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

NITROGEN MANAGEMENT FOR MID-SOUTH COTTON PRODUCTION - OVERVIEW

M. Wayne Ebelhar and Joseph O. Ware
Mississippi Agricultural and Forestry Experiment Station
Delta Research and Extension Center
Stoneville, MS

Introduction

Cotton, like all organisms, requires nitrogen (N) for normal growth and reproduction. Few soils actually contain enough naturally occurring N to sustain high yields in most agronomic crops like cotton. Nitrogen utilization and yield response to N are greatly influenced by the availability of the N, no matter where it comes from. Inorganic N sources or organic N sources can both supply the needed N for crop production and the plant cannot distinguish between different sources. Many transformations, either biological or chemical, take place in the atmosphere, the soil, or in the plant, and are regulated by the environment and influenced by soil reaction (pH), microbial populations, N source, and many other factors. The response to fertilizer additions is variable from year to year and an understanding how different factors affect that response is critical to managing fertilizer use and efficiency. The response to fertilizers measured in experiments of similar pattern are usually consistent from year to year on soils which are either nutritionally very poor (much fertilizer is always essential) or on soils which are nutritionally very rich (fertilizer has little or no effect). Soils with intermediate fertility vary annually as a result of weather, soil conditions, cultivation, and nutrient balance.

Plant Growth

Plant growth is a function of two variables of nutrition, 1) Intensity - the concentration of individual nutrient elements as reflected in the tissue concentrations at a given stage of growth; and 2) Balance - refers to the relationship of the concentration of one element to the concentration of all other essential elements. A general knowledge of growth patterns is essential for understanding the nutrition of the crop. Basic knowledge includes the fact that 1) growth is morphologically indeterminate; 2) each fruiting branch produces flower buds at a constant rate, and 3) the rate of production of flower buds increases for a time but becomes level as older branches stop production. Mason's Nutritional Theory of fruit and bud shedding says that the supply of nutrients (primarily N and carbohydrates) limits the number of fruit that can be matured. Thus, nutritional requirements must be considered with reference to the yield expected. Nutrition generally affects the yield far more than it affects quality.

Nitrogen in Cotton

Nitrogen is available to cotton in two primary forms, nitrate (NO_3^-) and ammonium (NH_4^+). The N is incorporated into protein and other vital complex molecules. It can be absorbed in large quantities with the excess stored as the carboxylase enzyme. When uptake does not meet the plant's demands, then the N can be re-mobilized. Cotton is a perennial crop managed as an annual which means that adverse reactions are possible from excess N. High N leads to larger leaves which shade lower fruiting sites. This shading contributes to boll shed, leads to increased boll rot and other diseases, and delays opening and causes more immature fibers. High N favors vegetative plant growth , reduces early boll retention, causes defoliation problems from rank growth and leads to decreased yields with poorer quality. Deficiencies generally affect the entire plant and lead to lower total leaf area (reduced leaf expansion) and mainstem node production. The lower total leaf area sets limits on total photosynthetic capability and thus the total number of bolls that can be matured. The root system is decreased which affects both N and phosphorus (P) uptake. Nitrogen deficiency as well as excess N can lead to delayed maturity.

Nitrogen Cycle

It is important to understand how N cycles in order to understand the different pools which may contribute to the available N supply. The nitrogen cycle (Figure 1) can be divided into six basic steps.

Step 1. _Fixation Plus Plant and Animal Residues_. Fixation includes atmospheric fixation (lightning), industrial fixation which is the main source of inorganic N fertilizers, biological fixation such as symbiotic organisms and plant and animal waste which make up the organic N sources. Nitrogen is added to the soil.

Step 2. _Mobilization/Mineralization/Immobilization_. The residues are rotted by soil organisms (mobilization) releasing ammonia (NH_3) which converts to ammonium (NH_4^+). Plant roots absorb a portion of the ammonium. In this step the unavailable organic forms of N are converted to available inorganic forms. Mineralization and immobilization occur simultaneously in soil as microorganisms use inorganic N to build proteins for their own body tissue.

Step 3. _Nitrification_. Under conditions favoring plant growth, ammonium-N in soil is converted to nitrate-N which is a biological oxidation carried out by nitrifying bacteria. The rate of nitrification is affected by the supply of ammonium, the population of nitrifying organisms, soil reaction, soil aeration, soil moisture, and temperature.

Step 4. *Plant Uptake*. Nitrate and ammonium is taken up by plant roots, producing crops which can be consumed by humans or fed to livestock. The livestock in turn can then be consumed. Harvested crops remove much of the N from the soil and the amount depends on the kind and quantity of crop. This step is a consumptive use of N but it may return to the system through other processes.

Step 5. *Leaching*. Nitrate is totally soluble in water thus may leach at any time. It is an anion which makes it free to move in all directions with water and also through the soil profile. Because nitrate moves with water, the water-holding capacity of the soil influences the depth that nitrate can move. Leaching is a non-consumptive use of N and the N can be totally removed from the system leading to the potential for environmental contamination.

Step 6. *Denitrification*. Denitrification is considered the final step in the nitrogen cycle and replenishes the supply of N to the atmosphere. Denitrification occurs as certain soil organisms thrive in the absence of air and by being able to obtain their oxygen supply from the oxygen contained in the nitrate. Denitrification becomes a dominant factor in N behavior when a good supply of nitrate is available, when a large amount of undecomposed plant residue is present, and when there is a low oxygen supply (poorly aerated soil) usually caused by water saturation.

Nitrogen Management

Several factors must be considered with respect to nitrogen management. These factors include 1) nitrogen rate, 2) nitrogen source, 3) nitrogen application timing, 4) nitrogen placement, and 5) the interaction of N rate and plant growth regulators. In most situations, year-to-year variability in crop response to added N is due to with irregularities in the soil, the site, and the crop. Field experiments sample biological variability caused by unpredictable, and often unidentifiable, effects of weather, both on total yield, and on the chemical availability and physical accessibility of nutrients in the soil. To examine the overall effects of the above mentioned factor, it is important to look at each factor as it relates to mid-South cotton production.

1. *Nitrogen Rate*. Figure 2 illustrates the lint yield response to increasing N rates over a 3-year period at the Delta Research and Extension Center. The N rates ranged from 60 to 150 lb N/acre each year with yields that are quite different depending upon the year. In 1987, there was no significant yield increase when N rates were raised greater than 90 lb/acre. Total lint yields ranged from 891 to 1003 lb/acre. In 1988, lint yields ranged from 1266 to 1419 lb/acre with mixed results (Figure 2). The highest lint yield was obtained with 150 lb N/acre which was significantly higher than the yield obtained with 120 lb N/acre but not significantly higher than that obtained with 90 lb N/acre. In 1989, total lint yields ranged from 1006 up to 1375 lb/acre with no significant response above 120 lb/N acre.
2. *Nitrogen Source*. There are several N sources available for use in cotton fertilization. The plants take up nitrate or ammonium and do not care what source is used to supply those forms. The inorganic sources include a) anhydrous ammonia (82% N), urea (46% N), urea-ammonium nitrate solutions (28 - 32% N), ammonium nitrate (34% N), ammonium sulfate (20.5% N, 24% S), calcium nitrate (15.5% N), sodium nitrate (16% N), and potassium nitrate (13% N). For these sources, a pound of N is a pound of N but the sources do vary in the rate of availability to the plant root.
3. *Nitrogen Application Timing*. Various application timings have been evaluated over the years. In general, the closer to the time of need the application can be made, the less likely for adverse affects. On a Dundee sandy loam soil at the Delta Research and Extension Center over a 4-year period, research has shown a significant response to delayed sidedress applications of N compared to 100% preplant (100PP) N applications (Figure 3). With 50% of the total N applied at mid-bloom, seedcotton yields were 7.5% higher than when all the N was applied prior to planting.. Sidedress applications at pin-head square were only 96.7 % of the 100PP system. The difference between sidedress application at pin-head square and mid-bloom was 10.8% (Figure 3).
4. *Nitrogen Placement*. Nitrogen placement can deal with several aspects of management and can include surface applications compared to incorporation, starter fertilizers, band verses broadcast, and combinations of topsoil and subsoil applications. In the mid-South surface applications are more prone to loss than those which have been incorporated. Starter fertilizer, predominantly ammonium poly-phosphate, has been evaluated and not found to consistently improve yields. In the case of phosphorus deficiency and cool wet growing conditions early in the season, some response to starter has been observed. However, under proper planting conditions, starter fertilizer has not been an effective means of improving yield. Most of the phosphorus and potassium are broadcast applied and then incorporated. Nitrogen has been applied both as a band and broadcast with most sidedress N applied in a band. Some research has been conducted in the Mississippi Delta to examine the effects of topsoil and subsoil applications over a 4-year period under non-irrigated conditions. In drier years, subsoil N was found to give about 4.3% higher yields (Figure 4). The subsoil N was applied directly below the row in a vertical band from nine to 15 inches deep.
5. *Interaction of N and Plant Growth Regulators*. N management with plant growth regulators has been evaluated for years with no consistent results. In many studies, results have varied from significant increases, to no response , to significant decreases with plant growth regulators. Because cotton in a perennial plant, N management becomes more complex. Fruit load greatly dictates the growth of cotton plants and early fruit set with good retention usually eliminates the need for high rates of growth regulator. Figure 5 illustrates a 5-year summary of research at the Delta Research and Extension

Center involving N rates (60, 90, 120, and 150 lb N/acre) and mepiquat chloride applied at a rate of 16 oz/acre plus and additional 8 oz/acre compared to low rate multiple applications of 2 oz/acre. In this study, with yields ranging from 1050 to 1350 lb lint/acre, there was no significant increase in lint yield from the addition of mepiquat chloride. The mepiquat chloride did reduce the height of the plants by reducing inner node length, however this reduction did not translate into higher yields.

Selecting Optimum Nitrogen Fertilizer Practices

The key to nitrogen management in the mid-South is in selecting optimum nitrogen fertilizer practices. There are five steps in this process all of which are important.

Step 1. *Estimate the Probable Yield*. To estimate the probable yield, producers should use published yield potential for particular soils. These can be estimated from Soil Survey Reports, however, many of these reports are old and outdated. It is better to use experience and actual yields from recent years. With the development of yield monitors, yields maps can be used if they are dependable and accurate. The estimates should be modified for improvements which may be planned such as land-forming, drainage, irrigation, liming, or several other factors.

Step 2. *Estimate the Amount of N that Will Become Available from the Soil During the Growing Season*. Nitrogen is inherent in the organic matter in the soil and mineralizes during the growing season which releases N for plant uptake. The higher the organic matter content of the soil, the higher the amount of N that could be available for the crop being grown. The amount of N from residues of preceding crops could affect the available N pool. Green manure crops or cover crops can provide substantial N for subsequent crops. Producers must also consider the rotational effects from crops such as corn as well as the carryover of N from previous fertilizer applications. With the high rainfall and warmer conditions in the mid-South, carryover may not yield much benefit to subsequent crops. Downward movement of nitrate-N may provide N for deeper rooted crops especially during dry years where the cotton crop may be more deeply rooted.

Step 3. *Consider the Nitrogen Supplied from the Different N Sources*. Organic N sources such as manure, green manure, gin trash, chicken litter, and others may release N slowly depending on the C:N ratio of the material either applied or grown. Legume cover crops can release quite a bit of N during the growing season but it may not be in time for optimum plant utilization. Surface application of sources such as urea or urea-ammonium-nitrate solutions could lead to substantial volatilization losses. High rainfall in the spring prior to planting could lead to run-off, leaching in some cases, or even denitrification if fields become flooded after initial applications. Ammonium N sources are held on the exchange sites of clays in the soil and are not lost as quickly as nitrate N sources. However, as sidedress N sources, nitrates are soluble and readily absorbed by plants.

Step 4. *Decide on the Amount of Fertilizer N Needed for Optimum Economic Return*. The foremost economic consideration is the actual cost of the nutrient plus the cost of application. While anhydrous ammonia is the least expensive N source based on the cost per unit of N, application is more expensive because it requires specialized equipment and is also more hazardous to handle. While anhydrous ammonia is well suited to preplant applications, it is not as well suited for sidedress applications. Early season applications are subject to spring rainfall and the potential for loss. Should extra N be added to adjust for this possibility? Can losses be made up with sidedress applications? These questions can only be answered by the individuals making the decisions on the farm. The other factors to consider are the costs of labor to make the applications, specialized equipment, aerial application vs ground application, and several others. The last question but not the least involves environmental considerations. Early applications which are subject to loss may lead to excess N in the water leaving the fields.

Step 5. *Select the Most Appropriate Method and Best Time to Apply N*. The fundamental guiding principle to assure efficient utilization and minimize loss is to supply nitrogen as nearly as possible to the time it is needed by the crop. The optimum time to apply integrates a) the crop to be grown, b) climate, c) soil type, d) chemical formulation, e) labor distribution, and f) the supply and price outlook. These factors vary with the season and require in-season adjustments to modify the original decisions. Even the best laid plans may need to be modified or supplemented after the season is underway.

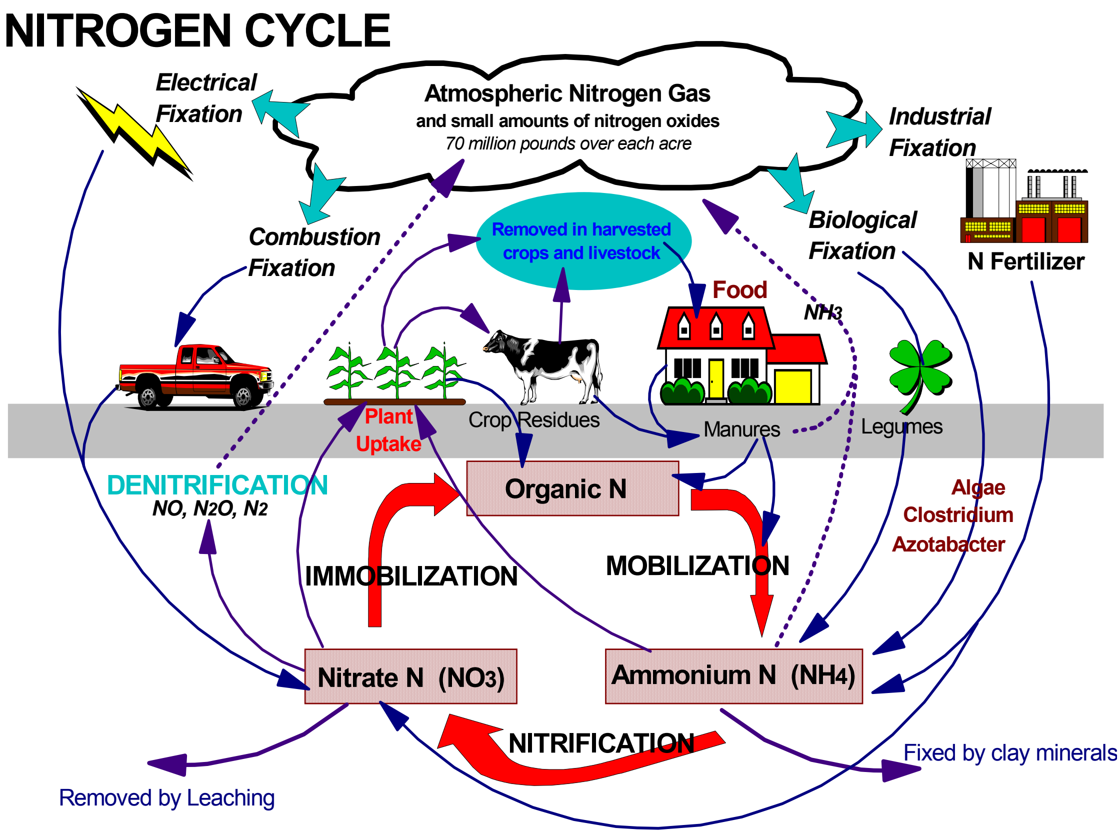

Figure 1. Nitrogen Cycle.

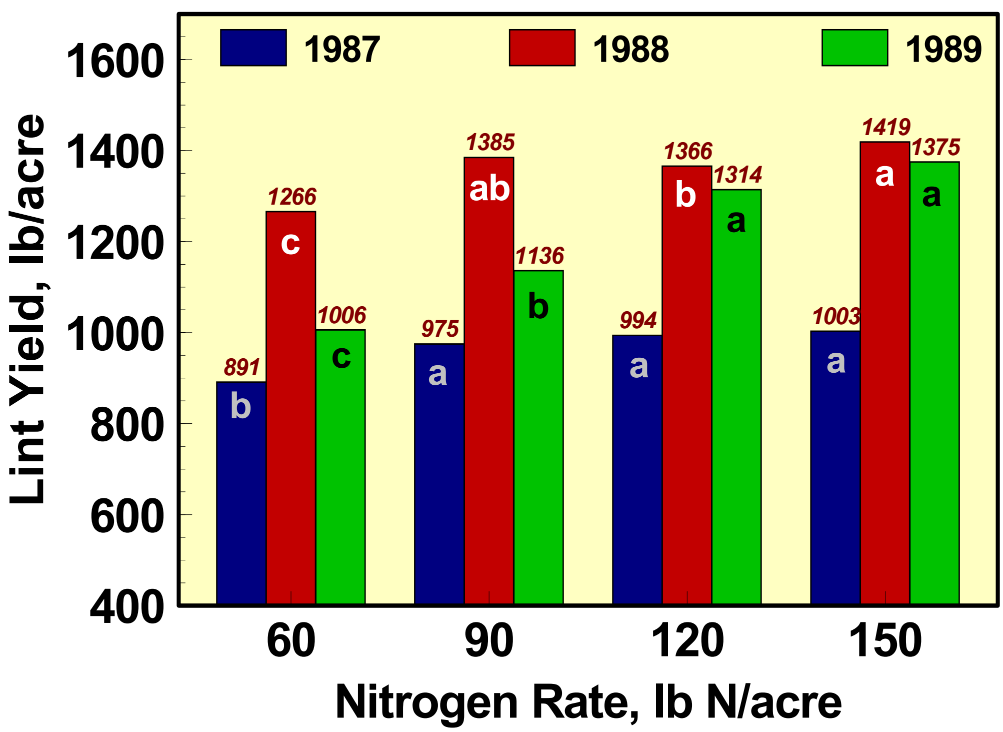

Figure 2. Total lint yield response to increasing nitrogen rates at the Delta Research and Extension Center, Stoneville, MS. 1987-1989.

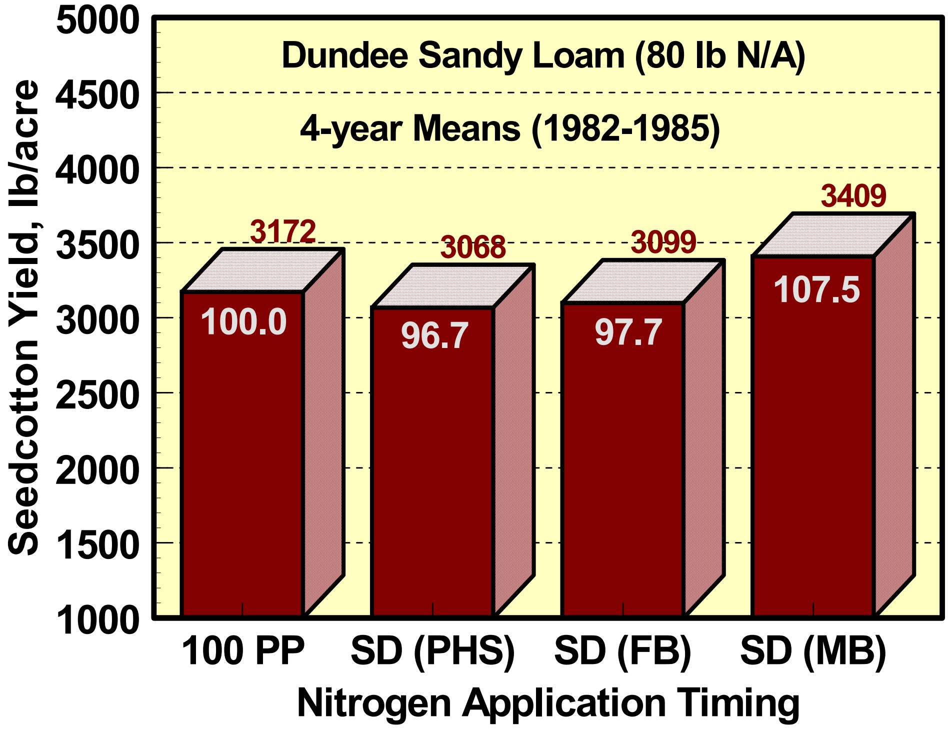

Figure 3. Total seed cotton yield response to sidedress nitrogen applications. 100 PP = 100% Preplant N; SD(PHS) = 50% PP + 50% at pin-head square; SD (FB) = 50% PP + 50% at first bloom: SD (MB) = 50% PP + 50% at mid-bloom. Delta Research and Extension Center, Stoneville, MS (1982-1985).

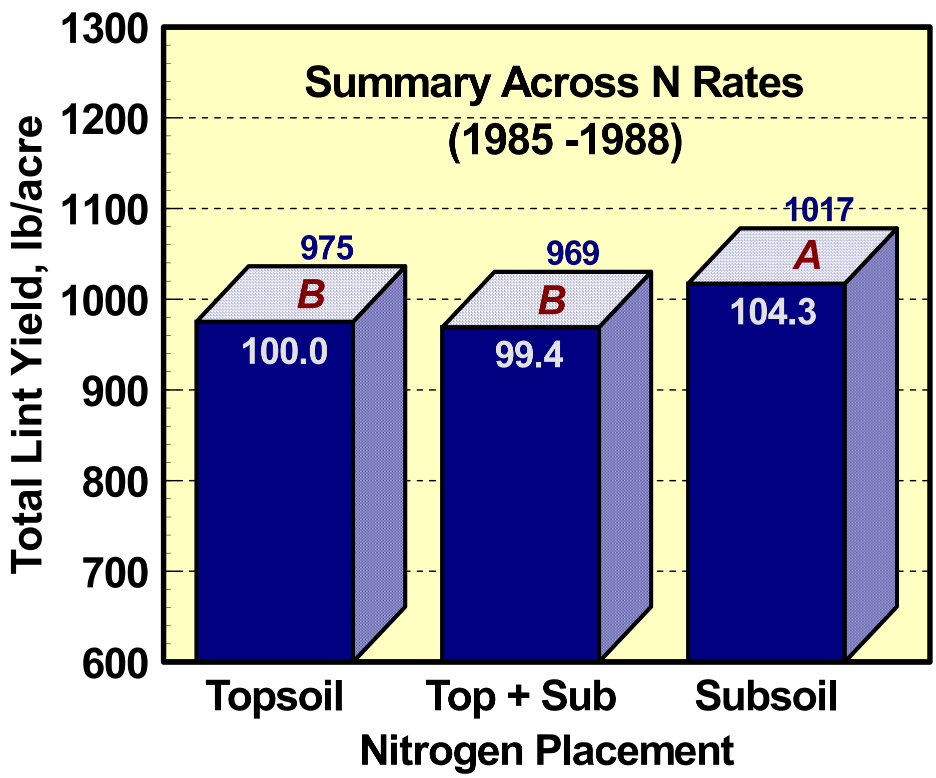

Figure 4. Four-year summary of the effects of nitrogen placement on total lint yield averaged across nitrogen rates. Delta Research and Extension Center, Stoneville, MS.

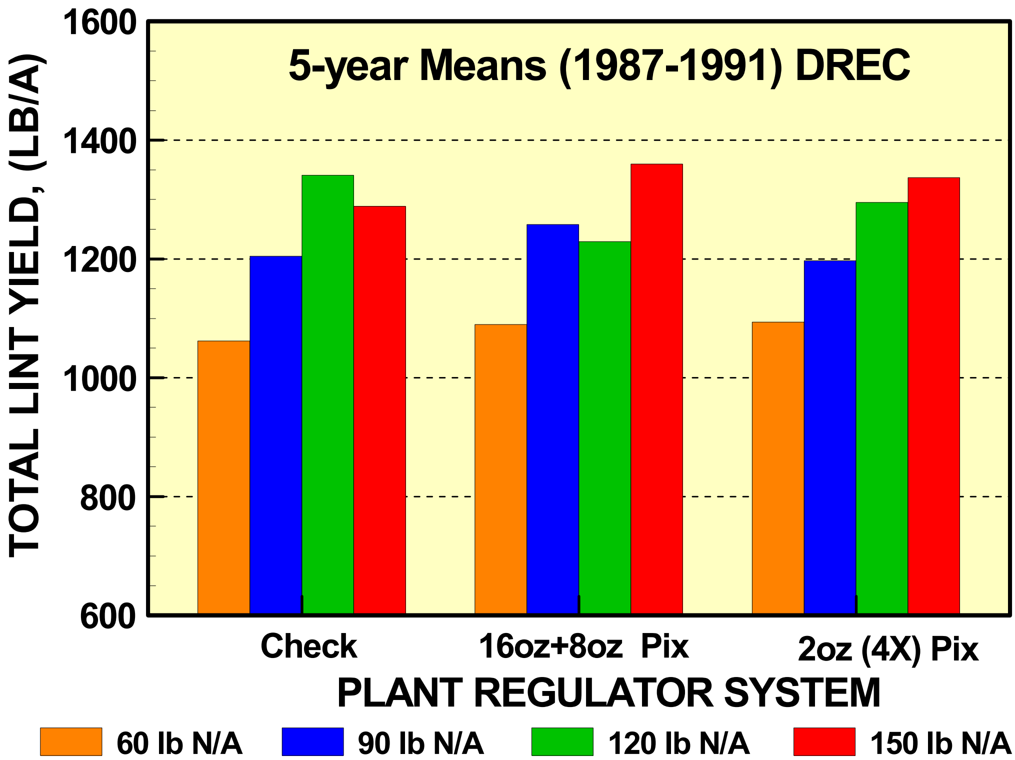

Figure 5. Total lint yield from the interaction of nitrogen rates and mepiquat chloride (Pix) at the Delta Research and Extension Center, Stoneville, MS. Five year means (1987-1991) on irrigated cotton.