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Impact of Pre-bloom Square Loss on Yield and Lint Quality in Louisiana Cotton Cropping Systems

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IMPACT OF PRE-BLOOM SQUARE LOSS ON YIELD AND LINT QUALITY IN LOUISIANA COTTON CROPPING SYSTEMS

A Thesis

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of
Master of Science

in

The School of Plant, Environmental, and Soil Sciences

by
Cory Cole
B.S., Louisiana State University, 2015
December 2017
Acknowledgements

I would like to first express my gratitude to my family and my girlfriend for their support and for the sacrifices they made so that I could further my education in agriculture.

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I appreciate the hard work and dedication of the research associates and student workers in our program that helped me complete my research.

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Abstract

During the 2016 growing season, research was conducted at three locations in the state of Louisiana to evaluate the impact of pre-bloom square loss on cotton lint yield and fiber quality. Two cotton varieties, Phytogen 499 WRF and Phytogen 222 WRF were chosen up which to imitate early season square loss due to tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois) and/or cotton fleahopper, *Pseudatomoscelis seriatus* (Reuter) feeding or unfavorable weather conditions. Thirty plants within each plot were selected and squares were counted. Squares were assigned numbers, and numbers were then randomized using a computerized number generator. To simulate intervals of minimum to maximum fruit loss, just prior to bloom, 0, 20, 40, 60, 80, and 100 percent squares were removed by hand. Throughout the growing season, weekly applications of insecticides were applied to keep plants insect free to avoid unwanted damage. At the end of the season, ten plants, within each plot, were plant mapped and each plot was hand harvested for lint yield and fiber quality analysis. Although there was evidence of potential yield compensation at each location, only the Alexandria and Winnsboro locations demonstrated definitive compensation. The St. Joseph location either did not compensate or had compensation masked by boll rot. The impact of pre-bloom square removal and compensation on fiber quality was minimal across locations. Although pre-bloom square loss had minimal impact on fiber quality, full season varieties appeared to be less affected than short season varieties. Based on this study, our recommendation to the cotton producers of Louisiana is to attempt to retain 80-90 percent of their pre-bloom squares to achieve the greatest possible yield with the least amount of negative impact.
Introduction

Cotton, one of the most important crops around the world, accounts for roughly 33 to 36 percent of the world’s fiber use (Senapati et al., 2014). In addition to lint, cotton is an important source of seed oil and protein meal for consumers and livestock around the globe (Smith and Cothren, 1999). The cotton plant was originally discovered as a perennial vine in certain geographical locations within Africa, Australia, Arabia, and Mesoamerica. The first documented use of cotton fiber was in Mexico approximately 7,000 years ago. Cotton production was also documented in the Indus River Valley in Pakistan dating back as far as 3,000 B.C. During the same period, Egyptians were also using cotton to craft their garments (NCCA, Unknown). Cotton, in its original form, is a tropical perennial plant with an indeterminate fruiting habit. A plant with an indeterminate fruiting habit will maintain production of new leaves even after it has produced seed. There are cotton varieties produced that reflect a more determinate fruiting habit. These determinate varieties produce a large amount of fruit during the early part of the season and then terminal buds become inactive and flower production declines. Determinate cultivars are sometimes categorized as early maturing varieties (Quisenberry and Roark, 1976).

Over time, humans have selected for and used different breeding techniques to create cotton cultivars that produce cotton more efficiently. Two predominant types of cotton are used for production in the United States, American upland (Gossypium hirsutum) and American pima (G. barbadense), or extra-long staple (ELS) cotton. The leading species of cotton planted throughout the United States is G. hirsutum, and comprises approximately 97 percent of cotton produced within the United States (AGMRC, 2012). Furthermore, the
United States is the leading exporter of cotton in the world and the third major producer of cotton for international trade, only behind China and India (NCCA, 2015). Based on statistics released by The United States Department of Agriculture (USDA), growers within the United States planted 8.58 million acres of cotton in 2015 and harvested approximately 8 million acres. Furthermore, cotton growers produced approximately 12.9 million bales (480 lbs/bale) of cotton during the 2015 growing season (Johansson and Harris, 2016). During the 2016 production season, cotton producers planted approximately 10.1 million acres of cotton, a 17 percent increase from the 2015 growing season. Additionally, about 17 million bales of cotton was produced in the United States during the 2016 growing season, which is an increase of roughly 4 million bales from the 2015 growing season (Campiche et al., 2017). Although surveys predict the production of millions of bales of cotton in the United States for the 2017 growing season, the value of cotton is considerably lower than in years past. Recently, cotton prices in the United States and around the world have significantly declined due to shifts in areas of production and to a change in the quantity of cotton imported and exported internationally. Further pressure on cotton has also arisen due to the increase in petrochemicals used for the production of synthetic fibers.

Cotton is not only internationally important, but also nationally important primarily as an export crop. In Louisiana, cotton is an economically important crop, though less so in recent years due to competition from other commodities. In 2014, the state of Louisiana grew approximately 164,132 acres of cotton. During the 2014 growing season, record high lint yields for Louisiana cotton growers were produced: on irrigated cropping systems an average lint yield was 1,322 pounds per acre; and on dryland cropping systems lint yields averaged 1,131 pounds per acre. During the 2014 growing season, Louisiana produced 195.9 million
pounds or 408,048 (480 lbs/bale) bales of cotton. Louisiana’s cotton production, as a whole, in 2014 was valued at approximately $197.9 million (LSU College of Agriculture, 2014). During the 2015 growing season, Louisiana producers planted approximately 115,000 acres and harvested roughly 112,000 of those acres on which 189,000 bales of cotton were produced. The 189,000 bales of cotton produced in Louisiana was valued at approximately $61.5 million (US NASS, 2016). Cotton producers in Louisiana planted roughly 25,000 more acres during the 2016 growing season when compared to the 2015 growing season. Louisiana cotton growers harvested approximately 137,000 acres in 2016, which was valued at nearly $85.5 million (US NASS, 2017). Even though the value of cotton is not at its highest point, Louisiana continues to produce a healthy cotton crop each year in hopes that cotton prices will eventually increase once again. With the possibility of almost $200 million in revenue from Louisiana cotton production, growers and researchers alike must understand the growth habits of the cotton plant in order to produce high yielding cotton crops each growing season.

Although new cotton cultivars are continually developed, cotton still possesses a perennial growth habit just as its ancestors did. Production is unique in that cotton, a perennial plant, is produced as an annual crop. Producing cotton as an annual crop presents unique challenges to cotton producers around the world due to cotton’s continued vegetative growth after flowering, which redirects the plant’s energy away from lint and seed production and into foliar growth (Ritchie et al., 2007). In advantageous conditions, cotton seedlings emerge five to ten days after planting. Once emergence occurs, the plant directs its energy to the growth of the root system so it can gather the necessary nutrients it will need to produce new fruit and foliage (Wakelyn and Chaundry, 2010). As a cotton plant continues to grow, the environmental conditions surrounding it can heavily influence the number of nodes and the
length of internodes that a particular cotton plant will produce. For example, when cotton plants are not able to obtain a sufficient water supply, new node development decreases tremendously. It is from these nodal positions that the formation of branches begins. There are two types of branches that form on a cotton plant, monopodial and sympodial (Wakelyn and Chaundry, 2010). A monopodial branch is a vegetative branch that is similar in structure to the main stem of the plant and grows from a single terminal bud in a vertical position. A sympodial branch is a fruiting branch formed on the main stem, usually beginning at the sixth or seventh main stem node and grows at an acute angle to the main stem. As the sympodial branch grows away from the main stem, fruiting nodes are produced, which possess their own leaf and square (fruited bud) at each node. After a square is produced, the growth of that particular branch is stopped, but a second leaf and square begins to grow from the axil of the first leaf, which continues the growth of the sympodial branch away from the main stem. Consecutive fruiting structures on the same sympodial branch are produced roughly six days apart. This process is repeated on each sympodial branch of a cotton plant.

Approximately three weeks after square formation, squares mature and flowering occurs with the subsequent development of bolls. Bolls reach their full size nearly three weeks after fertilization of the flower occurs; however, they do not mature until approximately four to five weeks after they have reached their full size. Overall, the process of boll maturation takes seven to eight weeks after flower fertilization occurs. The maturation process has a notable influence on the quality of cotton lint. Cotton quality is classified by various features including: maturity, percent gin out, loan value, color grade, trash, leaf grade, uniformity, strength, length, and micronaire of fiber (Cotton Incorporated, 2013). Cotton fibers obtain their maximum length approximately twenty-five days after fertilization, but the greatest fiber
growth rate takes place ten to fifteen days after fertilization (Wakelyn and Chaundry, 2010). Once cotton fibers approach their maximum length, they begin to thicken and continue to thicken until the boll reaches maturity. The extent at which thickening occurs can significantly affect fiber strength and maturity. Climate can also have a substantial effect on the rate of boll maturation and the quality of cotton fiber that is harvested (Wakelyn and Chaundry, 2010). Moreover, research must be conducted in specific geographical areas of the United States to ensure cotton growers have the knowledge base to produce high yielding cotton crops year after year.

In Louisiana, there are many different variables that must be taken into account in order to produce a high yielding, high quality cotton crop including: precipitation patterns, insect pressure, disease pressure, fertility, plant spacing, presence of nematodes, crop management practices, and temperatures. Fruit loss in cotton can occur following abiotic stresses such as lack of sunlight, fertility, temperature, water deficiencies, and biotic stresses such as disease and insect pressure (Jones et al., 1996). Each of these variables can cause injury to cotton plants throughout the growing season. Depending on the growth stage in which injury occurs, the plant may or may not be able to overcome and/or compensate for that injury. Compensation for lost fruit or plant injury can be dependent on many factors such as soil fertilization, age of fruit, cotton cultivars, density of planting, planting date fluctuations, amount of fruiting branches, and severity of injury (Stewart et al., 2001; Bi et al., 1991). Bilbro and Ray (1973) found that if cotton is planted at an ideal time and is given time to mature, a full season cotton cultivar would be a better choice over a short season variety to produce maximum yields. If cotton is planted at a less than ideal time (later planting date), a full season cotton cultivar may lack time to produce optimal yield, whereas an early maturing
cotton cultivar may produce higher yields. They found that delayed planting dates can cause reductions in yields, in percentage lint turn out, fiber length, and micronaire units; however, fiber strength was increased and some traits such as fiber elongation had no substantial changes due to variation in planting dates. Bauer et al. (1998) similarly reported that late planting dates triggered an increase in fiber elongation and fiber strength, but a decrease in micronaire and fiber maturity. Porter et al. (1996) conducted a study in the Coastal Plains region of South Carolina involving six cultivars, varying in maturation rate, which were planted at different dates ranging from early in the growing season to late in the growing season. From this research, they concluded that as planting dates were delayed, strength and elongation of fiber was improved, but fiber micronaire declined. Changes in planting dates had no effect on length of cotton fibers.

Research mimicking the loss of fruiting forms on cotton plants has been conducted in many cotton producing regions. Kerns et al. (2016) conducted a study within the Texas high plains on cotton’s ability to compensate for pre-bloom square loss due to weather, such as hail damage, and square feeding insects, such as the cotton flea-hopper, Pseudatomoscelis seriatus. They concluded that these factors have little or no influence on yield. In Mississippi, (Hamner, 1941) reported that removing squares once a week for six weeks, shortly after they were noticeable, had no significant influence on lint yield of cotton. Eaton (1931) discovered that fruit removal early in the growing season in Arizona caused an increase in yield at the end of the growing season. This research provides evidence that compensation for fruit loss in cotton can lessen the need for insecticide applications to combat fruiting body loss due to insects that feed on cotton early in the production season. In central Queensland, Passlow (1958) determined that research plots that received insecticide applications for square feeding insects, during early square
production, showed no significant differences in yield when compared to plots that were not treated with insecticides. Similarly, Wilson et al. (2003) studied the effect of fruit removal on cotton grown in New South Wales where they concluded that removing all young squares from the first four sympodial branches of a cotton plant did not affect yield, but maturity was delayed by nearly seven days. In North Carolina, Mistic et al. (1968) researched the effects of three different patterns of square removal: constant square removal, increasing square removal, and fluctuating square removal. They found that all patterns of fruit removal initiated an increase in square production, boll weight, and boll set. Although each square removal pattern increased fruit production in general, each type of square removal affected some fruiting aspects less than others. The increasing pattern of square removal influenced square production the least whereas the constant square removal pattern influenced boll weight the least and the fluctuating pattern of square removal had the least influence on boll set. With respect to yield, they determined that seasonal differences had the largest influence on the outcome of the three different patterns of square removal. Yield on plants that received constant square removal were found to be most affected by seasonal differences while yield on plants that received increasing square removal treatments were least affected. Overall, yield was not significantly different among applied treatments.

Dale (1959) discovered that plants that experienced fruit removal up to 23 weeks after planting produced an average of 280 buds per plant, while plants that experienced fruit removal up to 35 weeks after planting produced an average of 764 buds per plant. Cotton plants that did not undergo fruit removal produced considerably fewer buds per plant: twenty-three weeks after planting, untreated plants only produced 112 buds, whereas 35 weeks after planting, control plants produced only 160 buds. Additionally, plants that received fruit removal treatments
developed more vegetative branches with more secondary fruiting sites, which contributed to the increase in bud production. Both fruit removal treatments significantly increased plant size as well. This discovery again provides evidence that cotton plants have the ability to compensate for fruit loss, but a change in plant growth must occur in order to produce additional fruiting sites for compensation. Kennedy et al. (1986) conducted research on the effects of early season square removal on cotton growth habits in Baton Rouge, Louisiana. This research consisted of two different square removal treatments, square removal for 3 weeks at weekly intervals and square removal for 6 weeks at weekly intervals. They reported that, with increasing square removal, plant height, number of branches, and leaf area index all increased. They also found that plants that received square removal treatments had a significant increase in flowering when compared to plants that were untouched. This research helps us understand how a cotton plant compensates for fruit loss throughout the growing season. Likewise, a study was conducted in St. Joseph and Winnsboro, Louisiana where squares were removed during the first four weeks of flowering. It was found that cotton compensated for extensive square loss, during each week of flowering, but that the result was not consistent between locations (Fife, 2000). In Winnsboro, Louisiana significant reductions in yield were found where squares were removed during weeks 1, 2, and 4. In St. Joseph, Louisiana significant reductions in yield were found only when squares were removed during weeks 1 and 2. Because of the lack of continuity in results of the impact of square loss on cotton yield and lint fiber quality, additional research is warranted.
Materials and Methods

During the 2016 growing season, an experiment was conducted at three different research stations within Louisiana: Macon Ridge Research Station and Extension Center in Winnsboro, Louisiana; Northeast Research Station and Extension Center in St. Joseph, Louisiana; and Dean Lee Research Station and Extension Center in Alexandria, Louisiana. The soil type at each experiment station is as follows: Coushatta silt loam (Dean Lee Research Station), Gigger silt loam (Macon Ridge Research Station), and Commerce silt loam (Northeast Research Station). The Coushatta series (fine-silty, mixed, superactive, thermic Fluventic Eutrudepts) has a pH range of 5.6-8.4 (USDA, 2017), while the Gigger series (fine-silty, mixed, active, thermic Typic Fragiudalfs) has a strongly acid pH (USDA, 2003) and the Commerce series (Fine-silty, mixed, superactive, nonacid, thermic Fluvaquentic Endoaquepts) possesses a moderate to slightly alkaline pH (USDA, 2013). Experiments were planted May 6, 2016 at Dean Lee Research Station, April 25, 2016 at Macon Ridge Research Station, and May 12, 2016 at Northeast Research Station. The experimental design for this experiment consisted of a 2 x 6 factorial with four replications. The two factor treatments consisted of: 1) 0, 20, 40, 60, 80, and 100 percent manual square removal and 2) variety maturity: an early maturing cultivar (PHY 222 WRF) and a late season cotton cultivar (PHY 499 WRF). Initial whole plots at the Dean Lee Research Station were 2 rows wide by 38 feet long on 38 inch row spacing, while whole plots at the Northeast Research Station and Macon Ridge Research Station were 4 rows wide by 40 feet long on 40 inch row spacing. Within the initial whole plots, sub-plots were established by choosing a uniform section of row and measuring approximately 13.1 feet (1/1000th of an acre). Experiments at Macon Ridge and Northeast Research Stations were irrigated using furrow irrigation when needed to ensure plants remained healthy and free of drought stress, while cotton
at the Dean Lee Research Station was grown dryland. Insects were managed with insecticides as needed to prevent fruit damage or loss. Insecticides used were based on the recommendations of the LSU AgCenter. Weather data was obtained through weather stations located on each research station (Table 1).

Table 1. Monthly weather summary for Alexandria, St. Joseph, and Winnsboro, Louisiana.

<table>
<thead>
<tr>
<th>Month</th>
<th>Precipitation (inches)</th>
<th>Thermal Units (DD60)$^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Alexandria</td>
<td>St. Joseph</td>
</tr>
<tr>
<td>April</td>
<td>3.31</td>
<td>4.05</td>
</tr>
<tr>
<td>May</td>
<td>2.65</td>
<td>2.30</td>
</tr>
<tr>
<td>June</td>
<td>5.81</td>
<td>7.20</td>
</tr>
<tr>
<td>July</td>
<td>4.46</td>
<td>2.27</td>
</tr>
<tr>
<td>August</td>
<td>13.73</td>
<td>6.28</td>
</tr>
<tr>
<td>September</td>
<td>4.18</td>
<td>1.67</td>
</tr>
<tr>
<td>TOTAL</td>
<td>34.14</td>
<td>23.77</td>
</tr>
</tbody>
</table>

$^1$DD60 = (Max temp. + Min. temp.)/2 - 60.

Approximately 30 days after planting, each sub-plot at each location was thinned to 30 healthy and intact plants to ensure uniformity among plots. Thirty plants per sub-plot provided 30,000 plants per acre. For each test, square removal took place using a lottery system. Every square on every plant in each sub-plot was counted and assigned a number. The number of squares that were counted in a particular sub-plot was then entered into a random number generator (RANDOM.org) to randomly distribute the list of squares. Then for each percentage square removal treatment (0, 20, 40, 60, 80, or 100) assigned for a particular sub-plot, that percentage of the total squares beginning with the first square listed was used to determine which squares would be removed. The squares targeted for removal were then sorted in order, lowest to highest, and these squares were removed in order beginning at the front of each sub-plot. Squares were removed using fine-nosed forceps without inflicting damage on the plant. Square removal treatments were applied when cotton plants reached approximately 12 to 14
nodes, or just prior to first bloom. Squares removal took place on 21, 28, and 30 June at Macon Ridge, Northeast, and Dean Lee research stations, respectively.

At harvest, within each sub-plot at each location, 10 consecutive plants from each plot were plant mapped and the entire plot was hand harvested. Plant mapping was conducted according to Bourland and Watson (1990) where open bolls were noted as present or absent for each node and fruiting position on individual plants. All plants within each sub-plot were hand harvested for subsequent yield and fiber quality analysis. Plant mapping and harvest took place on September 10, 22, and 27, 2016 at the Macon Ridge Research Station, Northeast Research Station, and Dean Lee Research Station, respectively. Lint samples were machine ginned using a table top gin at the Dean Lee Research Station and sent to the LSU AgCenter Cotton Fiber Laboratory in Baton Rouge, Louisiana for HVI fiber analysis to obtain the following data: percent gin out, length, strength, percent uniformity, micronaire, and from this we calculated the loan value. Since lint samples were ginned on a table top gin, a 41-4 leaf and color grade was assigned to all fiber samples.

Yield, lint quality, and boll distribution data were analyzed using ANOVA and means were separated using an F-protected Tukey’s HSD (p ≤ 0.05) (SAS Enterprise Guide, 2010). Regression analyses were conducted using SigmaPlot (SigmaPlot 13: User’s Guide, 2014). Regression analyses were tested for assumptions of linearity using the Spearman rank correlation between the absolute values of the residuals and the observed value of the dependent variable, normality was tested using Shapiro-Wilk’s test (p < 0.05), and outliers were determined by plotting residual and predicted values. Based on a normal distribution, any data points with residual values more than three standard deviations from the predicted value were removed from analysis (GraphPad Prism version 7.00, 2016).
Results and Discussion

Dean Lee Research Station (Alexandria, Louisiana)

There was no variety × square removal interaction detected for yield so variety values were pooled. Yields were variable across square removal treatments but 0, 20, and 40 percent square removal treatments yielded significantly more lint than the 100 percent square removal treatment (Table 2).

Table 2. Mean ± SEM of yield across varieties subjected to various degrees of pre-bloom square removal for two cotton varieties at Alexandria, LA.

<table>
<thead>
<tr>
<th>Percentage of squares removed</th>
<th>Yield (lint lbs./acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1105.11 ± 77.03ab</td>
</tr>
<tr>
<td>20</td>
<td>1164.53 ± 77.04a</td>
</tr>
<tr>
<td>40</td>
<td>1156.95 ± 51.43ab</td>
</tr>
<tr>
<td>60</td>
<td>1070.97 ± 55.18abc</td>
</tr>
<tr>
<td>80</td>
<td>899.62 ± 29.44bc</td>
</tr>
<tr>
<td>100</td>
<td>818.91 ± 47.01c</td>
</tr>
</tbody>
</table>

Variety × square removal interaction  $p = 0.4515$

Means in a column within variety or percentage of squares removed followed by the same letter are not significantly different based on an F-protected Tukey’s HSD Test ($p ≥ .05$).

It was evident that when 100 percent of squares were removed just prior to bloom, plants were not able to fully compensate for that subsequent loss in yield.

Though the variety × square removal interaction was not significant for yield, each variety displayed some notable characteristics. Based on regression analyses, PHY 499 WRF demonstrated the ability to compensate or even overcompensate for yield after pre-bloom square removal occurred (Image 1). Based on a curvilinear regression model, yield tended to increase
from 0 to 20 percent pre-bloom square removal before declining. After 40 percent square removal, yield began to deteriorate, which suggests that plants were not able to fully compensate for more than 40 percent pre-bloom square loss. Phytogen 222 WRF demonstrated the ability to compensate for minor square loss as well (Image 2). Yields remained relatively flat until 60

**Image 1:** PHY 499 WRF yield as influenced by pre-bloom square removal. F (3, 20) = 4.36.

**Image 2:** PHY 222 WRF yield as influenced by pre-bloom square removal. F (2, 21) = 18.36.
percent pre-bloom square loss, when yields began to decrease dramatically. Thus it appears that at this locations, Phytogen 222 WRF was not able to compensate for more than 60 percent pre-bloom square loss. Both varieties at the Dean Lee Research Station did display the ability to compensate for some square loss.

Due to the lack of significant differences between varieties (p > 0.05), for the remainder of the discussion, varieties were pooled unless otherwise specified. At the 1<sup>st</sup> position, the percent open bolls for the 0 percent square removal treatment was significantly higher than the 40, 60, 80, and 100 percent treatments, but the 40, 60, 80, and 100 percent square removal treatments were statistically similar in reference to percentage of open bolls (Table 3).

Table 3. Mean ± SEM percentages of open bolls per plot by lateral branch positions across varieties subjected to various degrees of pre-bloom square removal for two cotton varieties at Alexandria, LA.

<table>
<thead>
<tr>
<th>Percentage of squares removed</th>
<th>1&lt;sup&gt;st&lt;/sup&gt; position</th>
<th>2&lt;sup&gt;nd&lt;/sup&gt; position</th>
<th>3&lt;sup&gt;rd&lt;/sup&gt;+ position</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>55.58 ± 1.61a</td>
<td>31.65 ± 1.37a</td>
<td>12.77 ± 1.73b</td>
</tr>
<tr>
<td>20</td>
<td>47.91 ± 1.31ab</td>
<td>31.45 ± 1.86a</td>
<td>20.64 ± 1.95ab</td>
</tr>
<tr>
<td>40</td>
<td>45.53 ± 2.21b</td>
<td>32.79 ± 1.26a</td>
<td>21.68 ± 1.91ab</td>
</tr>
<tr>
<td>60</td>
<td>39.80 ± 3.53b</td>
<td>35.17 ± 2.67a</td>
<td>25.03 ± 2.14a</td>
</tr>
<tr>
<td>80</td>
<td>39.65 ± 2.46b</td>
<td>30.08 ± 1.99a</td>
<td>30.27 ± 3.43a</td>
</tr>
<tr>
<td>100</td>
<td>40.46 ± 3.47b</td>
<td>30.05 ± 2.18a</td>
<td>29.49 ± 2.60a</td>
</tr>
</tbody>
</table>

Means in a column within variety or percentage of squares removed followed by the same letter are not significantly different based on an F-protected Tukey’s HSD Test (p ≥ 0.05).

As expected this provides evidence that a significant amount of square removal took place at the 1<sup>st</sup> position because square removal occurred at 12-14 nodes when 1<sup>st</sup> position fruit is more prevalent than 2<sup>nd</sup> and 3<sup>rd</sup>+ position fruit. The 2<sup>nd</sup> position showed no statistical differences among all square removal treatments. At the 3<sup>rd</sup>+ position, there was a significantly lower
percentage of open bolls in the 0 percent square removal treatment than the 60, 80, and 100 percent square removal treatments. Additionally, there was a significant increase in open bolls on the 3rd+ position beginning at the 60 percent square removal treatment when compared to the 0 percent square removal treatment. This suggests that plants compensated for square removal by retaining more bolls at the 3rd position.

Differences were also detected when comparing the distribution of bolls among the square removal treatments within the top 9+ and bottom 1-8 nodes of the plants across cotton cultivars (Table 4). The division between nodes 1-8 and 9+ was done to ensure all vegetative branches were included in the analysis for the bottom portion of the plant.

Table 4. Mean ± SEM percentages of open bolls per plot by vertical node position across varieties subjected to various degrees of pre-bloom square removal for two cotton varieties at Alexandria, LA.

<table>
<thead>
<tr>
<th>Percentage of squares removed</th>
<th>Top 9+</th>
<th>Bottom 1-8</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>72.55 ± 3.47c</td>
<td>27.45 ± 3.47a</td>
</tr>
<tr>
<td>20</td>
<td>75.22 ± 2.22c</td>
<td>24.78 ± 2.22a</td>
</tr>
<tr>
<td>40</td>
<td>82.02 ± 2.35bc</td>
<td>17.98 ± 2.35ab</td>
</tr>
<tr>
<td>60</td>
<td>78.28 ± 2.94bc</td>
<td>21.72 ± 2.94ab</td>
</tr>
<tr>
<td>80</td>
<td>87.56 ± 1.61ab</td>
<td>12.44 ± 1.61bc</td>
</tr>
<tr>
<td>100</td>
<td>92.47 ± 1.29a</td>
<td>7.53 ± 1.29c</td>
</tr>
</tbody>
</table>

Variety × square removal interaction $p = 0.7261$

Means in a column within variety or percentage of squares removed followed by the same letter are not significantly different based on an F-protected Tukey’s HSD Test ($p \geq 0.05$).

Where 100 percent of the squares were removed, plants typically had a higher percentage of open bolls in the top portion of the plant relative to where fewer squares were removed, but was not significantly different from the 80 percent square removal treatment. The 80 percent square
removal treatment did not differ from the 40 and 60 percent removal treatments, and only the 80 and 100 percent removal treatments differed from the 0 percent square removal treatment. This does not imply that plants compensated by producing more fruit higher on the plant, but rather reflects the physical removal of more squares just prior to bloom when the plants approximated 14 nodes.

A significant variety × square removal interaction ($p = 0.017$) was detected for the proportion of open bolls between vegetative and reproductive branches (Table 5). Phytogen 499 WRF had a significantly higher percentage of vegetative branch bolls when 80 and 100 percent of squares were removed (Image 3) and a lower percentage of reproductive branch bolls (Image 4). This suggests that full season varieties such as PHY 499 WRF may compensate for high square loss (80-100 percent) by producing a higher percentage of fruit on vegetative branches, while short season varieties may lack this capability.

<table>
<thead>
<tr>
<th>Percentage of squares removed</th>
<th>Vegetative%</th>
<th>Reproductive%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4.88 ± 1.58</td>
<td>95.12 ± 1.58</td>
</tr>
<tr>
<td>20</td>
<td>6.60 ± 2.27</td>
<td>93.40 ± 2.27</td>
</tr>
<tr>
<td>40</td>
<td>6.40 ± 1.31</td>
<td>93.60 ± 1.31</td>
</tr>
<tr>
<td>60</td>
<td>7.50 ± 1.52</td>
<td>92.50 ± 1.52</td>
</tr>
<tr>
<td>80</td>
<td>9.79 ± 2.12</td>
<td>90.21 ± 2.12</td>
</tr>
<tr>
<td>100</td>
<td>9.39 ± 2.83</td>
<td>90.61 ± 2.83</td>
</tr>
</tbody>
</table>

Variety × square removal interaction $p = 0.017$

1See images 3 and 4 for the significant variety × square removal interaction for percentage open bolls on vegetative and reproductive branches.
No statistical differences in fiber quality characteristics were detected, however a significant variety × square removal interaction was detected for micronaire and percent uniformity (Table 6). Phytogen 499 WRF tended to have higher micronaire values as square removal increased, while the micronaire for PHY 222 WRF tended to decrease with increasing square removal (Image 5). Higher micronaire is indicative of more mature lint fiber (NCCA,
Because PHY 499 WRF is a full season variety, it conceivably should have more time to mature its bolls relative to a short season variety such as PHY 222 WRF. The higher micronaire value for PHY 499 WRF with increased square removal along with lower yields at 80 and 100 percent square removal (Image 1) suggests that the remaining fruit were able to fully mature, whereas PHY 222 WRF lacked this ability.

Table 6. Mean ± SEM of fiber quality characteristics across varieties subjected to various degrees of pre-bloom square removal for two cotton varieties at Alexandria, LA.

<table>
<thead>
<tr>
<th>Percentage of squares removed</th>
<th>Gin out (percent)</th>
<th>Length (inches)</th>
<th>Uniformity(^1) (percent)</th>
<th>Strength (grams/tex)</th>
<th>MIC(^2)</th>
<th>Loan Value (cents/lb.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>40.79 ±0.62a</td>
<td>1.19 ± 0.01a</td>
<td>86.2 ± 0.22</td>
<td>31.4 ± 0.61a</td>
<td>4.1 ± 0.07</td>
<td>53.54 ± 0.01a</td>
</tr>
<tr>
<td>20</td>
<td>40.47 ± 0.80a</td>
<td>1.19 ± 0.01a</td>
<td>86.4 ± 0.21</td>
<td>32.3 ± 0.74a</td>
<td>4.1 ± 0.12</td>
<td>53.56 ± 0.01a</td>
</tr>
<tr>
<td>40</td>
<td>41.60 ± 0.94a</td>
<td>1.19 ± 0.01a</td>
<td>85.9 ± 0.32</td>
<td>32.0 ± 0.57a</td>
<td>4.1 ± 0.08</td>
<td>53.55 ± 0.01a</td>
</tr>
<tr>
<td>60</td>
<td>40.61 ± 0.53a</td>
<td>1.20 ± 0.01a</td>
<td>86.2 ± 0.15</td>
<td>32.1 ± 0.47a</td>
<td>4.1 ± 0.09</td>
<td>53.56 ± 0.01a</td>
</tr>
<tr>
<td>80</td>
<td>39.92 ± 0.51a</td>
<td>1.19 ± 0.01a</td>
<td>85.9 ± 0.46</td>
<td>32.4 ± 0.69a</td>
<td>4.1 ± 0.16</td>
<td>53.56 ± 0.02a</td>
</tr>
<tr>
<td>100</td>
<td>40.23 ± 0.79a</td>
<td>1.18 ± 0.01a</td>
<td>85.6 ± 0.26</td>
<td>32.0 ± 0.43a</td>
<td>4.0 ± 0.16</td>
<td>53.55 ± 0.01a</td>
</tr>
</tbody>
</table>

Variety × square removal interaction \( p = 0.26 \)  \( p = 0.68 \)  \( p = 0.0312 \)  \( p = 0.65 \)  \( p = 0.0002 \)  \( p = 0.39 \)

Means in a column within variety or percentage of squares removed followed by the same letter are not significantly different based on an F-protected Tukey’s HSD Test (\( p \geq 0.05 \)).

\(^1\)See image 6 for the significant the variety × square removal interaction for percent uniformity.

\(^2\)See image 5 for significant the variety × square removal interaction for MIC.

The reason for the variety × square removal interaction for percent uniformity was less clear due to the lack of a uniform trend (Image 6). Phytogen 222 WRF had a higher percent uniformity value when 40 percent of the squares were removed, but a lower value when 80 percent of squares were removed. The mean percent uniformity index for both varieties ranged from approximately 85 to 86.5 percent, this suggests that uniformity was very high regardless of the square removal treatment (Cotton Incorporated, 2013).
Thus the slight variation in the percent uniformity index observed between PHY 499 WRF and PHY 222 WRF was economically insignificant, and may represent artifacts in sample handling or may be attributed to differences in varietal maturities and their distribution of fiber qualities (Bauer et al., 2009).

**Image 5:** PHY 499 WRF and PHY 222 WRF micronaire.

**Image 6:** PHY 499 WRF and PHY 222 WRF uniformity.
Northeast Research Station (St. Joseph, Louisiana)

There was no detectable variety × square removal interaction for yield at the St. Joseph test location (Table 7). When pooled, yields tended to decrease with increasing square removal, but there was no significant difference between the 0 and 20 percent square removal treatments, which suggests some compensation.

Table 7. Mean ± SEM of yield across varieties subjected to various degrees of pre-bloom square removal for two cotton varieties at St. Joseph, LA.

<table>
<thead>
<tr>
<th>Percentage of squares removed</th>
<th>Yield (lint lbs./acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1099.59 ± 98.87a</td>
</tr>
<tr>
<td>20</td>
<td>901.26 ± 62.92ab</td>
</tr>
<tr>
<td>40</td>
<td>819.18 ± 74.28bc</td>
</tr>
<tr>
<td>60</td>
<td>803.79 ± 58.22bc</td>
</tr>
<tr>
<td>80</td>
<td>797.40 ± 80.68bc</td>
</tr>
<tr>
<td>100</td>
<td>603.89 ± 47.77c</td>
</tr>
</tbody>
</table>

Variety × square removal interaction $p = 0.6998$

Means in a column within variety or percentage of squares removed followed by the same letter are not significantly different based on an F-protected Tukey’s HSD Test ($p \geq 0.05$).

When compared to the 100 percent square removal treatment, the 0 and 20 percent square removal treatments yielded significantly higher (Table 7). It is evident that when 100 percent of squares were removed just prior to bloom, plants were not able to fully compensate for that subsequent loss in yield.

Though the variety × square removal interaction was not significant for yield, each variety displayed some important features. Based on the regression model, PHY 499 WRF may have partially compensated for pre-bloom square loss (Image 7). Approximately 300 lbs of yield was lost when 20-80 percent of pre-bloom squares were removed, while roughly 400 pounds of
yield was lost when 100 percent of pre-bloom squares were removed (Image 7). Yields appeared flat between 20 percent square removal and 80 percent square removal, which suggests that plants at the 40, 60, and 80 percent treatments may have been able to compensate for pre-bloom square loss equal to 20 percent square removal. However, compensation in this case is not certain; environmental factors may have prevented the 20 and 40 percent square removal treatments from additional compensation beyond the 60 and 80 percent square removal treatments. The yield response of Phytogen 222 WRF to square removal was linear, which suggests a consistent reduction in yield as a result of increasing square removal (Image 8). The apparent ability of PHY 499 WRF to maintain a consistent yield from 20 to 80 percent square removal relative to PHY 222 WRF, suggests that longer season varieties may physiologically have more time to compensate early season square loss than short season varieties, or that the shorter season variety was more severely impacted by adverse environmental conditions.

**Image 7:** PHY 499 WRF yield as influenced by pre-bloom square removal. $F (3, 20) = 6.076$. 

$Y = 1267.30 - 27.29x + 0.56x^2 - 0.0034x^3$ 

$R^2 = 0.48, P = 0.0041$
Louisiana received extremely high precipitation in 2016, especially during the month of August (Table 1).

The St. Joseph location exhibited a large amount of boll rot and hard lock symptomology. Although uncertain, it is conceivable that differential boll rot among square removal treatments may have contributed to the flat yield response from 20 to 80 percent square removal (Image 7). Wang and Pinckard (1973) reported that boll cuticle thickness, and the quantity of waxes and cutin acids, influence boll susceptibility to boll rotting pathogens. They also reported that these factors vary by variety and that waxes and cutin were rapidly deposited in young bolls until they reached approximately 17 days old, after which the bolls became resistant. Thus if square removal influenced the boll age structure, it could very well shift compensated or non-compensated boll cohorts towards greater or lesser susceptibility to boll rotting pathogens.

At the St. Joseph test location there was no detectable variety × square removal interactions with regard to the percentage of open bolls among 1st, 2nd, and 3rd+ position bolls (Table 8). Thus varieties were pooled for analysis. Although there were no significant
differences among square removal treatments at the 2nd position, differences were detected at the 1st and 3rd+ positions. At the 1st position, the 0 percent square removal treatment had a significantly higher percentage of open bolls when compared to the 100 percent square removal treatment, but did not differ from the 20, 40, 60, and 80 percent square removal treatments.

Table 8. Mean ± SEM percentages of open bolls per plot by lateral branch position across varieties subjected to various degrees of pre-bloom square removal for two cotton varieties at St. Joseph, LA.

<table>
<thead>
<tr>
<th>Percentage of squares removed</th>
<th>1st position</th>
<th>2nd position</th>
<th>3rd+ position</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>50.54 ± 2.48a</td>
<td>30.08 ± 2.05a</td>
<td>19.39 ± 2.13b</td>
</tr>
<tr>
<td>20</td>
<td>47.02 ± 2.93ab</td>
<td>31.52 ± 2.19a</td>
<td>21.45 ± 2.70ab</td>
</tr>
<tr>
<td>40</td>
<td>43.55 ± 3.08ab</td>
<td>28.41 ± 2.01a</td>
<td>28.05 ± 2.68ab</td>
</tr>
<tr>
<td>60</td>
<td>37.35 ± 4.03ab</td>
<td>31.63 ± 2.48a</td>
<td>31.02 ± 4.64a</td>
</tr>
<tr>
<td>80</td>
<td>41.05 ± 3.42ab</td>
<td>32.84 ± 1.57a</td>
<td>26.11 ± 2.36ab</td>
</tr>
<tr>
<td>100</td>
<td>36.63 ± 3.20b</td>
<td>32.79 ± 3.24a</td>
<td>30.58 ± 5.42ab</td>
</tr>
</tbody>
</table>

Variety × square removal interaction

\[ p = 0.1491 \quad p = 0.7382 \quad p = 0.1564 \]

Means in a column within variety or percentage of squares removed followed by the same letter are not significantly different based on an F-protected Tukey’s HSD Test \((p \geq 0.05)\).

Additionally, the 100 percent square removal treatment did not differ from the 20, 40, 60, or 80 percent square removal treatments. These findings were similar to the Alexandria location (Table 3) most likely because when square removal took place, there was more 1st position fruit than 2nd and 3rd+ position fruit due to the age of cotton plants during square removal. At the 3rd+ position, the 0 percent square removal treatment had a significantly lower percentage of open bolls when compared to the 60 percent square removal treatment. All other treatments were statistically similar (Table 8). This suggests that plants that received 60 percent pre-bloom square removal tried to compensate for that removal by retaining more 3rd+ position squares when compared to plants that received no square removal; however, this is not certain since none of the other square removal treatments differed from the 0 percent square removal treatment. These data suggest that
cotton at the St. Joseph location was actually unable to effectively compensate for pre-bloom square loss and that the flat portion of the yield × percentage square removal curve for PHY 499 WRF (Image 7) was most likely due to environmental factors.

At the St. Joseph test location varieties were pooled for analysis because there was no detectable variety × square removal interaction with regard to the percentage of open bolls among the top 9+ and bottom 1-8 node bolls (Table 9). On the top 9+ nodes, there tended to be more open bolls as square removal increased and conversely among the bottom 1-8 nodes.

<table>
<thead>
<tr>
<th>Percentage of squares removed</th>
<th>Top 9+</th>
<th>Bottom 1-8</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>58.84 ± 5.87b</td>
<td>41.16 ± 5.87a</td>
</tr>
<tr>
<td>20</td>
<td>60.93 ± 3.92b</td>
<td>39.07 ± 3.92a</td>
</tr>
<tr>
<td>40</td>
<td>69.03 ± 4.24b</td>
<td>30.97 ± 4.24a</td>
</tr>
<tr>
<td>60</td>
<td>70.46 ± 4.93ab</td>
<td>29.54 ± 4.93ab</td>
</tr>
<tr>
<td>80</td>
<td>73.71 ± 3.94ab</td>
<td>26.29 ± 3.94ab</td>
</tr>
<tr>
<td>100</td>
<td>86.61 ±3.76a</td>
<td>13.40 ± 3.76b</td>
</tr>
</tbody>
</table>

Means in a column within variety or percentage of squares removed followed by the same letter are not significantly different based on an F-protected Tukey’s HSD Test (p ≥ 0.05).

Table 9. Mean ± SEM percentages of open bolls per plot by vertical node positions across varieties subjected to various degrees of pre-bloom square removal for two cotton varieties at St. Joseph, LA.

Within the top 9+ nodes the 0, 20, and 40 percent square removal treatments had significantly less open bolls when compared to the 100 percent square removal treatment. On the bottom 1-8 nodes, the 0, 20, and 40 percent square removal treatments had significantly more open bolls when compared to the 100 percent square removal treatment, which is similar to the Alexandria location (Table 4). This simply reflects that more squares were removed from the lower portion of plants with increasing square removal, and that vertical compensation was not evident (Table 9).
Statistical differences were not apparent in percentage of open bolls on vegetative and reproductive branches (Table 10), which demonstrates that, across square removal treatments, cotton plants did not significantly compensate on vegetative or reproductive portions of the plant.

Table 10. Mean ± SEM percentages of open bolls per plot by vegetative and reproductive branches across varieties subjected to various degrees of pre-bloom square removal for two cotton varieties at St. Joseph, LA.

<table>
<thead>
<tr>
<th>Percentage of squares removed</th>
<th>Vegetative%</th>
<th>Reproductive%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>18.65 ± 2.13a</td>
<td>81.35 ± 2.13a</td>
</tr>
<tr>
<td>20</td>
<td>22.99 ± 2.68a</td>
<td>77.01 ± 2.68a</td>
</tr>
<tr>
<td>40</td>
<td>19.37 ± 2.63a</td>
<td>80.63 ± 2.63a</td>
</tr>
<tr>
<td>60</td>
<td>16.09 ± 2.71a</td>
<td>83.91 ± 2.71a</td>
</tr>
<tr>
<td>80</td>
<td>23.90 ± 1.78a</td>
<td>76.10 ± 1.78a</td>
</tr>
<tr>
<td>100</td>
<td>24.10 ± 3.25a</td>
<td>75.90 ± 3.25a</td>
</tr>
</tbody>
</table>

Variety × square removal interaction $p = 0.4734$

Means in a column within variety or percentage of squares removed followed by the same letter are not significantly different based on an F-protected Tukey’s HSD Test ($p ≥ 0.05$).

These data, among lateral and vertical boll distribution, and on vegetative or reproductive branches, further support the supposition that cotton at the St. Joseph location was unable to effectively compensate pre-bloom square removal, and that the flat portion of the yield × percentage squares removed regression (Image 7) probably does not truly reflect compensation.

Statistical differences were not apparent for any of the HVI fiber quality characteristics at the St. Joseph location (Table 11). Where boll compensation does occur, compensated fruit are often less mature (Kerns et al, 2016). The lack of differences in fiber quality at the St. Joseph location provides further evidence that compensation did not occur. Additionally, yield pooled across varieties (variety × square removal ($p = 0.70$)), across square removal treatments tended to decrease with increasing percentages of square removal (Table 7). The 100 percent square
removal treatment exhibited the lowest yield and was significantly lower than the 0 and 20 percent treatments. The 20 percent square removal treatment was the only treatment that did not differ from the 0 percent treatment. These data provide additional evidence that fruit compensation did not occur at the St. Joseph location.

Table 11. Mean ± SEM of fiber quality characteristics across varieties subjected to various degrees of pre-bloom square removal for two cotton varieties at St. Joseph, LA.

<table>
<thead>
<tr>
<th>Percentage of squares removed</th>
<th>Gin out (percent)</th>
<th>Length (inches)</th>
<th>Uniformity (percent)</th>
<th>Strength (grams/tex)</th>
<th>MIC</th>
<th>Loan Value (Cents/lb.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>39.39 ± 0.57a</td>
<td>1.21 ± 0.01a</td>
<td>86.6 ± 0.26a</td>
<td>32.4 ± 0.56a</td>
<td>4.4 ± 0.09a</td>
<td>56.55 ± 0.04a</td>
</tr>
<tr>
<td>20</td>
<td>38.79 ± 0.56a</td>
<td>1.21 ± 0.01a</td>
<td>86.2 ± 0.27a</td>
<td>32.0 ± 0.27a</td>
<td>4.4 ± 0.04a</td>
<td>56.55 ± 0.05a</td>
</tr>
<tr>
<td>40</td>
<td>39.05 ± 0.66a</td>
<td>1.21 ± 0.01a</td>
<td>86.3 ± 0.13a</td>
<td>32.9 ± 0.55a</td>
<td>4.4 ± 0.06a</td>
<td>56.56 ± 0.05a</td>
</tr>
<tr>
<td>60</td>
<td>38.72 ± 0.63a</td>
<td>1.21 ± 0.00a</td>
<td>85.9 ± 0.36a</td>
<td>31.6 ± 0.63a</td>
<td>4.4 ± 0.07a</td>
<td>56.54 ± 0.05a</td>
</tr>
<tr>
<td>80</td>
<td>38.45 ± 0.71a</td>
<td>1.19 ± 0.01a</td>
<td>86.4 ± 0.46a</td>
<td>32.7 ± 0.57a</td>
<td>4.3 ± 0.07a</td>
<td>56.55 ± 0.05a</td>
</tr>
<tr>
<td>100</td>
<td>38.29 ± 0.71a</td>
<td>1.21 ± 0.01a</td>
<td>86.8 ± 0.36a</td>
<td>32.7 ± 0.62a</td>
<td>4.3 ± 0.08a</td>
<td>56.55 ± 0.04a</td>
</tr>
</tbody>
</table>

Variety × square removal interaction

| p = 0.42 | p = 0.78 | p = 0.82 | p = 0.41 | p = 0.17 | p = 0.95 |

Means in a column within variety or percentage of squares removed followed by the same letter are not significantly different based on an F-protected Tukey’s HSD Test (p ≥ 0.05).
Macon Ridge Research Station (Winnsboro, Louisiana).

At the Winnsboro location, a significant variety × percentage square removal interaction was detected for yield (Table 12). Yields for PHY 499 WRF exhibited a curvilinear response, where yield remained primarily flat from the 0 to the 40 percent square removal treatments and then declined (Image 9).

Table 12. Mean ± SEM of yield across varieties subjected to various degrees of pre-bloom square removal for two cotton varieties at Winnsboro, LA

<table>
<thead>
<tr>
<th>Percentage of squares removed</th>
<th>Yield (lint lbs./acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>876.72 ± 123.45</td>
</tr>
<tr>
<td>20</td>
<td>843.70 ± 83.25</td>
</tr>
<tr>
<td>40</td>
<td>934.81 ± 103.84</td>
</tr>
<tr>
<td>60</td>
<td>964.78 ± 64.78</td>
</tr>
<tr>
<td>80</td>
<td>916.48 ± 54.95</td>
</tr>
<tr>
<td>100</td>
<td>880.93 ± 66.93</td>
</tr>
</tbody>
</table>

Variety × square removal interaction $p = 0.0162$

The fact that the curve remains primarily flat through 60 percent square removal does suggest that there may have been yield compensation for pre-bloom square loss. Phytogen 222 WRF responded differently, exhibiting increasing yield with increasing square removal (Image 10). It is conceivable that variability in boll age and susceptibility may have been a key factor in the increasing yields with increasing square removal for PHY 222 WRF. Boll age and susceptibility to environmentally induced loss may have been shifted more favorably by removing squares and delaying maturity. More fruiting sites could contribute to a higher yield in plants that suffered early season fruit loss. Plants that did not experience early season fruit loss did not produce more fruiting sites, therefore were less likely to compensate for climatic stresses throughout the growing season.
A significant variety × percentage square removal interaction was detected for 1st position open bolls at the Winnsboro location (Table 13). Phytogen 499 WRF had a higher percentage of open bolls at the 20 and 40 percent square removal treatments, but PHY 222 WRF had a significantly higher percentage of open bolls at the 80 percent square removal treatment (Image 11).

**Image 9**: PHY 499 WRF yield as influenced by pre-bloom square removal. $F(2, 21) = 4.06$.

**Image 10**: PHY 222 WRF yield as influenced by pre-bloom square removal. $F(2, 21) = 4.15$. 

Yield (lbs-lint/ac)

<table>
<thead>
<tr>
<th>Percentage squares removed</th>
<th>Yield (lbs-lint/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>800</td>
</tr>
<tr>
<td>20</td>
<td>1000</td>
</tr>
<tr>
<td>40</td>
<td>1200</td>
</tr>
<tr>
<td>60</td>
<td>1400</td>
</tr>
<tr>
<td>80</td>
<td>1600</td>
</tr>
<tr>
<td>100</td>
<td>1800</td>
</tr>
<tr>
<td>120</td>
<td>2000</td>
</tr>
</tbody>
</table>
Phytogen 499 WRF actually had a greater percentage of 1st positon open bolls when 20, 40, or 60 percent of the squares were removed relative to where 0 percent were removed. This indicates some compensation at the 1st fruting position, whereas 1st positon open bolls on PHY 222 WRF declined after 0 percent square removal and remained relatively flat until the 100 percent square removal treatment where it sharply declined.

Table 13. Mean ± SEM percentages of open bolls per plot by lateral branch position across varieties subjected to various degrees of pre-bloom square removal for two cotton varieties at Winnsboro, LA.

<table>
<thead>
<tr>
<th>Percentage of squares removed</th>
<th>1st position</th>
<th>2nd position</th>
<th>3rd+ position</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>45.61 ± 2.20</td>
<td>36.88 ± 4.43a</td>
<td>17.51 ± 4.36b</td>
</tr>
<tr>
<td>20</td>
<td>45.94 ± 3.23</td>
<td>34.61 ± 2.72a</td>
<td>19.45 ± 3.16ab</td>
</tr>
<tr>
<td>40</td>
<td>49.08 ± 2.89</td>
<td>32.61 ± 1.63a</td>
<td>18.32 ± 2.15ab</td>
</tr>
<tr>
<td>60</td>
<td>47.51 ± 4.20</td>
<td>29.93 ± 2.08a</td>
<td>22.56 ± 3.23ab</td>
</tr>
<tr>
<td>80</td>
<td>40.05 ± 3.44</td>
<td>29.50 ± 2.06a</td>
<td>30.45 ± 2.53ab</td>
</tr>
<tr>
<td>100</td>
<td>35.06 ± 5.33</td>
<td>30.84 ± 2.17a</td>
<td>34.10 ± 5.01a</td>
</tr>
</tbody>
</table>

Variety × square removal interaction $p = 0.0323$ $p = 0.6674$ $p = 0.1617$

Means in a column within variety or percentage of squares removed followed by the same letter are not significantly different based on an F-protected Tukey’s HSD Test ($p \geq 0.05$). $1$See image 11 for significant the variety × square removal interaction for 1st position bolls.

When pooled across varieties (no variety × percentage square removal interaction ($p = 0.67$)), there was no detectable differences among square removal treatments for 2nd position bolls (Table 13). However, differences were detected for 3rd position bolls. The 100 percent square removal treatment had a greater percentage of 3rd+ positon bolls than the 0 percent treatment, but neither the 0 nor the 100 percent treatment differed from the other treatments. This suggests that plants compensated for square removal by retaining more bolls on the 3rd+ positions.
There was no interaction between variety and percentage of squares removed for distribution of open bolls in the top 9+ or bottom 1-8 nodes ($p = 0.90$) (Table 14). When pooled across varieties there were no differences in vertical distribution of the percentage of bolls. This finding was contrary to what was observed at the Alexandria (Table 4) and St. Joseph (Table 9) locations. The 100 percent square removal treatment resulted in 92.47 percent and 86.61 percent of the open bolls being located in the top 9+ nodes of the plants at the Alexandria (Table 4) and St. Joseph (Table 9) locations, respectively. Whereas the Winnsboro location had 74.04 percent of its open boll in the top 9+ nodes of the plant (Table 14). This suggests greater lower plant fruit retention, or reduced lower canopy position boll rot at the Winnsboro location.

There was no variety × percentage square removal interaction ($p = 0.30$) for the percent vegetative to reproductive bolls at the Winnsboro location (Table 15). Across pooled varieties, the 40 percent square removal treatment had greater percent open bolls located on the reproductive branches, relative to the vegetative branches, than the 100 percent square removal

![Image 11: PHY 499 WRF and PHY 222 WRF 1st position open bolls.](image)
treatment. Because this effect was observed only for the 40 percent square removal treatment, it is unlikely that this indicates compensation based on branch physiology.

Table 14. Mean ± SEM percentages of open bolls per plot by vertical node positions across varieties subjected to various degrees of pre-bloom square removal for two cotton varieties at Winnsboro, LA.

<table>
<thead>
<tr>
<th>Percentage of squares removed</th>
<th>Top 9+</th>
<th>Bottom 1-8</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>61.64 ± 2.93a</td>
<td>38.36 ± 2.93a</td>
</tr>
<tr>
<td>20</td>
<td>63.13 ± 4.39a</td>
<td>36.87 ± 4.39a</td>
</tr>
<tr>
<td>40</td>
<td>61.11 ± 4.04a</td>
<td>38.89 ± 4.04a</td>
</tr>
<tr>
<td>60</td>
<td>64.04 ± 3.82a</td>
<td>35.96 ± 3.82a</td>
</tr>
<tr>
<td>80</td>
<td>73.81 ± 4.43a</td>
<td>26.19 ± 4.43a</td>
</tr>
<tr>
<td>100</td>
<td>74.04 ± 3.92a</td>
<td>25.96 ± 3.92a</td>
</tr>
</tbody>
</table>

Variety × square removal interaction  
\[ p = 0.8994 \]

Means in a column within variety or percentage of squares removed followed by the same letter are not significantly different based on an F-protected Tukey’s HSD Test (\( p \geq 0.05 \)).

Data were pooled across all HVI fiber analyses at the Winnsboro location because there were no variety × percentage square removal treatment interactions (\( p > 0.05 \)) (Table 15).

Table 15. Mean ± SEM percentages of open bolls per plot by vegetative and reproductive branches across varieties subjected to various degrees of pre-bloom square removal for two cotton varieties at Winnsboro, LA.

<table>
<thead>
<tr>
<th>Percentage of squares removed</th>
<th>Vegetative%</th>
<th>Reproductive%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>23.12 ± 3.37ab</td>
<td>76.88 ± 3.37ab</td>
</tr>
<tr>
<td>20</td>
<td>20.48 ± 2.35ab</td>
<td>79.52 ± 2.35ab</td>
</tr>
<tr>
<td>40</td>
<td>19.17 ± 2.04b</td>
<td>80.83 ± 2.04a</td>
</tr>
<tr>
<td>60</td>
<td>22.90 ± 2.92ab</td>
<td>77.10 ± 2.92ab</td>
</tr>
<tr>
<td>80</td>
<td>29.20 ± 3.68ab</td>
<td>70.80 ± 3.68ab</td>
</tr>
<tr>
<td>100</td>
<td>29.36 ± 2.53a</td>
<td>70.64 ± 2.53b</td>
</tr>
</tbody>
</table>

Variety × square removal interaction  
\[ p = 0.2972 \]

Means in a column within variety or percentage of squares removed followed by the same letter are not significantly different based on an F-protected Tukey’s HSD Test (\( p \geq 0.05 \)).
When pooled across varieties, statistical differences in fiber quality characteristics was apparent only for strength, where the 100 percent square removal treatment exhibited stronger fiber quality than the 0 and 20 percent square removal treatments. Although cotton subjected to water-deficit stress has been shown to exhibit reductions in fiber strength (Dagdelen et al., 2008), since cotton in these trials had excess water, varietal differences most likely resulted in the differences in strength reported here. Differences in strength noted at this location, although significant, were all rated very strong (≥ 31 g/tex) (Cotton Incorporated, 2013) however, it did appear to result in parallel significant differences in loan values (Table 16). But similar to the slight differences in strength, the difference in loan value between the 100 percent and the 20 percent square removal treatment was only 0.07 cent/lb, which does not represent a definitive difference.

Table 16. Mean ± SEM of fiber quality characteristics across varieties subjected to various degrees of pre-bloom square removal for two cotton varieties at Winnsboro, LA.

<table>
<thead>
<tr>
<th>Percentage of squares removed</th>
<th>Gin out (percent)</th>
<th>Length (inches)</th>
<th>Uniformity (percent)</th>
<th>Strength (grams/tex)</th>
<th>MIC</th>
<th>Loan Value (Cents/lb.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>43.35 ± 0.21a</td>
<td>1.15 ± 0.01a</td>
<td>85.5 ± 0.30a</td>
<td>31.6 ± 0.98b</td>
<td>5.0 ± 0.12a</td>
<td>53.55 ± 0.02ab</td>
</tr>
<tr>
<td>20</td>
<td>42.69 ± 0.56a</td>
<td>1.14 ± 0.01a</td>
<td>85.2 ± 0.47a</td>
<td>31.1 ± 1.00b</td>
<td>4.9 ± 0.16a</td>
<td>53.54 ± 0.02b</td>
</tr>
<tr>
<td>40</td>
<td>42.85 ± 0.41a</td>
<td>1.15 ± 0.01a</td>
<td>85.4 ± 0.32a</td>
<td>32.6 ± 0.71ab</td>
<td>5.0 ± 0.20a</td>
<td>53.57 ± 0.01ab</td>
</tr>
<tr>
<td>60</td>
<td>43.08 ± 0.49a</td>
<td>1.14 ± 0.01a</td>
<td>85.4 ± 0.54a</td>
<td>33.2 ± 0.75ab</td>
<td>4.8 ± 0.13a</td>
<td>53.58 ± 0.02ab</td>
</tr>
<tr>
<td>80</td>
<td>42.23 ± 0.64a</td>
<td>1.15 ± 0.01a</td>
<td>85.7 ± 0.25a</td>
<td>33.3 ± 0.47ab</td>
<td>4.8 ± 0.23a</td>
<td>53.58 ± 0.01ab</td>
</tr>
<tr>
<td>100</td>
<td>42.55 ± 0.35a</td>
<td>1.17 ± 0.01a</td>
<td>85.7 ± 0.41a</td>
<td>34.5 ± 0.77a</td>
<td>4.7 ± 0.13a</td>
<td>53.61 ± 0.02a</td>
</tr>
</tbody>
</table>

| Variety × square removal interaction | p = 0.87 | p = 0.15 | p = 0.83 | p = 0.38 | p = 0.74 | p = 0.38 |

Means in a column within variety or percentage of squares removed followed by the same letter are not significantly different based on an F-protected Tukey’s HSD Test (p ≥ 0.05).
Conclusion

In Louisiana it is not uncommon for cotton (*Gossypium hirsutum* L.) to experience pre-bloom square loss due to insect injury or abiotic factors. The objectives of this research were to quantify the effects of pre-bloom square loss on the yield and fiber qualities of early maturing vs. late season cotton cultivars. Experiments were conducted in 2016 at three distinct cotton production areas within Louisiana. These production areas were chosen based on unique soil types, production practices, and a history of cotton production. The locations selected were: Macon Ridge Research Station and Extension Center in Winnsboro, Louisiana; Northeast Research Station and Extension Center in St. Joseph, Louisiana; and Dean Lee Research Station and Extension Center in Alexandria, Louisiana. At each location, the impact of 0, 20, 40, 60, 80 and 100 percent pre-bloom square removal on cotton yield, fiber quality, and within plant boll distribution was evaluated on two cotton varieties. The varieties evaluated included a full season variety, Phytogen 499 WRF, and a short season variety Phytogen 222 WRF. In Louisiana during 2016, precipitation was abnormally high, especially late season during boll maturation. Thus incidences of boll rot likely influenced the results.

Although there was evidence of potential yield compensation at each location, only the Alexandria and Winnsboro location demonstrated definitive compensation. The St. Joseph location either did not compensate or had compensation masked by boll rot. The impact of square removal and compensation on fiber quality was minimal across locations. Overall, cotton in Louisiana does have the ability to compensate for 20-30 percent pre-bloom square loss with minimal impact on fiber quality. However, this ability can be variable and highly dependent on suitable environmental conditions. Although impact of pre-bloom square loss had minimal impact on fiber quality, full season varieties appear to be less affected than short season varieties.
Based on this study, our recommendation to the cotton producers of Louisiana is to attempt to retain 80-90 percent of their pre-bloom squares to achieve the greatest possible yield with the least amount of negative impact.


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Vita

Cory Lee Cole was born in Metairie, LA. After graduating from Archbishop Rummel High School in 2011, he attended LSU where he received a Bachelor of Science degree in plant and soil systems with a concentration in crop science. Upon graduation, he attended graduate school in the School of Plant, Environmental, and Soil Sciences. Cory’s graduate studies consisted of the impact of pre-bloom square loss on yield and lint quality in Louisiana cotton cropping systems. He will complete his graduate studies in December 2017.