2002 BELTWIDE COTTON CONFERENCES, ATLANTA, GA – JANUARY 8-12

WATER AND NITROGEN SOURCE INTERACTION WITH COTTON GROWTH AND DEVELOPMENT

J.P. Morgan and D.R. Krieg
Texas Tech University
Lubbock, TX

Abstract

On the Southern High Plains of Texas, there are approximately 1.5 million hectares of cotton (Gossypium hirsutum L.) planted annually. This semi-arid region has an annual rainfall average of 475-mm and an average growing season rainfall of 350-mm or 2-mm day^{-1} from May through September. The average summer potential evapotranspiration (PET) is 1000-mm or 6-mm day^{-1}, which makes it necessary to have supplemental irrigation if maximum yields are expected. Approximately 45% of the total acreage in the area is amenable to supplemental irrigation. Application of irrigation water is limited in most production systems and cannot replace losses due to evapotranspiration throughout the growing season. Low energy precision application (LEPA), rather than spray application of irrigation water is becoming more widely used. LEPA provides increased application efficiency and reduction of evaporation. When water supply can be managed through irrigation, the nitrogen supply becomes the next limiting factor. Most of the nitrogen in the soil system is in the nitrate form (NO_3^-). Nitrate must be reduced in the growing plant before it can be incorporated into amino acids for protein synthesis or incorporated into other organic-N compounds. Uptake and reduction of NO_3^- is an expensive process in terms of carbon energy requirements. The reduction process requires 8^- electrons for each NO_3^- molecule, the equivalent of half a mole of glucose or three reduced carbons. It requires only 2 to 5% of plants reduced carbon energy to incorporate NH_4^+ into organic-N compounds vs. 10 to 15% for NO_3^-. Ideally, NH_4^+ is the preferred nitrogen source since energy is saved and crop growth is often improved when crops are provided with both NH_4^+ and NO_3^- nutrition Ammonical nitrogen (NH_4^+-N) is an efficient source to plants. However, it is rapidly oxidized into NO_3^- by the bacterial system. Extensive research for the past 25 years has been directed towards controlling populations of nitrifying bacteria by nitrification inhibitors, but this effort has been unsuccessful for season long control. Fertigation offers the opportunity to provide the crop with a constant supply and readily available source of nitrogen. This study compared the growth, development and yield components of cotton as a response to NH_4^+ and NO_3^- ratios at a constant nitrogen supply across variable water supplies. Results of this study indicate that water use efficiency is increased by providing nitrogen through the water. Data indicate a direct response to water supply across all treatments. Within each water treatment, lint yield was found to be responsive to the nitrogen source. This response is most evident within the 75:25 (NH_4^+:NO_3^-) ratio. The 75:25 (NH_4^+:NO_3^-) a higher ammonical source out yielded the 100% NO_3^- source due. Lint yield increase was due to an increase in boll number rather than an increase in boll size. The major variability of cotton yields is 80% due to boll number/unit area, while boll size accounts for only 12-15% of yield variability in cotton. LEPA fertigation offers the opportunity to provide cotton with a season-long uniform supply of both NH_4^+ and NO_3^- nitrogen that will maximize the potential for optimum production.

Introduction

Water supply, growing season length and nutrient supply limit cotton production on the Southern High Plains of Texas. Average heat unit accumulation from May 1 to October 31 is 1400 (Base T=15°C) (Dugas and Heuer, 1984), with both cool springs and early freezes common, characterizing a short season environment. The amount of heat in this region is not sufficient for cotton yields to approach their genetic potential, but it is enough to support lint yields greater than 1000 kg ha^{-1} when water and nitrogen are not limiting (Morrow and Krieg, 1990). Nitrate and ammonium are the two major forms of nitrogen available for plant uptake and growth. Nitrogen is very dynamic within plant and soil systems. Both chemical and biological processes constantly transform nitrogen from one N-form to another. The rate in which NH_4^+ is produced by mineralization of organic matter is slower than nitrification. The greatest amount of applied NH_4^+ is transformed by nitrification into NO_3^- within three weeks after application to the soil during the summer months (Burt et al., 1998). Nitrogen availability is considered one of the major limitations in the growth, development and production of most agronomic crops. The type of plant and the growth stage determines the preference for either NH_4^+ or NO_3^- nutrition (Tisdale et al., 1993). Nitrate generally occurs in higher concentrations than NH_4^+. Nitrate is free to move to roots by mass flow and diffusion because it is a negatively charged anion, which is not held by cation exchange sites. Low amounts of mineralized NH_4^+ are always present and will influence plant growth and metabolism in different stages of development. NH_4^+ is a positively charged cation, which is held electrostatically on the soil cation exchange sites. This ion stays on the cation exchange sites until another positively charged nutrient (i.e., calcium, potassium, or magnesium) replaces the NH_4^+ on the same site. At which time, the NH_4^+ ion moves into the soil solution where the ion is available for plant uptake. A balanced blend of nitrate and ammonium nutrition is recommended for optimal plant growth. Researchers have found that corn yields increased from 8 to 25% with NH_4^++ NO_3^-, compared to yields with NO_3^- alone, which was related to increased numbers of kernels/plant and not to heavier kernels (Tisdale et al., 1993). Jones (1988) reported that maximum grain yield can be obtained when the nitrogen source is either an equal ratio of NO_3^- to NH_4^+ during the entire growing season, or the final nitrogen source is all NH_4^+ following the equal ratio source during vegetative development. The positive response of crops to NH_4^+ is related to the energy requirement for the uptake and assimilation of nitrogen forms. The assimilation of NO_3^- requires reduction, whereas NH_4^+ assimilation does not. The energy saved by assimilation of NH_4^+ vs. NO_3^- allows plants to utilize the conserved energy for other biochemical processes.

Materials and Methods

A field experiment was conducted to evaluate water and nitrogen source interaction with crop growth and development. The experiment was located at the Texas Tech University Crop Production Research farm in Terry County, Texas about 56-km southwest of Lubbock. The soil at this site is an Amarillo loamy fine sand (fine-loamy, mixed, thermic Aridic Paleustalf) that is typical of approximately 50% of the soil in cotton production across the Southern High Plains of Texas (Baumhardt et al., 1995). The experimental design consisted of 3 water supplies in concentric rings, and 5 nitrogen sources divided into pie wedges. Cotton was planted May 12th in circular rows to correspond to the variable water supplies. A narrow row spacing of 0.80 meters was used to maximize land area and plant spacing. Cotton was planted at an average rate of 135,000 seed ha^{-1}. Irrigation capabilities at this site consisted of a 4-span center pivot that was LEPA equipped. Three variable irrigation supplies 11, 15 and 19 liters min^{-1} ha^{-1} (3, 4, 5 GPMA) were used, which ranged from 4-mm day^{-1} to 7-mm day^{-1} replacement. This range in water supply represents 60 to 100% of the maximum daily crop water use for cotton. It was estimated that about 50% of the total crop water supply would be provided by stored soil water and in season rainfall. The fertigation schedule consisted of a six-day cycle with the first application beginning at first square and continuing through peak bloom. The different ratios of ammonical and nitrate (NH_4^+N: NO_3^-N) nitrogen applied were 100:0, 75:25, 50:50, 25:75 and 0:100. The fertilizer materials used to develop these ratios included, 34%-N as ammonium nitrate (NH_4NO_3), 32%-N as urea ammonium nitrate (NH_4NO_3 $CO(NH_2)_2$), and 46%-N as urea ($CO(NH_2)_2$). The 11, 15, and 19 liters min^{-1} ha^{-1} (3,4,5 GPMA) had approximately 67, 89, 111 kg ha^{-1} (60, 80, 100 lbs. ac^{-1}) of total nitrogen applied throughout the growing season. The total amount of nitrogen in the 100% nitrate and half of the nitrogen in the 25:75 pie was applied pre-plant with urea ammonium nitrate (UAN) fertilizer four weeks prior to planting, by knifing the fertilizer 10-cm into the furrow. The remainder of the fertilizer on the 25:75 pie was premixed to contain 10% nitrogen and was fertigated by an Inject-O-Meter™ piston pump at the rate of 2.25-kg-N ha^{-1} per 25-mm (1-acre inch) of irrigation water. The total amounts of nitrogen in the 50:50, 75:25 and 100% NH_4^+ pies were fertigated at the rate of 4.5-kg-N ha^{-1} per 25-mm (1-acre inch) of irrigation water. The 50:50 pie was fertilized with ammonium nitrate, which is an equal blend of both ammonical and nitrate nitrogen. The 75:25 pie was fertilized with UAN, which contains 75% ammonical and 25% nitrate nitrogen. Urea was used as the source of nitrogen for the 100% $NH4^+$ pie based upon the hydrolysis of urea to 100% ammonical nitrogen. All fertilizer materials were premixed to contain 20% nitrogen (20-0-0), so the fertigated amounts would be consistent within each plot.

One meter of row length was sampled within each plot at first flower and peak bloom. The leaf, stem and fruit were separated to determine the leaf area index (LAI), fresh weight and dry weight for each plot. At harvest, two rows by 4.88 meters (2/1000th acre) were harvested and the number of bolls and plants were counted to estimate yield and plant population. A 100-consecutive boll sample was harvested and ginned for lint weight, seed weight and percent lint turnout. Cotton development and boll distribution was monitored during the season by plant mapping 1-meter of row length at first flower, peak bloom and harvest. The lint samples were analyzed by the Texas Tech University International Textile Center in Lubbock, TX for fiber quality.

Discussion

The differences in growth, development and yield components were evident across all water supplies. Lint yield was greatly effected and determined by the variable water supplies (Fig. 1). As water supply increased lint yields increased due to more bolls produced hectare $^{-1}$ rather than boll weight (Fig. 2). Production and retention of fruiting sites increased with an increase in water supply. At peak bloom, the leaf area and total biomass (leaf, stem and fruit) were greatly increased due to a water supply response (Figs. 3 and 4). Nitrogen source responses were observed within plots. The higher ratio of NH_4^+-N vs. NO_3^--N had a greater effect on the growth, development and yield of cotton. Lint yield was significantly increased in the 75:25 ratios compared to the higher NO_3^--N ratios (Fig. 1). An increase of bolls $hectare^{-1}$ was observed within nitrogen treatments (Fig. 2). There was not a significant difference in boll size within nitrogen treatments. At peak bloom, there was a strong response to the higher NH_4^+-N ratios resulting in the increase of leaf area and total biomass (Figs. 3 and 4). This is due to the constant supply of nitrogen in the ammonical form available for uptake during the periods of peak demand. The positive response of growth, development and yield was due to the variable water supplies and nitrogen sources ratios rather than a water by nitrogen source interaction.

Conclusion

There is an increase in the water and nitrogen use efficiency of cotton when water and nitrogen are applied simultaneously through fertigation. Incremental applications of nitrogen in a balanced blend with the irrigation water enhances availability of nitrogen throughout the season. LEPA fertigation provides the opportunity for producers to manage fertilizer inputs relative to crop usage during peak demands, which in return will maximize productivity of growth, development and yield of cotton.

References

Baumhardt, L.R., Lascano, R.J., and Krieg D.R. 1995. Physical and hydraulic properties of a Pullman and Amarillo soil on the Texas South Plains. Texas Ag. Exp. Sta. Tech. Report. No. 95-1

Burt, C., O'Conner, K., and Ruehr, T. 1998. Fertigation. Irrigation Training and Research Center California Polytechnic State University. San Luis Obispo, CA.

Dugas, W.A., Jr and M.L. Heuer. 1984. Agroclimatic Atlas of Texas. Part 8. Heat Units. Texas Ag. Exp. Sta. Misc. Pub. No. 1561.

Jones, J.B., Jr., H.A. Mills, and E. Simonne. 1988. Effect of nitrogen form on growth and grain yield of corn. Fluid Fertilizer Foundation Symposium Proceedings. p. 179-184.

Morrow, M. and D.R. Krieg. 1990. Cotton management strategies for a short growing season environment: Water-nitrogen considerations. Agron. J. 84, p. 52-56.

Tisdale, S.L., W.L. Werner, J.D. Beaton, and J.L. Havlin. 1993. Soil fertility and fertilizers, 5th ed. Prentice Hall, Upper Saddle River, NJ.

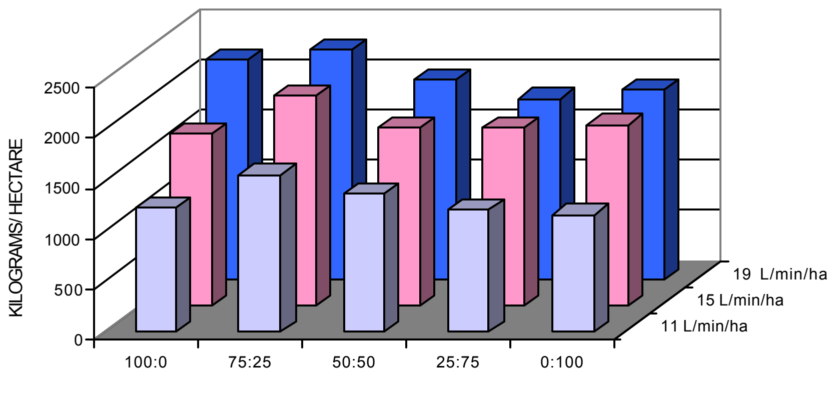

Figure 1. Effect of water supply and nitrogen source on lint yield.

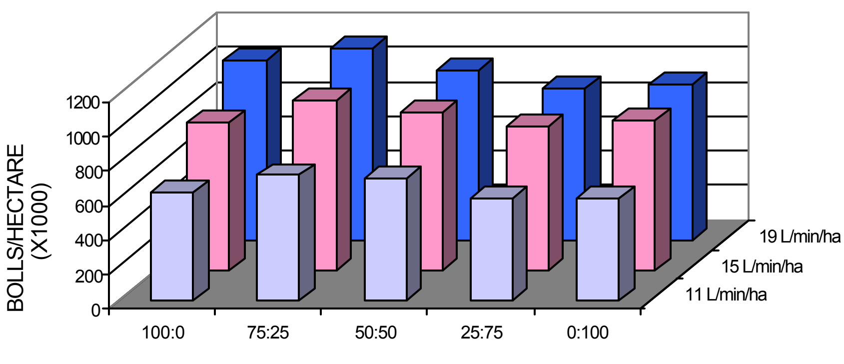

Figure 2. Effect of water and nitrogen source on boll number.

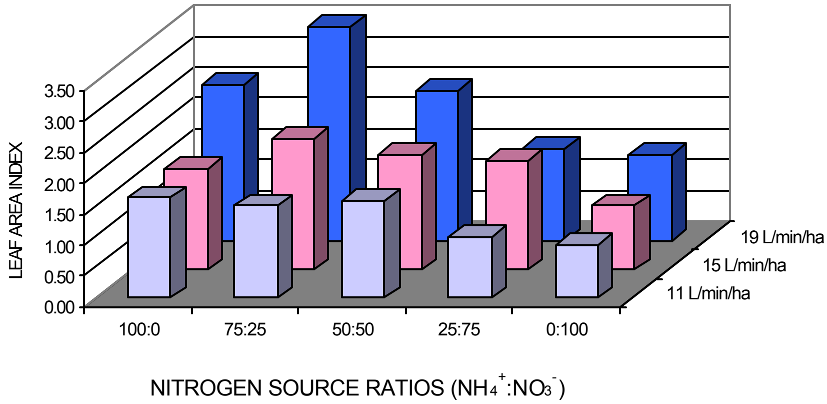

Figure 3. Effect of water and nitrogen source on leaf area at peak bloom.

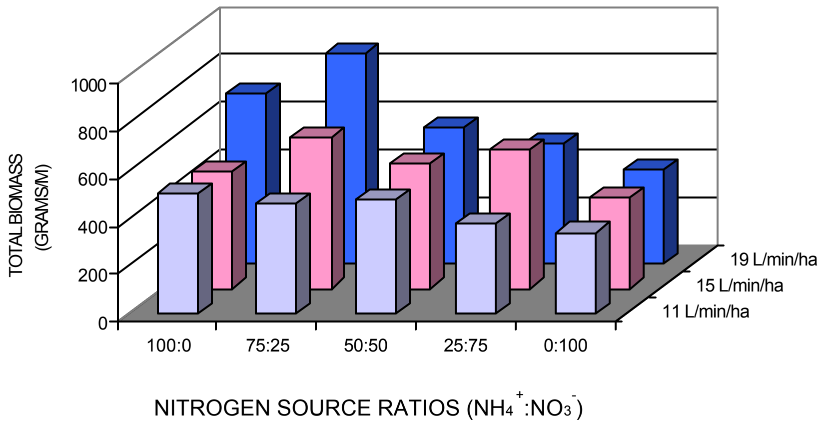

Figure 4. Effect of water and nitrogen source on total biomass at peak bloom.