concentration is illustrated in Figures 4 and 5. Data from Iowa are used to illustrate these relationships. While the slope of the relationships is between ear-leaf N concentration, and that of the various nutrient concentrations was unique for each element, the two hybrids performed similarly. The relationships for Iowa were linear in all cases, and generally similar for Illinois. Relationships between ear-leaf N versus P, K, and S were insignificant.

The above relationships in Figures 4 and 5 for Iowa compliment the data from the Illinois and Nebraska locations. In general, nutrient concentrations increased as ear-leaf N concentration increased up to the point of N adequacy (i.e., 2.75% N). Figure 6 illustrates that nutrient concentrations tended to reach a plateau when ear-leaf N concentrations exceeded 2.75 percent N. Perhaps these plateau concentrations could serve as reference values when using the DRIS approach for assessing nutrient adequacy.

**Be Careful**

One might be tempted to conclude that increasing fertilizer N rates should increase yields because it increases the concentrations of other nutrients. In fact, one might also conclude that a little N fertilizer (approaching the 130 percent N rate) might even compensate for small deficiencies in other nutrients. This conclusion is probably erroneous because when N ions (nitrate or ammonium) are taken up, plants must also take up a companion ion with the opposite net charge.

**Summing up**

The second year of this study, funded by the Fluid Fertilizer Foundation, confirmed preliminary observations made in 2012. The take-home lesson might be that when evaluating tissue testing data, make sure the ear-leaf N concentrations are adequate before drawing conclusions about the adequacy of other nutrients.

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**Figure 4.** Effect of ear-leaf N concentration on Mg and Ca concentrations at silking for two Pioneer brand hybrids in Iowa in 2013.

**Figure 5.** Effect of ear-leaf N concentration on zn and Cu concentrations at silking for two Pioneer brand hybrids in Iowa in 2013.

**Figure 6.** Effect of ear-leaf N concentration on Fe and Mn concentrations at silking for two Pioneer brand hybrids in Iowa in 2013.

**Summary:** At the TAREC location, the 2x2 band of phosphorus (P) and potassium (K) increased early-season plant height compared to standard nutrient management systems. Unfertilized control had the highest P concentrations in cotton petioles throughout the bloom period. The high petiole P concentration may be related to nitrogen (N) deficiency and if this proves to be true then N status will have to be evaluated before making in-season management decisions based on petiole P concentrations. When comparing the 2x2 band and deep placement across multiple application rates, the 2x2 band produced 144 lbs. of lint/acre more than the deep placement of P and K. The 2x2 band containing NPK sulfur significantly increased early-season vigor of cotton and increased lint yield over the deep placement strategy alone.

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**Objectives**

Objectives of this study were to:

- Determine the impact on early-season development of upland cotton (Gossypium hirsutum) through first square, nutrient status during the first nine weeks of bloom, and lint yield and quality of placing a fluid P and K fertilizer at multiple depths below the seed during strip-till cultivation
- Evaluate selected combinations of P and K placed at multiple depths in the strip-till process in combination with 2x2 banding of P and K solutions at planting on crop establishment, growth through first square, nutrient status during the first nine weeks of bloom, and lint yield and quality.

**Site characteristics**

- **Soil type** at the TAREC location was an Eulona loamy sand (fine-loamy, siliceous, semi-active, thermic Aquic Hapludults).
- The soil type at Lewiston was a Rains sandy loam (fine-loamy, siliceous, semi-active, thermic Typic Paleaquults).

**Soil samples** were taken from both locations to a total depth of 12 inches (30cm) and split into depths of 0-3, 3-6, 6-9, and 9-12 inches.

**Soil test.** The Mehlich I soil test levels for each location can be found in Table 1. Fertilizer rates. The base (100%) preplant P and K rates were 40 lbs P2O5/acre and 40 lbs K2O/acre and based on Mehlich I soil test levels. All other agronomic practices were conducted according to Virginia extension recommendations.

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**Experimental Design**

The study was conducted using four-row plots measuring 12 feet wide by 40 feet long at two locations. Each treatment was replicated four times in a randomized complete block design. The cotton variety grown was Phytoflex 499 WRF, a mid-maturing variety with a high yield potential. Thirteen treatments evaluated placement of P and K fluid fertilizers (Table 2). Treatment 1 was an unfertilized P and K control. However, at TAREC, unfertilized plots did not receive N or S, while the unfertilized check at Lewiston received 80 lbs. N per acre in a sidedress application. Two agronomic control treatments were implemented to simulate the current...
nutrient management systems in Virginia:

- All of the required P and K was broadcast prior to planting.
- 100 lbs of ammonium polyphosphate
  - 100 lbs of ammonium polyphosphate
  - All of the required P and K was broadcast prior to planting.

Treatments 4 through 9 evaluated the response to P and K nutrient fertilizers at 6, 9, and 12 inches below the soil surface during strip tillage. Treatment application

Deep placement treatments were applied with a two strip-tillage implement three days prior to planting at TAREC and 14 days prior to planting at Lewiston. Fertilizer placement with strip-tillage was accomplished with an apparatus depicted in Figure 1. To dispense fluid fertilizer at 6, 9, and 12 inches below the soil surface, holes drilled 90° to the direction of travel allowed the fluid fertilizer to exit each down-spout and maximize contact with the soil at the targeted depths. The 2 x 2 factorial use of rates and sources was tested, 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 in-line nozzles (Figure 1). The broadcast P and K were applied on the same strip 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 liquid phosphate source applied was ammonium polyphosphate (10-30-40) (APP) and the fluid potassium source was potassium thiosulfate (0-0-25-17S). The potassium thiosulfate supplied 40.8 lbs. S/acre when applied at the 150 percent rate, which is greater than the increased agronomic P rates in cereal grain production. Ammonium thiosulfate (12-0-026S) (ATS) was used to balance the S rate among treatments. In the treatments where deep placement of P and K was conducted, samples techniques were implemented, the added S was applied using deep placement to prevent any potential injury to cotton seedlings. Preplant 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 pounds N per acre. The N was balanced using the fluid urea-ammonium nitrate (UAN 30-0-0). The total N application rate was set at 115 lbs N/acre, with the remaining 80 lbs N being applied in a sidedress application using a 14:0:03S as TAREC and UAN30 at Lewiston, applied at match-head square. At TAREC, the unfertilized control treatment received no sidedress or S, while at Lewiston the unfertilized plots received the full 80 lbs of N/acre sidedress application. All of the treatments were applied based on the soil test recommendations.

In-season development

Plant population counts were taken at TAREC and Lewiston by counting the number of emerged seedlings in two ten-foot sections of row. Plant population counts were taken at 7, 10, and 21 days after planting. Plant heights were measured weekly beginning with the appearance of the second true leaf and measured from ground to the apex meristem. In most cases, the cotton plant had two flowered at the main stem node, and the cotton petioles were counted weekly on five randomly selected plants per plot. Plant height and total node measurements ceased with the appearance of the first white flower at each location. Tissue sampling

Beginning the first week of bloom, twenty-four cotton petioles were sampled from the first and fourth rows of each plot. 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 nine weeks of bloom. Petioles sampled during the seventh through ninth weeks of bloom were taken from the third leaf and the plant population was counted before the third leaf was removed from the main stem as there were not enough leaves in the fourth position for a complete sample. The maturity level of the third leaf was thought to be similar as vegetative growth had ceased prior to this stage of development. The plant tissue samples were sent to the Soil and Water Laboratories (Camilla, GA) for analysis. The petioles were analyzed for nitrogen-N, P, and S. Nutrient concentrations in petioles were plotted against time. Nutrient concentrations were collected during the first and fifth weeks of bloom only, and a complete nutrient analysis was conducted on the leaf tissue. Defoliation

Defoliation timing of cotton varies, depending on the growing season and development of the cotton crop. Defoliation was delayed when 50 to 60 percent of the bolls were opened. Harvesting

Seed cotton was harvested using two-row commercial cotton pickers modified for small plot harvesting. The center two rows of each plot were harvested and plot weights recorded. Cotton lint

A one pound subsample of seed cotton was ginned on a 10-secon- droin 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 (HV) to determine fiber length (staple), strength, micronaire, color, and leaf (trash) grade. Statistical analysis

The data set separated into two separate data sets and analysis of variance (ANOVA), using PROC MIXED in SAS 9.3, was used to determine differences among treatments. The first data set consisted of the different nutrient management systems tested at the 100 percent 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. Analysis of variance was performed for each set of data using the Tukey-Kramer HSD at α = 0.1 level of significance. Results

General comments.

The 2013 growing season was very unique in the upper Southeast coastal plain of the United States. A cool wet May delayed cotton planting for up to two weeks and cooler than normal temperatures prevailed for much of the growing season. The shorter cotton season seemed to have little impact on yield in Virginia as the two study locations produced exceptional yields. The Lewiston location was planted later than was expected and suffered sand burn damage very early in the growing season. The decision was made not to abandon the location since treatments had been applied. Luckily, the first sampling for plant population had been conducted before the damage and another plant population count was conducted after the damage. With the two different plant population sampling intervals it was found that, on average, the injury reduced plant populations by two plants per ten feet of row. This is not an insignificant loss of stand and represents a decrease in the plant population of 2,904 plants per acre. The cotton was slow to recover from the damage and in-season plant population measurements were affected by the variation introduced by the sand burn damage at Lewiston. The delay in development of the cotton at Lewiston allowed the first initial petiole results to come in for TAREC. The petiole results indicate elevated P concentration in petiole for the unfertilized checks, as well as N deficiency. The decision was made to apply sidedress N at Lewiston and test the hypothesis that N deficiency produces elevated P concentration in cotton petals. If this hypothesis is proven to be true, then decisions about P management in cotton cannot be made off petiole concentrations if there is a known N deficiency. For growers looking to improve nutrient use efficiencies with petiole testing, this knowledge will increase the efficacy of their in-season nutrient management decisions. Nutrient management

Plant growth. In-season plant growth measurements were initiated seven days after planting with plant population counts. Among the nutrient management systems there were no differences in plant population at any sampling intervals (data not shown). Emergence

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

<table>
<thead>
<tr>
<th>Depth</th>
<th>TAREC</th>
<th>Lewiston</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-3</td>
<td>49 (H+)</td>
<td>99 (H+)</td>
</tr>
<tr>
<td>3-6</td>
<td>31 (H)</td>
<td>86 (M+)</td>
</tr>
<tr>
<td>6-9</td>
<td>20 (H)</td>
<td>73 (M)</td>
</tr>
<tr>
<td>9-12</td>
<td>19 (H)</td>
<td>68 (M)</td>
</tr>
</tbody>
</table>

Image 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.

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Figure 2: Sand-burn injury 6/17 (A) and 7/2 (B)
The data indicate that the 2 x 2 band (100%) program produced significantly taller plants than the unfertilized control on June 20 (Table 3). Plant heights in TAREC were not significantly different on the first sampling interval, except one (Table 3). The plant heights in TAREC were not significantly different on the first sampling interval, except one (Table 3).

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There were no leaf N or P differences between nutrient management systems at the Lewiston location (data not shown). The unfertilized control received 80 lbs. of N at sidedress to provide a location where N was not limiting. Leaf K levels at Lewiston differed during the first week of bloom. However, there was no clear trend in the differences. The unfertilized control did have the lowest leaf K levels (1.09%) and the 2 x 2 band (100%) (1.25%) produced the highest leaf K levels during the first week of bloom at Lewiston. The only other leaf tissue differences observed at Lewiston were for sulfur concentrations during the first and fifth weeks of bloom. The unfertilized control was significantly lower in leaf S concentration than the 2 x 2 band (100%) treatment during both sampling intervals.

Potassium (A), phosphorus (B), nitrate (C) and sulfur (D) concentrations at Lewiston.  

<table>
<thead>
<tr>
<th>Placement</th>
<th>Plant Population (plants / 10 ft row)</th>
<th>Plant Height (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% 17-May 21-May 24-May 31-May 4-Jun 13-Jun 20-Jun 26-Jun 3-Jul 10-Jul</td>
<td></td>
</tr>
<tr>
<td>-</td>
<td>50 16.87 28.8 b 29.8 29.7 5.0 8.7 11.0 16.5 b 24.1 31.2</td>
<td></td>
</tr>
<tr>
<td>-</td>
<td>100 18.25 31.1 a 30.9 31.3 5.1 9.1 11.7 17.7 ab 24.9 31.5</td>
<td></td>
</tr>
<tr>
<td>+</td>
<td>150 17.43 29.6 ab 29.9 31.1 5.1 9.3 11.6 18.1 a 25.0 31.9</td>
<td></td>
</tr>
<tr>
<td>2X2 Band</td>
<td>18.5 a 30.3 30.8 a 31.3 a 5.1 9.2 11.5 17.9 a 25.5 a 32.0 a</td>
<td></td>
</tr>
<tr>
<td>Deep Placement</td>
<td>16.5 b 29.4 29.6 b 30.1 b 5.0 8.8 11.4 17.0 b 23.9 b 30.9 b</td>
<td></td>
</tr>
<tr>
<td>2X2 Band</td>
<td>18.0 a 29.3 31.1 ab 31.1 4.9 8.7 10.6 16.4 24.8 31.3</td>
<td></td>
</tr>
<tr>
<td>2X2 Band</td>
<td>20.0 a 31.4 30.4 ab 31.8 5.2 9.4 12.1 18.6 25.9 32.0</td>
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<tr>
<td>2X2 Band</td>
<td>17.5 a 30.3 30.8 ab 30.9 5.2 9.5 11.7 18.7 25.8 32.8</td>
<td></td>
</tr>
<tr>
<td>Deep Placement</td>
<td>15.8 a 28.3 28.4 b 28.3 5.1 8.7 11.3 16.7 23.5 31.0</td>
<td></td>
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<tr>
<td>Deep Placement</td>
<td>16.5 a 30.9 31.4 a 30.9 4.9 8.7 11.3 16.9 23.9 30.9</td>
<td></td>
</tr>
<tr>
<td>Deep Placement</td>
<td>17.4 a 29.0 29.1 ab 31.3 5.0 9.1 11.6 17.4 24.2 30.9</td>
<td></td>
</tr>
</tbody>
</table>

ANOVA (Pr > F)  

| P and K Rate | NS* | 0.0030 | NS | NS | NS | NS | NS | 0.0591 | NS | NS |
| Placement | 0.0545 | 0.0675 | 0.0942 | NS | 0.0099 | 0.0214 | NS |

† 100% of the recommended rate is equal to 40 lbs P2O5 and 40 lbs K2O per acre

Comparisons to the unfertilized control were made using a Duncan’s Multiple Range Test at the α = 0.1 level of significance. The ANOVA for that fixed effect in the model was not significant at α = 0.1.

On average, the 2 x 2 placement produced two more plants per row foot than deep placement. Faster emergence rates would be beneficial in Virginia cotton production as weather patterns in May can be highly variable. A key question is, if there is enough root growth present at time of emergence to take advantage of the 2 x 2 band placement, can this effect be replicated over multiple locations and years?

Lent yields at both locations were exceptional, considering the 2013 growing season and the planting date at Lewiston, NC, in conjunction with the early-season injury. Yields at TAREC ranged from 1,184 to 2,024 lbs. per acre and Lewiston ranged from 1,100 to 1,469 lbs. per acre. The unfertilized control was significantly higher plant populations at both locations during both sampling intervals at Lewiston were for sulfur concentrations (Table 4). This was the only other leaf tissue difference observed at Lewiston (data not shown). Phosphorus concentrations in leaf tissue differed during the first week of bloom with the deep placement having higher P concentrations than the 2 x 2 band at Lewiston (data not shown). The difference in P concentration was not observed during the fifth week of bloom at Lewiston. Potassium concentration in cotton leaves differed among application rates and placement during the first and fifth weeks of bloom (data not shown). Lewiston had the lowest soil test levels of K out of the two locations and was why the location was more responsive to K rate than TAREC. Leaf K concentrations increased as application rate increased during both sampling intervals at Lewiston (data not shown). The 2 x 2 band also increased leaf K concentration during both sampling intervals (data not shown).

These findings suggest that the leaf tissue analysis may be more sensitive to changes in plant K status than petiole testing. Also, K concentrations in the leaf tissue are more stable than petiole K concentrations throughout the bloom period in cotton. Leaf K concentrations may be more indicative of K status of cotton during the bloom period than petiole K.

Plant height. No differences in plant heights were observed between P and K rates and placement methods until June 26 (Table 4). On June 26 plant heights for the 150 percent P and K rates were significantly higher than the 50 percent P and K rate at TAREC (Table 4). This was the only sampling interval where plant heights differed among P and K rates. The 2 x 2 band placement produced taller plants from June 26 through July 10 at TAREC (Table 4). Plants grown using the 2 x 2 band placement at TAREC consistently showed increased early-season vigor throughout the 2013 study.

Leaf tissue analysis was more sensitive to differences among placement and application rates of P and K at Lewiston than petiole nutrient concentrations (data not shown).
Lint yield was not affected by P and K application rates at either location during 2013. At TAREC, lint yields were increased with the 2 x 2 band placement compared to the deep placement of P and K (Figure 6A). The 2 x 2 band produced 2,002 lbs. of lint at TAREC while the deep placement of nutrients yielded 1,858 lbs. of lint at TAREC. At Lewiston, lint yields with the 2 x 2 band were not significantly different from the deep placement system, however there was a 79 lb. lint difference between the two treatments, with 1,333 lbs. lint/acre and 1,254 lbs. lint/acre, respectively. No differences in fiber quality were observed between the 2 x 2 band and deep placement at either location (data not shown).

The 2013 growing season in Virginia presented challenges to cotton producers. However, the lint yields were an exception for the study. Sand-burn injury at Lewiston introduced variability, which ultimately could not be overcome during the growing season. However, the injury did provide some data on nutrient status of cotton under early-season stress and this could be valuable to producers and consultants when making management decisions in the future. The TAREC data indicate that the 2 x 2 placement of a complete nutrient blend increased early-season growth. In areas such as Virginia, early-season vigor is extremely important in cotton production, due to temperature changes and insect pressure. The experiment also demonstrated that placing fluid fertilizers under the row with strip-tillage could be achieved and performance with this technique was similar to current nutrient management systems. When comparing the 2 x 2 band to deep placement, the 2 x 2 band increased early season growth and higher yields at TAREC during 2013. More data are needed to confirm the findings of the 2013 study, but preliminary results indicate that nutrients placed in banded zones, especially a 2 x 2 band, are equal to current nutrient management systems.

Summing up

The Fluid Fertilizer Foundation was established by the fluid fertilizer industry 33 years ago! A few of the achievements of the Fluid Fertilizer Foundation since its inception in 1982 include:

- Supported millions of dollars of applied crop production research
- Provided technical and agronomic education to thousands of agricultural professionals
- Published hundreds of scientific articles in our flagship publication, the Fluid Journal

This year’s Fluid Forum will be at the Talking Stick Resort, 9800 East Indian Bend Rd. on February 16-18, 2015 in Scottsdale AZ 85256.

For additional information about the 2015 Forum, please see our website at http://www.fluidfertilizer.com

Not a Fluid Fertilizer Foundation member yet? Please contact us at 785-776-0273 or by e-mail at fluidfertilizer@fff.kscoxmail.com