Dr. Daniel Krieg

Proper Nutrient/Water Input—Key To High-yielding Cotton

Management of nutrient supplies, especially nitrogen and phosphorus, ensures deficiencies will not occur during early stages of fruit development.

***Summary:** Proper management of production inputs (nutrients and water) is essential if maximum cotton yield is to be achieved within the constraints of the physical environment we experience in Texas. The recommended rates of applied nitrogen (N) and phosphorus (P) will ensure that deficiencies do not occur during the early stages of fruit development, thus maximizing fruit retention while avoiding over-applying and wasting money so critical to assuring the highest possible profits. Through funding from the Fluid Fertilizer Foundation (FFF) and the Foundation for Agronomic Research (FAR) we clearly have demonstrated proper and efficient nutrient management strategies for center-pivot irrigated cotton on the Texas High Plains. We believe the principles are transferable to all parts of the cotton-producing world.*


Photo courtesy of USDA NRCS

Water and nutrient management under both rain-fed and irrigation conditions has been the focus of my research over the past 35 years in West Texas where we grow 35 percent of the U.S. cotton acreage. Our results suggest that 24 to 26 inches of water are required to grow the crop if the risk of water stress reducing productivity is to be minimized within the constraints of the typical evaporative demand on the Texas High Plains.

Water supply and growing season length moderate the genetic influence with respect to both main-stem nodes and fruiting sites on a fruiting branch. A "typical" cotton plant in today's varieties will initiate fruiting branch formation at the sixth to seventh node and progress upward at a three-day interval for 50 to 60 days, producing 22 to 24 main-stem nodes and 15 to 16 fruiting branches.

Fruiting sites. Depending on plant density and available environmental resources, a typical cotton plant can produce 30 to 50 fruiting site in 60 days. Each main-stem node and fruiting site on a branch is associated with a leaf. Each fruiting site requires approximately 500 heat units (HUs) from initiation to flower concurrent with expansion of its subtending leaf. Therefore, each fruit develops under slightly different weather conditions; however, the need for mineral nutrients is the same for each seed it contains. The capsule and each seed increase volume very rapidly following flowering, reaching maximum volume in 18 to 20 days.

Development. The embryo develops rapidly during this period and its major demand is for reduced carbon, reduced organic N compounds, and P for energy metabolism and membrane structure. Potassium (K) is the primary inorganic osmoticum providing the driving force for water influx to increase the volume of both the capsule and seed. Large quantities of K are accumulated from 10 to 15 days after post-anthesis. The individual fibers are initiated from epidermal cells on the seed-coat and elongate for 18 to 20 days coincident with volume increases in the boll and seed. K also provides the inorganic osmoticum for water influx into the fiber, allowing elongation to occur rapidly.

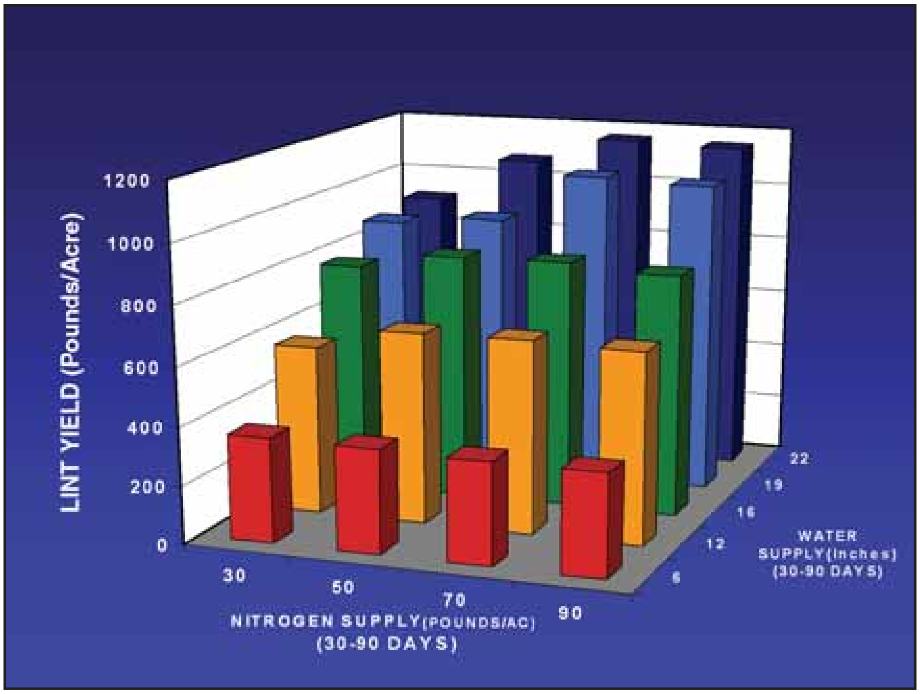

Figure 1. Effect of water and N supplied at varying levels on lint yield of cotton

Embryo abortion. Although there are about 40 ovules per boll (8 to 10 ovules/compartment; 4 to 5 compartments/boll) rarely do we find 40 mature seeds/boll. The typical boll contains 25 to 30 mature seeds and 10 to 15 aborted ovules. Embryo abortion is primarily caused by inadequate nutrition from both organic and inorganic supplies. The lack of adequate reduced N-compounds is the primary causal agent for embryo abortion, in my opinion.

Cotton produces a large number of floral buds during its life but only a small percentage of the young fruit ever matures and contributes to yield. When viable embryo numbers drop below 20 seeds/boll, the entire fruit usually aborts about 5 to 7 days post anthesis. As the embryo dies, ethylene is produced, and as ethylene concentrations increase with increasing numbers of dead embryos, the boll aborts. This represents a significant loss of both reduced Carbon (C) and minerals. Boll abortion is quite pronounced in cotton where it ranges from 85 to 90 percent in low-yielding environments to 65 to 80 percent in high-yielding environments.

Adequate water. Maintaining an adequate water supply to minimize the risk of plant water stress reducing photosynthesis and N metabolism, and maintaining an adequate supply of N, P, K, and S in the soil solution during the early phase of each fruit's development are very critical to capitalizing on the inherent yield potential of this crop plant. The biology of the cotton plant is basically that of a woody perennial with an indeterminate growth habit. Seed production is insignificant to its survival as a plant species. Any minor disturbance in its supply of environmental resources required for growth will result in shedding of small fruit to maintain vegetative tissue for regrowth when the stress is relieved. In today's production systems we emphasize earliness, which means we want to retain a very high percentage of the first three to four weeks of flowering. Water and nutrient supplies during the critical stages of development of each young fruit determine whether it is retained to maturity or aborts.

Sparse root density. One other major problem with cotton that increases the probability of water and nutrient stress is the root system. Cotton is a tap-rooted plant that has the potential to exploit considerable soil depth. However, cotton has an extremely low root length density (root length/soil volume) throughout the depth of the profile, averaging only one cm/cm3 of soil. This sparse density causes significant problems with both water and nutrient acquisition at a sufficient rate to meet the demands of a high-yielding crop, especially in environments with high evaporative demand.

Peak water demand

Peak water demand occurs from 70 to 110 days after planting and averages about 0.25 inches/day. With average rainfall and 4 gallons/minute/A of irrigation water supply, we can maximize yield of high-quality fiber within the temperature constraints of our growing season. We have developed management strategies involving plant density (row spacing/plant population/row length) to minimize the risk of excessive plant water stress during critical developmental periods in the life of the plant. We have clearly demonstrated that narrow rows (30-inch) and an in-row population of three plants/foot of drill row are ideal; however, populations from 2 to 4 plants/foot are not yield limiting.

Water/N relationships

Under irrigated conditions, the amount of N required per acre depends entirely on water supply (Figure 1). We determined that cotton requires 5 pounds N/inch of water supply available during the growing season. We apply all our in-season N through the water using LEPA or Sub-Surface Drip application systems. We typically apply 30 to 35 lbs N (32-0-0) as a carrier for our preplant application of yellow-herbicide. The remainder of the N goes through the water at the rate of 10 to 12 lbs of N/inch of irrigation water (27,300 gallons). Application starts during the squaring stage and continues through the third week of flowering or until August 5 to 10, whichever occurs later. This N management strategy ensures that soil N reserves are low in case September rains occur. Bolls that set in late August to early September have a very low probability of maturing.

Recent research has been directed toward the impact of N form. The hypothesis was that a continuous supply of ammoniacal N during the rapid fruit development would reduce the cost of N acquisition and deduction, possibly leaving more of the daily photosynthate for early fruit growth. By fertigating various NH_4:NO_3 ratios with different water volumes, we were able to determine that a $75NH_425NO_3$ ratio resulted in greater yields per N unit and water (Figure 2).

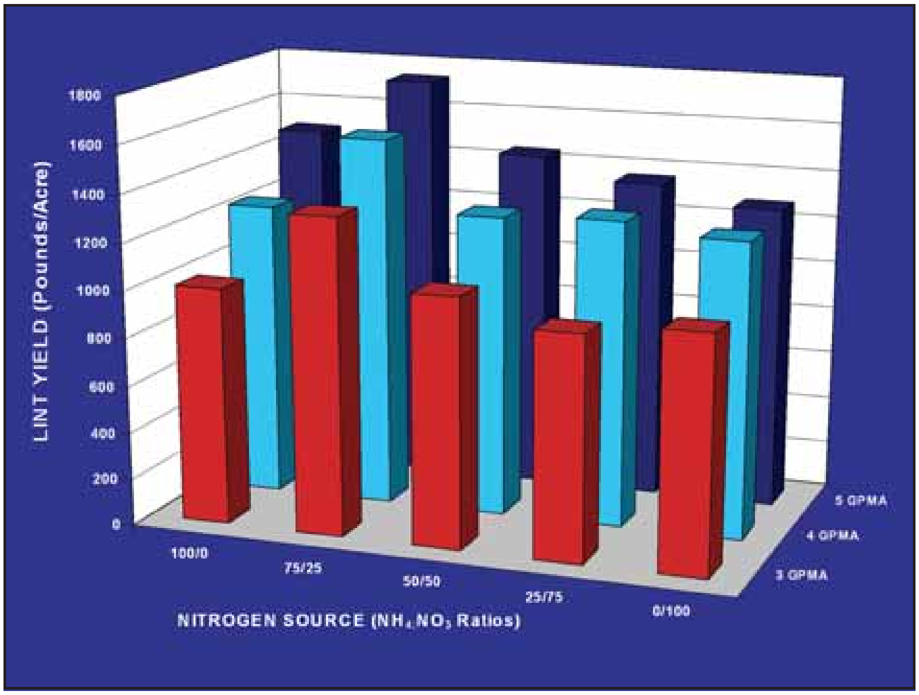

Figure 2. Effect of NH_4:NO_3, applied at varying ratios and water rates, on lint yield of cotton

Soil chemistry

Soil chemistry, including pH and an abundance of soluble cations that can precipitate P, is of major concern in how it affects P availability in the soil solution. Using fertigation, we have clearly demonstrated that a 5:1:0:0.5 ratio of N:P_2O_5:K_2O:S maximizes nutrient-use efficiency when applied through irrigation water at a rate of 10 to 12 lbs/in of N from first square through the third week of flowering. It was rather interesting that the 5:2 ratio produced lower yields across all water supplies during the three years of this experiment, compared with the 5:1 or 5:3 N:P ratios (Figure 3). The 5:2 ratio is what both private labs and the Texas Cooperative Extension Service have recommended for 40 years to West Texas cotton producers, based upon all P being applied preplant, usually broadcast.

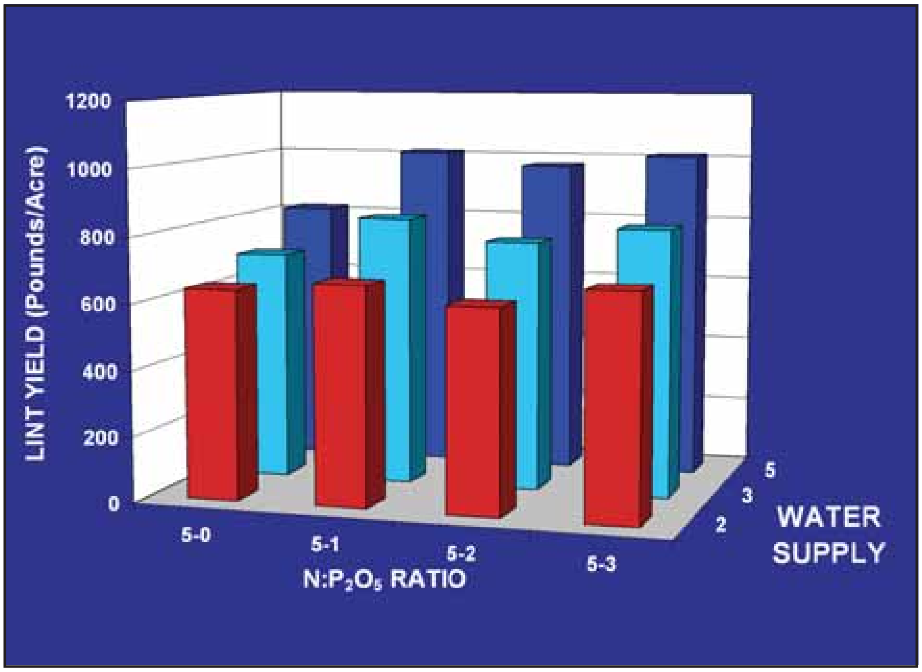

Figure 3. Effect of varying N:P rates, applied at varying water rates, on lint yield of cotton.

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