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Precision Management of Inputs in Cotton and Soybean Production in South Carolina

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PRECISION MANAGEMENT OF INPUTS IN COTTON AND SOYBEAN PRODUCTION IN SOUTH CAROLINA

A Thesis
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science
Plant and Environmental Sciences

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by
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Accepted by:
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ABSTRACT

The adoption of precision agriculture technologies and developing specific product use recommendations in cotton and soybean production could help farmers reduce input costs and optimize overall farm profitability. The objectives of this research were to evaluate whether or not the use of variable rate seeding in cotton could increase profitability and to determine the rainfast interval of commonly used insecticides in cotton and soybean production. The first trial, variable rate seeding in cotton, was implemented at the Edisto Research and Education Center near Blackville, SC across five years to evaluate variable rate seeding in cotton. Results from trials in South Carolina across five years to compare variable rate seeding with six different uniform seeding rates indicated that using variable rate seeding in did not appear to improve overall profitability over the optimum uniform seeding rate, but more data are needed with the strategy under variable circumstances (additional varieties, irrigation versus dryland, etc.) to test the reliability of the approach.

The second trial, insecticide efficacy at various washoff intervals, was evaluated in cotton and soybean at the Edisto REC in 2021 and 2022. After various intervals of simulated rainfall events (ranging from $\leq$ 0.5 hour up to 24 hours after application of insecticide), the contact efficacy of selected insecticides against numerous important insect species in cotton and soybeans was minimally reduced, suggesting that commonly used insecticides can have a short rainfast interval ($\leq$ 0.5 hour) in the crops. These results should caution against the common practice of automatic reapplication of insecticide following a rainfall event and encourage an assessment of insect control before retreatment, potentially reducing input costs.

DEDICATION

I would like to dedicate this thesis to my family. Everyone has shown and given me unconditional love and support during my time in graduate school and every day. Dad and mom, you have always supported me my entire life and encouraged me to work hard and be diligent in every step of life. Without your guidance and advice in life, I would not be able to accomplish what I have and what I will in the future. I will always be thankful and blessed to be able to call you my parents and have both of you in my life. I would also like to dedicate this thesis to my grandfather, Butch Smith. You have supported me throughout my entire college career, through my time at Abraham Baldwin Agricultural College and during my time at Clemson University. I appreciate the endless support and encouragement you constantly give, and I promise I will make you proud.

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CHAPTER ONE

LITERATURE REVIEW

Because of rising costs of agricultural inputs in recent years, farmers have been looking for ways to increase their profit margins through reducing input costs. With high input costs, profit margins are slimmer, making it harder for farmers to be profitable and sustainable. The use of various emerging technologies have been adopted by today's producers, for example, precision agriculture technologies or new seed technologies. Both technologies come with a price and opportunity cost that must be considered. Other input costs, such as pesticide and fertilizer inputs, often narrow profit margins. Intentional management of input costs is essential to profitability of farmers in the southeastern United States.

In the southeastern United States, cotton (*Gossypium hirsutum* L.) and soybean (*Glycine max* L.) are two significant commodities grown in the region. In South Carolina, approximately 85,000 and 160,000 hectares of cotton and soybean, respectively, were planted in 2021 (USDA NASS, 2021). Both crops have a significant impact on the state's economy, especially producers' incomes. Maximizing profit margins of these crops are essential to the farmer. With profit margins narrowing for both crops, farmers must seek ways to reduce input costs where possible, such as through adoption of precision agriculture practices. The release of public use of Global Positioning Systems (GPS) in 1983 enabled the development of map-based precision agriculture technologies (Lowenberg-DeBoer and Erickson, 2019). Some of these technologies include GPS guidance systems, soil electrical conductivity (EC) mapping systems (1990s), grain yield monitors (1992), and variable rate fertilizer controllers (1980s) (Lowenberg-DeBoer and Erickson, 2019). Seed technologies have also advanced significantly including traits, such as those using genes from *Bacillus thuringiensis* (Bt) in various crops to control insects or genes for herbicide tolerance or nematode resistance. Farmers have several options and opportunities to assist with pest management starting with seed. Although these seed technologies are extremely helpful to farmers, they do not come without cost causing input costs to increase. Seed and pesticide represent significant input costs (Clemson Cooperative Extension Crop Production Budgets, 2023), reducing these two input costs or otherwise optimizing use of the inputs can help increase the profit margins for our farmers. Research is needed to determine ways to reduce input costs and where best fit.

Variable Rate Technology

Variable rate technology (VRT) is used in several agricultural input applications, such as fertilizer, seeding, and irrigation. It is generally described as adjusting the application rate depending on the application area. Sawyer (1994) defined VRT as changing a crop production input within a field in response to spatially variable factors that affect the optimum application rate. Some of the first studies conducted using VRT were in fertilizer and lime applications in the mid-1980s (Mulla and Khosla, 2015). After evaluating variable rate fertilizer and lime applications, VRT for other inputs, such as herbicide and irrigation applications were evaluated. Using GPS and geographic information systems (GIS), VRT controllers have the ability to adjust the input rate based on site-specific prescriptions. Adoption rate of VRT was low at the beginning of its commercial availability due profitability constraints (Bullock et al., 2009). Early adoption rates of variable rate fertilizing were greater in higher-value specialty crops than bulk commodities such as corn, soybean, and wheat (Bullock et al., 2002). Variable rate seeding (VRS) was least adopted, falling behind variable rate pesticide application. Over time, variable rate seeding was investigated more, and research was conducted across the U.S. Corn Belt evaluating VRS in corn (*Zea mays* L.). Studies demonstrate mixed results on the economic return of VRS in corn. According to a study conducted by Taylor et al. (2000), VRS had the potential to increase gross profit. However, that did not include the costs associated with collecting the necessary data used for the variable rate application and the equipment itself. After those additional costs were accounted for, uniform seeding resulted in the most economic return. Another research study in the Midwestern U.S. Corn Belt evaluated if variable rate seeding in corn was profitable. Bullock et al. (1998) found that if the farmer knows the relationship between plant density and grain yield in their field, then the potential for VRS to be profitable is greater. This study also demonstrated how the farmer could obtain this necessary information for VRS. The first method used a series of agronomic test strips or plots using a wide range of plant densities placed randomly across the field. Yield data collected on each strip or plot was then used to estimate an economically optimal density for each strip or plot. Another way to gain this information is for the researchers to develop information that indicates which field characteristics are significant to the relationship between plant density and grain yield. Therefore, the value of good research can be important for the farmer in making variable rate prescriptions. This article also indicated that the relationship between VRT and yield mapping is highly complementary. Without the correct precision technology, such as guidance maps, yield maps, and GIS technology, it is harder to be profitable and sustainable using VRT in seeding. In another study conducted by Lowenberg-DeBoer (1999), the findings showed that VRT in corn seeding had potential benefits if the farmer has a field with low-yielding (< 6,285.07 kg ha^{-1}) areas. If the field was a mix of high and medium-yielding areas, it was not economically feasible to use VRT, and uniform rates were more profitable.

Research has also been conducted in the past evaluating the relationship and response between cotton lint yield and plant population. Several studies have investigated a wide range of planting populations, along with different varieties, to determine the response in lint yield. One study conducted by Harrison et al. (2009) found that, after evaluating a wide range of seeding rates (32,110-160,550 seeds/ha), reducing the seeding rate without a negative impact on lint yield is possible in optimum conditions. These conditions consist of those associated with establishing a good plant stand and include uniform seed placement for a given population, quality seed, and good growing conditions. However, it can be hard to achieve the desired plant stand due to crusting or other conditions; therefore, over-seeding may be used to compensate for the potential reduction in emergence. Seeding rate also did not affect the fiber quality in this study. Gwathmey (2010) reported that cotton under irrigation could be seeded at a wide range (71,630-215,137 seeds ha^{-1}) without detrimental effects to profit. The results suggested that at lower seeding rates, the cotton plant increased production to compensate for lower plant densities. Another study also showed that seeding rates did not affect lint yield, but there was a difference in maturity (Bednarz et al., 2000). In this study fruiting positions changed, but lint yields were not affected. Lower population densities resulted in greater retention of and production at individual fruiting sites.

With new technologies (insect and nematode protection and herbicide tolerance) incorporated into seed, costs of seed are high, so there is great interest in reducing cotton seeding rates to save on input costs. Farmers are extremely interested in research that would allow them to increase profit margins. Many farmers have purchased and equipped their planters with VRT, but research is needed in the southeastern United States to evaluate the potential of reducing seed costs and developing recommendations with VRT in the region.

Insecticide Efficacy

Each year, farmers in the southeastern United States battle pestiferous insects in their crops and must be timely with insecticide applications to preserve yields. Pesticide applications make up about 17% of total input costs in cotton production and about 26% in soybean production, according to the Clemson Cooperative Extension Crop Production Budgets (2023). With the high costs of the chemicals themselves, farmers need to be as efficient with each application as possible. Some of the main economic insect pests in cotton production for South Carolina are tobacco thrips, *Frankiella fusca* (Hinds), bollworm, *Helicoverpa zea* (Boddie), and several species of stink bugs (Pentatomidae). These pests typically cause a negative impact on lint yield in cotton production.

Bollworm, also known as podworm in soybean, and stink bugs negatively impact soybean. Other pests negatively affecting soybean are other lepidopteran species, such as soybean looper (*Chrysodeixis includens*) and velvetbean caterpillar (*Anticarsia gemmatalis*). Kudzu bug (*Megacopta cribraria*) and threecornered alfalfa hopper (*Spissistilus festinus*) are other common pests in soybean. These insect pests are typically divided into three groups, pod feeders, stem feeders, and defoliators.

Tobacco thrips are small insects with piercing-sucking and rasping mouthparts that typically feed on and damage cotton seedlings from emergence to around the 5-leaf stage. Adult tobacco thrips are identified by the dark brown or tan color bodies that are 1 to 2 mm in length with fully functioning or rudimentary wings and bodies. Immature tobacco thrips are wingless, yellow in color, and smaller than adults (Greene et al., 2020). Tobacco thrips feed on new and emerging leaves of the cotton seedling plant, resulting in a wrinkled or shriveled appearance to the leaves. Research has shown that tobacco thrips can have a negative impact on plant height (Burris et al., 1989). Tobacco thrips can also impact root growth and development (Roberts et al., 2009). Thrips injury can also delay crop maturity and fruit development (Greene et al., 2020). Chemical control is the primary source of control for tobacco thrips, whether it is an in-furrow liquid or granular at-plant application, a seed treatment, or a foliar insecticide application. Acephate is a very common insecticide choice for control of tobacco thrips, and it can be applied as a seed treatment, in-furrow liquid spray, or foliar spray application.

Bollworm is another important insect pest managed by Bt cotton and applications of foliar insecticides. Because Bt traits increase seed costs and have become less effective on bollworm, supplemental applications of insecticide are used to control the species in cotton. Commonly used foliar insecticides used to control bollworm surviving Bt traits include pyrethroids, such as bifenthrin (Brigade® 2 EC) or non-pyrethroids, such as chlorantraniliprole (Prevathon® 0.43 SC). However, bollworm has developed some tolerance/resistance to pyrethroid insecticides; therefore, farmers are relying more on non-pyrethroid products, such as chlorantraniliprole, which are more expensive. The high costs of insecticides have resulted in producers trying to be as efficient as possible with each spray.

Stink bugs are also another concerning pest in cotton production in South Carolina. These pests have piercing-sucking mouthparts and feed on developing bolls of the cotton plant. The feeding on the bolls results in staining of the lint inside the boll, destruction of seed, and, eventually, boll rot. Significant reductions in cotton lint yield and reduced fiber quality due to stink bug feeding have been shown in previous research (Barbour, 1990). Stink bugs will also feed on soybean plants, primarily on the soybean seed. Feeding can cause several issues, such as deformation, stained or aborted seeds, and a reduction in seed quality. This injury from feeding increases the potential for grain yield loss in soybean production. Chemical control is the primary method used to control stink bugs in both cotton and soybean. Pyrethroids, such as bifenthrin, are commonly used due to their inexpensive application costs and their effectiveness in controlling stink bugs.

Research on insecticide efficacy before various rainfall intervals in row crops is minimal. Previous research in cotton evaluating the rainfastness of bifenthrin paired with various adjuvants indicated that the more time the products spent on the leaves, the better control before a rainfall event (Mulrooney and Elmore 2000). In another study testing three different insecticides in cotton (methyl parathion, toxaphene, and fenvalerate) that are no longer commonly used, the findings indicated that no matter the rainfall timing, it still washed off a percentage of the products (McDowell et al., 1985). In other research evaluating the effect of rainfall events on insecticides, five insecticides, including bifenthrin, and their rainfastness degraded over time to control Japanese Beetle (*Popillia, japonica*) in grape production (Hulbert et al., 2011). The findings from the study indicate that bifenthrin was only affected by rainfall if the residual was field aged. The other insecticides did have a reduction in efficacy due to the rainfall events. Japanese beetle (*Popillia japonica*) was investigated in blueberry production, and all of the insecticide products experienced a reduction in efficacy following a rainfall event (Hulbert et al., 2012). Another study in blueberries evaluating insecticide effectiveness during simulated rainfall on spotted wing drosophila (*Drosophila suzukii*) found that rainfall events decreased insecticide efficacy and that adding an adjuvant helped to prolong the residual of the insecticide after a rainfall event (Gautam et al. 2015). They also stated that rainfall intensity did not affect the rainfastness of the insecticide.

Future research is needed to evaluate commonly used insecticides for efficacy after rainfall (natural or simulated) events in row crop production, specifically cotton and soybean. With the relatively high costs of application and products, it is important to generate additional data on insecticide performance after unexpected rainfall following applications. This research can help increase profit margins and sustainability in South Carolina row crop production.

CHAPTER TWO

UTILIZING PRECISION AGRICULTURE TO IMPROVE SUSTAINABILITY AND PROFITABILITY THROUGH VARIABLE RATE SEEDING IN COTTON PRODUCTION

Abstract

Because commodity prices have decreased and input costs have increased in recent years, growers must look for ways to remain competitive, sustainable, and profitable. The vast amount genetic technology included in cottonseed today has resulted in high upfront costs for seed that can typically exceed 10 to 15% or more of the total input costs in South Carolina. Because of the high price of cottonseed, the availability and use of precision planter technologies has increased across farms in the southeastern United States. The objective of this research was to determine if variable rate seeding in cotton can increase profitability. Field experiments were conducted during 2017, 2019-2022 near Blackville, SC to evaluate variable rate seeding in cotton using Directed R_x variable rate prescription development method. 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. No one seeding rate treatment provided a maximum lint yield or profit across site-years but depending on the uniform seeding rate selected or the implementation of variable rate seeding, lint yield varied 11 to 36% and profitability varied 9 to 23% among treatments.

Introduction

Producers of cotton (*Gossypium hirsutum* L.) in South Carolina must manage input costs to maximize profit. Seed costs for cotton producers range from $200-300 per hectare, depending on market seed price, seed technology, and seeding rate planted (Clemson Cooperative Extension Crop Production Budgets, 2023). With seed accounting for 10 to 15% of total input cost, optimizing seeding rates could increase profit if input savings exceeds 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 32,110-160,550 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 prescription. Throughout the southeastern United States, cotton is a valuable and profitable commodity. In 2022, cotton revenue was $248 million on approximately 107 hectares in South Carolina (USDA NASS 2022). As an indeterminate crop, cotton has the ability to 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.

While hardware enables growers to vary seed rates at planting, optimized variable rate prescriptions must be developed using a science-based method to consistently, or at least more than often 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 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 known as Directed R_x (D-R_x) (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, required a two-year process for execution of the variable rate prescription. Because there is limited published research on evaluating variable rate seeding in cotton in the southeastern United States, 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, 2019 to 2022. Irrigated research sites utilized were fields E7A (33º20’44” N, 81º19’5” W) and C8B (33º20’45” N, 81º19’30” W). Soil type in both fields was a Barnwell Loamy Sand (fine-loamy, kaolinitic, thermic Typic Kanhapludults) (USDA-NRCS, 2023). Soil electroconductivity (EC) data were collected prior to planting using a Veris 3100 EC cart (Veris Technologies, Salina, KS) and management zones (Figures 2.1 and 2.2) were developed for both fields using contoured shallow (0-30.5 cm) EC data. These management zones were used in the prescription development for evaluation of most profitable seeding rate, by zone. Prior to planting each year, field preparation was conducted by spraying a burndown herbicide and 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).The experimental design was 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 (PGR) applications (Jones, 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 E7A (Table 2.1). In 2019, an additional treatment was included, which represented the D-R_x variable rate prescription that maximized profit in 2017. In years 2020 to 2022, the experiment was conducted in field C8B. The six uniform seeding rates were 59,280, 74,100, 88,920, 103,740, 118,560, and 133,380 seed ha^{-1} (Table 2.2). In 2020 only, additional rates of 24,700 and 197,600 seed ha^{-1} were added for comparison purposes. In 2021 and 2022, a variable rate seeding treatment was also included to the experiment using the D-R_x variable rate prescription that maximized profit in the prior crop year for 2021 and that for the prior two crop years for 2022 (Figures 2.5 and 2.6). Prescription maps were developed using Trimble Farm Works (Trimble Inc., Westminster, CO) software, setting rates according to the discussion below.

For each year of testing, each field was divided into 3.9 m wide strips to represent the 4-row plots. The D-R_x prescription map development process involved creating seven, equal area management zones for each field based on the shallow EC data for the field (Figures 2.1 and 2.2). Treatments, which included uniform seeding rate treatments in all years and D-R_x prescriptions in 2019, 2021, and 2022 were assigned to the strip plots in a random 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, Moline, IL) equipped with a calibrated John Deere cotton yield monitor.

Statistical Analysis

Yield data 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 (kg) 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 the 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-R_x prescription. Returns above variable input costs was normalized by dividing RAVIC for a given yield point by the average RAVIC for all points each year. 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 in 2020-2022 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 counted in each plot, by counting the number of cotton plants in a randomly placed 3.05 m (10 ft) length of row. 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 seedcotton. Fiber quality was determined using a High-Volume Instrument (HVI®) at the Fiber and Biopolymer Research Institute, Lubbock, TX.

Results & Discussion

The growing seasons in 2017, 2019, and 2020 to 2022 at the Edisto REC 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 2.3).

Plant Height and Total Nodes

Plant height and node count data differed significantly among the uniform seeding rates. 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} (Table 2.4). Previous research has indicated similar results to 2020 where 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 ($P = 0.2495$) (Tables 2.5 and 2.6). There were no significant differences 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 ($P < 0.0001$). 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 (Table 2.6). Plant height and total nodes between seeding rates were also significantly different within each soil EC zone. In 2021 and 2022, there were significant differences 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} (Table 2.7). 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 (Table 2.8). These findings are similar to previous research conducted by Jones and Wells (1997), Bednarz et al. (2000), and Siebert and Stewart (2006) which 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 (Table 2.9). 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.

Emergence and Stand Counts

Seeding rate had a significant effect ($P < 0.0001$) on the number of emerged plants. Overall, the higher targeted seeding rates resulted in more plants emerging (Table 2.10). This indicated that, as the seeding rate increased, so did the final plant population (Table 2.11).

Lint Yield

Significant differences were observed in lint yield every year, except in 2022 (Table 2.12 and 2.13). 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. 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 seeding 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 (907.31 kg ha^{-1}) and the highest yielding seeding rate of 88,920 seed ha^{-1} (1176.75 kg ha^{-1}). These findings contradict other research which generally indicated that seeding rate did not influence lint yield (Adams et al., 2018). Yield differences between years could have been a function of varying temperatures and rainfall among years and the field (E7A – 2017, 2019, and C8B 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 vary seeding rate.

Returns Above Variable Input Costs (RAVIC)

The returns above variable input costs (RAVIC) were significantly different between seeding rate treatments in 2019 and 2021 (Tables 2.14 and 2.15). 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, the RAVIC were 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 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 returns above variable input costs. In 2022 no differences in yield were detected that had any significant influenced 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. Our data indicated 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 we used. These results also indicated 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 the strategy under variable circumstances (additional varieties, environmental conditions, irrigated versus dryland, etc.). 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 may not provide an economic or agronomic benefit.

Table 2.1. Seeding rates for cotton to evaluate effects of variable plant population on yield and profitability in South Carolina in 2017 and 2019.

Treatment (Field E7A)	Seeding Rate (seeds ha^{-1})
2017	
1	50966
2	67655
3	84941
4	101929
5	118918
6	135907
2019	
1	50966
2	67655
3	84941
4	101929
5	118918
6	135907
7	D-Rx [a]

[a] Variable seeding rate using uniform seeding rate data from 2017 and Directed Rx prescription development method.

Table 2.2. Seeding rates for cotton to evaluate effects of variable plant population on yield and profitability in South Carolina in 2020-2022.

Treatment (Field C8B)	Seeding Rate (seeds ha^{-1})
2020	
1	24700
2	59280
3	74100
4	88920
5	103740
6	118560
7	133380
8	197600
2021	
1	D-Rx [a]
2	59280
3	74100
4	88920
5	103740
6	118560
7	133380
2022	
1	59280
2	74100
3	88920
4	103740
5	118560
6	133380
7	D-Rx [b]

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

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

Table 2.3. Average temperatures[a] and rainfall totals[c] at the Edisto Research and Education Center (EREC) in Blackville, SC, 2017, 2019-2022.

Year	Maximum Average Temperature ˚C [b]	Minimum Average Temperature ˚C [b]	Rainfall (cm)[c]
2017	24.8	13.2	104.0
2019	27.8	15.9	66.1
2020	26.9	16.2	100.4
2021	23.8	12.7	141.7
2022	31.7	11.4	73.6

[a] Temperature and rainfall data from EREC Weather Data from Clemson Cooperative Extension Services

[b] Average daily maximum and minimum temperature during the growing season (March-November)

[c] Sum of total rainfall for the growing season

Table 2.4. Average total plant height and total number of mainstem nodes for each seeding rate for cotton at the Edisto Research and Education Center (EREC) in Blackville, SC, in 2020 [a].

Seeding Rate (seeds ha^{-1})	Plant Height (cm) [b]	Mainstem Nodes [b]
24700	90.50 cd	17.13 a
59280	87.88 d	16.38 a
74100	91.63 bcd	15.75 a
88920	92.50 abcd	16.63 a
103740	98.50 a	16.50 a
118560	95.50 abc	14.88 a
133380	93.75 abcd	15.63 a
197600	98.00 ab	16.25 a
P value [c]	0.0355	0.2290

[a] Field C8B at EREC.

[b] Means followed by the same lowercase letter are not significantly different at α = 0.05.

[c] P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

Table 2.5. Average total plant height and total number of mainstem nodes for each seeding rate for cotton at the Edisto Research and Education Center (EREC) in Blackville, SC, in 2021 [a].

Seeding Rate (seeds ha^{-1})	Plant Height (cm) [b]	Mainstem Nodes [b]
D-Rx [d]	119.22 a	17.81 a
59280	114.41 a	17.74 a
74100	113.19 a	17.67 a
88920	121.74 a	17.31 a
103740	117.99 a	17.21 a
118560	117.93 a	17.56 a
133380	116.19 a	17.00 a
P value [c]	0.9484	0.9632

[a] Field C8B at EREC.

[b] Means followed by the same lowercase letter are not significantly different at α = 0.05.

[c] P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

[d] Variable rate seeding treatment.

Table 2.6. Average total plant height and total number of mainstem nodes for each seeding rate for cotton at the Edisto Research and Education Center (EREC) in Blackville, SC, in 2022[a].

Seeding Rate (seeds ha^{-1})	Plant Height (cm) [b]	Mainstem Nodes [b]
59280	106.56 a	21.89 a
74100	108.51 a	21.04 ab
88920	105.91 a	20.49 bcd
103740	105.33 a	20.78 bc
118560	107.47 a	19.67 d
133380	105.78 a	20.00 cd
D-Rx [d]	109.62 a	20.24 bcd
P value [c]	0.2495	<0.0001

[a] Field C8B at EREC.

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

[c] P values were obtained from ANOVA table in output of SAS using PROC GLIMMIX procedure.

[d] Variable rate seeding treatment.

Table 2.7. Average total plant height and total number of mainstem nodes for cotton at each seeding rate in a zone of low soil EC [a] in South Carolina in 2021 and 2022.

Seeding Rate (seeds ha^{-1})	Plant Height (cm) [b]	Mainstem Nodes [b]
2021		
59280	89.00 a	15.44 a
74100	87.00 a	15.11 ab
88920	84.37 a	13.69 bc
103740	79.80 a	12.94 bc
118560	83.11 a	14.11 abc
133380	85.78 a	13.78 bc
D-Rx [c]	77.11 a	14.11 abc
P value [d]	0.1841	0.0367
2022		
59280	104.80 a	20.53 a
74100	106.80 a	19.87 abc
88920	101.80 a	20.07 ab
103740	99.40 a	18.87 cd
118560	104.00 a	19.53 abcd
133380	104.60 a	19.00 bdc
D-Rx [c]	102.93 a	18.67 d
P value [d]	0.2783	0.0055

[a] Low soil electroconductivity zone (1.473 mS/m).

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

[c] Variable rate seeding treatment.

[d] P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

Table 2.8. Average total plant height and total number of mainstem nodes for cotton at each seeding rate in a zone of medium soil EC [a] in South Carolina in 2021 and 2022.

Seeding Rate (seeds ha^{-1})	Plant Height (cm) [b]	Mainstem Nodes [b]
	2021	
59280	127.78 a	18.89 a
74100	113.33 a	18.00 a
88920	130.00 a	18.67 a
103740	135.56 a	18.78 a
118560	133.11 a	18.44 a
133380	127.33 a	17.56 a
D-Rx [c]	133.22 a	19.22 a
P value [d]	0.1787	0.7827
	2022	
59280	107.07 bc	23.07 a
74100	108.00 bc	20.53 bc
88920	109.00 abc	20.27 bc
103740	108.40 abc	21.07 b
118560	111.73 ab	19.67 c
133380	104.00 c	20.67 bc
D-Rx [c]	114.13 a	20.27 bc
P value [d]	0.0356	<0.0001

[a] Medium soil electroconductivity zone (2.905 mS/m).

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

[c] Variable rate seeding treatment.

[d] P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

Table 2.9. Average total plant height and total number of mainstem nodes for cotton at each seeding rate in a zone of high soil EC [a] in South Carolina in 2021 and 2022.

Seeding Rate (seeds ha^{-1})	Plant Height (cm) [b]	Mainstem Nodes [b]
	2021	
59280	126.44 b	18.89 a
74100	138.22 a	19.89 a
88920	146.89 a	19.22 a
103740	142.67 a	20.33 a
118560	137.56 ab	20.11 a
133380	135.44 ab	19.67 a
D-Rx [c]	147.33 a	20.11 a
P value [d]	0.0186	0.7648
	2022	
59280	107.80 a	22.07 ab
74100	110.73 a	22.73 a
88920	106.93 a	21.13 bcd
103740	108.20 a	22.40 ab
118560	106.93 a	19.80 d
133380	108.73 a	20.33 cd
D-Rx [c]	111.80 a	21.80 abc
P value [d]	0.5751	0.0010

[a] High soil electroconductivity zone (4.914 mS/m).

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

[c] Variable rate seeding treatment.

[d] P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

Table 2.10. Average number of emerged cotton plants in 2020.

Seeding Rate (seeds ha^{-1})	Emergence_A [a, e]	Emergence_B [b, e]	Emergenced_C [c, e]
24700	3.25 e	3.00 f	3.13 d
59280	6.75 cde	7.25 e	6.00 c
74100	5.75 de	9.88 d	7.13 c
88920	6.00 cde	10.13 d	7.88 c
103740	7.63 bcd	13.88 c	11.13 b
118560	10.38 bc	13.50 c	12.50 b
133380	10.75 b	16.63 b	13.00 b
197600	17.38 a	24.63 a	20.00 a
P value [d]	<0.0001	<0.0001	<0.0001

[a] Emergence counts 1st day of emergence.

[b] Emergence counts two days after emergence.

[c] Emergence counts three days after emergence.

[d] P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

[e] Means followed by the same lowercase letter are not significantly different at α = 0.05.

Table 2.11. Analysis of variance P values for stand counts as affected by seeding rate in 2021 and 2022.

Year	P value [a]
2021	<0.0001*
2022	0.0022*

[a] P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

P values with (*) are significantly different at α = 0.05.

Table 2.12. Average lint yield for cotton as affected by seeding rate in 2017 and 2019.

Seeding Rate (seeds ha^{-1})	Lint Yield (kg ha^{-1}) [a]
2017	
50966	1187.65 cd
67955	1250.85 cd
84941	1138.11 d
101929	1269.98 bc
118918	1371.69 ab
135907	1391.06 a
P value [c]	0.0006
2019	
50966	876.98 b
67955	882.33 b
84941	904.09 b
101929	994.92 a
118918	1006.11 a
135907	1005.87 a
D-Rx [b]	991.44 a
P value [c]	<0.0001

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

[b] Variable rate seeding treatment.

[c] P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

Table 2.13. Average lint yield for cotton as affected by seeding rate in 2020-2022.

Seeding Rate (seeds ha^{-1})	Lint Yield (kg ha^{-1}) [a]
2020	
24700	557.77 c
59280	699.38 bc
74100	734.61 ab
88920	670.54 bc
103740	814.33 ab
118560	811.75 ab
133380	776.94 ab
197600	881.31 a
P value [c]	0.0244
2021	
59280	907.31 c
74100	1030.51 bc
88920	1176.75 a
103740	985.46 bc
118560	1081.84 ab
133380	991.33 bc
D-Rx [b]	1094.41 ab
P value [c]	0.0092
2022	
59280	1381.76 a
74100	1461.27 a
88920	1442.84 a
103740	1480.24 a
118560	1563.67 a
133380	1426.60 a
D-Rx [b]	1403.78 a
P value [c]	0.6959

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

[b] Variable rate seeding treatment.

[c] P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

Table 2.14. Average returns above variable input costs (RAVIC) in cotton as affected by seeding rate in 2017 and 2019.

Seeding Rate (seeds ha^{-1})	RAVIC (\$/ha) [a, d]
2017	
50966	1696.03 a
67955	1749.03 a
84941	1531.11 a
101929	1689.87 a
118918	1802.18 a
135907	1787.69 a
P value [c]	0.0561
2019	
50966	1194.27 b
67955	1181.99 b
84941	1193.17 b
101929	1303.12 a
118918	1299.19 a
135907	1278.90 a
D-Rx [b]	1303.85 a
P value [c]	<0.0001

[a] Returns above variable input costs – seed costs subtracted from revenue.

[b] Variable rate seeding treatment.

[c] P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

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

Table 2.15. Average returns above variable input costs (RAVIC) in cotton as affected by seeding rate in 2020-2022.

Seeding Rate (seeds ha^{-1})	RAVIC (\$/ha) [a, d]
2020	
24700	756.00 a
59280	891.33 a
74100	912.58 a
88920	790.44 a
103740	968.43 a
118560	935.09 a
133380	855.18 a
197600	877.49 a
P value [c]	0.6612
2021	
59280	1869.05 c
74100	2122.85 bc
88920	2424.12 a
103740	2030.05 bc
118560	2228.59 ab
133380	2042.13 bc
D-Rx [b]	2254.49 ab
P value [c]	0.0232
2022	
59280	3272.12 a
74100	3430.65 a
88920	3346.28 a
103740	3400.37 a
118560	3568.62 a
133380	3190.03 a
D-Rx [b]	3481.36 a
P value [c]	0.8198

[a] Returns above variable input costs – seed costs subtracted from revenue.

[b] Variable rate seeding treatment.

[c] P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

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

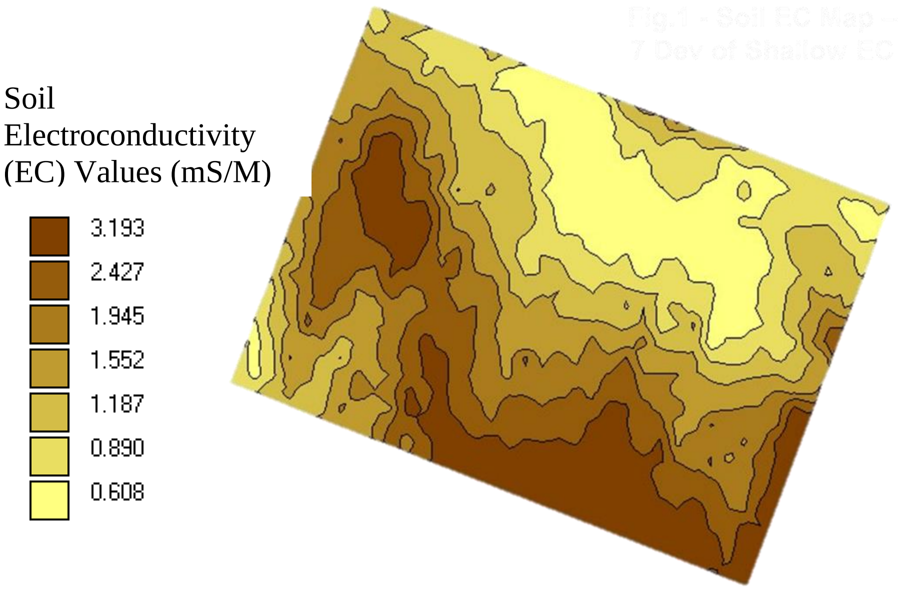

Figure 2.1. Image of the soil EC management zones for field E7A at EREC used in 2017 & 2019 for the cotton seeding prescription development.

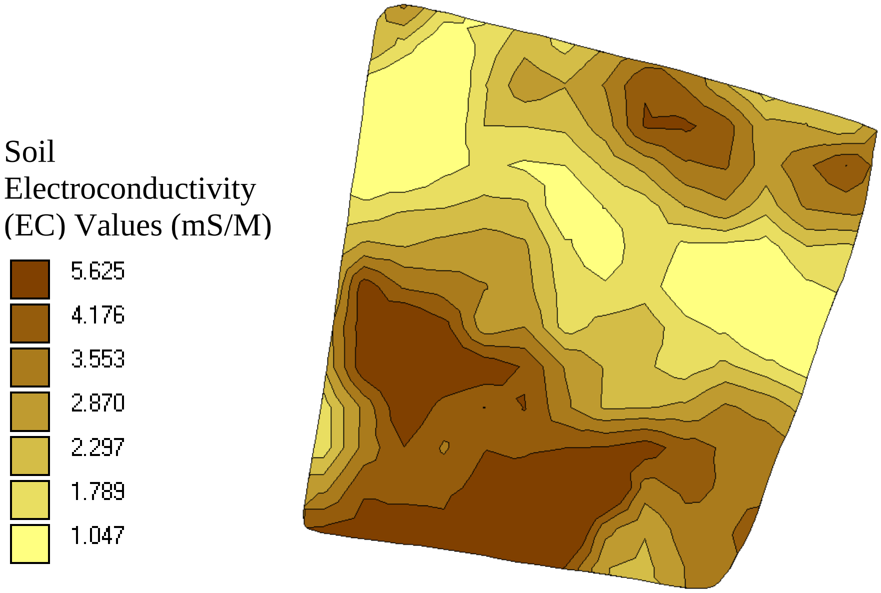

Figure 2.2. Image of the soil EC management zones for field C8B at EREC used in 2020 to 2022 for the cotton seeding prescription development.

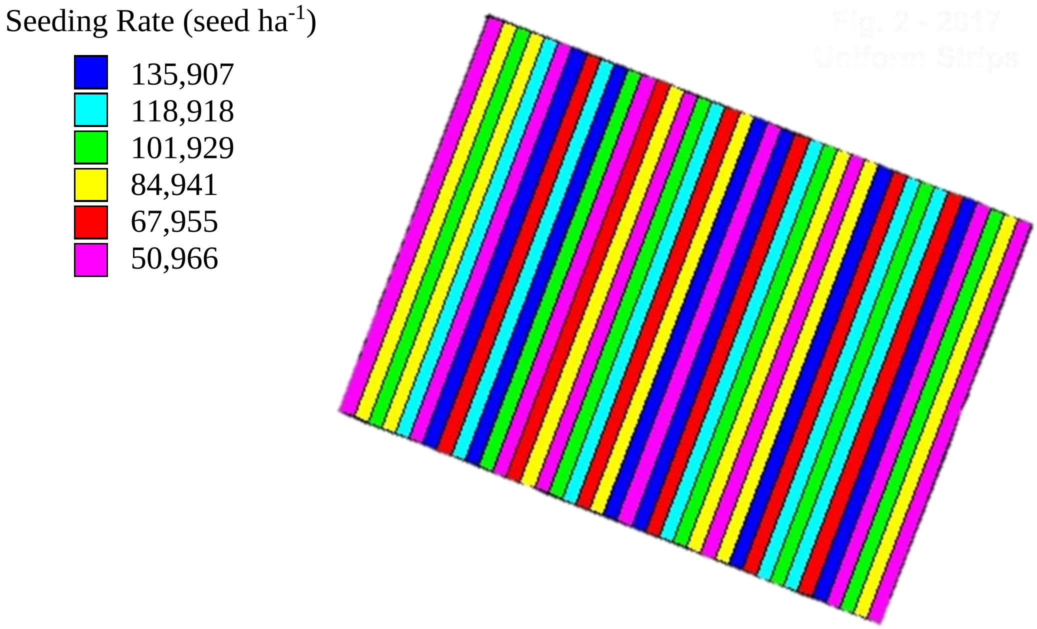

Figure 2.3. The prescription map representing the uniform seeding rate strips placed across field E7A in 2017

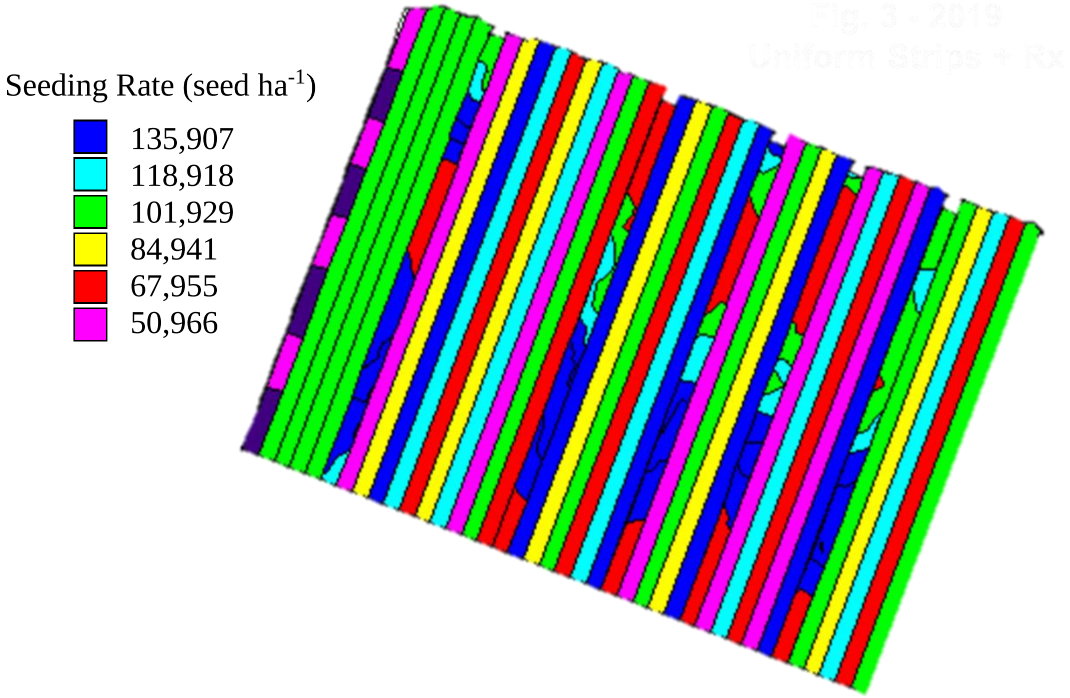

Figure 2.4. The Directed R_x prescription map representing the uniform and variable rate seeding rates placed across field E7A in 2019.

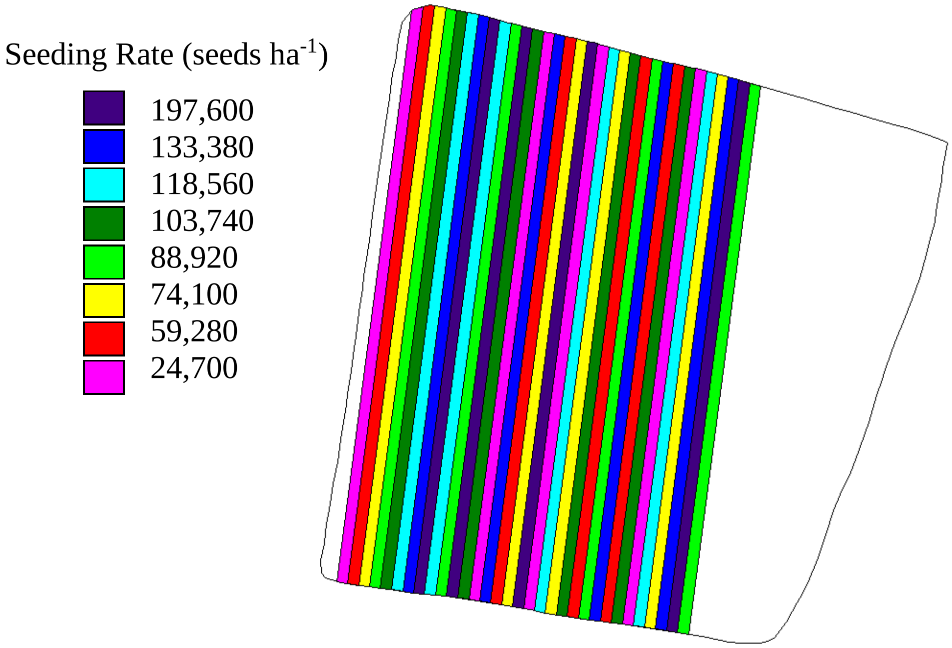

Figure 2.5. The prescription map representing the uniform seeding rate strips placed across field C8B for cotton in 2020.

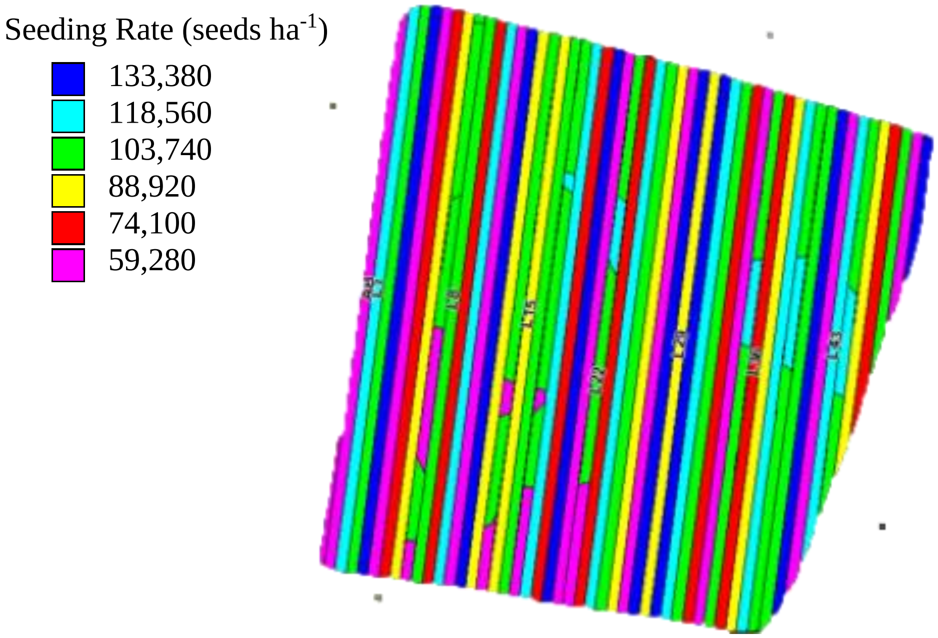

Figure 2.6. The Directed R_x prescription map representing the uniform and variable rate seeding rates placed across field C8B in 2021.

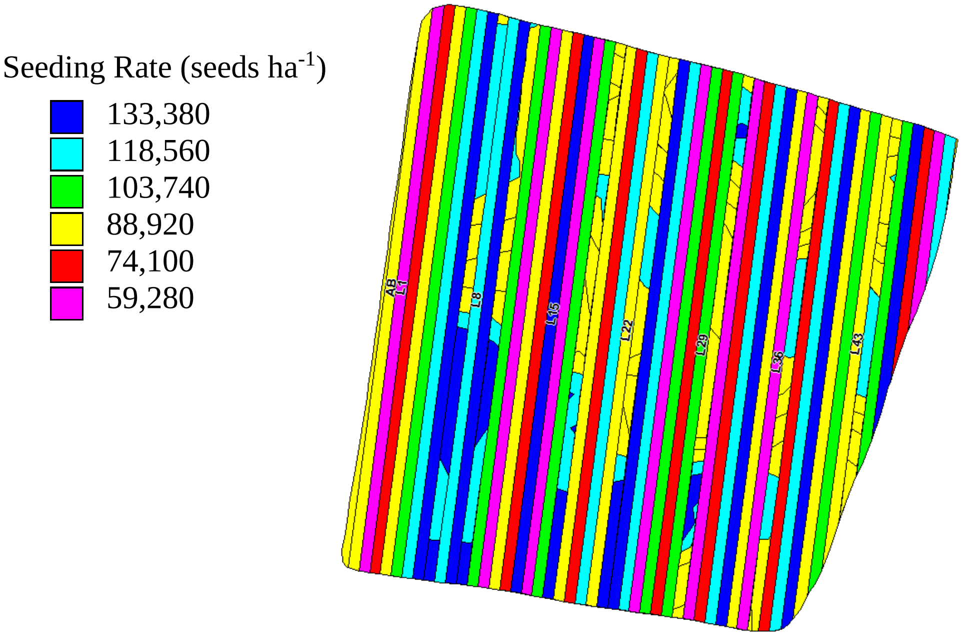

Figure 2.7. The Directed R_x prescription map representing the uniform and variable rate seeding rates placed across field C8B in 2022.

CHAPTER THREE

EVALUATION OF INSECTICIDE EFFICACY AT VARIOUS WASHOFF INTERVALS IN COTTON AND SOYBEAN

Abstract

Unexpected rainfall events are common in the southeastern United States, especially during the summer months of the growing season, farmers are often unaware if pesticide applications remain effective after an unexpected rainfall event. Pesticide labels are often vague and do not provide specific information regarding the rainfast interval of insecticides. With input costs rising, farmers must manage their inputs as efficiently as possible to maximize profit. The objective of this research was to evaluate insecticide efficacy at various simulated rainfall intervals in cotton and soybean. An experiment was conducted in 2021 and 2022 near Blackville, SC, to evaluate the rainfast interval of commonly used insecticides in cotton and soybean production. Each year, approximately 0.48 cm of simulated rainfall was applied to specific plots at six different time intervals (no washoff, 0-0.5 , 1-1.5, 3–4, 6-7, and 24 hours) after application of insecticide), with additional unsprayed and washoff only treatments included for comparison. Tobacco thrips (*Frankiella fusca*), bollworm (*Helicoverpa zea*), and stink bugs (Pentatomidae) were evaluated in cotton, and stink bugs (Pentatomidae), along with other insect pests, were evaluated in soybean. Results from the experiment indicated that the insecticides acephate, chlorantraniliprole, or bifenthrin provided adequate control in managing insect pests after simulated rainfall events, regardless of timing interval.

Introduction

In the southeastern United States, unexpected rainfall is a common occurrence in the summer months. During the growing season, insect pest pressure typically increases, resulting in farmers making pesticide applications to prevent economic losses. Due to the likelihood of a rainfall event occurring during or immediately after a pesticide application, research data are needed to determine the efficacy of a pesticide following a rainfall event. With this information, farmers can make educated decisions on whether to retreat a field for a specific pest.

Cotton (*Gossypium hirsutum* L.) and soybean (*Glycine Max* L.) are host crops for numerous insect pests that cause economic impacts on crop yield. Common insect pests that can cause economic injury to cotton in South Carolina are tobacco thrips (*Franliniella fusca*), bollworm (*Helicoverpa zea*), and various species of stink bugs (Pentatomidae). Tobacco thrips have piercing-sucking and rasping mouthparts and typically feed on cotton seedlings from plant emergence to about the 5-true-leaf stage. This feeding occurs on the plant's apical meristem and can negatively affect the plant, resulting in delayed maturity, reduced above-ground biomass, and stunted root growth and development (Burris et al., 1989; Roberts et al., 2009; Greene et al., 2020). Typical damage and injury from thrips appear as wrinkled or shriveled leaves. If thrips populations and injury are high, previous research has indicated that significant reductions in cotton yield can occur (Cook et al., 2011). Bollworm, also known as podworm, causes economic damage in both cotton and soybean by feeding on the reproductive tissues, such as bolls, pre-floral buds (squares), blooms, and pods (Towles et al., 2017). In cotton, seed technologies have been commercialized to help control bollworm and other lepidopteran pests by incorporating genes from the bacterium *Bacillus thuringiensis* (Bt), referred to as Bt cotton. This trait is helpful in cotton production, but bollworm resistance to Bt proteins has been documented, and supplementary applications of insecticide are often warranted to control bollworm in the crop. Stink bugs have piercing-sucking mouthparts and feed on developing seeds in cotton bolls and soybean pods. This feeding causes damage to the cotton boll, leading to boll rot, stained lint, yield loss, and reduced fiber quality (Barbour, 1990).

Common insect pests that can cause economic injury in soybean include several lepidopteran species such as podworm (*Helicoverpa zea*), soybean looper (*Chrysodeixis includens*), and velvetbean caterpillar (*Anticarsia gemmatalis*). Additional pests, such as kudzu bug (*Megacopta cribraria*), threecornered alfalfa hopper (*Spissistilus festinus*), and stink bugs (Pentatomidae) can also be yield-limiting pests. These species can be classified as either defoliators (consuming leaf material), stem feeders (feeding exclusively on stems and petioles), or pod feeders (feeding exclusively on seed in pods).

Numerous insecticides are commercially available for control of insect pests in cotton and soybean. However, product labels rarely include information on the rainfastness of the product. Previous research in cotton evaluating the efficacy of different insecticides after various rainfall intervals found that rainfastness of bifenthrin, paired with adjuvant use, was preserved with increasing time between application and rainfall events (Mulrooney and Elmore, 2000). Additional research on horticulture crops, such as blueberries and grapes, found that only aging residues of bifenthrin were affected by rainfall (Hulbert et al., 2011 Hulbert et al., 2012). Due to the increasing input costs of pesticides, farmers need to maximize efficacy while remaining profitable, and establishing rainfast intervals for commonly used insecticides could generate information that could help achieve these goals.

Materials and Methods

Plots (7.71 m wide and 12.19 m long with 16 rows spaced 97 cm apart) of cotton and soybean were planted on an irrigated Barnwell Loamy Sand (fine-loamy, kaolinitic, thermic Typic Kanhapludults) soil (USDA-NRCS, 2023) at the Clemson University Edisto Research and Education Center (EREC) in Blackville, SC, in 2021 and 2022 (33º21’55” N, 81º19’47” W). Using a split-plot design, spray treatments of acephate (Orthene® 97SG, AMVAC Chemical Corporation, Collierville, TN) (0.21 kg ai ha^{-1}) for tobacco thrips, chlorantraniliprole (Prevathon®, FMC Corporation, Philadelphia, PN) (0.075 kg ai ha^{-1}) for bollworm, or bifenthrin (Brigrade 2EC®, FMC Corporation, Philadelphia, PN) (0.112 kg ai ha^{-1}) for stink bugs in cotton or stink bugs and other species in soybeans were made to half of each plot (8 rows) with a high-clearance sprayer delivering water at 93.5 liters ha^{-1} (10 gallons acre^{-1}) and 3.51-4.22 kg cm^{-1} (50-60 psi) through TXVS-6 hollow-cone tips. Rainfall events were simulated at intervals of 0 to 0.5, 1 to 1.5, 3 to 4, 6 to 7, and 24 hours using another high-clearance sprayer delivering 909.6 L (240 gallons) of water using TeeJet flood-type tips (TeeJet® Technologies, Glendale Heights, IL) to the main plot (16 rows). Plots untreated with insecticide, with and without simulated rainfall were included as control plots for comparison. Experimental plots were arranged in a split-plot experimental design consisting of twelve treatments and four replications where washoff interval was the main plot factor (16 rows) and insecticide application was the sub-plot factor (8 rows). A list of the twelve treatments are as follows:

1. No Washoff x No Insecticide (Untreated Control)
2. No Washoff x Insecticide
3. 0 – 0.5 Hour Washoff x No Insecticide
4. 0 – 0.5 Hour Washoff x Insecticide
5. 1 – 1.5 Hour Washoff x No Insecticide
6. 1 – 1.5 Hour Washoff x Insecticide
7. 3 – 4 Hour Washoff x No Insecticide
8. 3 – 4 Hour Washoff x Insecticide
9. 6 – 7 Hour Washoff x No Insecticide
10. 6 – 7 Hour Washoff x Insecticide
11. 24 Hour Washoff x No Insecticide
12. 24 Hour Washoff x Insecticide

In 2021 and 2022, all cotton plots were harvested using a 4-row John Deere 9986 spindle cotton picker modified for small plot research. The yield for each plot was collected from the weights recorded by the picker weigh system. All data were subjected to analysis of variance (ANOVA) using the PROC GLIMMIX procedure in SAS v.9.4 (SAS Institute Inc., Cary, NC), and means were separated using multiple pairwise t-tests at $\alpha=0.05$.

Tobacco Thrips

In 2021, field preparation was done by application of a burndown herbicide and strip-tilling using a Unverferth ripper/bedder implement (Unverferth, Kalida, OH). Using a John Deere 1720 4-row vacuum planter (John Deere, Moline, IL), PHY 480W3FE cotton variety was planted on 30 April and did not include an insecticide seed treatment. The planting date was based on the thrips model (NC State, 2023) to ensure seedlings would emerge when thrips pressure reached its peak. At the 3-4 leaf stage (Figure 3.1), the insecticide application of acephate and simulated rainfall treatments were implemented. After the 24-hr washoff interval, thrips were sampled, injury ratings were estimated, and plant heights and stand counts were recorded one day after application (DAA) of the final washoff interval. On each sampling date, 10 plants per plot were pulled from the six center rows and placed into labeled jars filled with 50% isopropyl alcohol and taken to the thrips laboratory at EREC for counting using filtration procedures. On each sampling date, thrips injury was recorded on a scale from 0-5, where a rating of “0” indicated no visible injury, and a rating of “5” indicated severely stunted plants or death of the terminal or entire plant (Kerns et al., 2018). At 42 DAP, five random plants were cut per sub-plot (8 rows) and plant height, number of mainstem nodes, and fresh weights were measured before placed into dryers. The number of nodes were counted starting at the cotyledonary nodes, representing node “0”. Plants were reweighed to measure dry weight.

In 2022, field preparation consisted of spraying a burndown herbicide application and then the experiment location was disked using an Athens disk harrow (Athens Plow

Company, Athens, TN). The experimental location was disked in 2022 as an attempt to increase thrips presence in the field. Untreated Deltapine DP 1646B2XF cotton was planted on 26 April using a John Deere 1720 planter (John Deere, Moline, IL), the planting date reflected the optimum planting date for maximized thrips pressure according to the thrips model (NC State, 2023). On 18 May, acephate was applied to 1-2 true-leaf cotton followed by the simulated rainfall treatments. Thrips were sampled and rated for injury 1, 4, 7, and 13 (injury and plant height only) DAA of final washoff treatment. Seed cotton samples were collected in 2022 by hand harvesting 25 bolls from each plot and then ginned using an 8-saw laboratory tabletop gin. Gin turnout was calculated by dividing the lint weights by the seed cotton weights and multiplying by 100. Turnout was used to calculate the total lint yield for each plot.

Bollworm

In 2021 and 2022, field preparation consisted of spraying a burndown herbicide application followed by conservational tillage (strip-till) using a 4-row Unverferth ripper/bedder implement (Unverferth, Kalida, OH). Using a 4-row John Deere 1720 vacuum planter, cotton was planted on 26 May 2021. The variety was NexGen NG 4050 in 2021, which is a non-Bt variety. Non-Bt cotton does not have the *Bacillus thuringiensis* proteins used to control lepidopterans. In 2022, the variety was Deltapine DP 1822 (non-Bt) and was planted on 8 June 2022. On 4 August 2021 and 3 August 2022, chlorantraniliprole was applied and simulated rainfall treatments were implemented. Due to an unexpected rainfall event on 3 August 2022, the 24-hour washoff interval did not occur, and the final washoff was 8.5 hours after application. In 2022, counts of bollworm larvae and damage to terminals, squares, blooms, and bolls were made by examining the structures of each plant part on 25 random plants per plot from the four middle rows. These counts were not collected in 2021 due to extremely low bollworm pressure. Harvest dates were 2 December 2021 and 13 December 2022.

Stink Bugs

In 2021 and 2022, field preparation consisted of spraying a burndown herbicide and conservational tillage (strip-till). On 26 May 2021, Deltapine DP 2055 B3XF was planted; on 8 June 2022, Deltapine DP 2127 B3XF cotton varieties were planted. A John Deere 1720 vacuum planter was used to plant treatments. On 10 August 2021 and 6 September 2022, bifenthrin was applied followed by simulated rainfall treatments being implemented. In 2021, boll damage was rated 12 DAA by sampling 10 bolls per plot, cutting them open, and examining each boll for stink bug damage. Percent damage was calculated by dividing the number of damage bolls by 10 and multiplying by 100. In 2022, this same procedure was completed; 7 DAA and 25 bolls were collected per plot instead of 10. Percent damage was calculated by dividing the damage bolls by 25 and multiplying by 100. Additionally, in 2022, prior to harvest, 25 seed cotton bolls were collected per plot and ginned using an 8-saw blade laboratory tabletop gin. Gin turnout was calculated by dividing the lint weight by the seed cotton weight and multiplying by 100.

Soybean Insects

Insecticide efficacy was also evaluated at various washoff intervals in soybean. Using the same methodology from the cotton experiments, treatments were established in soybean in both years. On 30 June 2021, Asgrow AG69XF0 variety of soybean was planted and on 16 June 2022, Asgrow AG46XF2 variety of soybean was planted using a 4-row John Deere 1720 vacuum planter. Applications of bifenthrin was on 30 September 2021 and 14 September 2022 immediately followed by the simulated rainfall treatments. After the simulated rainfall events occurred, each plot was with a standard insect sweep net 1,8, and 12 DAA in 2021 and 2 and 14 DAA in 2022. After each plot was swept, the contents of the sweep net were put in a pre-labeled plastic bag and placed in a freezer. The samples were pulled from the freezer, and the insects were counted and recorded per plot (Figure 3.5). The primary insects counted were kudzu bug (*Megacopia crobraria*), grasshoppers (Caelifera), threecornered alfalfa hopper (*Spissistilus festinus*), stink bugs (Pentatomidae), and lepidopteran species. The 2 center rows from each plot were harvested with a Kincaid 8XP (Kincaid, Haven, KS) plot combine equipped with a HarvestMaster weight system (Juniper Systems & HarvestMaster, Inc., Logan, UT), and moisture was corrected to 13%. Fixed effects were washoff interval treatment, year, and location. Random effects were replication. All data were subjected to analysis of variance (ANOVA) using PROC GLIMMIX means were separated using multiple pairwise t-tests at α=0.05.

Results & Discussion

Tobacco Thrips

In 2021, there were no significant differences among the thrips counts (P = 0.3998), injury ratings (P = 0.6792), plant heights (P = 0.7765), biomass (P = 0.7718), number of mainstem nodes (P = 0.7529), or yield (P = 0.5768), regardless of washoff interval or whether or not the plots received insecticide (Tables 3.3, 3.7 – 3.12). This could be a result of the low thrips pressure that was experienced in the field in 2021. In 2022, there were no significant differences in the number of adult thrips on the first sampling date 1 DAA (Table 3.4); however, there were significant differences in the number of immature thrips counted. At 4 DAA, there were no differences in immature counts by treatment; however, adult thrips numbers did differ where, counts from the no washoff x insecticide, 0-0.5 hour washoff x insecticide, 1-1.5 hour washoff x no insecticide, and 1-1.5 hour x insecticide treatments had more adult thrips than the 3-4 hour x no insecticide treatment (Table 3.5). We speculate that these differences were observed due to the low pest pressure in the field during 2022 and how the thrips moved after the initial treatment application. At the 7 DAA sampling no significant differences in the number of adult or immature thrips counts were observed (Table 3.6). Injury ratings (P = 0.5786) and plant heights (P = 0.0749) had no significant differences at the 1 DAA sampling period (Tables 3.7 and 3.8). The 4 DAA sampling period resulted in a significant difference in plant height (P = 0.0386), unlike the 1 and 7 DAA (P = 0.0790) sampling. The use of insecticide did not appear to have an impact on plant height, with the exception of the 6-7 and 24 hour washoff timings. The 13 DAA injury ratings (P = 0.0008) and plant height measurements (P = 0.0005) indicated that where insecticide was applied, the injury ratings were lower compared with where no insecticide was applied. This indicated that the insecticide did help reduce feeding on cotton plants. The timing of the insecticide washoff did not make a difference in the amount of injury. The use of an insecticide did not have an effect on plant height; however, no washoff timing did result in taller plants. Similar to 2021, there were no significant differences in the number of mainstem nodes (P = 0.5897), plant biomass (P = 0.2264), plant height at 25 DAA (P = 0.1031), or yield (P = 0.4333) in 2022. This agrees with previous research where yield was not affected even though thrips were present (Cook et al., 2013). Overall, washoff timings did not affect insecticide applications, but the use of an insecticide did reduce thrips at sampling.

Bollworm

In both 2021 and 2022, there were no significant differences in lint yield (Table 3.13). This could be due to the low bollworm pressure in both years, resulting in low damage to fruiting structures. Also, in 2022, an unusually early frost occurred around 18 October, before the majority of bolls had opened and before the initial defoliation application. This could have eliminated treatment effects within the trial. There were significant differences in the number of damaged terminals. The absence of the insecticide resulted in more damage, indicating that the insecticide reduced bollworm pressure resulting in a decrease of damage. However, the timing of simulated rainfall events did not alter damage results. Though the bollworm population was considered low, differences were observed where the insecticide was applied compared with where plots were left untreated. No significant differences were observed in the number of damaged bolls or blooms (Table 3.14). In years with greater bollworm pressure, results may vary indicating the timing of simulated rainfall could potentially effect insecticide efficacy more than our results demonstrated.

Stink Bugs

In 2021, significant differences occurred in the percentage of boll damage caused by stink bugs (Table 3.15). The untreated control (no washoff and no insecticide) treatment resulted in the highest percentage of damaged bolls (47.5%) compared with the sprayed 24-hour washoff interval with the least amount of damage (2.5%). Overall, the insecticide application did result in a reduction of boll damage. In 2022, there were no significant differences in the percentage of damaged bolls sampled (P = 0.4459). In 2021, there were no significant differences in lint yield among the treatments (P = 0.5214), but significant differences in lint yield occurred in 2022 (P = 0.0303) (Table 3.16). Based on the data, lint yield was affected by 30% between treatments. Previous research has shown similar results where high levels of damage from stink bugs resulted in reduced lint yield (Barbour et al., 1990). Seemingly, bifenthrin continues to be efficacious on stink bugs, and rainfall events can negatively affect performance of the insecticide.

Soybean Insects

In 2021, there were significant differences in the number of threecornered alfalfa hoppers, stink bugs, and total number of insects counts across all sampling dates (1, 8, and 12 DAA) (Tables 3.17, 3.18, and 3.19). No significant differences among treatments were observed in counts of lepidopteran species on all sampling dates. Significant differences were observed in the counts of kudzu bugs and grasshoppers at 1 and 12 DAA sampling dates. Significant differences were observed at the 8 DAA in grasshoppers counts. Based on the results across all sampling dates, the data suggested that the insecticide application reduced the number of insects, and simulated rainfall did not affect the efficacy of the insecticide. In 2022, significant differences were observed on both sampling dates (2 and 14 DAA) in the number of kudzu bug, threecornered alfalfa hopper, and stink bugs counted (Tables 3.20 and 3.21). Only during the 2 DAA sampling date did a significant difference appear in the counts of grasshoppers. Similar to 2021, where the insecticide was applied, it resulted in lower insect counts, and the washoff timing interval did not affect the efficacy. On either sampling date, lepidopteran species had no significant differences in counts, again similar to the 2021 samplings. No significant differences were observed in plant height, the number of mainstem nodes in 2022, or grain yield in both years (Tables 3.22 and 3.23). Overall, insect populations were significantly reduced in soybean where bifenthrin was applied, and it appears that simulated rainfall did not impact insecticide efficacy.

Conclusions

This research was conducted to evaluate insecticide efficacy at various washoff intervals in cotton and soybean production. Our data indicated that insecticide efficacy of commonly used insecticides was not affected by simulated rainfall on important insect pests such as tobacco thrips, bollworm, and stink bugs. Furthermore, simulated rainfall alone without the application of an insecticide did not have an impact on insect pest populations in sampled plots. Apparently, the rainfast interval of these products was relatively quick. Insect density and damage should be reassessed before a product is assumed to have been washed off of plants after an unexpected rainfall event. Ultimately, the evaluation of these products in this research trial will help aid South Carolina farmers to reduce input costs and increase profitability.

Table 3.1. Crop, target insect, and dates for planting, final simulated rainfall (washoff), and harvest for field trials conducted near Blackville, SC, in 2021 and 2022.

Crop/Insect	Planting Date	Final Washoff Date[a]	Harvest Date
2021			
Cotton – Thrips	April 30	May 24	November 3
Cotton – Bollworm	May 26	August 4	December 2
Cotton – Stink bugs	May 26	August 26	December 2
Soybean – Multiple	June 30	September 30	November 8
2022			
Cotton – Thrips	April 26	May 18	September 27
Cotton – Bollworm	June 8	August 3	December 13
Cotton – Stink bugs	June 8	September 6	December 13
Soybean – Multiple	June 16	September 14	October 26

[a] Each washoff date consisted of the 24-hour washoff interval, except 2022 bollworm due to an unexpected rainfall event.

Table 3.2. Average daily maximum and minimum temperatures[a] and rainfall totals[b] for the Edisto Research and Education Center (EREC) in Blackville, SC, during the growing season[c] in 2021 and 2022.

Year	Maximum Average Temperature ºC	Minimum Average Temperature ºC	Rainfall (cm)
2021	23.8	12.7	141.7
2022	31.7	11.4	73.6

[a] Temperature and rainfall data from EREC Weather Data from Clemson Cooperative Extension Services (need link for weather data here unless locked for internal use only)

[b] Sum of total rainfall for the growing season (March – November)

[c] Average daily maximum and minimum temperature during the growing season (March-November)

Table 3.3. Average thrips counts on cotton plants 1 day after application (DAA) for washoff interval and insecticide [a] application near Blackville, SC, in 2021.

Treatment	Adult [b]	Immature [b]	Total [b]
No Washoff X No Insecticide	4.50 a	4.00 a	8.50 a
No Washoff X Insecticide	1.50 a	2.75 a	4.25 a
0-30 min Washoff X No Insecticide	5.25 a	6.75 a	12.00 a
0-30 min Washoff X Insecticide	6.25 a	5.00 a	11.25 a
1-1.5 hr Washoff X No Insecticide	2.25 a	5.25 a	7.50 a
1-1.5 hr Washoff X Insecticide	3.00 a	4.75 a	7.75 a
3-4 hr Washoff X No Insecticide	6.00 a	9.75 a	15.75 a
3-4 hr Washoff X Insecticide	2.75 a	2.50 a	5.25 a
6-7 hr Washoff X No Insecticide	6.75 a	6.00 a	12.75 a
6-7 hr Washoff X Insecticide	1.50 a	2.50 a	4.00 a
24 hr Washoff X No Insecticide	5.50 a	3.00 a	8.50 a
24 hr Washoff X Insecticide	5.50 a	6.25 a	11.75 a
P value [c]	0.6517	0.6301	0.3998

[a] Acephate (Orthene 97) applied at 0.21 kg ai ha^{-1}

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

P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

Table 3.4. Average thrips counts on cotton plants 1 day after application (DAA) for washoff interval and insecticide [a] application at EREC in 2022.

Treatment	Adult [b]	Immature [b]	Total [b]
No Washoff X No Insecticide	4.25 a	37.75 abc	42.00 abcd
No Washoff X Insecticide	1.75 a	37.75 abc	39.50 abcd
0-30 min Washoff X No Insecticide	5.25 a	58.25 a	63.50 ab
0-30 min Washoff X Insecticide	2.25 a	23.00 bc	25.25 cd
1-1.5 hr Washoff X No Insecticide	5.00 a	50.00 ab	55.00 abc
1-1.5 hr Washoff X Insecticide	1.25 a	26.00 bc	27.25 cd
3-4 hr Washoff X No Insecticide	1.00 a	11.50 c	12.50 d
3-4 hr Washoff X Insecticide	1.50 a	10.75 c	12.25 d
6-7 hr Washoff X No Insecticide	8.50 a	59.00 a	67.50 a
6-7 hr Washoff X Insecticide	1.25 a	32.25 abc	33.50 bcd
24 hr Washoff X No Insecticide	3.50 a	16.25 c	19.75 d
24 hr Washoff X Insecticide	1.75 a	16.75 c	18.50 d
P value [c]	0.1179	0.0092	0.0152

[a] Acephate (Orthene 97) applied at 0.21 kg ai ha^{-1}

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

P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

Table 3.5. Average thrips counts on cotton plants 4 day after application (DAA) for washoff interval and insecticide [a] application at EREC in 2022.

Treatment	Adult [b]	Immature [b]	Total [b]
No Washoff X No Insecticide	2.50 bc	57.00 a	59.50 a
No Washoff X Insecticide	4.75 ab	49.75 a	54.50 a
0-30 min Washoff X No Insecticide	3.75 bc	42.75 a	46.50 a
0-30 min Washoff X Insecticide	8.75 a	58.25 a	67.00 a
1-1.5 hr Washoff X No Insecticide	4.75 ab	50.00 a	54.75 a
1-1.5 hr Washoff X Insecticide	6.75 ab	28.25 a	35.00 a
3-4 hr Washoff X No Insecticide	0 c	9.25 a	9.25 a
3-4 hr Washoff X Insecticide	2.50 bc	11.00 a	13.50 a
6-7 hr Washoff X No Insecticide	4.25 bc	50.00 a	54.25 a
6-7 hr Washoff X Insecticide	3.00 bc	47.00 a	50.00 a
24 hr Washoff X No Insecticide	2.5 bc	48.00 a	50.50 a
24 hr Washoff X Insecticide	4.00 bc	24.00 a	28.00 a
P value [c]	0.0328	0.3399	0.3177

[a] Acephate (Orthene 97) applied at 0.21 kg ai ha^{-1}

[b] Means within a column followed by the same lowercase letter are not significantly different at α = 0.05.

[c] P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

Table 3.6. Average thrips counts on cotton plants 7 day after application (DAA) for washoff interval and insecticide [a] application at EREC in 2022.

Treatment	Adult [b]	Immature [b]	Total [b]
No Washoff X No Insecticide	9.50 a	60.00 a	69.50 a
No Washoff X Insecticide	8.50 a	32.50 a	41.00 a
0-30 min Washoff X No Insecticide	10.75 a	67.00 a	77.75 a
0-30 min Washoff X Insecticide	7.75 a	37.00 a	44.75 a
1-1.5 hr Washoff X No Insecticide	10.50 a	48.50 a	59.00 a
1-1.5 hr Washoff X Insecticide	4.75 a	25.25 a	30.00 a
3-4 hr Washoff X No Insecticide	1.50 a	17.00 a	18.50 a
3-4 hr Washoff X Insecticide	4.50 a	8.25 a	12.75 a
6-7 hr Washoff X No Insecticide	5.00 a	79.75 a	84.75 a
6-7 hr Washoff X Insecticide	6.50 a	49.75 a	56.25 a
24 hr Washoff X No Insecticide	7.25 a	53.25 a	60.50 a
24 hr Washoff X Insecticide	5.50 a	29.00 a	34.50 a
P value [c]	0.1141	0.1023	0.0920

[a] Acephate (Orthene 97) applied at 0.21 kg ai ha^{-1}

[b] Means within a column followed by the same lowercase letter are not significantly different at α = 0.05.

P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

Table 3.7. Average visual injury ratings for thrips feeding damage on cotton plants on days after application (DAA) for washoff interval and insecticide [a] application at EREC in 2021 and 2022.

Treatment	Year				
	2021	2022			
	1 DAA [b]	1 DAA [b]	4 DAA [b]	7 DAA [b]	13 DAA [b]
No Washoff X No Insecticide	3.00 a	3.75 a	3.50 a	3.63 a	3.75 ab
No Washoff X Insecticide	2.88 a	3.38 a	3.13 a	3.25 a	3.00 d
0-30 min Washoff X No Insecticide	3.38 a	3.75 a	3.38 a	3.63 a	3.63 abc
0-30 min Washoff X Insecticide	3.13 a	3.50 a	3.25 a	3.63 a	3.25 cd
1-1.5 hr Washoff X No Insecticide	3.13 a	3.63 a	3.63 a	3.88 a	3.75 ab
1-1.5 hr Washoff X Insecticide	3.00 a	3.75 a	3.13 a	3.63 a	3.38 bcd
3-4 hr Washoff X No Insecticide	3.50 a	3.50 a	3.00 a	3.63 a	3.88 a
3-4 hr Washoff X Insecticide	3.50 a	3.50 a	3.13 a	3.25 a	3.34 bcd
6-7 hr Washoff X No Insecticide	3.38 a	3.63 a	3.25 a	3.75 a	3.63 abc
6-7 hr Washoff X Insecticide	3.25 a	3.63 a	3.50 a	3.50 a	3.25 cd
24 hr Washoff X No Insecticide	3.13 a	3.75 a	3.25 a	3.88 a	3.75 ab
24 hr Washoff X Insecticide	3.38 a	3.50 a	3.50 a	3.50 a	3.13 d
P value [c]	0.6792	0.5786	0.1104	0.0970	0.0008

[a] Acephate (Orthene 97) applied at 0.21 kg ai ha^{-1}

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

P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

Table 3.8. Average plant height (cm) for thrips on days after application (DAA) for washoff interval and insecticide [a] application at EREC in 2021 and 2022.

Treatment	Year				
	2021	2022			
	1 DAA [b]	1 DAA [b]	4 DAA [b]	7 DAA [b]	13 DAA [b]
No Washoff X No Insecticide	6.24 a	8.50 a	10.93 a	11.83 a	18.65 ab
No Washoff X Insecticide	5.84 a	8.80 a	10.80 a	11.55 a	20.15 a
0-30 min Washoff X No Insecticide	5.89 a	7.88 a	9.93 ab	11.43 a	17.10 bcd
0-30 min Washoff X Insecticide	6.41 a	7.88 a	9.83 ab	11.28 a	16.40 cd
1-1.5 hr Washoff X No Insecticide	6.19 a	7.90 a	8.78 b	10.73 a	15.68 cd
1-1.5 hr Washoff X Insecticide	6.59 a	7.43 a	8.53 b	10.45 a	15.73 cd
3-4 hr Washoff X No Insecticide	6.89 a	7.45 a	8.48 b	10.38 a	15.33 d
3-4 hr Washoff X Insecticide	6.63 a	7.70 a	8.55 b	9.85 a	16.30 cd
6-7 hr Washoff X No Insecticide	5.86 a	7.98 a	8.93 b	10.88 a	16.48 cd
6-7 hr Washoff X Insecticide	6.00 a	7.85 a	9.90 ab	11.70 a	17.40 bc
24 hr Washoff X No Insecticide	5.96 a	8.03 a	9.08 b	11.45 a	16.70 cd
24 hr Washoff X Insecticide	6.21 a	8.20 a	9.88 ab	12.15 a	16.30 cd
P value [c]	0.7765	0.0749	0.0386	0.0790	0.0005

[a] Acephate (Orthene 97) applied at 0.21 kg ai ha^{-1}

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

P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

Table 3.9. Average plant biomass weight (g) thrips for washoff interval and insecticide [a] application at EREC in 2021 and 2022.

Treatment	Year	
	2021 Biomass [b]	2022 Biomass [b]
No Washoff X No Insecticide	56.85 a	110.72 a
No Washoff X Insecticide	64.78 a	64.55 a
0-30 min Washoff X No Insecticide	56.88 a	92.10 a
0-30 min Washoff X Insecticide	72.85 a	91.73 a
1-1.5 hr Washoff X No Insecticide	51.53 a	88.55 a
1-1.5 hr Washoff X Insecticide	60.20 a	76.78 a
3-4 hr Washoff X No Insecticide	72.03 a	74.28 a
3-4 hr Washoff X Insecticide	60.13 a	89.88 a
6-7 hr Washoff X No Insecticide	56.15 a	85.98 a
6-7 hr Washoff X Insecticide	56.75 a	114.25 a
24 hr Washoff X No Insecticide	64.15 a	85.88 a
24 hr Washoff X Insecticide	49.15 a	100.15 a
P value [c]	0.7718	0.2264

[a] Acephate (Orthene 97) applied at 0.21 kg ai ha^{-1}

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

P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

Table 3.10. Average plant biomass height (cm) thrips for washoff interval and insecticide [a] application at EREC in 2021 and 2022.

Treatment	Year	
	2021 Biomass Height [b]	2022 Biomass Height [b]
No Washoff X No Insecticide	16.53 a	20.60 a
No Washoff X Insecticide	15.48 a	24.65 a
0-30 min Washoff X No Insecticide	16.10 a	20.75 a
0-30 min Washoff X Insecticide	17.03 a	21.35 a
1-1.5 hr Washoff X No Insecticide	15.45 a	19.25 a
1-1.5 hr Washoff X Insecticide	16.43 a	20.15 a
3-4 hr Washoff X No Insecticide	17.43 a	18.95 a
3-4 hr Washoff X Insecticide	16.65 a	21.00 a
6-7 hr Washoff X No Insecticide	15.93 a	20.70 a
6-7 hr Washoff X Insecticide	15.38 a	23.05 a
24 hr Washoff X No Insecticide	14.93 a	18.90 a
24 hr Washoff X Insecticide	14.35 a	23.85 a
P value [c]	0.4559	0.1031

[a] Acephate (Orthene 97) applied at 0.21 kg ai ha^{-1}

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

P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

Table 3.11. Average plant mainstem nodes for thrips cotton for washoff interval and insecticide [a] application at EREC in 2021 and 2022.

Treatment	Year	
	2021 Nodes [b]	2022 Nodes [b]
No Washoff X No Insecticide	7.20 a	8.30 a
No Washoff X Insecticide	8.05 a	9.10 a
0-30 min Washoff X No Insecticide	7.10 a	8.50 a
0-30 min Washoff X Insecticide	7.60 a	8.10 a
1-1.5 hr Washoff X No Insecticide	8.15 a	8.40 a
1-1.5 hr Washoff X Insecticide	7.35 a	8.50 a
3-4 hr Washoff X No Insecticide	8.20 a	8.65 a
3-4 hr Washoff X Insecticide	7.80 a	8.85 a
6-7 hr Washoff X No Insecticide	7.85 a	9.10 a
6-7 hr Washoff X Insecticide	7.85 a	9.35 a
24 hr Washoff X No Insecticide	7.70 a	8.10 a
24 hr Washoff X Insecticide	7.20 a	9.45 a
P value [c]	0.7529	0.5897

[a] Acephate (Orthene 97) applied at 0.21 kg ai ha^{-1}

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

P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

Table 3.12. Average cotton lint yield (kg ha^{-1}) affected by thrips for washoff interval and insecticide [a] application at EREC in 2021 and 2022.

Treatment	Year	
	2021 [b]	2022 [b]
No Washoff X No Insecticide	3966.73 a	3508.20 a
No Washoff X Insecticide	3587.01 a	3496.26 a
0-30 min Washoff X No Insecticide	3756.57 a	3512.98 a
0-30 min Washoff X Insecticide	3895.09 a	3520.14 a
1-1.5 hr Washoff X No Insecticide	3601.34 a	3166.69 a
1-1.5 hr Washoff X Insecticide	3505.82 a	3052.06 a
3-4 hr Washoff X No Insecticide	4107.63 a	2822.80 a
3-4 hr Washoff X Insecticide	4098.08 a	2822.80 a
6-7 hr Washoff X No Insecticide	3398.35 a	3224.01 a
6-7 hr Washoff X Insecticide	3665.82 a	3546.41 a
24 hr Washoff X No Insecticide	3176.25 a	3281.32 a
24 hr Washoff X Insecticide	3243.12 a	3407.89 a
P value [c]	0.5768	0.4333

[a] Acephate (Orthene 97) applied at 0.21 kg ai ha^{-1}

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

P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

Table 3.13. Average cotton lint yield (kg ha^{-1}) affected by bollworm for washoff interval and insecticide [a] application at EREC in 2021 and 2022.

Treatment	Year	
	2021 [a]	2022 [a]
No Washoff X No Insecticide	2622.20 a	1712.30 a
No Washoff X Insecticide	2935.04 a	2077.68 a
0-30 min Washoff X No Insecticide	2794.14 a	1657.37 a
0-30 min Washoff X Insecticide	2758.32 a	1707.52 a
1-1.5 hr Washoff X No Insecticide	2371.44 a	1731.40 a
1-1.5 hr Washoff X Insecticide	2770.26 a	1932.01 a
3-4 hr Washoff X No Insecticide	2538.61 a	1690.66 a
3-4 hr Washoff X Insecticide	2908.77 a	1764.83 a
6-7 hr Washoff X No Insecticide	2235.31 a	1592.89 a
6-7 hr Washoff X Insecticide	2338.01 a	1354.07 a
24 hr Washoff X No Insecticide [c]	2572.05 a	1676.47 a
24 hr Washoff X Insecticide [c]	2615.03 a	1590.50 a
P value [b]	0.7712	0.6084

[a] Chlorantraniliprole (Prevathon) applied at 0.075 kg ai ha^{-1}

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

[c] P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

[d] 2022 did not experience a full 24-hour time interval, it was reduced to 8.5 hr due to a rainfall event.

Table 3.14. Percent of bollworm damage observed among washoff interval and insecticide [a] application at EREC in 2022.

Treatment	Terminal[b]	Square[b]	Bloom[b]	Boll[b]	Total[b]
No Washoff X No Insecticide	13 ab	3 bc	3 a	2 a	22 b
No Washoff X Insecticide	5 de	0 c	1 a	1 a	7 b
0-30 min Washoff X No Insecticide	8 bcd	1 c	3 a	6 a	23 b
0-30 min Washoff X Insecticide	2 e	4 bc	2 a	1 a	10 b
1-1.5 hr Washoff X No Insecticide	2 e	2 bc	5 a	0 a	10 b
1-1.5 hr Washoff X Insecticide	2 e	1 c	1 a	1 a	5 b
3-4 hr Washoff X No Insecticide	11 bc	12 a	6 a	5 a	42 a
3-4 hr Washoff X Insecticide	7 cde	0 c	1 a	3 a	12 b
6-7 hr Washoff X No Insecticide	17 a	8 ab	6 a	5 a	43 a
6-7 hr Washoff X Insecticide	4 de	2 bc	4 a	4 a	17 b
24 hr Washoff X No Insecticide [d]	6 cde	2 bc	5 a	0 a	17 b
24 hr Washoff X Insecticide [d]	5 de	1 c	0 a	0 a	6 b
P value [c]	< 0.0001	0.0162	0.1990	0.4362	0.0010

[a] Chlorantraniliprole (Prevathon) applied at 0.075 kg ai ha^{-1}

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

[c] P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

[d] 2022 did not experience a full 24-hour time interval, it was reduced to 8.5 hr due to a rainfall event.

Table 3.15. Percent of stinkbug damage in cotton bolls for washoff interval and insecticide [a] application at EREC in 2021 and 2022.

Treatment	Year	
	2021 [b]	2022 [b]
No Washoff X No Insecticide	47.5 a	41 a
No Washoff X Insecticide	25.0 abc	19 a
0-30 min Washoff X No Insecticide	35.0 ab	21 a
0-30 min Washoff X Insecticide	22.5 abc	22 a
1-1.5 hr Washoff X No Insecticide	40.0 ab	29 a
1-1.5 hr Washoff X Insecticide	7.5 cd	16 a
3-4 hr Washoff X No Insecticide	42.5 a	16 a
3-4 hr Washoff X Insecticide	12.5 bcd	8 a
6-7 hr Washoff X No Insecticide	40.0 ab	35 a
6-7 hr Washoff X Insecticide	25.0 abc	23 a
24 hr Washoff X No Insecticide	17.5 abc	25 a
24 hr Washoff X Insecticide	2.5 d	10 a
P value [b]	0.0077	0.4459

[a] Bifenthrin (Brigrade 2EC) applied at 0.112 kg ai ha^{-1}

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

[c] P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

Table 3.16. Average cotton lint yield (kg ha^{-1}) affected by stinkbugs for washoff interval and insecticide [a] application at EREC in 2021 and 2022.

Treatment	Year	
	2021 [b]	2022 [b]
No Washoff X No Insecticide	3835.38 a	2634.12 abcd
No Washoff X Insecticide	4071.81 a	2889.65 ab
0-30 min Washoff X No Insecticide	4162.56 a	2772.64 abc
0-30 min Washoff X Insecticide	4174.50 a	2911.15 a
1-1.5 hr Washoff X No Insecticide	4334.51 a	2610.24 abcd
1-1.5 hr Washoff X Insecticide	4059.87 a	2693.82 abcd
3-4 hr Washoff X No Insecticide	3988.22 a	2263.96 de
3-4 hr Washoff X Insecticide	4289.13 a	2576.81 abcd
6-7 hr Washoff X No Insecticide	3498.65 a	2409.64 bcde
6-7 hr Washoff X Insecticide	4188.83 a	2588.75 abcd
24 hr Washoff X No Insecticide	4372.72 a	2034.70 e
24 hr Washoff X Insecticide	4475.41 a	2337.99 cde
P value [c]	0.5214	0.0303

[a] Bifenthrin (Brigrade 2EC) applied at 0.112 kg ai ha^{-1}

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

[c] P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

Table 3.17. Average insect counts for soybean 1 day after application (DAA) for washoff intervals and insecticide[i] application at EREC in 2021.

Treatment	1 DAA					
	KB [a, c]	GH [a, d]	TCAH [a, e]	SB [a, f]	LEP [a, g]	Total [a, h]
1	2.50 bc	0.75 bc	5.50 ab	20.75 b	0.50 a	30.00 bc
2	0 c	0 c	1.50 bc	2.00 d	0.50 a	4.00 d
3	3.75 bc	2.50 a	6.75 a	21.75 ab	5.50 a	40.25 ab
4	0.25 bc	0 c	0.75 bc	3.25 d	0.50 a	4.75 cd
5	3.00 bc	1.25 b	7.00 a	21.25 ab	6.75 a	39.25 ab
6	0.25 bc	0 c	0.25 c	1.00 d	1.00 a	2.50 d
7	4.75 ab	1.00 bc	9.25 a	12.00 c	7.75 a	34.75 b
8	0 c	0 c	0 c	1.00 d	0 a	1.00 d
9	2.75 bc	1.25 b	7.75 a	19.25 bc	17.00 a	48.00 ab
10	0 c	0 c	1.25 bc	2.75 d	0 a	4.00 d
11	8.50 a	0.75 bc	10.00 a	29.00 a	14.50 a	62.75 a
12	0.25 bc	0 c	1.50 bc	0.75 d	0.50 a	3.00 d
P value [b]	0.0127	0.0004	0.0001	<0.0001	0.3375	<0.0001

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

[b] P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

[c] Kudzu bugs

[d] Grasshopper

[e] Three-cornered alfalfa hopper

[f] Stinkbug

[g] Lepidopteran species

[h] Total sum of all insects

[i] Bifenthrin (Brigrade 2EC) applied at 0.112 kg ai ha^{-1}

Table 3.18. Average insect counts for soybean 8 days after application (DAA) for washoff intervals and insecticide [i] application at EREC in 2021.

Treatment	8 DAA					
	KB [a, c]	GH [a, d]	TCAH [a, e]	SB [a, f]	LEP [a, g]	Total [a, h]
1	3.00 a	1.25 a	7.50 a	22.25 bc	0 a	34.00 ab
2	0 a	0 b	0 c	0.50 d	0.50 a	1.00 c
3	3.5 a	0.75 ab	5.75 ab	23.00 bc	2.00 a	35.00 a
4	0.50 a	0.75 ab	1.25 bc	8.50 cd	0.25 a	11.25 bc
5	1.50 a	1.25 a	6.00 ab	23.25 b	4.00 a	36.00 a
6	0.25 a	0.25 b	0.50 c	1.25 d	0.25 a	2.50 c
7	3.00 a	0 b	5.75 ab	23.75 ab	3.50 a	36.00 a
8	0 a	0.25 b	0.25 c	0.50 d	0 a	1.00 c
9	2.25 a	0 b	9.25 a	22.25 bc	1.50 a	35.25 a
10	0 a	0 b	0.25 c	0.50 d	0.25 a	1.00 c
11	2.75 a	0 b	8.5 a	38.25 a	0 a	49.50 a
12	0 a	0 b	1.25 bc	0.25 d	0 a	1.50 c
P value [b]	0.3344	0.0023	0.0008	<0.0001	0.7259	<0.0001

[a] Means within a column followed by the same lowercase letter are not significantly different at α = 0.05.

[b] P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

[c] Kudzu bugs

[d] Grasshopper

[e] Three-cornered alfalfa hopper

[f] Stinkbug

[g] Lepidopteran species

[h] Total sum of all insects

[i] Bifenthrin (Brigrade 2EC) applied at 0.112 kg ai ha^{-1}

Table 3.19. Average insect counts for soybean 12 days after application (DAA) for washoff intervals and insecticide [i] application at EREC in 2021.

Treatment	12 DAA					
	KB [a, c]	GH [a, d]	TCAH [a, e]	SB [a, f]	LEP [a, g]	Total [a, h]
1	2.25 ab	0.50 a	5.75 ab	15.25 bcd	0.25 a	24.00 bc
2	0 c	0.25 a	1.00 cd	1.50 e	1.00 a	3.75 d
3	1.75 abc	0.75 a	7.00 a	19.00 b	0.50 a	29.00 b
4	0.25 bc	0.25 a	0.75 cd	3.50 e	0.50 a	5.25 d
5	0.75 bc	0.75 a	4.50 abcd	12.25 cd	1.50 a	19.75 c
6	0 c	0.25 a	0.75 cd	2.25 e	0.50 a	3.75 d
7	1.75 abc	0.75 a	7.00 a	11.25 d	0.75 a	21.50 bc
8	0.25 bc	0 a	0.50 d	1.50 e	0.25 a	2.50 d
9	1.25 abc	1.00 a	7.25 a	11.25 d	1.25 a	27.25 bc
10	0 c	0.25 a	0.75 cd	1.25 e	0 a	1.25 e
11	3.25 a	0 c	5.25 abc	29.75 a	0.25 a	38.50 a
12	0 c	0 c	1.75 bcd	1.25 e	0 a	3.00 d
P value [b]	0.0468	0.0521	0.0051	<0.0001	0.0821	<0.0001

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

[b] P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

[c] Kudzu bugs

[d] Grasshopper

[e] Three-cornered alfalfa hopper

[f] Stinkbug

[g] Lepidopteran species

[h] Total sum of all insects

[i] Bifenthrin (Brigrade 2EC) applied at 0.112 kg ai ha^{-1}

Table 3.20. Average insect counts for soybean 2 days after application (DAA) for washoff intervals and insecticide [i] application at EREC in 2022.

Treatment	2 DAA					
	KB [a, c]	GH [a, d]	TCAH [a, e]	SB [a, f]	LEP [a, g]	Total [a, h]
1	174.50 abc	2.00 bc	8.25 a	19.75 a	13.25 a	217.75 abc
2	5.25 c	0 c	1.25 c	0.50 b	0.25 a	7.25 c
3	134.25 abc	3.75 ab	9.00 a	16.75 a	1.00 a	164.75 abc
4	4.5 c	0 c	1.25 c	1.00 b	0 a	6.75 c
5	82.25 c	1.75 bc	7.25 ab	11.00 ab	0.50 a	102.75 c
6	2.25 c	0 c	0.50 c	1.25 b	0.50 a	4.50 c
7	98.50 bc	3.25 abc	7.75 a	19.25 a	0.25 a	129.00 bc
8	2.75 c	0.50 bc	2.00 bc	1.75 b	0 a	7.00 c
9	325.75 a	3.75 ab	9.50 a	19.00 a	13.50 a	371.50 a
10	2.50 c	0.25 bc	0.25 c	0.75 b	0 a	3.75 c
11	309.50 ab	6.50 a	9.25 a	19.75 a	3.25 a	348.25 ab
12	2.50 c	0.25 bc	0.75 c	1.00 b	0.25 a	4.75 c
P value [b]	0.0232	0.0096	0.0005	0.0009	0.4385	0.0109

[a] Means within a column followed by the same lowercase letter are not significantly different at α = 0.05.

[b] P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

[c] Kudzu bugs

[d] Grasshopper

[e] Three-cornered alfalfa hopper

[f] Stinkbug

[g] Lepidopteran species

[h] Total sum of all insects

[i] Bifenthrin (Brigrade 2EC) applied at 0.112 kg ai ha^{-1}

Table 3.21. Average insect counts for soybean 14 days after application (DAA) for washoff intervals and insecticide [i] application at EREC in 2022.

Treatment	14 DAA					
	KB [a, c]	GH [a, d]	TCAH [a, e]	SB [a, f]	LEP [a, g]	Total [a, h]
1	70.75 ab	0.50 a	6.75 a	6.75 a	2.75 a	87.50 ab
2	7.00 b	0.50 a	1.75 cde	1.25 bc	0 a	10.50 b
3	105.25 a	0.50 a	4.00 abcd	4.50 abc	0 a	114.25 a
4	2.25 b	0.75 a	1.00 de	1.75 bc	0 a	5.75 b
5	64.75 ab	0.50 a	3.75 abcd	5.25 ab	0.25 a	74.50 ab
6	3.25 b	0.75 a	0.75 de	1.00 c	0.25 a	6.00 b
7	116.25 a	0.75 a	4.50 abc	6.50 a	0 a	128.00 a
8	7.75 b	0.75 a	1.50 cde	1.75 bc	0.25 a	12.00 b
9	137.25 a	1.50 a	5.75 ab	3.75 abc	1.50 a	149.75 a
10	3.00 b	0.75 a	0.25 e	1.25 bc	0 a	5.25 b
11	100.75 a	0.50 a	2.75 bcde	4.00 abc	0.50 a	108.50 a
12	2.75 b	0.50 a	1.75 cde	0.75 c	0 a	5.75 b
P value [b]	0.0032	0.8752	0.0079	0.0343	0.2222	0.0018

[a] Means within a column followed by the same lowercase letter are not significantly different at α = 0.05.

[b] P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

[c] Kudzu bugs

[d] Grasshopper

[e] Three-cornered alfalfa hopper

[f] Stinkbug

[g] Lepidopteran species

[h] Total sum of all insects

[i] Bifenthrin (Brigrade 2EC) applied at 0.112 kg ai ha^{-1}

Table 3.22. Average soybean plant height and mainstem nodes for washoff intervals and insecticide [a] applications at EREC in 2022.

Treatment	Plant Height (cm) [b]	Mainstem Nodes [b]
No Washoff X No Insecticide	74.45 a	16.20 a
No Washoff X Insecticide	73.70 a	16.00 a
0-30 min Washoff X No Insecticide	70.60 a	16.15 a
0-30 min Washoff X Insecticide	73.00 a	16.60 a
1-1.5 hr Washoff X No Insecticide	76.05 a	16.65 a
1-1.5 hr Washoff X Insecticide	74.90 a	16.45 a
3-4 hr Washoff X No Insecticide	74.25 a	16.30 a
3-4 hr Washoff X Insecticide	75.15 a	16.90 a
6-7 hr Washoff X No Insecticide	80.40 a	16.80 a
6-7 hr Washoff X Insecticide	78.15 a	16.90 a
24 hr Washoff X No Insecticide	74.90 a	16.55 a
24 hr Washoff X Insecticide	75.70 a	16.65 a
P value [c]	0.9986	0.9958

[a] Bifenthrin (Brigrade 2EC) applied at 0.112 kg ai ha^{-1}

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

[c] P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

Table 3.23. Average grain yield (g ha^{-1}) for soybean affected by washoff intervals and insecticide [a] applications at EREC in 2021 and 2022.

Treatment	Year	
	2021 [b]	2022 [b]
No Washoff X No Insecticide	3526.05 a	2341.88 a
No Washoff X Insecticide	3704.17 a	2359.77 a
0-30 min Washoff X No Insecticide	3642.26 a	2391.32 a
0-30 min Washoff X Insecticide	3675.77 a	2974.56 a
1-1.5 hr Washoff X No Insecticide	3502.16 a	2753.37 a
1-1.5 hr Washoff X Insecticide	3611.96 a	3032.79 a
3-4 hr Washoff X No Insecticide	3332.62 a	2761.17 a
3-4 hr Washoff X Insecticide	3450.98 a	2642.34 a
6-7 hr Washoff X No Insecticide	3725.60 a	3063.49 a
6-7 hr Washoff X Insecticide	3817.57 a	3109.56 a
24 hr Washoff X No Insecticide	3825.73 a	2674.74 a
24 hr Washoff X Insecticide	3553.39 a	2633.88 a
P value [c]	0.3635	0.8226

[a] Bifenthrin (Brigrade 2EC) applied at 0.112 kg ai ha^{-1}

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

[c] P values were obtained from ANOVA table in the output of SAS using PROC GLIMMIX procedure.

Figure 3.1. Image of thrips feeding damage on 3-4 leaf cotton during the thrips washoff date

Figure 3.2. Image of MudMaster plot sprayer simulating rainfall after the insecticide application in the thrips study

Figure 3.3. Image of stinkbug nymphs in the soybean washoff plots.

Figure 3.4. Image of MudMaster plot sprayer simulating rainfall in the soybean washoff study.

Figure 3.5. Image of dead kudzu bugs and other insects being counted from a soybean washoff plot that did not receive the insecticide application.

CONCLUSION

Data from these trials did not indicate a specific agronomic or economic benefit from variable rate seeding in cotton or an influence on insecticide efficacy from simulated rainfall. In the variable rate seeding trial, our data indicate that variable rate seeding in cotton performs as well as the best uniform seeding rate. These results also indicate that manipulating seeding rate in varying soil textures could affect total plant height and mainstem nodes. From this, variable rate seeding could be beneficial to cotton farmers when dealing with growth management in cotton, thought the response observed in this study were specific to the field and cotton variety selected. 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 may not provide an economic or agronomic benefit.

In the insecticide efficacy trial, results indicate that insecticide efficacy of commonly used products is not affected by simulated rainfall on insect pests evaluated in this trial. Furthermore, simulated rainfall alone without the application of an insecticide did not have an impact on insect pest populations in sampled plots. By knowing that the rainfast interval of these products is relatively quick, the over application of insecticide from a perceived product failure following a rainfall event could be eliminated. Ultimately, the evaluation of these products in this research trial will help aid South Carolina farmers to reduce input costs and increase profitability.

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