MEMORANDUM

To: Maria Francis

From: Pierre Mishra

Date: 10/13/2019

Subject: Results of cotton yield analysis

Overview

Organic cotton is a safer alternative for conventional cotton because the water and agrochemical requirements of organic cotton are relatively lower than those of latter. The client is considering certifying her 300 acres of fallow cropland organic. This analysis compares the productivity of cotton grown by conventional, Integrated Pest Management (IPM) and organic management practices under different soil treatments. It also studies the effect of different concentrations of fertilizer application and identify possible interaction effect between treatments and management practices. One-way Analysis of Variance (ANOVA) test was performed on logged cotton yield to investigate the effect of management practices and the effect of fertilizer applications. A two-way ANOVA was also conducted to compare the means of logged cotton yield between groups based on management practices and fertilizer application. Significant differences were determined by a post-hoc analysis called Tukey Honest Significant Difference to observe how groups compare with each other. Conventional and IPM farms were found to have higher cotton yield than organic farms. It was also found that organic farms require high amount of nitrogen fertilizer to compete with the productivity of conventional and IPM cotton. If the client prioritizes environmental and social benefits of cultivating organic cotton, high productivity can be achieved with higher fertilizer application. But conventional and IPM farming might be better choices if the client prefers to save costs on fertilizers. The assumptions of normality and equal variances for ANOVA test were not met and, therefore, some differences can occur in real world. Moreover, a few outliers were also observed in the cotton yield.

Introduction

Organic cotton is high in demand in North Carolina because of its benefits over conventional cotton. It requires far less water and agrochemicals than its conventional counterpart. Organic cotton is safer for public health and natural resources as its cultivation does not employ the use of chemical pesticides, fertilizers, and insecticides, exposure to which could be carcinogenic to living beings. Such factors necessitate the need of organic cotton. However, there are challenges to growing organic cotton in North Carolina. Weed growth and insect pressure are among the major challenges. One of the alternatives to mechanical weed removal is the use of cover crop mulches. However, a study done by North Carolina State University and Rural Advancement Foundation International have shown that the success of cover crop mulches to limit insects and weeds might be dependent on soil type, previous land use and weed pressure. Researchers are dedicated to finding better agricultural practices for organic farming. Therefore, organic farming should not be overlooked because of its challenges but should be considered for a safer healthier society and ecosystem.

Description of Data

Our data consisted of cotton yield for parcels of land that was divided into 270 one-acre plots and were managed by different agricultural practices. 90 acres of land was randomly selected to be in organic, conventional, and integrated pest management (IPM) while 30 acres of land was randomly treated with

50, 75 and 100 lbs of nitrogen fertilizer per acre each. The distribution of cotton yield was positively skewed (Figure 1 and Figure 3). Overall, land parcels resulted in a wide variation of cotton yield ranging from 5.22 kg/acre to 1,931.56 kg/acre, therefore, having a range of 1,926.34 kg/acre and standard deviation of 291.62 kg/acre. Comparing across management practices, the mean cotton yield was the highest for the IPM while it was lowest for organic farming. Similarly, the median cotton yield was the highest for IPM and the lowest for organic (Figure 5). The range of cotton yield decreased from IPM to organic to conventional farming, while the standard deviation increased from organic to conventional to IPM. Comparing across fertilizer practices, 50 lbs nitrogen/acre yielded the least cotton while mean cotton yield for 75 and 100 lbs nitrogen/acre was almost the same. Similar observations were made with regards to the median (Figure 6). The range of cotton yield decreased from 50 to 100 lbs nitrogen/acre, while the standard deviation first increased going from 50 to 75 lbs nitrogen/acre while it decreased from further increasing the fertilizer quantity to 100 lbs nitrogen/acre. For detailed summary statistics for each management and fertilizer practice, refer to Table 1.

The distribution of cotton yield in the study was not normal. We require that our data distribution is normal in order to meet one of the requirements for our statistical analysis. Therefore, we logged our data to achieve a distribution that is closer to a normal distribution which would strengthen our statistical analysis.

Statistical Analysis

We performed statistical analysis with logged cotton yields because it looked more normal than the distribution of unlogged cotton yield. We conducted a Shapiro Wilt test of normality on logged data to find out that the logged cotton yield distribution was not normal ($p<0.05$). This is to be kept in mind when we interpret the results. First, we performed two one-way ANOVA tests to investigate the effect of management practices and the effect of fertilizer applications on logged cotton yield. Our null hypothesis was that the management practices or fertilizer applications did not incur any significant difference while alternative hypothesis was that they did have a significant difference on logged cotton yields across the management and fertilizer practices. Our factor variable was logged cotton yield (kg/acre) while our response variable was management practices and fertilizer applications. The test detected a significant difference in logged cotton yield across the groups ($F2,267=48.59$, $p<0.05$) for management practices and a significant difference in logged cotton yield across each fertilizer application ($F2,267=5.982$, $p<0.05$). In order to test the validity of our results we had to ensure that we meet the assumptions of our ANOVA test. Each group (or order) had to have normally distributed logged cotton yield and of equal variances in order to meet the assumptions. We conducted a Shapiro Wilk test of normality and Bartlett test of equal variance for each group (i.e. for organic, conventional and IPM and for 50, 75 and 100 lbs N/acre). The results revealed that the assumptions of normality and equal variance across each group was not met. Therefore, we conducted a non-parametric Kruskal Wallis test that tests whether there are differences in distribution among groups. One advantage of the non-parametric test is that it does not depend on the aforementioned assumptions of normality and equal variance. The test confirmed that there are differences in distribution of logged cotton yield among each group therefore, supporting our one-way ANOVA results for management practices and fertilizer applications. A post-hoc analysis called Tukey Honest Significant Difference was then performed to see how groups compare with each other. We then back transformed the logged values to discuss it in our discussion section.

We also conducted a two-way ANOVA to compare the means of logged cotton yield between groups based on two independent variables which were management practices and fertilizer application.

This was done to improve the certainty of our on-way ANOVA results because of higher f-value in two-way ANOVA and to understand if there is an interaction between the two independent variables. We detected a significant effect of management practices on logged cotton yield ($F_{2,261}=63.82$, $p<0.05$), a significant effect of fertilizer application on logged cotton yield ($F_{2,261}=10.26$, $p<0.05$) and a significant interaction between management practices and fertilizer application ($F_{4,2161}=17.29$, $p<0.05$). We then performed a Tukey test to understand those differences further and back transformed logged values for result analysis in next section.

Discussion of Analysis

In terms of the effect of each management practice on cotton yield, our statistical analysis told us that cotton yield in conventional farming was 2.4 times that of the organic farming and IPM farming was 2.97 times that of the organic farming. There were no significant differences in the yield of conventional and IPM farming. In terms of the effect of each fertilizer application, 100 lbs nitrogen/acre resulted in cotton yield 1.48 and 1.5 times than those of 50 and 75 lbs nitrogen/acre. However, we should also focus on how fertilizer application within each management practice affected cotton yield because we did find a significant interaction between management and fertilizer practices.

Generally organic farming resulted in lower yield even when it was treated with 75 lbs N/acre or 50 lbs/acre compared to any quantity of nitrogen fertilizer in convention and IPM farming. While different fertilizer application did not yield significant differences between IPM and conventional even when we compare lowest fertilizer quantity in IPM to highest fertilizer quantity in conventional or vice-versa. One thing to note is that there were no significant differences in cotton yield when we compare organic farms with 100 lbs N/acre to conventional or IPM with any quantity of fertilizer applied. This means that if organic farms are applied with 100 lbs N/acre, it can yield same amount of cotton as with conventional or IPM farming.

Conclusion

Conventional and IPM farms were found to have higher cotton yield than organic farms. But that does not mean that there is reduced profitability with organic farms. If you apply high amounts of nitrogen fertilizer to organic farms, you can achieve the same level of cotton production as with conventional and IPM farming. But if you prefer to maximize cotton yield while saving costs on nitrogen fertilizers, then conventional or IPM farming would be your better choices.

One thing to note is that, although Tukey HSD corroborated our ANOVA results, we still have to keep in mind that we did not meet the assumptions of normality and equal variances for ANOVA test and therefore, some differences can occur in real world. Moreover, we also had some outliers in our data. But because we are not sure what factors would have caused those outliers, it was safer to not exclude those from our analysis as those factors might vary in certain years. One such example could be of soil conditions, temperatures, humidity, and such.

Before applying the results of our study to other places than Hyde County, North Carolina, people should keep in mind that agricultural output depends on various factors such as soil type, weather patterns, rainfall, humidity, presence of predator insects and such. Therefore, it is safer to not base decisions solely on this study but rather use the study as a reference to predict possible yield outcomes for cotton in geographical areas of similar weather, soil type and other natural conditions.

APPENDIX

Table 1

Treatments	Minimum	1st Quartile	Median	Mean	3rd quartile	Maximum	Standard deviation	Range	Interquartile range
Overall	5.22	198.33	287.31	343.10	385.33	1931.56	291.62	1926.34	187.00
Organic	5.22	53.26	152.47	228.01	287.33	1781.23	257.57	1776.01	234.065
Conventional	184.50	202.50	255.90	370.00	385.30	1500.90	277.88	1316.42	182.85
IPM	250.80	294.00	336.00	431.30	418.70	1931.60	302.48	1680.75	124.67
50 lbs N/acre	13.64	179.02	254.71	315.42	360.25	1931.56	306.72	1917.92	181.23
75 lbs N/acre	5.22	135.92	293.71	357.41	413.25	1882.04	352.96	1876.82	277.33
100 lbs N/acre	185.00	252.00	294.70	356.50	381.20	1419.00	192.94	1233.98	129.20

Summary statistics of cotton yield (kg/acre) across different management practices and different concentrations of nitrogen fertilizer (lbs/acre)

Figure 1

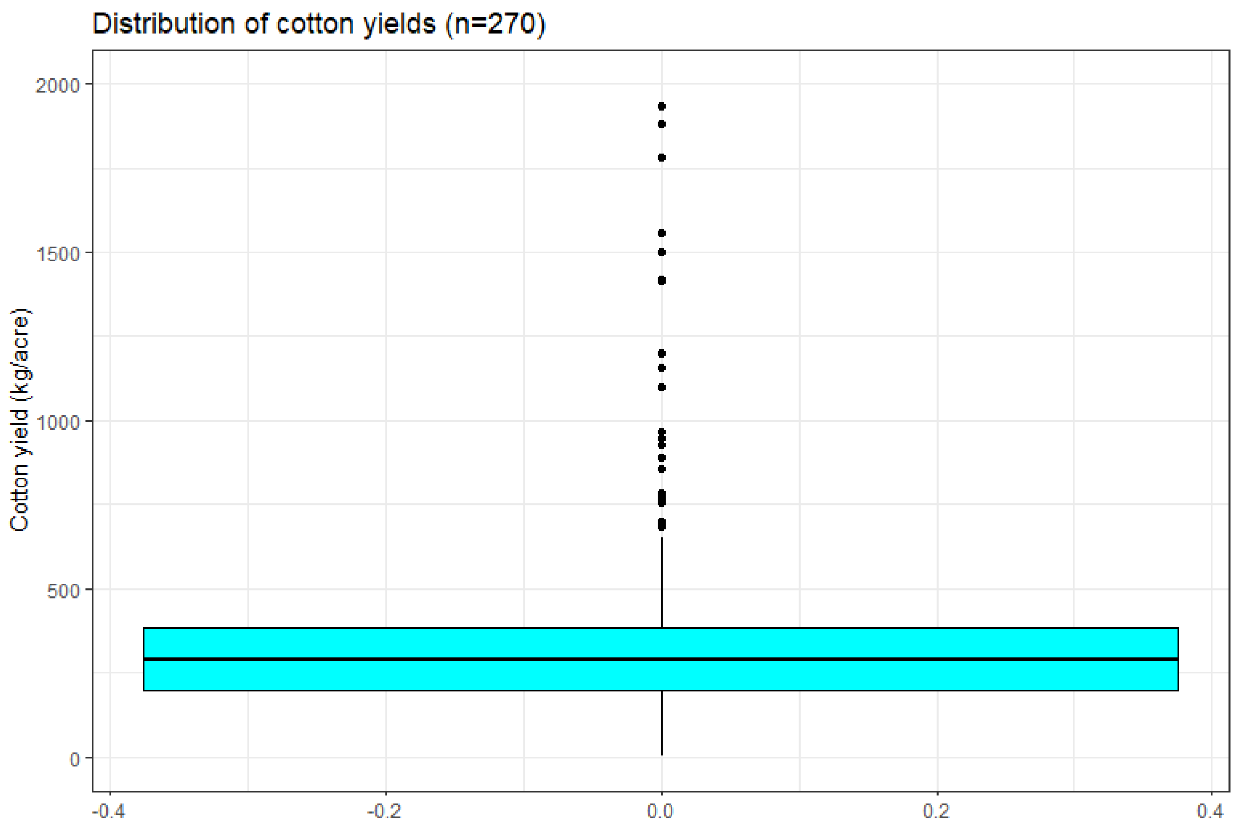


Figure 2

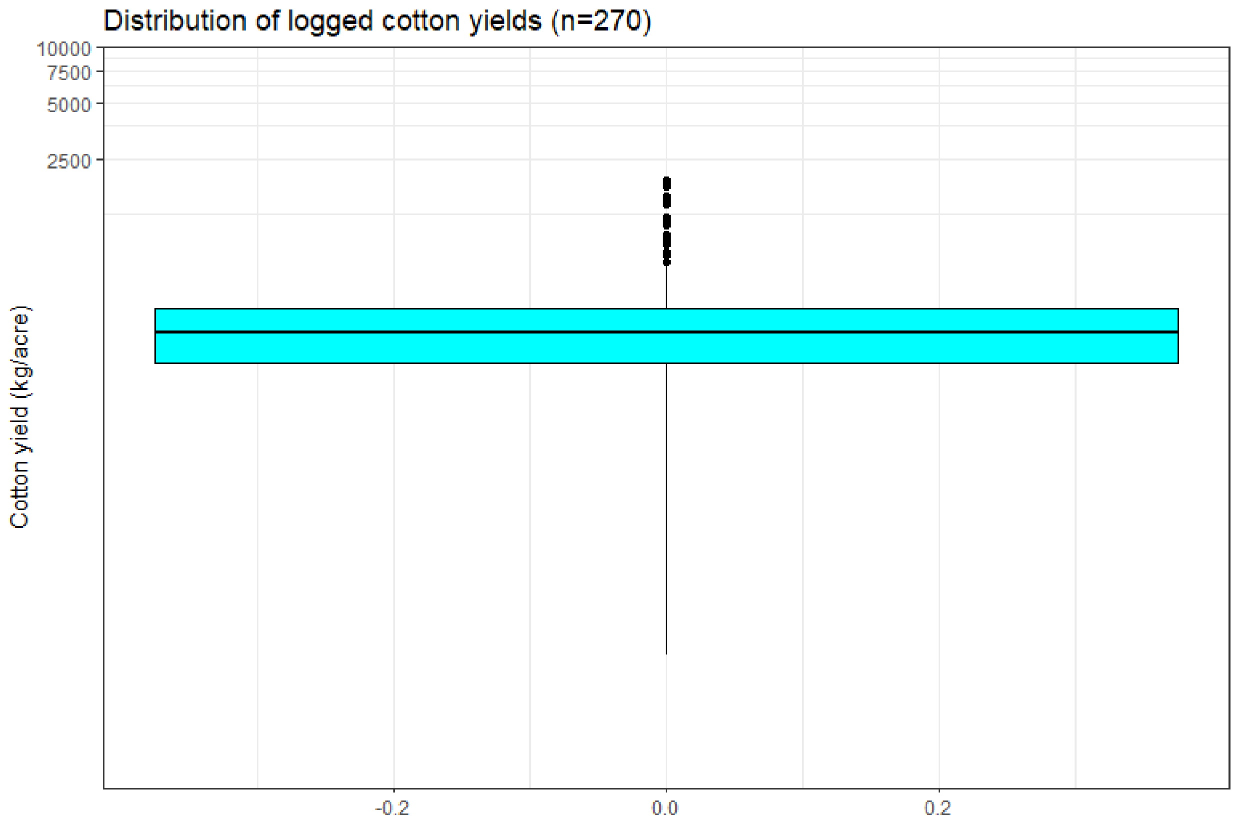

Distribution of logged cotton yields (n=270)
10000
7500
5000
2500
Cotton yield (kg/acre)
-0.2
0.0
0.2

FIGURE 3

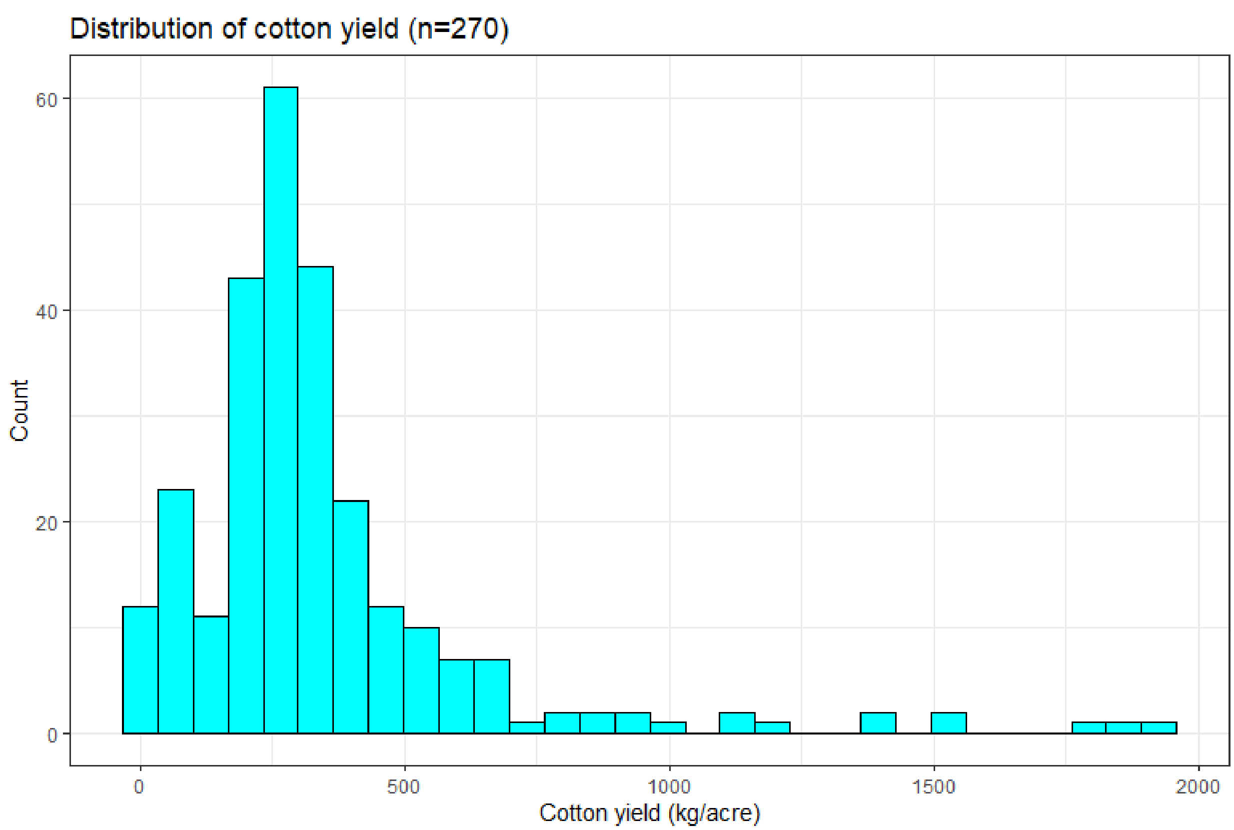

Distribution of cotton yield (n=270)
60
40
20
0
Count
0
500
1000
1500
2000
Cotton yield (kg/acre)

FIGURE 4

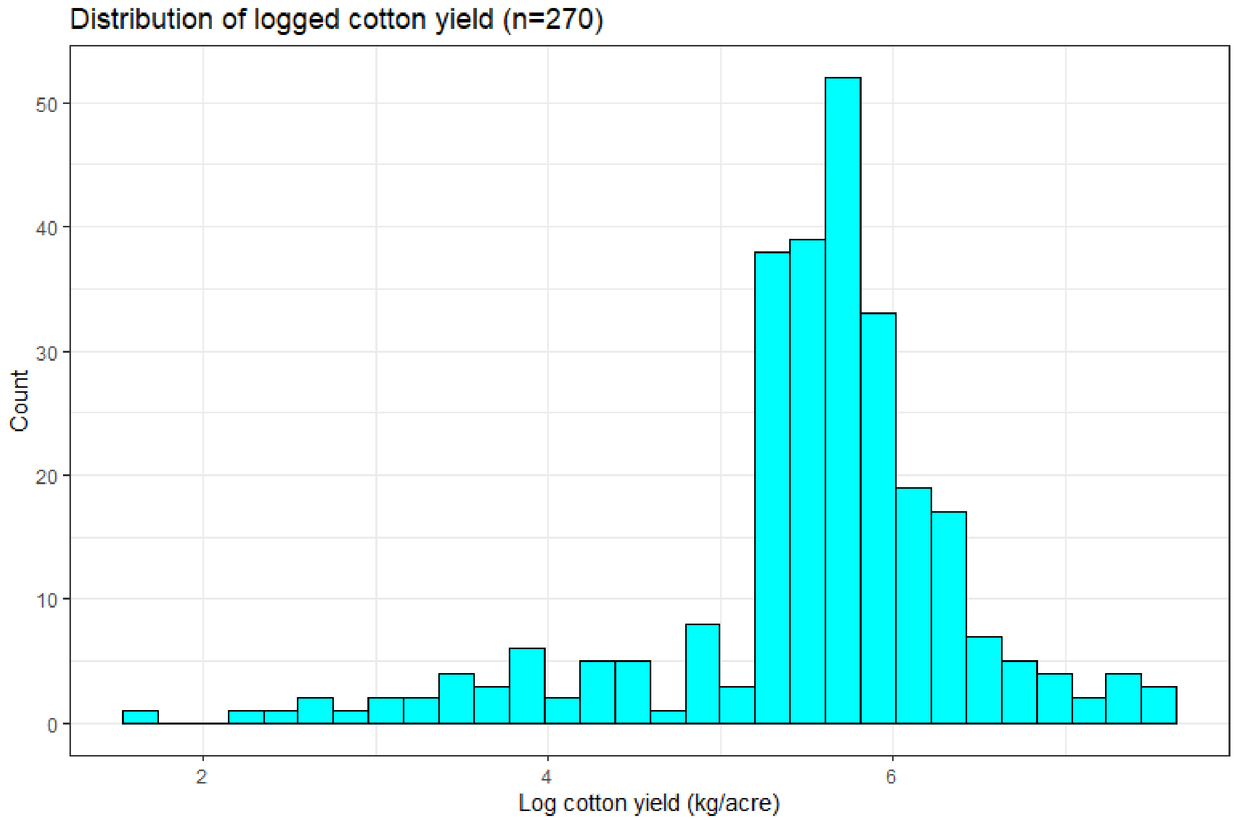

Distribution of logged cotton yield (n=270)
Count
0
10
20
30
40
50
2
4
6
Log cotton yield (kg/acre)

FIGURE 5

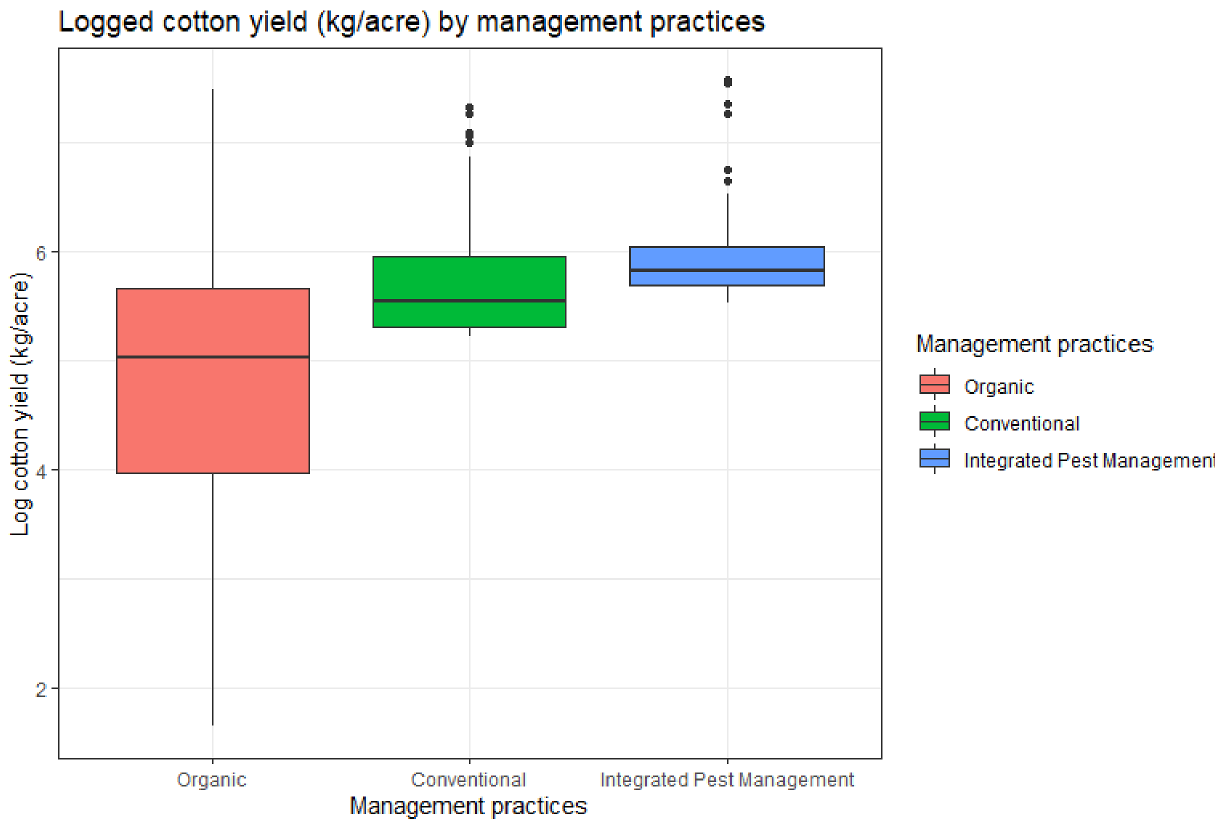
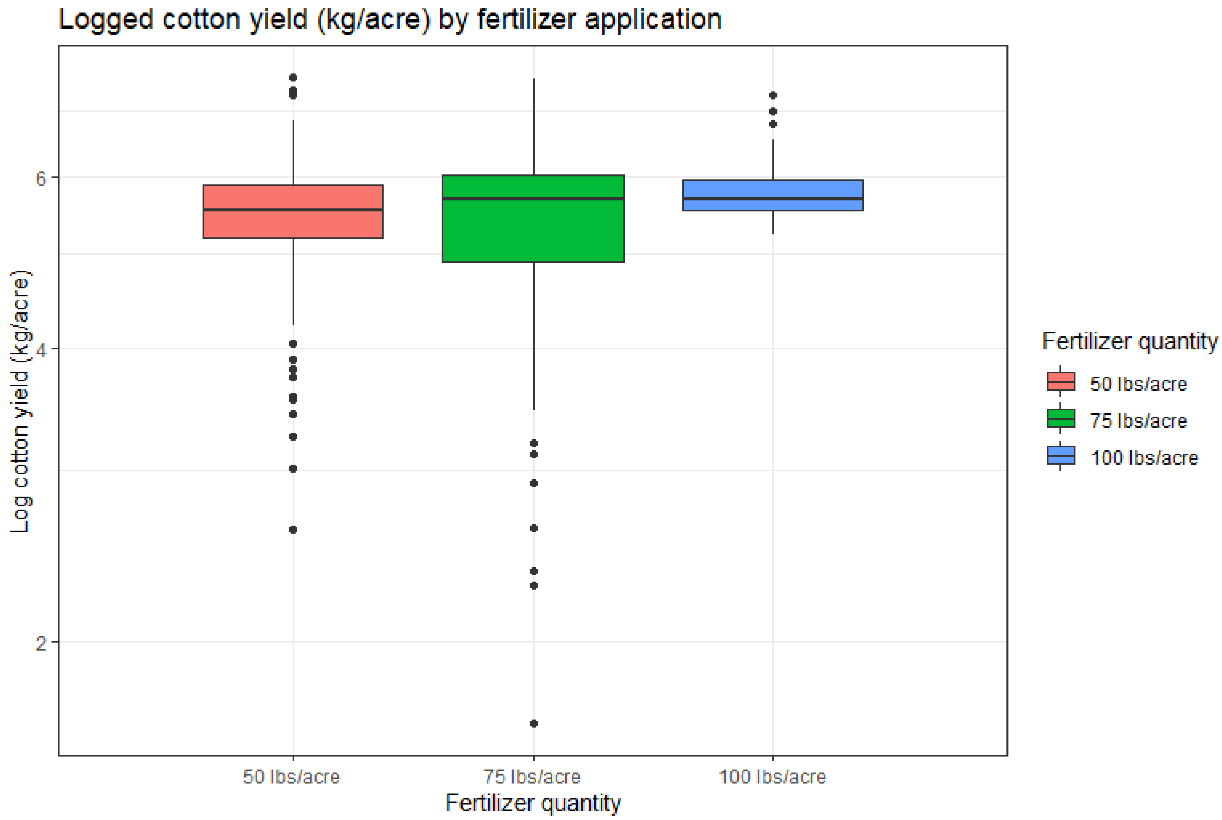
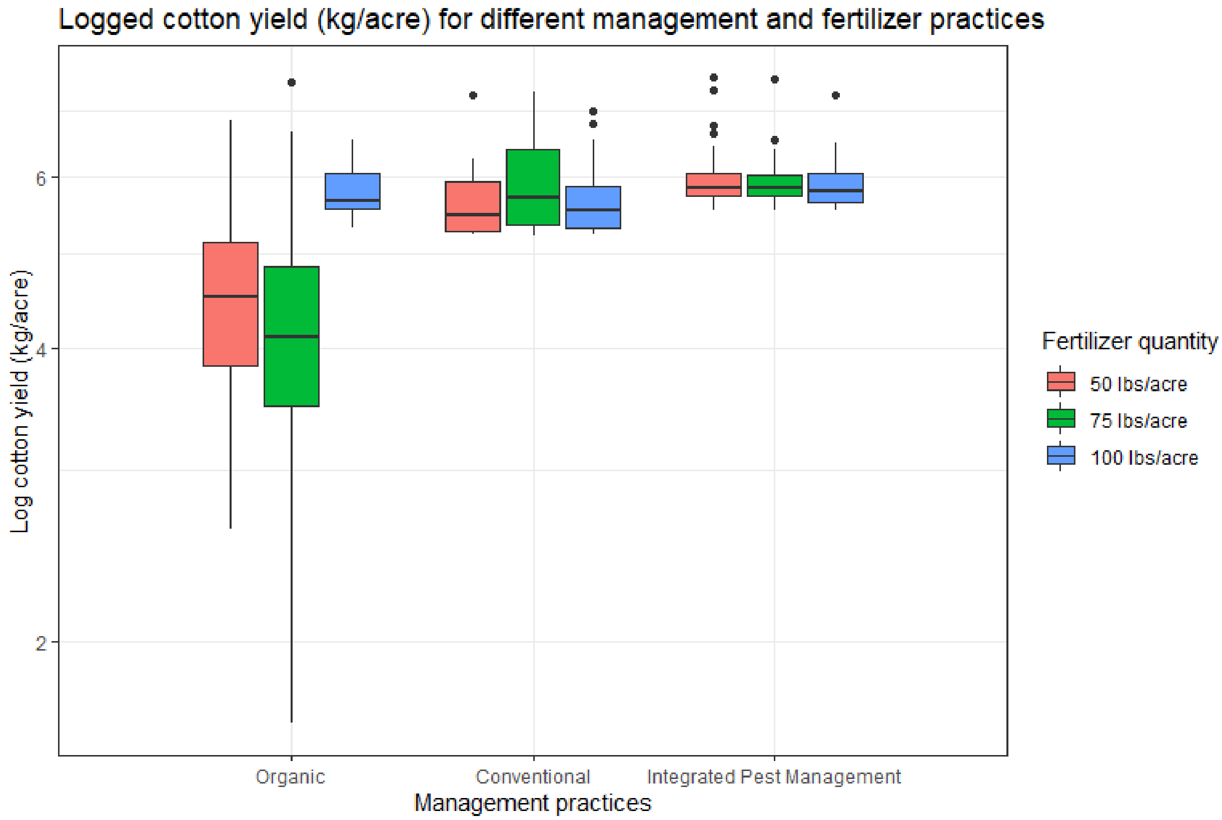

Logged cotton yield (kg/acre) by management practices
Log cotton yield (kg/acre)
6
4
2
Organic
Conventional
Integrated Pest Management
Management practices
Management practices
Organic
Conventional
Integrated Pest Management

FIGURE 6



Logged cotton yield (kg/acre) by fertilizer application
Log cotton yield (kg/acre)
6
4
2
50 lbs/acre
75 lbs/acre
100 lbs/acre
Fertilizer quantity
Fertilizer quantity
50 lbs/acre
75 lbs/acre
100 lbs/acre

FIGURE 7



Logged cotton yield (kg/acre) for different management and fertilizer practices
Log cotton yield (kg/acre)
6
4
2
Organic
Conventional
Integrated Pest Management
Management practices
Fertilizer quantity
50 lbs/acre
75 lbs/acre
100 lbs/acre