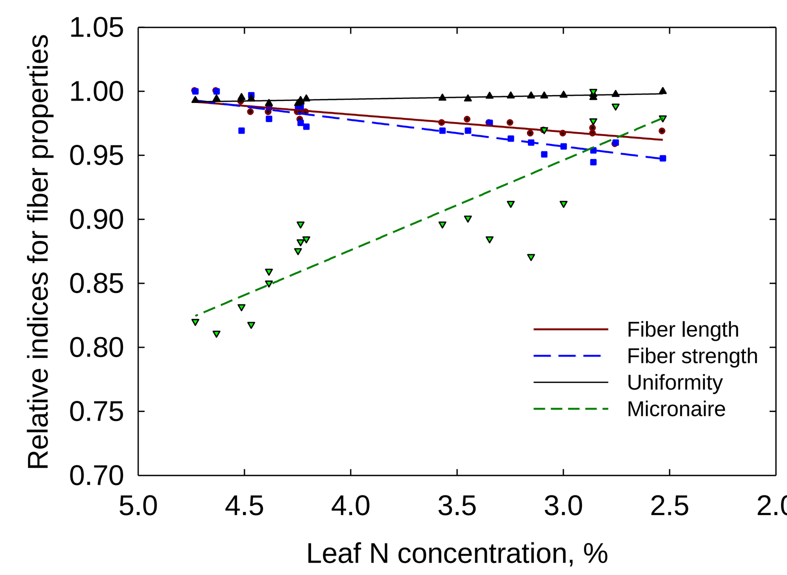


Fig. 7. Relationship between nitrogen and (A) fiber uniformity and (B) micronaire as function of leaf nitrogen content.

- Unlike fiber length and strength, fiber uniformity (r^2= 0.65, Fig. 7A) and micronaire (r^2= 0.77, Fig. 6B) decreased with increase in leaf N levels.

V. Relative responses



- Fiber length
  y = 0.92 + 0.014x; (r^2 = 0.81)
- Fiber strength
  y = 0.89 + 0.021x; (r^2 = 0.79)
- Uniformity
  y = 1.00 - 0.003x; (r^2 = 0.61)
- Micronaire reading
  y = 1.15 - 0.07x; (r^2 = 0.77)

Fig. 8. Relative responses of fiber quality parameters to cotton leaf nitrogen concentration

- Although fiber strength and length shows declining trends with decrease in leaf N concentration, fiber strength was more responsive to changes leaf N than fiber length (Fig. 8).
- Among all the fiber properties, micronaire was more responsive to changes in leaf N concentration followed by fiber strength, length and uniformity (Fig. 8).

Conclusions

- Cotton leaf photosynthesis rate and leaf chlorophyll content declined substantially in nitrogen stressed plants when compared to plants growth under optimum N levels.
- Total biomass and number of bolls per plant were significantly reduced under N deficient conditions. The weight of retained bolls under N stressed plants, however, was not different from that of plants with sufficient N.
- Fiber parameters that are of interest to textile industry were all altered by nitrogen stress; length and strength increased with leaf N while fiber uniformity and micronaire declined with leaf N levels.
- Nitrogen deficiency produced cotton with shorter fibers, lower strength and high micronaire and uniformity values.
- The functional algorithms developed in this study could be useful in developing quantitative nitrogen response functions for fiber quality and if incorporated in cotton simulation models will enhance the usefulness of the model applications.

References

Read, J.J., K.R. Reddy, and J.N. Jenkins. Yield and fiber quality of Upland cotton as influenced by nitrogen and potassium nutrition. *European Journal of Agronomy*, 2006. 24(3): p. 282-290.

Reddy, K.R., et al. Interactive effects of carbon dioxide and nitrogen nutrition on cotton growth, development, yield, and fiber quality. *Agronomy Journal*, 2004. 96(4): p. 1148-1157.