2003 BELTWIDE COTTON CONFERENCES, NASHVILLE, TN – JANUARY 6-10

ESTIMATING COTTON'S NITROGEN NEEDS

R.L. Nichols
Cotton Incorporated
Cary, NC
C.J. Green
Texas Tech University
Lubbock, TX

Abstract

Nitrogen (N) is frequently the most expensive plant nutrient applied to cotton (*Gossypium hirsutum*). A single, inexpensive soil-test that would predict the availability of N from the soil during the growing season is desirable. However, because N is chemically dynamic in the environment, no single soil-test accurately fulfills this need. Therefore, the amount of supplemental, fertilizer N required to achieve optimum cotton yields cannot be readily determined by soil testing alone. Consequently, cotton's annual N needs are often estimated by means of a material-balance analysis. Research suggests that cotton removes about 50-55 lbs. of N/bale as seed plus lint. Thus 2- and 3-bale crops would require about 100-110 and 150-165 lbs. N/acre-year, respectively. However, not all of the N taken up by cotton must be applied as fertilizer, since there are several environmental sources of N. Rainfall and/or irrigation water often supply 20 lbs. N/acre-year. Also, nitrate-N in the soil profile, above the 4-ft. depth, should be readily accessible to cotton roots. Recent research in California and Texas suggests that 50 lbs. N/acre are usually present in the 4-ft horizon, and depending on the previous crop and winter rainfall, larger amounts are frequently found. About a half-ton of organic N is present in the first half-foot of soil for every percent of organic matter in the soil. While few estimates of the rate of turnover of soil organic N are available for cotton production systems, an estimated conversion of 30- 50 lbs. N from organic forms to nitrate-N per 1% organic matter per year is probably conservative. With the present lack of yield increase in cotton, the trend to increasing rates of N fertilization is probably unjustified. Rather, growers are encouraged to make realistic estimates of crop yields, utilize knowledge of cropping history and recent rainfall, and use spring soil nitrate tests, as appropriate, to adjust rates of N fertilizer. Recent research suggests that N rates greater than 75-100 lbs. or 120-150 lbs. N/acre for 2 or 3-bale crops, respectively, infrequently cause yields to increase above the levels achieved by these rates. In fact, when fertilizer N is applied in excess of such rates, cotton management costs may increase due to increased vegetative growth, increased susceptibility to certain insects, delayed maturity and/or difficulty in preparing for harvesting.

Estimating Yield Goals

Environmental conditions are frequently the largest sources of crop yield variation, especially if the crop is grown without supplemental irrigation. Thus, all pre-season yield estimates are speculative in part. However, conservative yield goals can be derived from recent field histories and the present year's management intentions. To control costs by utilizing only realistic inputs, we suggest that if a manager projects a greater than 10% increase above a field's most recent five-year average, the manager should identify the agronomic factors that would provide the basis for the anticipated increase. Factors that may cause a substantial yield increase include planting cotton after a rotation crop in a field that had been a cotton monoculture, or identifying and developing a plan to treat a previously undiagnosed or ineffectively treated pest problems, such as the presence of plant parasitic nematodes that were found above threshold levels.

Estimating Nitrogen in the Cotton Crop

The cotton plant's harvest index, the ratio of the lint plus seed to the total biomass, varies with variety, environment, and management (Boquet & Breitenbeck, 2000). However, research from different parts of the Cotton Belt suggests that high-yielding cotton crops contain about 50-55 lbs. N/bale (Basset et al., 1970; Mullins & Burmester, 1990; Unruh and Silvertooth, 1996).

Based on crop removal of N, the total quantity of N required by the crop per acre can be estimated as follows:

1. Estimated Yield in lbs. per acre
2. Divide by 480 lbs./bale
3. Multiply by 50-55 lbs. N/bale

Result = Estimate of lbs. of N in the Crop.

Estimating Nitrogen Availability and Fertilizer Needs

An optimal N rate may be defined as the highest rate of applied N that will provide an incrementally significant yield increase ($P < 0.05$). For a specific field and season, the optimal N rate can only be known conclusively after the fact from the results of an on-site, N-rate response test. However, the principles of estimating crop nutrient needs from crop nutrient budgets are well documented, and can be used to estimate the rate of supplemental N fertilization that will achieve a specific yield goal (Magdoff et al. 1997). Furthermore, tools are available to determine the crop's N status during the growing season (Bronson and Green, 2003).

Whereas atmospheric nitrogen (N_2) is not reactive, several reduced and oxidized forms of N occur naturally in the biosphere. Higher plants, including cotton, will take up N from all biologically available forms whether they originate in air, water, or soil. Thus, estimation of N that is freely available from the environment is essential to making efficient use of fertilizer N. Increased combustion of fossil fuels, production and distribution of synthetic N fertilizers, and concentrated animal husbandry, has approximately doubled the supply of reactive N circulating in the biosphere above the background level that occurred in the recent past (Galloway and Cowling, 2002). Therefore, more reactive, and thus more biologically available N is now present in the environment than in former years. Atmospheric deposition of reactive nitrogen varies greatly among sites, depending on proximity of the location to emission source(s), but a conservative estimate of deposition, principally through rainfall, is 20 lbs. N/acre-year (Cowling et al. 2001). Soil organic matter is a relatively large N reserve, approximating one-half ton N/acre-foot per 1% organic matter, and soil N forms are continuously being cycled (Jansson and Persson 1982). While N turnover rates in soil vary greatly among sites, depending chiefly on temperature and moisture, a conservative estimate of soil N availability would be about 30- 50 lbs. N/acre-year from the type of low-organic matter (< 2%) agricultural soils that are characteristic of the Cotton Belt. For many agricultural soils where cotton is grown, long histories of N fertilization apparently have resulted in large pools of soil-nitrate in the upper 4 foot of the soil profile (Hutmacher et al. submitted to Agron J.; Hons et al. 2001). Soil samples taken in the spring give a good indication of N that is readily available at planting.

Crops grown following legumes often require less supplemental fertilizer N than they would otherwise. Such a reduction in the economically optimum N fertilizer rate is known as a *nitrogen credit*. As the crop residue of leguminous crops breaks down in the soil, *N mineralization* occurs and releases N for subsequent crops. Mitchell (2000) states that, "Cotton following a good soybean or peanut crop will benefit from some residual N, but predicting the response is difficult." In Alabama, the contribution of peanuts to a succeeding crop is estimated at 30-40 lbs. N/acre (Mitchell, 2000). In Georgia, N recommendations are about 30-40 lbs. N/acre for cotton grown in rotation with peanuts and about 80 lb. N/acre for continuous cotton (Harris and Baker, 1997). However, Harris and Baker (1997) reported no yield response above 20 lbs. N/acre for cotton grown following peanuts. Considering the factors stated above, an estimation of the supplemental mineral fertilizer N required to achieve the yield goal can made by finding the difference between the N in the crop, and the N that will be available from environmental sources.

Lbs. of N in the Crop, as Estimated from the Yield Goal

- minus estimated lbs. of Atmospheric Deposition
- minus estimated lbs. of N mineralized from Soil Organic Matter
- minus estimated lbs. of Soil Nitrate N measured in the spring
- minus N credit from a preceding legume crop, as applicable
- minus N derived from animal wastes or other organic amendments

Result = Minimum lbs. of Fertilizer N to ensure Sufficient N to Achieve the Yield Goal

Costs of Under or Over Applying Fertilizer Nitrogen

An obvious cost of under estimating and consequently under supplying N for cotton is loss of yield. While fertilizer N-sources are inexpensive, and when lint prices are profitable, there is little incentive to risk yield loss for relatively small savings in fertilizer costs. However, substantial over-application of N to cotton has costs, above that of the unnecessary fertilizer, that are well documented. The plant cell elongation inhibitor, mepiquat chloride, is widely used in cotton production to limit plant height. Because excess N tends to accelerate vegetative, at the expense of reproductive growth in cotton, the apparent need for height management, and, therefore, plant growth regulator treatment, is increased. While not readily apparent from the crop's appearance, overuse of N and remedial application of mepiquat chloride act as opposing effects. In such a situation, costs are increased by unnecessary over use of both N and mepiquat chloride, while yields are not increased and may be decreased (McConnell et al. 1992, Ebelhar and Welch, 1996). While the effect of excess N to increase the potential for boll rot has long been known (Boquet and Moore, 2000), increased susceptibility to cotton aphid (*Aphis gossypii*) in response to excess N has more recently been documented (Slosser et al., 1997; Cisneros and Godfrey, 2001). If over fertilization with N is a major contributing factor in mid-season aphid problems in Texas and California, the effect could be very costly, as multiple insecticide applications are often required in both areas, and aphid resistance to insecticides has been a major concern in recent years. The effect of excess N to delay crop maturity is well documented (McConnell et al. 1993), and closely related to increased difficulty and cost of defoliation when excess N persists late in the season (Roberts et al. 1996). Thus there are potentially substantial accumulating costs to over estimating cotton N needs as well as to under estimating them.

Effects of Miscalculation of Cotton's Fertilizer N Needs

Under Estimation of N Fertilizer Needs and Application of an Insufficient Rate:

- Loss of Yield, proportional to shortfall
- Consumption of Soil N reserve, depletion of soil fertility

Over Estimation of N Fertilizer Needs and Application of a Supra-optimal Rate:

- Excess Vegetative Grow, Increased Plant Growth Regulation Required
- Increased Susceptibility to Aphids
- Increased Susceptibility to Boll Rot
- Delayed Crop Maturity
- Increased Difficulty to Defoliate
- Potential for Long-Term Decrease in Soil Organic Matter
- Increased Need for Liming, through Soil Acidification

Literature Cited

Bassett, D.M., W.D. Anderson, and C.H. E. Werkhoven. 1970. Dry matter production and nutrient uptake in irrigated cotton (*Gossypium hirsutum* L.) Agronomy Journal. 62:299-303.

Boquet, D.J. and G.A. Breitenbeck. 2000. Nitrogen Rate Effect on Partitioning of Nitrogen and Dry Matter in Cotton. Agronomy Journal. 40:1685-1693.

Bronson, K.F. and C.J. Green. 2003. Cotton Nitrogen Requirements and In-Season Diagnostics. Proc. Beltwide Cotton Conf. CD-ROM.

Cisneros, J.J. and L.D. Godfrey. 2001. Midseason pest status of cotton aphid (Homoptera: Aphididae) in California cotton: Is nitrogen a key factor? Environmental Entomology 30:501-510.

Cowling et al. 2001. Optimizing Nitrogen Management in Food and Energy Production and Environmental Protection. Proc. of the 2nd International Nitrogen Conf. on Science and Policy. Potomac, MD. Oct. 14-18. vol. 1:1-9.

Ebelhar, M.W. and R.A. Welch. 1996. Evaluation of Plant Growth Regulators with Varying Nitrogen Management. Proc. Beltwide Cotton Conf. vol. (2):1415-1418.

Galloway, J.N. and E.B. Cowling. 2002. Reactive Nitrogen and the World: 200 Years of Change. Ambio 31(2):64-71 (a Journal of the Royal Swedish Academy of Sciences.)

Harris, G., and S. Baker. 1997. Nitrogen management for cotton following cotton on Coastal Plain soils. Proc. Beltwide Cotton Conf. vol. 1:576-577.

Hons, F.M., M.L. McFarland, and R.G. Lemon. 2001. Assessment of an Improved Nitrogen Recommendation System for Cotton. Cotton Incorporated Summary Reports. Cary, NC, pp. 154-155.

Hutmacher, R.B., R.L. Travis, D.L. Rains, B.A. Roberts, R.N. Vargas, B.L. Weir, S.D. Wright, D.S. Munk, B.H. Marsh, M.P. Keeley, F.B. Fritschi, D.J. Munier, and R.L. Nichols. Response of Acala Cotton to Variable Nitrogen Rates in the San Joaquin Valley of California: A case for new fertilizer guidelines. (submitted to Agronomy Journal Dec. 2002)

Jansson, S.L. and J. Persson. 1982. Mineralization and immobilization of soil nitrogen. pp. 229-252. *In* F.J. Stevenson (ed.) Nitrogen in Agricultural Soils. Agronomy Monograph. 22. ASA, CSSA, and SSSA. Madison, WI.

Magdoff, F., L.K. Lanyon, and B. Liebhardt. 1997. Nutrient Cycling, Transformation, and Flows: Implications for a More Sustainable Agriculture. Advances in Agronomy. 60:1-73.

McConnell, J.S., W.H. Baker, B.S. Frizzell, and J.J. Varvil. 1992. Response of Cotton to Nitrogen Fertilization and Early Multiple Applications of Mepiquat Chloride. Journal of Plant Nutrition. 15(4): 457-468.

McConnell, J.S. W.H. Baker, D.M Miller, B.S. Frizzell, and J.J. Varvil. 1993. Nitrogen Fertilization of Cotton Cultivars of Differing Maturity. Agronomy Journal 85:1151-1156.

Mitchell, C.C. 2000. Nitrogen rates for cotton in Alabama's long-term experiments. Proc. Beltwide Cotton Conf. vol. 2:1388-1392.

Mullins, G.L. and C.H. Burmester. 1990. Dry matter, nitrogen, phosphorus, and potassium accumulation by four cotton varieties. Agronomy Journal. 729-736.

Roberts, B.A., R.G. Curley, T.A. Kerby, S.D. Wright, and W.D. Mayfield. 1996. Defoliation, harvest and ginning. pp. 305-323. *In* S.J. Hake, T.A. Kerby, and K.D. Hake (eds.) Cotton Production Manual. Univ. of California, Div. of Ag. and Nat. Res. Pub. 3352. Oakland, CA.

Slosser, J.E., R. Montadon, W.E. Pinchak, and D.R. Rummel. 1997. Cotton aphid response to nitrogen fertility in dry land cotton. Southwestern Entomologist. 22:1-10.

Unruh, B.L. and J. C. Silvertooth. 1996. Comparisons between and Upland and Pima Cotton Cultivar: II. Nutrient uptake and partitioning. Agronomy Journal. 88: 589-595.