COTTON FRUITING PATTERNS AND LINT YIELD AS AFFECTED BY WATER AND FERTILITY MANAGEMENT

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Abstract

Water supply, growing season length, and nutrient supply limit cotton (*Gossypium hirsutum*) production on the Southern High Plains of Texas. Approximately one-half of the total cotton acreage in the area is capable of supplemental irrigation however, the supply is usually considerably less than the demand and deficit water management is common. Irrigation management is often limited by available water quantity that cannot be controlled by the producer. The use of LEPA (low energy precision application) rather than spray application of the irrigation water is becoming more widely adapted because of reduced evaporation losses of water. Growing season length is limited by heat unit accumulation rather than frost-free days with both cool springs and falls common. The major factor left to the producer's control is fertility. Fertility management can affect fruit retention and boll size of cotton, which can affect water use efficiency. Nitrogen requirements and application timing relative to the water supply has clearly been established for the region. The development of more efficient phosphorus management strategies is needed to maximize use of all available resources in cotton production. The main concern of phosphorus fertilization is that the soil system has a high pH and abundant free calcium that forms insoluble calcium phosphates that limit phosphorus availability to cotton. Applying multiple applications of a balanced nutrient blend in small amounts through the irrigation water during the time of peak crop use will increase phosphorus availability and maximize use efficiency of water and other nutrients. This study compared different methods of phosphorus application (no phosphorus, pre-plant, sidedress, and fertigation) to determine if there is a real difference in the plant response to the application methods. The ratio of nitrogen:phosphorus was compared to determine which phosphorus level is most effective through fertigation. The ratios were 5:0, 5:1, 5:2, and 5:3 (lb. N:lb P_2O_5) per inch of total water. In three years of research we have found that fertigation is an acceptable method of applying phosphorus to the cotton crop and that higher phosphorus ratios give a yield response through more lint per boll. Using fertigation as an application method will give producers the opportunity to manage their fertilizer inputs based on in season yield potential saving them both time and money.

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Introduction

The current method of phosphorus supplementation is broadcast dry granular soil applications of P_2O_5 applied several months in advance of planting. The calcareous nature of the Southern High Plains soils presents a problem with available phosphorus in the soil due to high pH (7.4-7.8) and free $CaCO_3$ often at the soil surface. The soil pH range for optimal phosphorus availability is pH 6.0-7.0. Above pH, 7.0 abundant calcium causes the formation of calcium phosphates (Ca-P). These insoluble Ca-P complexes fix inorganic phosphorus from fertilizers as well as mineralized organic phosphorus (Tisdale et al., 1993). The plant utilization efficiency of phosphorus is about 5-25% of applied phosphorus due to soil fixation reactions (Lange, 1977). Phosphorus is most available immediately after soil application and over time less soluble compounds are formed through soil reactions (Olsen and Flowerday, 1973). Research by Nelson (1949) in North Carolina showed that phosphorus applications increased boll size but had little effect on boll numbers or lint quality. Nelson (1949) also concluded that the largest increase in yield across all fertility treatments (N, P, and K) was due to increased boll numbers. Research at Texas Tech has shown that over 80% of cotton yield variability is due to boll number per unit area. The boll size accounts for 12-15% of yield variability in cotton. A strong negative interaction exists between boll number and boll size where increased boll numbers tend to cause a decrease in boll size. Phosphorus may not have a direct effect on boll number or size but can work in tandem with other nutrients to increase boll properties. Coleman (1944) found that in Mississippi cotton and oats responded to phosphorus only when adequate nitrogen was available. He also noted that that crops with adequate nitrogen also required more phosphorus than nitrogen limited crops. This work shows that variable amounts of phosphorus are needed to correspond with variable nitrogen rates. Morrow and Krieg (1990) have demonstrated the optimum nitrogen to water ratio for maximizing cotton yield. This justifies the need to examine nitrogen to phosphorus ratios for optimum yields under different water levels. Water supply has the most influence in determining lint yield of cotton and applying nitrogen through the water increases the water use efficiency of cotton. By applying other nutrients through the water, we can increase the water use efficiency even more by ensuring these nutrients are not limiting. The use of fertigation may allow us to apply less phosphorus if it is used more efficiently when applied through the water.

Materials and Methods

This study was conducted at the Crop Production Research Lab in Terry County, Texas (approx. 35 miles SW of Lubbock). The center pivot is equipped with LEPA application technology and nozzled to apply 5, 3, and 2 gallons per minute per acre (GPM/A) which corresponds with 33%, 50%, and 90% PET replacement, respectively. These water supplies also represent the irrigation capabilities throughout the Southern High Plains region. The irrigation frequency was on a five-day schedule starting at first square and adjusted according to rainfall. Application method treatments and $N:P_2O_5$ ratios were applied in blocks within each water supply. The four application methods are no phosphorus (control), pre-plant, sidedress, and fertigation. All application method treatments received 100 lb. N and the pre-plant, sidedress, and fertigation treatments received 40 lb. P_2O_5. The pre-plant P_2O_5 was banded with a sweep rig 4 weeks prior to planting. The sidedress P_2O_5 was banded with the sweep rig and split into three equal applications at pre-plant, first square, and first flower. The fertigation was applied at least four times starting at first square and continued through peak bloom. The $N:P_2O_5$ ratios are 5:0, 5:1, 5:2, and 5:3 (lb N:lb P_2O_5) per inch of total water. The control (5:0) received only nitrogen and the 5:2 ratio supplies 40 lbs. P_2O_5 which is the standard recommendation in the area. Each water supply received a different amount of nitrogen and phosphorus based on total water applied throughout the season. Cotton development and boll distribution was monitored during the season by plant mapping at first flower, peak bloom, and at harvest. Yields were determined by hand harvesting samples and ginned in a plot gin. Lint samples were taken for fiber quality measurements at the International Textile Center in Lubbock, TX.

Discussion

The weather throughout the three-year study provided a range of conditions commonly experienced on the Southern High Plains. Heat unit accumulation, rainfall, and planting date varied considerably from year to year (Table 1). This weather pattern tested the treatments in a variety of growing conditions and showed the value of having flexibility in nutrient management programs. Cotton lint yield is foremost determined by water supply available to the crop. As more water is applied to the crop, lint yield increases due to more bolls produced per plant. The application method comparison showed that fertigation is very successful in supplying phosphorus to the cotton crop and increases lint yield (Fig. 1). Fertigation allowed pulse feeding of a balanced nutrient blend in a moist soil region where a large percentage of plant roots are located. Fertigation proved to be the most consistent method of increasing yield across the three years of the study. The banded pre-plant application provided a yield response over the control and sidedress method. The sidedress application showed that late season cultivation negates the benefits of multiple nutrient applications due to severe root pruning. The sidedress yield suffered due to the interruption of water uptake at the critical flowering stage of development. The lint yield increase was due to an increased number of bolls and an increase in boll size (Figs. 2 and 3). Boll numbers are related to an increase in bolls found on the $6\text{-}10^{th}$ fruiting branches whereas boll size was a function of increased micronaire (more mature fibers)(Fig. 4). The $N:P_2O_5$ ratios showed that cotton response to phosphorus is largely determined by water supply. The 2 GPMA water supply did not respond to added phosphorus as water was the most limiting factor. At the 3 and 5 GPMA water supply lint yield responded to added phosphorus but increasing phosphorus rates did not significantly affect lint yield (Fig. 5). The lack of a response is likely due to the number of bolls (Fig. 6). The $N:P_2O_5$ ratios did increase the boll size as the phosphorus rates increased (Fig. 7). The increased boll size is a function of higher micronaire owing to more mature fibers in the bolls (Fig. 8).

Summary

Fertigation is an effective method for phosphorus application. Fertigation can be used throughout the boll development period to supply a balanced nutrient blend without injury to the cotton plant. The ratio of $N:P_2O_5$ in irrigation water enhances the nutrient and water use efficiency by preventing phosphorus from being a limiting nutrient. Phosphorus rates need to be adjusted according to the water supply available due to water being the primary limiting nutrient in most situations. Fertigation practices give the producer more flexibility to manage fertilizer inputs and the associated economic and yield advantages.

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Table 1. Planting dates, rainfall, and heat unit accumulation.

	1997	1998	1999
Planting Date	May 19	May 12	June 15
Rainfall (mm)	216	138	160
Rainfall (in)	8.5	5.4	6.3
Heat Units (C)	1259	1649	1105
Heat Units (F)	2121	2811	1871

Table 2. Total water supply per irrigation treatment.

	1997			1998			1999		
GPMA	2	3	5	2	3	5	2	3	5
Irrigation (mm)	81	119	192	156	225	351	78	119	197
Irrigation (in)	3.2	4.7	7.6	6.2	8.9	14	3.1	4.7	7.7
Total (mm)	296	335	408	294	362	489	237	279	356
Total (in)	12	13	16	12	14	19	9	11	14

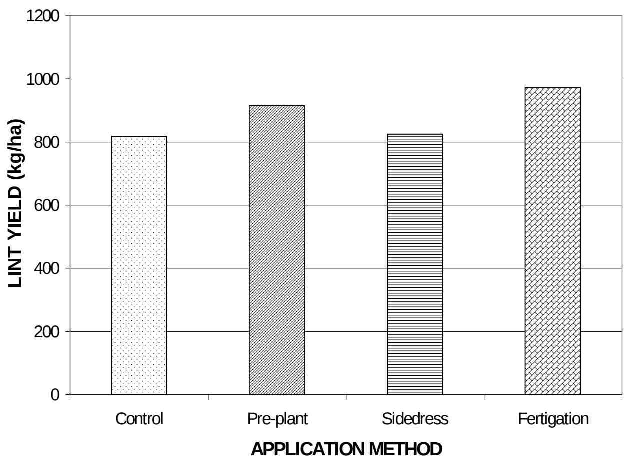

Figure 1. Effect of application method on lint yield.

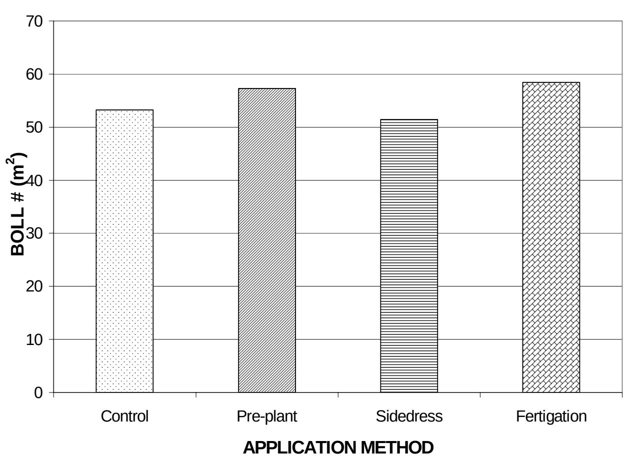

Figure 2. Effect of application method on boll number.

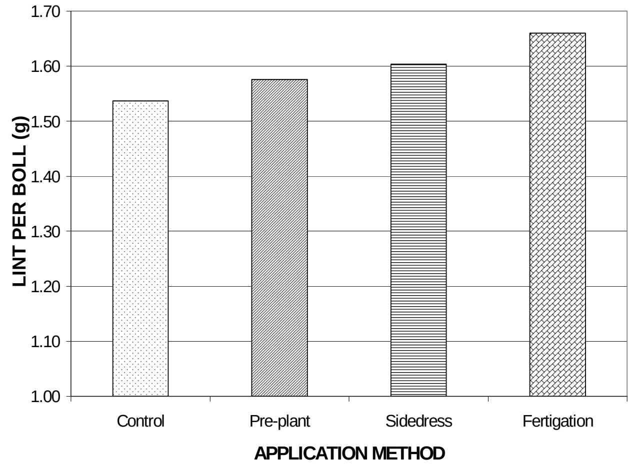

Figure 3. Effect of application method on boll size.

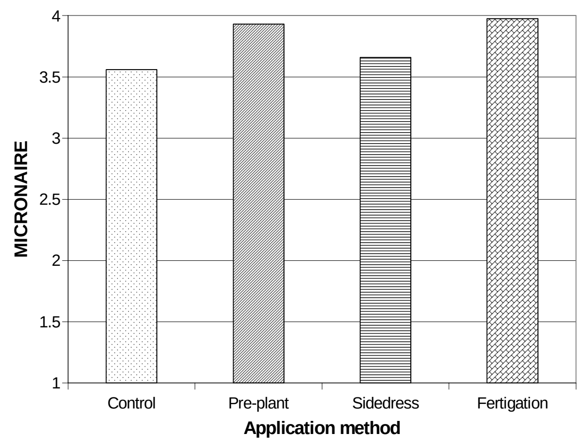

Figure 4. Effect of application method on micronaire.

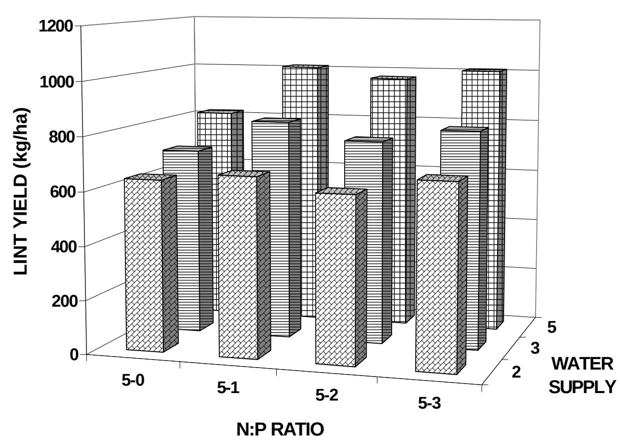

Figure 5. Effect of $N:P_2O_5$ ratio on lint yield.

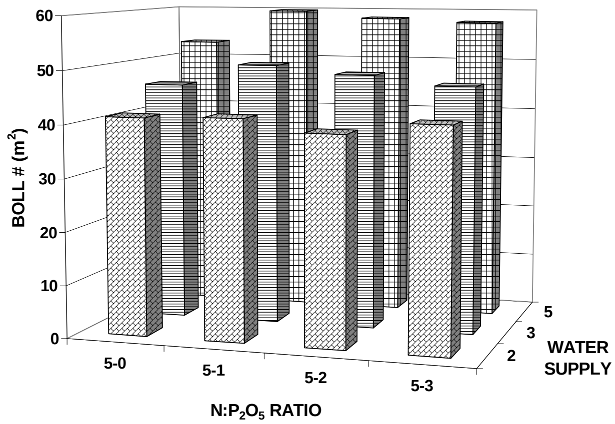

Figure 6. Effect of N:P_2O_5 ratio on boll number.

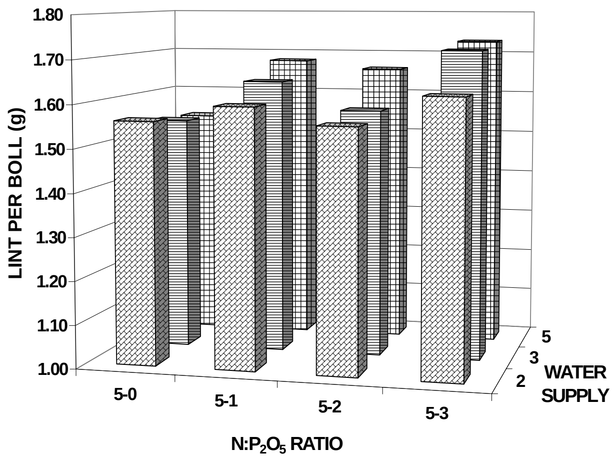

Figure 7. Effect of N:P_2O_5 ratio on boll size.

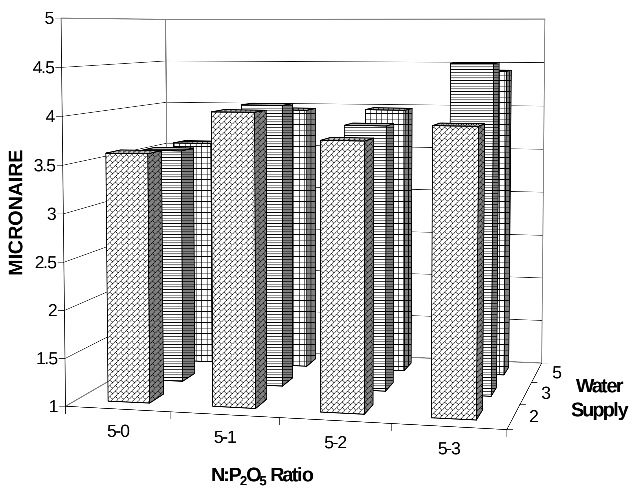

Figure 8. Effect of N:P_2O_5 ratio on micronaire.