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# AGRONOMY & SOILS

## Variable Rate Seeding in Cotton Production

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### ABSTRACT

**Fluctuating commodity prices and increasing input costs force growers to look for ways to remain competitive, sustainable, and profitable. The vast amount of genetic technology included in cotton seed today has resulted in high upfront costs for seeds that typically can exceed 10 to 15% or more of the total input costs in South Carolina. Additionally, the availability and use of precision planter technologies have increased across farms in the southeastern U.S. The objective of this research was to determine if variable rate seeding in cotton can increase profitability. Field experiments were conducted during 2017 and 2019 to 2022 near Blackville, SC to evaluate variable rate seeding in cotton. Each year, six to eight uniform seeding rates (24,700-197,600 seeds ha$^{-1}$) were planted in addition to a variable rate treatment. Results from experiments indicated that variable rate seeding performed as well as the best uniform seeding rate and no one seeding rate provided a maximum lint yield or profit across site-years. However, depending on the uniform seeding rate selected or the implementation of variable rate seeding, lint yield varied from 558 to 1564 kg ha$^{-1}$ and profitability varied between 756 to 3569 \$/ha$^{-1}$ among treatments. Based on the results from this research, variable rate seeding in cotton did not improve profitability over certain uniform seeding rates.**

Throughout the southeastern U.S., cotton is a valuable and important agronomic commodity. In 2022, cotton revenue was $248 million on approximately 107,000 hectares in South Carolina (USDA NASS, 2023). As an indeterminate crop, cotton can compensate for changing environmental conditions and variable agronomic practices, including varying plant densities (Gwathmey, 2010). If seeding rate could be optimized or reduced, it would help save money on inputs and increase profitability. Cotton (*Gossypium hirsutum* L.) producers must manage input costs to maximize profit. Seed costs for cotton producers range from $200 to 300 per hectare, depending on market seed price, seed technology, and seeding rate (Mickey and Smith, 2023). With seed accounting for 10 to 15% of total input cost, optimizing seeding rates could increase profit if input savings exceed revenue loss.

Studies show that cotton can be seeded at a wide range without impacting yield or profit. Research conducted by Gwathmey et al. (2010) demonstrated that seeding cotton at rates ranging from 74,000 to 110,000 seeds per hectare did not affect profit. Another study showed that cotton seeding rates from 32,110 to 160,550 seeds per hectare did not negatively impact lint yield (Harrison et al., 2009). Over the last decade, planter technologies have enabled farmers to vary seeding rates across the field as a function of spatial location. Soil textures in the coastal plain of South Carolina vary considerably and are a possible factor in determining the yield potential of a field and areas within the field. Other spatially variable factors affecting cotton yield include infiltration, soil structure, organic matter, and topography (Corwin et al., 2003). Understanding the relationship between optimum seeding rates and these spatially variable factors is critical to make a profitable and consistent planting prescription. Although hardware enables growers to vary seed rates at planting, optimized variable rate prescriptions must be developed using a science-based method to consistently maximize profit.

Previous work on development of variable rate prescriptions stated that variable rate seeding is only effective if the farmer understands the relationship between different seeding rates and yield responses (Bullock et al., 1998). This study also defined various methods of obtaining this knowledge by implementing agronomic experiments in the specific field in which variable rate seeding would be implemented. The experiments included multiple years of data

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evaluating various plant densities and their accompanying yields to determine the optimal seeding rate in each area of the field (Bullock et al., 1998). One method to create variable rate prescriptions using site-specific data from individual fields is Directed Rx (D-Rx) (Kirk, 2017), which uses uniform seeding rate strips at various rates, a spatial data layer such as soil electroconductivity (EC), and profit response, as a function of yield and seeding rate, to create the prescription map. In this process, a prescription is developed in year one and applied in year two. Because there is limited published research on evaluating variable rate seeding in cotton in the southeastern U.S., the objective of this study was to evaluate the profitability of variable rate seeding in cotton on the coastal plain soils pervasive in the region.

## MATERIALS AND METHODS

Experiments were conducted at the Clemson University Edisto Research and Education Center (EREC) in Blackville, SC (33º21'55" N, 81º19'47" W), in 2017 and 2019 to 2022. Two overhead irrigated field locations, Field 1 and Field 2, consisting of a Barnwell Loamy Sand (fine-loamy, kaolinitic, thermic Typic Kanhapludults) (USDA NRCS, 2023), were used for these studies. Soil EC data were collected prior to planting using a Veris 3100 Soil EC mapper (Veris Technologies, Salina, KS), and management zones (Figs. 1 and 2) were developed for both fields using contoured shallow (0-30.5 cm) EC data. These management zones were delineated from the soil EC data and separated into seven equal zones across the fields for evaluation of most profitable seeding rate, by zone. The seven equal zones had varied EC ranges based on soil EC data from each field (Figs. 1 and 2).

Prior to planting each year, field preparation was conducted by spraying a burndown herbicide and

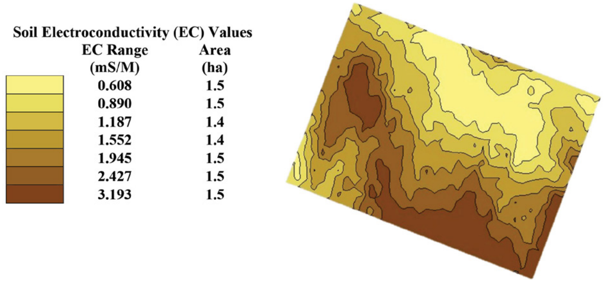


**Figure 1. Image of the soil EC management zones for Field 1 at EREC used in 2017 and 2019 for the cotton seeding prescription development.**

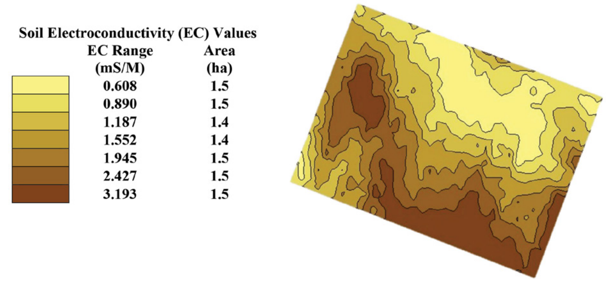


**Figure 2. Image of the soil EC management zones for Field 2 at EREC used in 2020 to 2022 for the cotton seeding prescription development.**

then strip-tilling using a 4-row Unverferth strip-till implement (Unverferth Mfg. Co., Inc., Kalida, OH) set to 96.5-cm row spacing. Deltapine 1646 B2XF (Bayer CropScience, St. Louis, MO) was planted using a 4-row John Deere 1700 vacuum planter (John Deere, Moline, IL) equipped with Precision Planting vDrive and vSet2 seed metering system (Precision Planting, LLC, Tremont, IL). These experiments were conducted in a randomized complete block design at both locations, with 4-row strip plots whose length encompassed the entire field, increasing the likelihood that each treatment passed through each soil EC zone. Other than seeding rate treatments, all plots were managed throughout the growing season according to Clemson Extension recommendations for cotton production, including fertility, irrigation, pesticide applications, and plant growth regulator applications (Jones et al., 2021).

In 2017 and 2019, six uniform seeding rates (50,966, 67,955, 84,941, 101,929, 118,918, and 135,907 seed ha$^{-1}$) were replicated nine times across Field 1 (Table 1; Fig. 3). In 2019, an additional treatment was included, which represented the D-Rx variable rate prescription that maximized profit in 2017 suggested by the soil EC zones and uniform seeding rate yield data (Fig. 4). In years 2020 to 2022 in Field 2, six uniform seeding rates of 59,280, 74,100, 88,920, 103,740, 118,560, and 133,380 seed ha$^{-1}$ were used (Table 1). In 2020 only, additional rates of 24,700 and 197,600 seed ha$^{-1}$ were added for comparison purposes (Fig. 5). Moreover, in 2021 and 2022, a variable rate seeding treatment also was included using the D-Rx variable rate prescription that maximized profit in the prior crop year for 2021 (Fig. 6) and for the previous two crop years for 2022 (Fig. 7). Prescription maps were developed using Trimble Farm Works (Trimble Inc., Westminster, CO) software, setting rates according to the discussion below.

**Table 1. Seeding rates for cotton to evaluate effects of variable plant population on yield and profitability in South Carolina**

| Year | Treatment | Seeding Rate (seeds ha$^{-1}$) |
|---|---|---|
| 2017[z] | 1 | 50,966 |
| | 2 | 67,655 |
| | 3 | 84,941 |
| | 4 | 101,929 |
| | 5 | 118,918 |
| | 6 | 135,907 |
| 2019[z] | 1 | 50,966 |
| | 2 | 67,655 |
| | 3 | 84,941 |
| | 4 | 101,929 |
| | 5 | 118,918 |
| | 6 | 135,907 |
| | 7 | D-Rx[y] |
| 2020[x] | 1 | 24,700 |
| | 2 | 59,280 |
| | 3 | 74,100 |
| | 4 | 88,920 |
| | 5 | 103,740 |
| | 6 | 118,560 |
| | 7 | 133,380 |
| | 8 | 197,600 |
| 2021 & 2022[x] | 1 | 59,280 |
| | 2 | 74,100 |
| | 3 | 88,920 |
| | 4 | 103,740 |
| | 5 | 118,560 |
| | 6 | 133,380 |
| | 7 | D-Rx[w] |

[z] Field 1 Location.

[y] Variable seeding rate using uniform seeding rate data from 2017 and Directed Rx prescription development method in Field 1.

[x] Field 2 Location.

[w] Variable seeding rate using uniform seeding data from 2020 and 2021 and Directed Rx prescription development method.

For each year of testing, each field was divided into 3.9-m wide strips to represent the 4-row plots. The D-Rx prescription map development process involved creating seven equal area management zones for each field based on the shallow EC data for the field (Figs. 1 and 2). Treatments, which included uniform seeding rate treatments in all years and D-Rx prescriptions in 2019, 2021, and 2022, were assigned to the strip plots in a randomized complete block design using a random number generator in Microsoft Excel. Each year, a ramped seeding rate border strip was incorporated into the planting prescription map to ensure the planter was working appropriately. Strip plots were harvested with a John Deere 9996 Spindle Cotton Picker (John Deere) equipped with a calibrated John Deere cotton yield monitor.

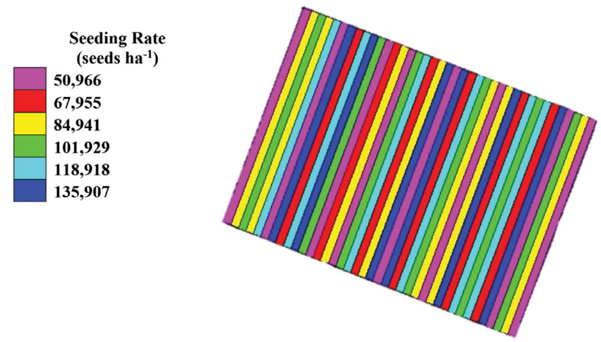


**Figure 3. The prescription map representing the uniform seeding rate strips placed across Field 1 in 2017.**

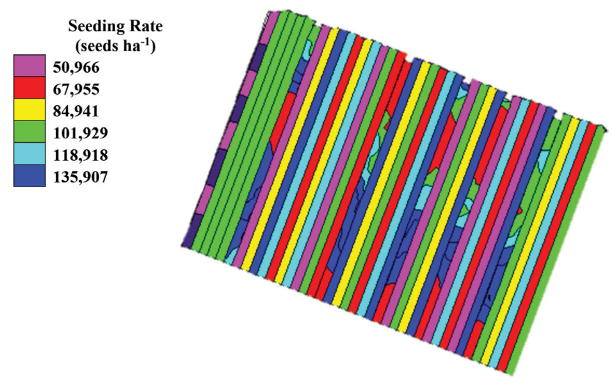


**Figure 4. The prescription map representing the uniform and variable rate seeding rates placed across Field 1 in 2019.**


**Figure 5. The prescription map representing the uniform seeding rate strips placed across Field 2 for cotton in 2020.**

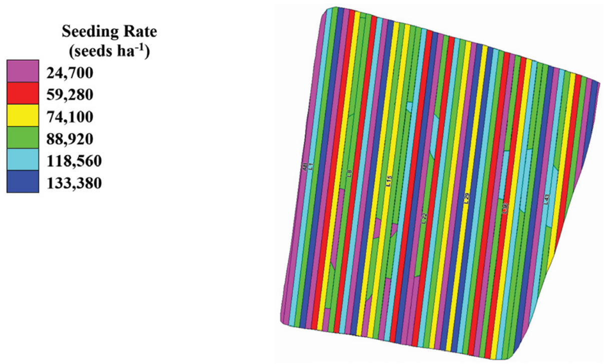


**Figure 6. The prescription map representing the uniform and variable rate seeding rates placed across Field 2 in 2021.**

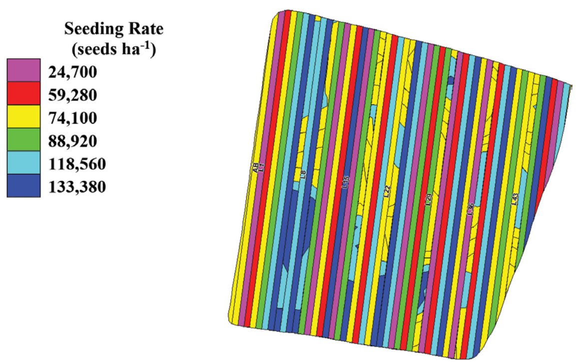


**Figure 7. The prescription map representing the uniform and variable rate seeding rates placed across Field 2 in 2022.**

**Statistical Analysis**. Yield data points residing with seeding rate and soil EC zones polygons were analyzed using JMP Pro 16 (SAS Institute Inc., Cary, NC) to determine which seeding rate had the greatest profit potential for each soil EC zone. Yield outliers were removed from the original dataset using Tukey's Outlier Method (Tukey, 1977). After removing outliers, the returns above variable input costs (RAVIC) were calculated for each yield data point as the revenue minus the seed cost for the respective seeding rate in that location. Revenue was calculated using an average cotton market price of $1.54 per kilogram multiplied by lint yield. An analysis of variance (ANOVA) test was performed based on RAVIC by seed rate treatment to determine the optimum seeding rate for each soil EC zone. Regression models were created to smooth the yield response and RAVIC by soil EC zone. This procedure was used to develop variable rate seeding strip plots in the 2019, 2021, and 2022 prescriptions. In 2019 and 2021, the prior year RAVIC was used to define the D-Rx prescription. Returns above variable input costs were normalized by dividing RAVIC for a given yield point by the average RAVIC for all points each year. Data were analyzed by year and field location separately. Fixed effects were seeding rate treatment, year, and location. Random effects were replication. All data were subjected to analysis of variance (ANOVA) using PROC GLIMMIX procedure in SAS v.9.4 (SAS Institute Inc., Cary, NC), and means were separated using multiple pairwise t-tests at $\alpha = 0.05$.

**Data Collection**. Data collection from 2020 to 2022 consisted of plant stand counts in each plot collected 14 days after planting (DAP), in-season plant heights, total node counts based on the seeding rate treatment in each soil EC zone, and seed cotton samples for fiber quality at harvest. Plant stand counts were evaluated in each plot, by counting the number of cotton plants in a randomly placed 3.05 m (10 ft) length of row. From 2020 to 2022, plant height and mainstem nodes were evaluated to provide additional data of plant architecture differences between the relationship of seeding rates and soil EC zones. Plant heights and total node counts were collected by using a GPS-equipped tablet with the soil EC map to verify EC zone per plot. In three subsets of the seven equal area EC zones, five randomly selected plants were used to evaluate plant heights and mainstem nodes. These data were collected after defoliation and prior to harvest. These subsets were three equal area zones consisting of low, medium, and high EC levels based on the seven original zones in Field 2 only. Low EC zone consisted of the lower two EC zones (1.047-1.789 mS/m$^2$), medium EC zone consisted of the middle three EC zones (2.297-3.553 mS/m$^2$), and the high EC zone consisted of the higher two EC zones (4.176-5.625 mS/m$^2$). Cotton samples were collected based on each soil EC zone; 25 bolls were collected per EC zone and ginned using a tabletop cotton gin to determine if fiber quality or lint turnout varied by soil texture and seed rate. Seed and lint were weighed to calculate lint turnout by dividing the weight of lint by the total weight of seed cotton. Fiber quality was determined using a High-Volume Instrument (HVI®) at the Fiber and Biopolymer Research Institute, Lubbock, TX.

## RESULTS AND DISCUSSION

The growing seasons in 2017, 2019, and 2020 to 2022 at Edisto Research and Education Center all varied in average temperatures and rainfall. In 2019 and 2022, temperatures were higher than the other years; 2019 experienced the least rainfall (66.1 cm) (Table 2).

**Table 2. Average temperatures^z and rainfall totals at the Edisto Research and Education Center in Blackville, SC, 2017, 2019-2022**

| Year | Max. Avg. Temp.^y | Min. Avg. Temp.^y | Rainfall^x |
|---|---|---|---|
| | ------------------------------- °C | ------------------------------- | --------- cm --------- |
| 2017 | 28.2 | 16.9 | 60.4 |
| 2019 | 30.1 | 16.7 | 53.9 |
| 2020 | 28.1 | 17.6 | 78.6 |
| 2021 | 27.6 | 16.5 | 80.0 |
| 2022 | 33.4 | 10.9 | 58.4 |

^z Temperature and rainfall data from EREC Weather Data from Clemson Cooperative Extension Services.

^y Average daily maximum and minimum temperature during the growing season (May-November).

^x Sum of total rainfall for the growing season.

**Emergence and Stand Counts**. Seeding rate had a significant effect ( $p < 0.0001$ and I = 0.0022) on the number of plants emerged. Overall, the higher targeted seeding rates resulted in more plants emerging (Table 3). This indicated that, as the seeding rate increased, so did the final plant population.

**Table 3. Analysis of variance p-values for stand counts as affected by seeding rate in 2020-2022**

| Year | *p*-value^z |
|---|---|
| 2020 | <0.0001* |
| 2021 | <0.0001* |
| 2022 | 0.0022* |

^z *p*-values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure; *p*-values with (*) are significantly different at $\alpha = 0.05$.

**Plant Height and Total Nodes**. Plant height and node count data differed significantly among the uniform seeding rates (Table 4). The data were analyzed separately for each year. In 2020, a uniform seeding rate of 103,740 seed ha$^{-1}$ resulted in taller plants, compared with the seeding rates of 59,280, 74,100, and 24,700 seed ha$^{-1}$, but similar in height as 118,560, 133,380, and 197,600 seed ha$^{-1}$. Previous research has indicated similar results to 2020 when plant height increased as plant population increased (Siebert et al., 2006). No significant differences in plant height were observed in 2021 ( $p = 0.9484$) or 2022 ( $p = 0.2495$).

Furthermore, no significant differences were observed in the total number of nodes per plant in 2020 or 2021; however, significant differences were observed in the total number of nodes in 2022 ( $p < 0.0001$) (Table 4). Plants seeded at 59,280 seed ha$^{-1}$ resulted in a 5 to 10% increase in the number of total nodes than plants seeded at 88,920, 103,740, 118,560, or 133,380 seed ha$^{-1}$ or the variable rate strip.

Plant height and total nodes between seeding rates also were significantly different within each soil EC zone (Table 5). In 2021 and 2022, significant differences were observed between total nodes in the low soil EC zone with 59,280, 74,100, and 118,560 seed ha$^{-1}$, resulting in more total nodes compared with 103,740 and 133,380 seed ha$^{-1}$. The uniform seeding rate of 88,920 seed ha$^{-1}$ had fewer total nodes in 2021 than in 2022. In 2022 in the medium soil EC zone, the 59,280 seed ha$^{-1}$ seeding rate had the highest number of total nodes. These findings are similar to research conducted by Jones and Wells (1997), Bednarz et al. (2000), and Siebert and Stewart (2006) that showed an increase in plant mainstem nodes in lower plant populations. In 2021, the seeding rate of 59,280 seed ha$^{-1}$, resulted in the shortest plants in the high soil EC zone compared with uniform seeding rates of 74,100, 88,920, and 103,740 seed ha$^{-1}$ and the variable rate treatment. No significant differences were observed in the number of total nodes in the medium ( $p = 0.7827$) or high ( $p = 0.7648$) soil EC zones in 2021. Generally, lower seeding rates produced the greatest number of mainstem nodes, and the higher seeding rates produced taller plants.

**Lint Yield**. Significant differences were observed in lint yield every year, except in 2022 (Table 6). In 2017 and 2019, the 118,918 and 135,907 seed ha$^{-1}$ seeding rates, respectively, had higher yields compared with 50,966, 67,955, and 84,941 seed ha$^{-1}$. Among the uniform seeding rates in both years, 88,920 seed ha$^{-1}$ was a low yielding rate in 2020 but a high yielding rate in 2021. This difference could be an effect of cooler temperatures and more rainfall in 2021. In 2020, there was a yield difference of 36.7% between the lowest yielding seeding rate of 24,700 seed ha$^{-1}$ and the highest yielding seed-

**Table 4. Average total plant height and total number of mainstem nodes for each seeding rate for cotton at the Edisto Research and Education Center in Blackville, SC[z]**

| Year | Seeding Rate | Plant Height | Mainstem Nodes |
|---|---|---|---|
| | (seeds ha$^{-1}$) | (cm) | |
| 2020 | 24,700 | 90.50 cd[y] | 17.13 a |
| | 59,280 | 87.88 d | 16.38 a |
| | 74,100 | 91.63 bcd | 15.75 a |
| | 88,920 | 92.50 abcd | 16.63 a |
| | 103,740 | 98.50 a | 16.50 a |
| | 118,560 | 95.50 abc | 14.88 a |
| | 133,380 | 93.75 abcd | 15.63 a |
| | 197,600 | 98.00 ab | 16.25 a |
| | *p*-value[x] | 0.0355 | 0.2290 |
| 2021 | 59,280 | 114.41 a | 17.74 a |
| | 74,100 | 113.19 a | 17.67 a |
| | 88,920 | 121.74 a | 17.31 a |
| | 103,740 | 117.99 a | 17.21 a |
| | 118,560 | 117.93 a | 17.56 a |
| | 133,380 | 116.19 a | 17.00 a |
| | D-Rx[w] | 119.22 a | 17.81 a |
| | *p*-value | 0.9484 | 0.9632 |
| 2022 | 59,280 | 106.56 a | 21.89 a |
| | 74,100 | 108.51 a | 21.04 ab |
| | 88,920 | 105.91 a | 20.49 bcd |
| | 103,740 | 105.33 a | 20.78 bc |
| | 118,560 | 107.47 a | 19.67 d |
| | 133,380 | 105.78 a | 20.00 cd |
| | D-Rx[w] | 109.62 a | 20.24 bcd |
| | *p*-value | 0.2495 | <0.0001 |

[z]Field 2 at EREC.

[y]Means followed by the same lowercase letter are not significantly different at $\alpha = 0.05$.

[x]*p*-values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

[w]Variable rate seeding treatment.

ing rate of 197,600 seed ha$^{-1}$. In 2021, there was a 22.8% difference in yield from the lowest yielding seeding rate of 59,280 (907 kg ha$^{-1}$) and the highest yielding seeding rate of 88,920 seed ha$^{-1}$ (1177 kg ha$^{-1}$). In this study, lint yield was affected by seeding rate compared to other studies (Adams et al., 2018). However, the trend was inconsistent across years. Yield differences between years could have been a function of varying temperatures and rainfall among years and the field (Field 1: 2017, 2019 and Field 2: 2020-2022). Seeding rates did not affect fiber quality in 2021 or 2022. This agrees with previous research by Harrison et al. (2009), which observed little to no impact on fiber quality from variable seeding rate.

**Returns Above Variable Input Costs**. RAVIC was significantly different between seeding rate treatments in 2019 and 2021 (Table 6). In 2019, the uniform seeding rates of 101,929, 118,918, and 135,907 seed ha$^{-1}$ and the variable seeding rate treatment were the most profitable compared with uniform seeding rates of 50,966, 67,955, and 84,941 seed ha$^{-1}$. In 2021, RAVIC was also significant ( $p$ = 0.0232), where the uniform seeding rates of 88,920 and 118,560 seeds ha$^{-1}$ and the variable rate treatment had the best returns above seed costs compared with 59,280 seed ha$^{-1}$. It appears that yield was the biggest influence of RAVIC in 2021. Despite weather patterns being categorized as hot and dry in 2019, and

**Table 5. Average total plant height and total number of mainstem nodes for cotton at each seeding rate in low, medium, and high EC subzones in South Carolina in 2021 and 2022**

| | | LOW EC[z] | | MEDIUM EC[z] | | HIGH EC[z] | |
|---|---|---|---|---|---|---|---|
| Year | Seeding Rate | Plant Height | Mainstem Nodes | Plant Height | Mainstem Nodes | Plant Height | Mainstem Nodes |
| | (seeds ha$^{-1}$) | (cm) | | (cm) | | (cm) | |
| 2021 | 59,280 | 89.00 a[y] | 15.44 a | 127.78 a | 18.89 a | 126.44 b | 18.89 a |
| | 74,100 | 87.00 a | 15.11 ab | 113.33 a | 18.00 a | 138.22 a | 19.89 a |
| | 88,920 | 84.37 a | 13.69 bc | 130.00 a | 18.67 a | 146.89 a | 19.22 a |
| | 103,740 | 79.80 a | 12.94 bc | 135.56 a | 18.78 a | 142.67 a | 20.33 a |
| | 118,560 | 83.11 a | 14.11 abc | 133.11 a | 18.44 a | 137.56 ab | 20.11 a |
| | 133,380 | 85.78 a | 13.78 bc | 127.33 a | 17.56 a | 135.44 ab | 19.67 a |
| | D-Rx[x] | 77.11 a | 14.11 abc | 133.22 a | 19.22 a | 147.33 a | 20.11 a |
| | *p*-value[w] | 0.1841 | 0.0367 | 0.1787 | 0.7827 | 0.0186 | 0.7648 |
| 2022 | 59,280 | 104.80 a | 20.53 a | 107.07 bc | 23.07 a | 107.80 a | 22.07 ab |
| | 74,100 | 106.80 a | 19.87 abc | 108.00 bc | 20.53 bc | 110.73 a | 22.73 a |
| | 88,920 | 101.80 a | 20.07 ab | 109.00 abc | 20.27 bc | 106.93 a | 21.13 bcd |
| | 103,740 | 99.40 a | 18.87 cd | 108.40 abc | 21.07 b | 108.20 a | 22.40 ab |
| | 118,560 | 104.00 a | 19.53 abcd | 111.73 ab | 19.67 c | 106.93 a | 19.80 d |
| | 133,380 | 104.60 a | 19.00 bdc | 104.00 c | 20.67 bc | 108.73 a | 20.33 cd |
| | D-Rx | 102.93 a | 18.67 d | 114.13 a | 20.27 bc | 111.80 a | 21.80 abc |
| | *p*-value | 0.2783 | 0.0055 | 0.0356 | <0.0001 | 0.5751 | 0.001 |

[z]Low soil electroconductivity zone (1.473 mS/m); Medium soil electroconductivity zone (2.905 mS/m); High soil electroconductivity zone (4.914 mS/m).

[y]Means followed by the same lowercase letter are not significantly different at $\alpha = 0.05$.

[x]Variable rate seeding treatment.

[w]*p*-values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

**Table 6. Average lint yield and returns above variable input costs (RAVIC) for cotton as affected by seeding rate**

| Year | Seeding Rate | Lint Yield[z] | RAVIC[z, y] |
|---|---|---|---|
| | (seeds ha$^{-1}$) | (kg ha$^{-1}$) | ($/ha) |
| 2017 | 50,966 | 1187.65 cd | 1696.03 a |
| | 67,955 | 1250.85 cd | 1749.03 a |
| | 84,941 | 1138.11 d | 1531.11 a |
| | 101,929 | 1269.98 bc | 1689.87 a |
| | 118,918 | 1371.69 ab | 1802.18 a |
| | 135,907 | 1391.06 a | 1787.69 a |
| | *p*-value[x] | 0.0006 | 0.0561 |
| 2019 | 50,966 | 876.98 b | 1194.27 b |
| | 67,955 | 882.33 b | 1181.99 b |
| | 84,941 | 904.09 b | 1193.17 b |
| | 101,929 | 994.92 a | 1303.12 a |
| | 118,918 | 1006.11 a | 1299.19 a |
| | 135,907 | 1005.87 a | 1278.90 a |
| | D-Rx[w] | 991.44 a | 1303.85 a |
| | *p*-value | <0.0001 | <0.0001 |

**Table 6. continued**

| Year | Seeding Rate | Lint Yield[z] | RAVIC[z, y] |
|---|---|---|---|
| | (seeds $ha^{-1}$) | (kg $ha^{-1}$) | ($/ha) |
| 2020 | 24,700 | 557.77 c | 756.00 a |
| | 59,280 | 699.38 bc | 891.33 a |
| | 74,100 | 734.61 ab | 912.58 a |
| | 88,920 | 670.54 bc | 790.44 a |
| | 103,740 | 814.33 ab | 968.43 a |
| | 118,560 | 811.75 ab | 935.09 a |
| | 133,380 | 776.94 ab | 855.18 a |
| | 197,600 | 881.31 a | 877.49 a |
| | *p*-value | 0.0244 | 0.6612 |
| 2021 | 59,280 | 907.31 c | 1869.05 c |
| | 74,100 | 1030.51 bc | 2122.85 bc |
| | 88,920 | 1176.75 a | 2424.12 a |
| | 103,740 | 985.46 bc | 2030.05 bc |
| | 118,560 | 1081.84 ab | 2228.59 ab |
| | 133,380 | 991.33 bc | 2042.13 bc |
| | D-Rx | 1094.41 ab | 2254.49 ab |
| | *p*-value | 0.0092 | 0.0232 |
| 2022 | 59,280 | 1381.76 a | 3272.12 a |
| | 74,100 | 1461.27 a | 3430.65 a |
| | 88,920 | 1442.84 a | 3346.28 a |
| | 103,740 | 1480.24 a | 3400.37 a |
| | 118,560 | 1563.67 a | 3568.62 a |
| | 133,380 | 1426.60 a | 3190.03 a |
| | D-Rx | 1403.78 a | 3481.36 a |
| | *p*-value | 0.6959 | 0.8198 |

[z]Means followed by the same lowercase letter are not significantly different at $\alpha = 0.05$.

[y]Returns above variable input costs: seed costs subtracted from revenue.

[x]*p*-values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

[w]Variable rate seeding treatment.

2021 experiencing slightly cooler temperatures and more rainfall, the variable rate seeding and uniform seeding rate of 118,560 seeds $ha^{-1}$ still performed well. During 2017, 2020, and 2022, there were no significant differences between seeding rates and RAVIC. In 2022, no differences in yield were detected that had any significant influence on RAVIC. Based on these results, variable rate seeding in cotton did not significantly increase RAVIC across two fields and five years, but it performed as good as the best uniform seeding rate.

## CONCLUSIONS

This research was conducted to determine if variable rate seeding in cotton can increase profitability. These data indicate that variable rate seeding in cotton performed as well as the best uniform seeding rate, with no economic or yield benefit to variable rate seeding with the cotton variety used. These results also indicate that manipulating seeding rate in varying soil textures could affect total plant height and mainstem nodes, potentially influencing inputs for growth regulation and reducing costs. However, the responses observed in this study were specific to trial location and cotton variety selected.

More data are needed with this strategy under variable circumstances (e.g., additional varieties, environmental conditions, irrigated versus dryland). Overall, variable rate seeding in cotton does not appear to negatively impact lint yield or economic return; however, depending on current uniform seeding rate and other opportunity costs associated with each cotton production system, variable rate seeding in cotton might not provide an economic or agronomic benefit. Before implementing variable rate seeding, it is important to implement uniform seeding rate strips on-farm on a field-by-field basis to determine the most profitable and optimum seeding rate based on soil EC. Multiple years of data are needed to determine the best uniform seeding rate due to other factors such as environmental conditions and variety selection as these factors could possibly vary the results.

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