# Improving Cotton Production Efficiency

*With differing nutrient placement.*

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***Summary:** Responses to P and K during the study were limited as sites chosen were based on medium to high soil test P and K levels. Overall, the study was valuable in evaluating the performance and placement of P and K fluid sources on cotton growth and performance in the upper southeast coastal plain.*

The trials were conducted at two locations during 2015: theTidewater Agricultural Research and Extension Center (TAREC) located in Holland, Virginia, and the North Carolina Department of Agriculture and Consumer Services Peanut Belt Research Station located in Lewiston, North Carolina. The soil type at the TAREC location was a Eunola loamy sand (fine-loamy, siliceous, semi-active, thermic Aquie Hapludults). The soil type at Lewiston was a combination of Lynchburg and Goldsboro sandy loams (Fine-loamy, siliceous, semi-active , thermic Aeric Paleaquult and Fine-loamy, siliceous, sub-active thermic Aquic Paleudult). Soil samples were taken from both locations to a total depth of 12 inches (30 cm) and split into depths of 0-3, 3-6, and 9-12 inches. The Mehlich 1 soil test levels for each location can be found in Table 1. The base (100%) pre-plant phosphorus and potassium fertilizer rates were 40 lbs. $P_20_5$/A and 40 lbs. $K_2O$ /A and based on Mehlich I soil test levels. All other agronomic practices were conducted according to Virginia extension recommendations. Treatment application, and harvest dates can be found in Table 2.

### Experimental design

The study was conducted using four row plots measuring 12 feet wide by 35 feet long at both locations. Each treatment was replicated four times in a randomized complete block design. The cotton variety grown was Phytogen 499 WRF, an early to mid-maturing variety with a high yield potential. Thirteen treatments evaluated placement of phosphorus (P) and potassium (K) fluid fertilizers (Table 3). Treatment 1 was an unfertilized P and K control, however at TAREC unfertilized plots did not receive nitrogen (N) or sulfur (S), while theunfertilized check at Lewiston received 80 lbs. N per acre in a side-dress application.

> **"Results were very consistent from year to year"**

Two agronomic control treatments were implemented to stimulate the current nutrient management systems in Virginia: 1) all of the required P and K broadcast prior to planting, and 2) 100 lbs. starter material (10-34-0) per acre applied in a 2 X 2 band at planting with the remainder of the P and K broadcast prior to planting (Table 3). Treatments 4-9 evaluated the responses to P and K fluid fertilizer applied in the 2 x 2 band at planting and deep placement during strip-tillage at 50, 100, and 150% of the recommended rates based on soil tests. The remaining treatment combinations evaluated a series of combinations of the 2 x 2 band and deep placement, all totaling the 100% of the recommended P and K fertilization rates (Table 3).

### Treatment application

Treatments were applied with a strip-tillage implement and dates for implementation can be found in Table 2. Fertilizer placement with strip tillage was accomplished with an apparatus depicted in Figure 1 and placement of fertilizer is detailed in Figure 2. To dispense fluid fertilizers at 6, 9, and 12 inches below the soil surface, holes drilled 90o to the direction of travel allowed the fluid fertilizer to exit each down spout and maximize contact with soil at the targeted depths. The 2 x 2 banded fertilizer was applied at planting using a double disk opener mounted on the toolbar of a two row Monosem planter. The application rate for the fluid P and K sources was controlled by a carbon dioxide pressurized system and the application rates were controlled using inline orifices

(Figure 1).

The broadcast P and K were applied on the same day as the strip tillage cultivation and deep placement of P and K for both locations. Diammonium phosphate (DAP) (18-46-0) and muriate of potash (0-0-60) were used as the P and K sources for the broadcast agronomic control treatment. The fluid phosphorus source applied was ammonium polyphosphate (10-34-0) (APP) and the fluid potassium source was potassium thiosulfate (0-0-25-17S).

The potassium thiosulfate supplied 40.8 lbs sulfur (S)/A when applied at the 150% rate, which is greater than the recommended agronomic S rates in cotton for Virginia. Ammonium thiosulphate (12-0-0-26S) (ATS) was used to balance the S rate among treatments. In the treatments where a combination of placement techniques were implemented, the balance of S was applied using deep placement to prevent any potential injury to cotton seedlings. Preplant nitrogen (N) was balanced at the same level as the broadcast agronomic control plus additional N from ATS. The preplant N rate for the P and K fertilized treatments was 35 lbs. N/A. The N was balanced using urea-ammonium nitrate fluids (30-0-0). The total N application rate was set at 115 lbs N/A with the remaining 80 lbs. N being applied in a sidedress application using a 24-0-0-3S at TAREC and UAN30 at Lewiston applied at matchhead square. Other nutrients were applied based on the soil test recommendations.

### Development/sampling

Plant population was measured by counting the number of emerged seedlings in two ten-foot sections of row. Plant population counts were taken at 7,10, 14, and 21 days after planting. Plant heights were measured weekly beginning with the appearance of the second true leaf and measured from the ground to the apical meristem on five randomly selected cotton plants per plot. Plant height and total node measurements ceased with the appearance of the first white flower at each location. During the bloom period, nodes above white flower (NAWF) were counted on five randomly selected plants per plot until NAWF ≤ 3.

Beginning during the first week of bloom, twenty-four cotton petioles were sampled from the first and fourth rows of each plot.

**Table 1: Mehlich I extractable phosphorus and potassium at 0-3, 3-6, 6-9, 9-12 inch depths at TAREC and Lewiston**

| Depth | | TAREC | | Lewiston | |
|---|---|---|---|---|---|
| inches | | P | K | P | K |
| | | ppm | | | |
| 0-3 | | 46 (H+)¶ | 80 (M+) | 21 (H-) | 81 (M+) |
| 3-6 | | 50 (H+) | 83 (M+) | 19 (H-) | 58 (M) |
| 6-9 | | 35 (H) | 66 (M) | 13 (M) | 43 (M-) |
| 9-12 | | 25 (H-) | 59 (M) | 8 (M-) | 44 (M-) |

¶ Indicates the soil test level based on Virginia's soil test calibration

**Table 2: Strip-tillage, planting, and harvesting dates for all locations during the 2014 growing season**

| Location | Strip-tillage | Planted | Harvested |
|---|---|---|---|
| TAREC | 5/4 | 5/18 | 11/4 |
| Lewiston | 5/19 | 5/27 | 11/24 |

**Table 3: Treatment List for 2014 Locations**

| Trt | Placement | Description |
|---|---|---|
| 1 | Unfertilized Control | No P or K Fertilization |
| 2 | Broadcast Agronomic Control | P + K Broadcast – Soil test recommendation‡ |
| 3 | Starter Agronomic Control | 100 lbs /acre† of 10-34-0 in 2X2 band + Remaining P+K broadcast |
| 4 | 2X2 Band | 50%P + 50%K¶ |
| 5 | 2X2 Band | 100%P + 100%K |
| 6 | 2X2 Band | 150%P + 150%K |
| 7 | Deep Placement | 50%P + 50%K |
| 8 | Deep Placement | 100%P + 100%K |
| 9 | Deep Placement | 150%P + 150%K |
| 10 | 2X2 + Deep Placement | (80%P + 80% K) + (20%P + 20%K) |
| 11 | 2X2 + Deep Placement | (60%P + 60% K) + (40%P + 40%K) |
| 12 | 2X2 + Deep Placement | (40%P + 40% K) + (60%P + 60%K) |
| 13 | 2X2 + Deep Placement | (20%P + 20% K) + (80%P + 80%K) |

† 100 lbs/acre of 10-34-0 is the recommended rate for cotton placed in a 2X2 band at planting in by North Carolina State University Cooperative Extension.
‡ Recommended nutrient application rates applied based on Mehlich 1 extractable phosphorus and potassium and Virginia Cooperative Extension Recommendations
¶ Percentages represent the proportion of recommended nutrient application rates applied based on Mehlich 1 extractable phosphorus and potassium and Virginia Cooperative Extension Recommendations.

**Table 4: Early season plant height of cotton grown under different nutrient management systems at TAREC**

| Nutrient Systems | Plant Height | | | | | |
|---|---|---|---|---|---|---|
| | 3rd‡ | 4th | 5th | 6th | 7th | 8th |
| | --------------------------- in. --------------------------- | | | | | |
| Unfertilized Control | 4.3 b* | 7.8 b | 13.5 c | 19.5 c | 24.3 b | 26.4 b |
| Broadcast Agronomic Control | 4.6 ab | 7.7 b | 14.9 bc | 21.5 b | 28.1 a | 32.8 a |
| Liquid Starter Control | 5.0 a | 9.2 a | 17.1 a | 24.1 a | 29.7 a | 34.9 a |
| 100% 2X2 N-P-K-S | 4.4 b | 7.6 b | 14.6 bc | 21.8 b | 27.8 a | 32.8 a |
| 100% Deep Placement N-P-K-S | 4.4 b | 8.0 ab | 15.2 b | 22.5 ab | 29.1 a | 33.1 a |

*Values with the same letter are not significantly different at α=0.05
‡ Week after Planting

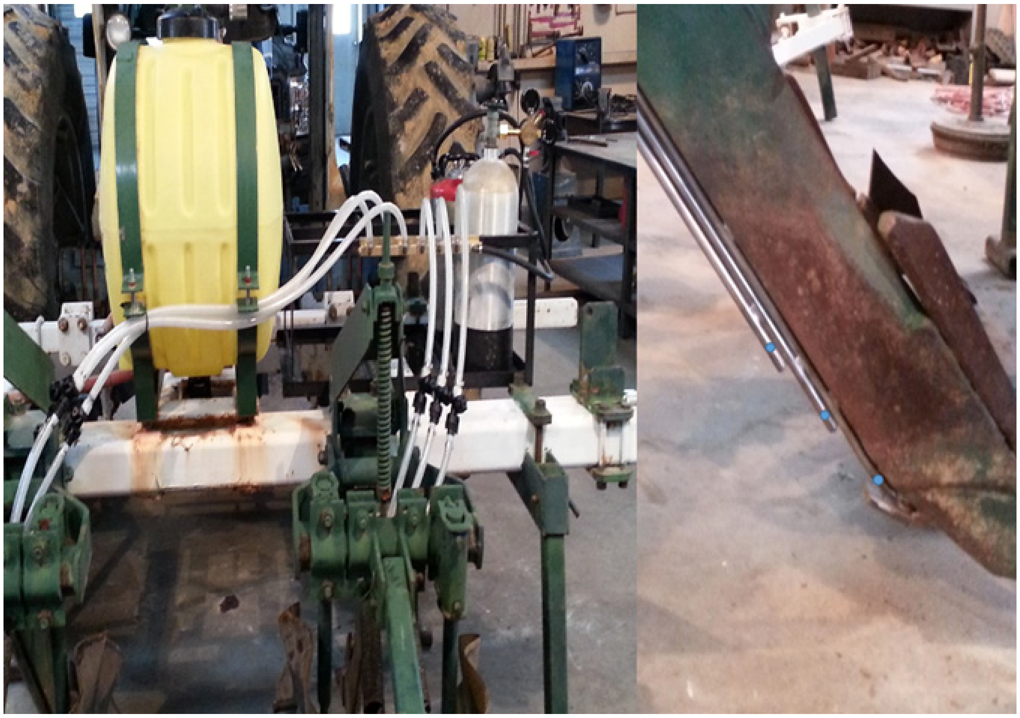

**Fig. 1:** Picture of the strip-tillage fertilizer systems and shank to place fluid phosphorus and potassium fertilizers at 6, 9, and 12 inches below the soil surface during strip tillage.

**Fig. 2;** Demonstration of fertilizer placement with two row strip-tillage implement showing the accuracy of fertilizer (blue dye) placement with the developed applicator.

The fourth leaf and petiole down the main stem of the cotton plant were sampled and separated immediately. Petioles were sampled weekly for the first five weeks of bloom. The petiole sampling was scaled back to minimize the number of samples and no treatment differences were observed during the late bloom period in the previous two years. The plant tissue samples were sent to Water's Agricultural Laboratories (Camilla, GA) for analysis. The petioles were analyzed for nitrate-N, phosphorus, potassium and sulfur. Nutrient concentrations in petioles were plotted against time. Leaf samples were collected during the first and fifth weeks of bloom only, and a complete nutrient analysis was conducted on the leaf tissue.

### Defoliation and quality

Defoliation timing for cotton varies, depending on the growing season and development of the crop. The trials were defoliated when 50-60% of the bolls were opened. Seed cotton was harvested using two-row commercial cotton picker modified for small plot harvest. The center two rows of each plot were harvested and plot weights recorded. A one pound sub-sample of seed cotton was ginned on a 10-saw micro-gin to determine lint percentage. Seed cotton weights were multiplied by the lint percentage to calculate lint yields. Cotton lint was sent to the USDA cotton quality lab in Florence, SC for lint quality analysis. The lint was analyzed using a High Volume Instrument (HVI) to determine the fiber length (staple), strength, micronaire, color, and leaf (trash) grade.

### Statistical analysis

The data set was separated into three separate datasets and analysis of variance (ANOVA), using PROC MIXED in SAS 9.3 to determine among treatments (SAS Institute, 2012). The first data set consisted of the different nutrient management systems tested at the 100% P and K rate based on soil test recommendations. The nutrient management systems were analyzed as single treatment factors in a randomized complete block design. The second data set was to determine the effect of P and K rate and placement on each of the measured dependent variables. The data set was analyzed as a 3 x 2 factorial treatment design in a randomized complete block design using ANOVA.

The last data set evaluated the different proportions of P and K applied to the 2 x 2 band and deep placement at the 100% application rate. Combinations were tested as single treatment factors using ANOVA. Differences in among treatments in each analysis were determined using the Tukey-Kramer HSD at α = 0.05 level of significance.

## Results

The 2015 growing season for cotton in Virginia was challenging as average lint yields were well below 2014 with 823 lbs. lint per acre in 2015 compared to 1,239 lbs. lint per acre in 2014. A dry August and three weeks of cloudy and rainy weather at the end of September ended the season with shed fruit and severe boll rot on the remaining fruit. Plant growth, petiole and tissue, and lint yield data followed similar trends in 2015 when compared to the two previous years of the study. For the study locations, lint yields ranged between 750 to 1,500 lbs. lint per acre at TAREC and 1,250 to 1,400 lbs. lint per acre at Lewiston, NC. Differences among P and K rates and placement (Trts. 4-9), as well as the placement combinations (Trts. 5, 8, 10, 12, and 13) were limited among all dependent variables measured at both locations. This reinforces observations made during the 2013 and 2014 studies (data not shown). As a result, only the nutrient management systems (Trts. 1, 2, 3, 5, and 8) will be discussed for this report.

***Growth measurements.*** Plant height measurements were initiated at the appearance of a fully unfurled second true leaf. The fluid starter control treatment had the tallest plants in each from the 3rd week after planting (WAP) to the 8th WAP (Table 4) at TAREC. The fluid starter control had significantly taller plants than the unfertilized control in all sampling intervals (Table 4). All fertilized plots were significantly taller than the unfertilized control from the 6th WAP through the 8th WAP (Table 4). When comparing the fertilized treatments at TAREC, the fluid starter control produced significantly taller plants than the 100% 2x2 N-P-K-S treatment from the 3rd WAP through the 6th WAP, significantly different from the 100% deep placement treatment during the 3rd and 5th WAP, and significantly different than the broadcast control during the 4th through the 6th WAP (Table 4).

Unlike at TAREC, the unfertilized control treatments at Lewiston were fertilized with nitrogen at match-head square. This was done to keep the Lewiston location consistent during all three years of the study. No plant height differences were observed during any sampling interval at Lewiston during 2015 (Table 5). Crop growth was slower at Lewiston than the TAREC location during the 2015 growing season.

In addition to plant heights, a Greenseeker® Crop Sensor (Trimble Navigation Limited, Sunnyvale, CA) was used to measure normalized vegetative index (NDVI) for each plot.

**Table 5: Early season plant height of cotton grown under different nutrient management systems at Lewiston, NC**

| Nutrient Management Systems | Plant Height | | | | | |
|---|---|---|---|---|---|---|
| | 3rd‡ | 4th | 5th | 6th | 7th | 8th |
| | ------------------ in. ------------------ | | | | | |
| Unfertilized Control | 3.8 | 7.2 | 8.8 | 13.7 | 21.5 | 26.9 |
| Broadcast Agronomic Control | 3.7 | 7.1 | 9.1 | 14.6 | 21.5 | 27.9 |
| Liquid Starter Control | 3.7 | 7.5 | 9.6 | 16.3 | 23.2 | 28.5 |
| 100% 2X2 N-P-K-S | 3.5 | 6.9 | 8.5 | 14.5 | 20.9 | 26.6 |
| 100% Deep Placement N-P-K-S | 3.9 | 7.5 | 9.8 | 16.8 | 23.5 | 28.9 |

‡ Week after Planting

**Table 6: Normalized difference vegetative index (NDVI) for cotton grown under different nutrient management systems at TAREC**

| Nutrient Management Systems | Normalized Difference Vegetative Index (NDVI) | | | | | |
|---|---|---|---|---|---|---|
| | 4th‡ | 5th | 6th | 7th | 8th | 9th |
| Unfertilized Control | 0.38 ab* | 0.80 | 0.83 b | 0.78 b | 0.78 b | 0.78 b |
| Broadcast Agronomic Control | 0.41 ab | 0.83 | 0.86 a | 0.85 a | 0.89 a | 0.87 a |
| Liquid Starter Control | 0.45 a | 0.84 | 0.86 a | 0.86 a | 0.90 a | 0.88 a |
| 100% 2X2 N-P-K-S | 0.35 b | 0.82 | 0.85 a | 0.84 a | 0.88 a | 0.87 a |
| 100% Deep Placement N-P-K-S | 0.40 ab | 0.83 | 0.85 a | 0.85 a | 0.89 a | 0.87 a |

*Values with the same letter are not significantly different at α=0.05
‡ Week after Planting

**Table 7: Normalized difference vegetative index (NDVI) for cotton grown under different nutrient management systems at Lewiston, NC.**

| Nutrient Systems | Normalized Difference Vegetative Index (NDVI) | | | |
|---|---|---|---|---|
| | 7th‡ | 8th | 9th | 10th |
| Unfertilized Control | 0.72 | 0.80 | 0.83 | 0.88 |
| Broadcast Agronomic Control | 0.75 | 0.79 | 0.83 | 0.88 |
| Liquid Starter Control | 0.74 | 0.81 | 0.81 | 0.87 |
| 100% 2X2 N-P-K-S | 0.76 | 0.81 | 0.83 | 0.87 |
| 100% Deep Placement N-P-K-S | 0.78 | 0.81 | 0.85 | 0.87 |

*Values with the same letter are not significantly different at α=0.05
‡ Week after Planting

**Table 8: Total Nodes and nodes above white flower (NAWF) for cotton grown under different nutrient management systems at TAREC**

| Nutrient Systems | Total Nodes | | | NAWF | |
|---|---|---|---|---|---|
| | 6th‡ | 7th | 8th | 9th | 10th |
| Unfertilized Control | 7.7 | 8.0 | 8.2 | 4.1 b | 2.2 |
| Broadcast Agronomic Control | 8.3 | 8.5 | 9.5 | 5.9 a | 3.5 |
| Liquid Starter Control | 8.6 | 9.2 | 9.5 | 6.0 a | 3.7 |
| 100% 2X2 N-P-K-S | 8.5 | 8.9 | 9.1 | 5.4 a* | 4.3 |
| 100% Deep Placement N-P-K-S | 8.2 | 8.8 | 9.9 | 5.8 a | 3.6 |

*Values with the same letter are not significantly different at α=0.05
‡ Week after planting

Measurements were initiated at the 4th WAP and 7th WAP for TAREC and Lewiston respectively (Tables 6 and 7). Nutrient management systems were significantly different during the 4th WAP at TAREC, with the fluid starter control having significantly higher NDVI values than the 100% 2 x 2 N-P-K-S (Table 6). From the 6th WAP to the 8th WAP the only significant differences occurred at TAREC between the fertilized and unfertilized treatments. By the 5th WAP, NDVI values were greater than 0.8 for all treatments, indicating that biomass and reflectance increased the most from the 4th to the 5th WAP at TAREC. No differences were observed in NDVI at Lewiston. One possible cause for this was that readings were initiated after sidedress N was applied and all nutrient management systems received N at sidedress (Table 7). Again, NDVI values were greater than 0.7 for all treatments at Lewiston during 2015 from the 7th WAP through the 10th WAP.

**Table 9: Total Nodes and nodes above white flower (NAWF) for cotton grown under different nutrient management systems at Lewiston, NC**

| Nutrient Systems | Total Nodes | | | | NAWF | |
|---|---|---|---|---|---|---|
| | 5th‡ | 6th | 7th | 8th | 9th | 10th |
| Unfertilized Control | 5.2 | 6.2 | 8.7 | 9.9 | 3.8 | 2.7 |
| Broadcast Agronomic Control | 5.1 | 6.4 | 7.8 | 9.9 | 4.1 | 2.6 |
| Liquid Starter Control | 5.3 | 6.5 | 8.3 | 9.7 | 3.4 | 2.9 |
| 100% 2X2 N-P-K-S | 4.8 | 6.1 | 8.0 | 9.5 | 3.8 | 2.9 |
| 100% Deep Placement N-P-K-S | 5.6 | 6.9 | 7.8 | 10.1 | 3.8 | 2.5 |

*Values with the same letter are not significantly different at α=0.05
‡ Week after Planting

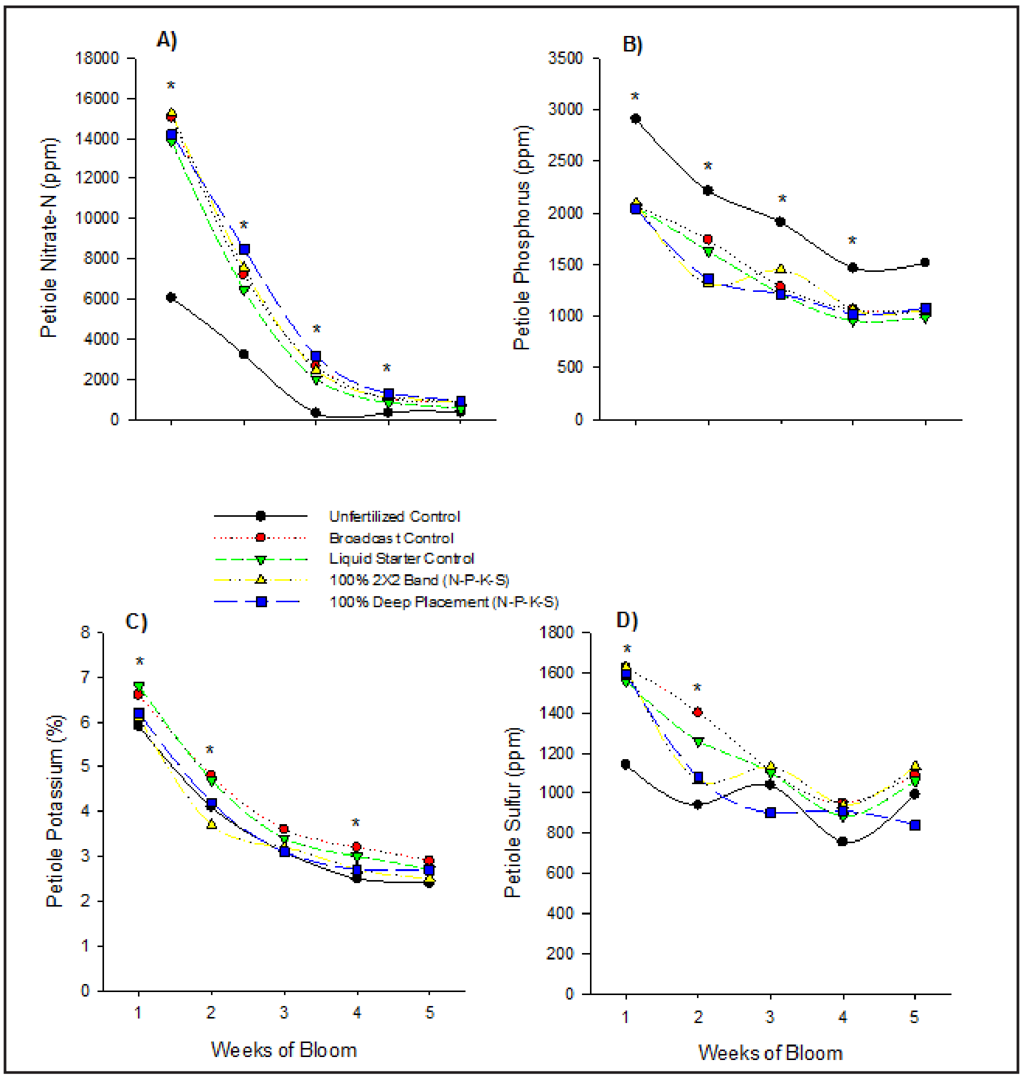


**Fig. 3:** Nitrate-N (A), phosphorus (B), potassium (C), and sulfur (D) concentrations in cotton petioles using different nutrient application management systems during the 1st nine weeks of bloom at TAREC (*ANOVA was significant at α = 0.05 for that sampling interval).

No differences were observed at either location during 2015 in the total number of nodes among nutrient management systems (Tables 8 and 9). The total number of nodes was similar at both locations and increased as the growing season progressed. The NAWF were significantly different among nutrient management systems at TAREC during the 9th WAP with the unfertilized control having significantly fewer NAWF than all other systems (Table 8). No differences in NAWF were observed at Lewiston among nutrient management systems (Table 9). Both locations were below the cutout point for NAWF (< 5 nodes) during the second week of bloom, indicating that the bloom period was significantly shortened during 2015 due to environmental conditions during August.

***Petiole/tissue analyses.*** Overall petiole and tissue analyses were similar to 2013 and 2014 in the trends observed during the first five weeks of bloom. Petiole nutrient concentrations for TAREC and Lewiston are in Figures 3 and 4. At both locations, petiole nitrate N concentrations dropped quickly and were below 3,000 ppm by the third week of bloom at each location (Figures 3A and 4A). The only petiole nitrate-N concentration differences observed were at TAREC with the unfertilized control having significantly less petiole nitrate N concentrations than the fertilized treatments (Figure 3A).

At Lewiston, the unfertilized controls received N at sidedress and no differences among nutrient management systems in petiole nitrate N concentrations were observed during the bloom period. For petiole phosphorus concentrations, again the unfertilized control treatments at TAREC, which received no sidedress N, had significantly higher petiole P concentrations during weeks 1 through 4 than fertilized plots (Figure 3B). No differences in petiole P concentrations were observed at Lewiston during the bloom period (Figure 4B). The elevated petiole P concentrations when N was deficient was observed in 2013 and 2014 as well. At TARAEC, the petiole P concentrations decreased from 2000 ppm P to 1,000 ppm P during the first five weeks of bloom at TARAEC where concentrations decreased from 1,700 ppm to 1,500 ppm during the same time period at Lewiston (Figures 3B and 4B).

At TAREC, petiole K concentrations were significantly different for 3 out of 5 weeks of bloom with the unfertilized control having significantly lower petiole K concentrations than the fluid starter control during the 1st, 2nd, and 4th weeks of bloom (Figure 3C). During the 2nd and 4th weeks of bloom, the broadcast control produced significantly higher petiole K concentrations than the unfertilized control (Figure 3C). No differences in petiole K concentrations were observed at Lewiston. However, the unfertilized control had the lowest petiole K concentrations during each week of bloom (Figure 4 C).

The last petiole nutrient evaluated was S and both locations had significant petiole S responses during bloom (Figures 3D and 4D). At TAREC, the unfertilized control had significantly lower petiole S concentrations during the first week of bloom than all other treatments and significantly lower than the broadcast control during the 2nd week of bloom (Figure 3D). At Lewiston, the 100% 2x2 N-P-K-S blend had significantly higher petiole S concentrations than the unfertilized control during the 1st, 3rd, and 4th weeks of bloom and was significantly higher than all fertilized treatments during the 3rd week of bloom (Figure 4D). The results at Lewiston indicated that placing S in a 2 x 2 band at planting was highly effective in supplying S throughout the growing season when 32% UAN was used as the sidedress N source. Whereas at TAREC, 24-0-0-3S UAN/AMS fluid was used as the side-dress N source.

During the 1st and 4th weeks of bloom, leaf tissue was sampled to determine differences among nutrient management systems and compared sensitivity of petiole and leaf nutrient concentrations when determining in-season nutritional status. At TAREC, leaf N for the unfertilized control was significantly lower than all fertilized treatments (Table 10). The broadcast agronomic control had significantly higher leaf K concentrations than the unfertilized control during the 1st week of bloom and all nutrient management systems produced significantly higher leaf K concentrations than the unfertilized control (Table 10). The only other leaf tissue response at TAREC was during the 1st week of bloom for leaf S concentrations with the unfertilized control having significantly lower leaf S

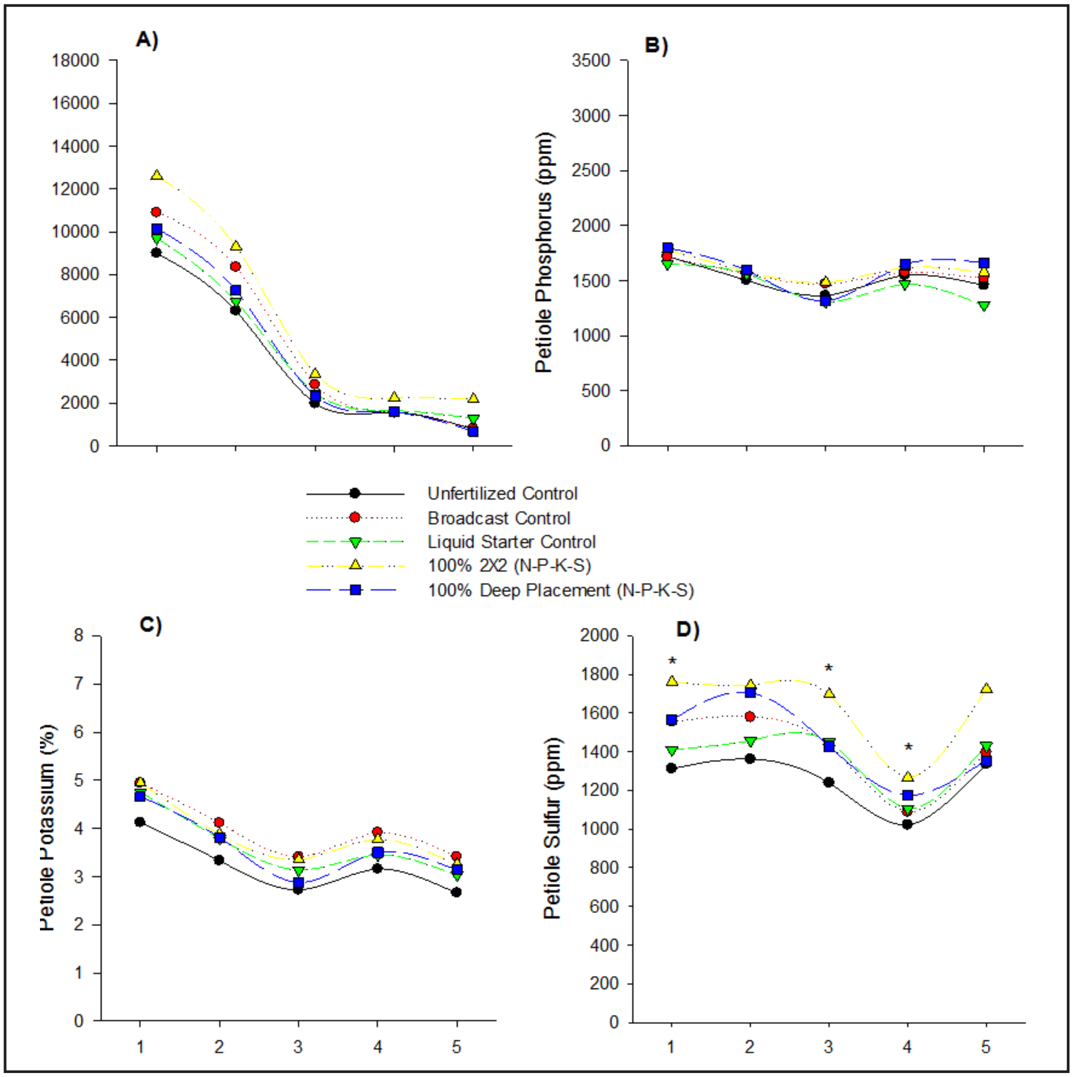


**Fig. 4:** Nitrate-N (A), phosphorus (B), potassium (C), and sulfur (D) concentrations in cotton petioles using different nutrient application management systems during the 1st nine weeks of bloom at Lewiston, NC (*ANOVA was significant at α = 0.05 for that sampling interval).

**Table 10: Nitrogen, phosphorus, potassium, and sulfur concentrations in cotton leaf tissue during the 1st and 5th weeks of bloom at TAREC**

| Nutrient Systems | Leaf Nutrient Concentrations | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1st‡ | | | | 5th | | | |
| | N | P | K | S | N | P | K | S |
| | ------------------- % ------------------- | | | | | | | |
| Unfertilized Control | 4.24 b | 0.34 | 1.40 b | 0.60 b | 2.89 b | 0.24 | 1.16 b | 0.65 |
| Broadcast Agronomic Control | 5.15 a | 0.35 | 1.69 a | 0.97 a | 3.62 a | 0.25 | 1.44 a | 0.82 |
| Liquid Starter Control | 5.19 a | 0.36 | 1.64 ab | 0.90 a | 3.54 a | 0.26 | 1.40 a | 0.83 |
| 100% 2X2 N-P-K-S | 5.21 a | 0.35 | 1.51 ab | 0.94 a | 3.63 a | 0.25 | 1.43 a | 0.77 |
| 100% Deep Placement N-P-K-S | 5.09 a | 0.34 | 1.57 ab | 0.92 a | 3.62 a | 0.24 | 1.41 a | 0.77 |

*Values with the same letter are not significantly different at α = 0.05
‡ Week of bloom

than all other fertilized treatments (Table 10).

At Lewiston, no differences in Leaf N and P concentrations were observed during the 1st and 5th weeks of bloom (Table 11). Leaf K concentrations were significantly higher for the 100% 2 x 2 N-P-K-S compared to the broadcast agronomic control, fluid starter control and unfertilized control during the 1st week of bloom (Table 11). The leaf K concentrations at Lewiston were below current sufficiency ranges for K during early bloom of 1.5 to 3.0% K (Mitchell and Baker, 2009). The only other difference in leaf nutrient concentrations observed at Lewiston was during the 5th week of bloom when the 100% 2 x 2 N-P-K-S and deep placement systems produced significantly higher leaf S concentrations than the unfertilized control (Table 11).

***Lint yield.*** Lint yields were again exceptional during the 2015 study at both locations. The only response observed during the 2015 study was at TAREC, with the unfertilized control having significantly less lint yield compared to all other fertilized nutrient management systems (Figure 5). At Lewiston, there was no difference in lint yields among nutrient management systems indicating that N was the most limiting nutrient at that location. However, there is a trend that the unfertilized control (1,293 lbs. lint per acre) had the lowest lint yield (Figure 5). These are similar responses to what was observed in 2013 and 2014 at both locations.

**Table 11: Nitrogen, phosphorus, potassium, and sulfur concentrations in cotton leaf tissue during the 1st and 5th weeks of bloom at Lewiston, NC**

| Nutrient Systems | Leaf Nutrient Concentrations | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1st‡ | | | | 5th | | | |
| | N | P | K | S | N | P | K | S |
| | ------------------------------------ % ------------------------------------ | | | | | | | |
| Unfertilized Control | 4.03 | 0.27 | 0.93 b | 0.64 | 4.02 | 0.31 | 1.10 | 0.85 b |
| Broadcast Agronomic Control | 3.90 | 0.25 | 1.00 b | 0.67 | 4.27 | 0.32 | 1.29 | 0.91 ab |
| Liquid Starter Control | 4.09 | 0.25 | 1.01 b | 0.67 | 4.46 | 0.30 | 1.20 | 0.92 ab |
| 100% 2X2 N-P-K-S | 4.07 | 0.26 | 1.16 a | 0.82 | 4.47 | 0.31 | 1.17 | 0.95 a |
| 100% Deep Placement N-P-K-S | 4.03 | 0.26 | 1.03 ab | 0.73 | 4.15 | 0.33 | 1.20 | 0.95 a |

*Values with the same letter are not significantly different at α = 0.05
‡ Week of bloom

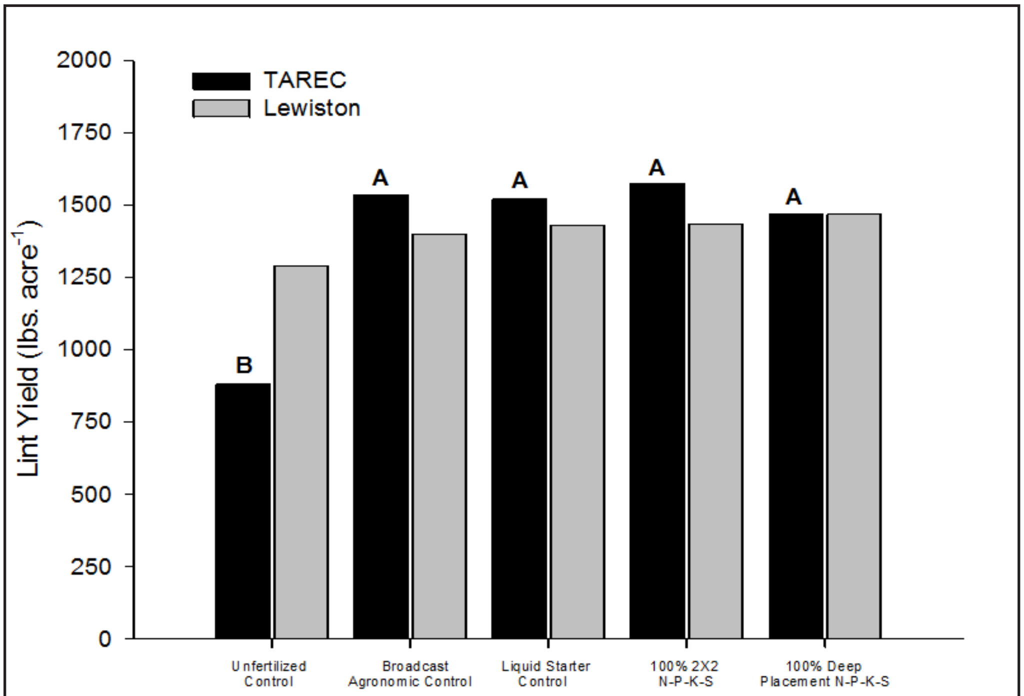


**Fig. 5:** Lint yield and nutrient management systems at TAREC and Lewiston, NC. Bars with the same letter are not significantly different at α = 0.05 within location.

## Summing up

The results of the trial were very consistent among nutrient management systems from year to year and within each location and side-dress N management. Responses to P and K rate as well as 2 x 2 deep placement combinations were limited across all locations in terms of plant growth, petiole and tissue nutrient concentrations, and lint yield during the three years of the study. When N was deficient petiole P concentrations were artificially high, most likely due to a concentration of P in lower biomass for N deficient plots. Petiole and leaf K concentrations were not affected by N status during bloom and results indicate that broadcasting K may be more efficient, based on petiole K data in this study.

Sulfur is the one nutrient in cotton where data are limited in the upper southeast coastal plain. At Lewiston, when 32% UAN was used as the side-dress N source, the 100% 2 x 2 N-P-K-S placement at planting produced higher petiole S concentration, which indicates that this placement technique was more efficient in delivering S in cotton than the other techniques. However, for the broadcast and fluid starter agronomic control, the balance of S was applied with the deep placement strip-tillage implement. More data are needed to ascertain if broadcasting S will perform similar to the 2 x 2 placement.

For lint yield, N was the most limiting nutrient during the study with only lint yield differences occurring in the unfertilized control at TAREC each of the three years. Responses to P and K during the study were limited, as sites chosen were based on medium to high soil test P and K levels. Overall, the study was valuable in evaluating the performance and placement of new P and K fluid sources on cotton growth and performance in the upper southeast coastal plain.

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