2019

Impact of Temperature and Precipitation on Apple and Peach Yields in Southern Illinois

Parker Flamm
parkerflamm@siu.edu

IMPACT OF TEMPERATURE AND PRECIPITATION ON APPLE AND PEACH YIELDS IN SOUTHERN ILLINOIS

by

Parker L. Flamm

B.S., Southern Illinois University, 2018

A Research Paper
Submitted in Partial Fulfillment of the Requirements for the
Master of Science

Department of Agribusiness Economics
in the Graduate School
Southern Illinois University Carbondale
December 2019

IMPACT OF TEMPERATURE AND PRECIPITATION ON APPLE AND PEACH YIELDS IN SOUTHERN ILLINOIS

by

Parker L. Flamm

A Research Paper Submitted in Partial

Fulfillment of the Requirements

for the Degree of

Master of Science

in the field of Agribusiness Economics

Approved by:

Dr. Dwight Sanders, Chair

Graduate School
Southern Illinois University Carbondale
October 21, 2019

AN ABSTRACT OF THE RESEARCH PAPER OF

Parker L. Flamm, for the Master of Science degree in Agribusiness Economics, presented on October 21, 2019 at Southern Illinois University Carbondale.

TITLE: IMPACT OF TEMPERATURE AND PRECIPITATION ON APPLE AND PEACH YIELDS IN SOUTHERN ILLINOIS

MAJOR PROFESSOR: Dr. Dwight Sanders

The purpose of this research paper is to examine the monthly minimum temperature for March and April and the average precipitation for the months of June, July, and August in Southern Illinois to observe how they affect the yearly yields of apple and peach production at Flamm Orchards in Cobden, Illinois. The data that was observed is only a portion of the total acreage that is in production at Flamm Orchards. There was one block of apples selected and one block of peaches, both of which had the most harvest records available for use. There has been minimal research done that specifically analyzes how weather variables in particular, temperature and precipitation, affect apple and peach yields. The results from the model show that the impact of minimum temperature in March and April and precipitation in June, July, and August is low in determining yield variation of apples and peaches. This research will provide crucial data to growers not only in Southern Illinois, but nationwide as to whether or not their climate is suitable for the production of apples and peaches and what to expect for yields earlier in the season.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 1

INTRODUCTION

The factors that influence the yield outcome of apple production are cultivars, rootstocks, climate, soil, spacing, and different management practices (Rather, 2018). While five out of the six of these key factors are controllable, one of the most important which is not controllable, is climate. With that being said, two of the most important factors of climate that impact yield are temperature and precipitation (Westcott & Jewison, 2013). There are many other climatic variables that can be taken into consideration, but the most critical are temperature around the bloom stage and water availability near the “final swell” (Morton, et. al., 2017). With so much liability lying in the hands of mother nature, from year to year, apple growers are seeking to find a way to better asses the vulnerabilities and risks that their businesses undergo due to the changing short and long-term weather patterns (Morton, et. al., 2017).

Along with apple growers, peach producers are also impacted by many factors, including weather (Lopez, Johnson, & DeJong, 2007). Research has shown that early-spring temperatures at bloom and 30 days thereafter have a significant impact on early peach growth and the size of the fruit at harvest (Lopez, Johnson, & DeJong, 2007). According to Fereres (1990), during extreme high or low temperatures, a result in tree death can occur, while intermediate temperatures affect all physiological processes, mainly in the reproductive organs. Depending upon location, some growers worry about not receiving the proper amounts of required chilling hours during the winter, while others are more concerned with the potential risk for a late frost, both resulting in a decrease in total yield.

The interest was found in this research topic while discussing the potential impacts that temperature and precipitation have on peaches and apples that are grown in southern Illinois at Flamm Orchards. With there being a limited number of peach and apple acreage in the region, there is a lack of studies done that analyze how significant these two factors are in forecasting yields. It has been suspected that temperature is most crucial during spring, in order to avoid a frost, which would result in a crop loss. As far as precipitation, it is considered to be most important during the summer months according to Flamm Orchards. That is why this research only covers the temperature of March and April and the precipitation of June, July, and August, in order to see if this holds true.

In this research, there will be a slight altering the methodology of previous studies. I will be analyzing the impact (if any) on the overall yields for apples and peaches in Southern Illinois, specifically located at Flamm Orchards in Cobden, Illinois. The research will conducted based off of one peach orchard (11.84 acres) and one apple orchard (14.79 acres) over the entire lifespan of each orchard. Expected results would be a significant decrease in yields when the average temperatures in the months of March and April are lower. Likewise, it is expected to see a decrease in yields when there is a significant excess or lack of precipitation during the months of June, July, and August. The purpose of conducting this research is to better-forecast yields when these extreme weather conditions come into factor.

CHAPTER 2

LITERATURE REVIEW

A study conducted by Lopez et. al. (2007), in California, analyzed what the effects of early spring temperatures had on peach, fruit, size at harvest. The study looked at the fruit size over a 20 year time period (1985-2004) in order to determine if there was a correlation between early spring temperatures and packed fruit size. Previous research has been done and indicates that early spring temperatures, 30 days after bloom, have a significant effect on early fruit growth as well as the fruit size at harvest. This research leads to two trends: fruit size has increased over the last 20 years and early spring temperatures that are high have a tendency to decrease the size of packed fruit at harvest, for any year. Lopez et. al. (2007) believes that the increase in fruit size over the last 20 years can be attributed to the advancement in cultural practices. As for their reasoning behind the effects of high early spring temperatures, they conclude, "the tree cannot supply resources rapidly enough to support the potential fruit growth rates associated with high rated of phonological development" (Lopez et. al., 2007). Fruit size can be directly correlated with yield amounts at the end of each season. Larger fruit size will result in more bushels, thus raising the yields. Bakshi (2015) also strongly agrees with these findings. He concludes that there is a very strong correlation between climatic factors and vegetative growth of peach trees.

The Shopian District in India relies heavily on apple production; nearly 83% of its farmland under horticulture is in apple production (Rather, 2018). Rather (2018) conducted a non-linear regression analysis to determine whether the climatic variables of minimum and maximum temperature, rainfall, and snowfall had any significance, statistically, on influencing apple production. The non-linear analysis took into consideration rainfall, snowfall, and temperature as independent variables and apple production as the dependent variable. The research looked at these variables over a 9 year time period and broke down the independent variables based on monthly climate. Rather (2018) created an alternative hypothesis that stated "There is a significant influence of climate variability on apple production at the flowering stage" He created the same alternative hypothesis during the "Fruit Developmental Stage" and "Post-Harvest Stage". Since the post-harvest is not relevant to my research, this research will only analyze the flowering stage and fruit development stages of his research.

During the flowering stage, he concluded that the alternative hypothesis is accepted ($p<=0.05$) due to the P-values of 0.005 (minimum temp.), 0.01(maximum temp.), and 0.05 (rainfall). Also the F-ratio values indicate that all of the parameters are significant at a level of 0.05. For minimum and maximum temperature there is a positive impact but for rainfall there is a negative impact. From the analysis, it can be concluded that in the flowering stage, during the minimum temperature, apple production is highly effected compared to the other variables.

The same alternative hypothesis was made during the fruit developmental stage. Looking at the data, we can conclude from the F-ratio values that minimum and maximum temperature have no significant influence on production ($p>0.05$). The minimum temperature has a p-value of 0.34 and the maximum temperature has a p-value of 0.64. Rainfall does show a significant influence with a p-value of 0.03 ($p<=0.05$). As a result, the alternative hypothesis is accepted on for the variable of rainfall $P<=0.05$.

Finally, during the fruit developmental stage, it is concluded that rainfall highly influences apple production compared to the other variables.

While there has been little research done on the effects of precipitation and temperature on apples and peaches, there has been significant research on corn and soybeans. Sanders et. al. (2014) set out to determine the determinants of soybean yields in Illinois and to quantify the increases in Illinois soybean yields that can be caused by increased technology. The yield data collected ranges from 1950-2010, making a total of 61 annual observations. Weather data for this research was collected from the National Climatic Data Center (NCDC). From the NCDC the average temperature for each month and cumulative daily rainfall over the month was collected. The analysis of weather impacts was started in April and went through September, according to Sanders et. al. (2014), this is considered the growing season. A multiple regression model was run in order to evaluate the statistical significance and impacts of temperature and precipitation on Illinois Soybean yields. The regression model found that April temperatures had no impact on soybean yields. Although, it did show that temperatures in the month of May have a positive impact, as a result, a warm spring may be beneficial. We can also conclude that August is the most crucial month in terms of temperature impact on yields. Most areas in Illinois lost over 0.50 bushels for each 1 degree increase in the August average temperature according to Sanders et. al. (2014). The regression analysis came to the conclusion from its results that a warm planting season (May-June) with a cool growing season (July-August) is the ideal growing conditions for soybeans in Illinois, with temperatures in August being the most important. When analyzing precipitation, the model suggests that June, July, and August have positive signs on linear rainfall, with August, once again, being the most important. According to this research, July is the second most important month for rainfall, behind August. From looking at this model, it is also concluded that the optimum amounts of precipitation in the key months of July, August, and September fall within the range of 5.0 to 7.0 inches.

In similarity to the conclusions of the impacts that temperature and precipitation have on soybean yields (discussed above) Avila et. al. (2013) had similar results. They found that soybeans best grow at temperatures between 68 degrees Fahrenheit and 86 degrees Fahrenheit. With temperatures above 86 degrees Fahrenheit having negative impacts on seed number and weight, thus reducing the total yield and quality. They also concluded that if the high temperatures are associated with a drought, the yield losses are even higher. As far as water availability for maximum soybean yields, Avila et. al. (2013) also seemed to follow the findings of Sanders et. al. (2014). They concluded that there are three periods during soybean development that heavily rely on water: germination, emergence, and flowering. The most detrimental for receiving an excess or lack of water is during the germination stage Avila et. al. (2014). They concluded this because the germination stage is when the crop is established, and if the crop receives the wrong amounts of precipitation during this time then the plant population is going to be poor. For maximum yields, they found that 5/16 inches of precipitation daily is ideal during the flowering stage.

Another soybean analysis on the effects of precipitation during the growing season was conducted by Tannura et. al. (2008). The study conducted a multiple regression analysis on soybean yields in Illinois, Iowa, and Indiana while looking at monthly temperature and precipitation over the years of 1960-2006. The results showed that dry weather during the summer months decreased soybean yield while wet weather increased it. It also showed that the precipitation in the month of August had the largest influence on yield potential for Illinois and Iowa, while the month of June had the largest impact on Indiana. As far as temperature, the data concludes that cooler weather in July and August is ideal for maximum yields, along with a warmer June as long as there is a sufficient amount of precipitation. This follows closely to the findings of Sanders et. al. (2014) and Avila et. al. (2014). Similar to the other crops discussed, corn yields are also heavily dependent on precipitation and temperature during its stage of growth. In 1988 and 2012 there was an extreme drought amongst the 8 primary corn-producing states (Iowa, Illinois, Indiana, Ohio, Missouri, Minnesota, South Dakota, and Nebraska). As a result of these two uncharacteristic years Westcott and Jewison (2013) created a model to examine the yield variances of corn and soybeans under stressful growing conditions, in order to help predict yield losses when similar events occur in the future. For corn, they looked at the response it had to dry weather in the month of June and the yield response to temperatures in July. Adjustments were made in the study to account for the extremely dry Junes in 2012 and 1988. The average precipitation for the month of June amongst the 8 major corn-producing states is 4.33 inches. A minimum shortfall of 1.82 inches from its average, in June, is needed to trigger this variable in the model (Westcott & Jewison, 2013). According to Westcott and Jewison (2013), in 1988 the precipitation shortage was 2.82 inches in June from its average, while in 2012 it was 1.96 inches from its June average. From their findings, they ran their model based off of having a 2-inch shortage of precipitation in the month of June. Their results found that corn yields would lose 19.1 bushels per acre if there were a 2-inch shortage, from the average, of June precipitation in the 8 major corn-producing states. When seeing how July temperatures would influence the corn yields, they concluded that if the average temperature for the 8 major corn-producing states is lower than corn yields would increase, while hotter temperatures would decrease yields. This is similar to the finding that Sanders et. al. (2014) found with soybean yields.

Pathak (2012) also agrees with the conclusion of these findings when relating temperature and precipitation to corn yields. His research was conducted throughout 61 of the 93 counties in the state of Nebraska. He found that temperature and precipitation for July had a large significance. July temperature was significant for 100% of the counties with July rainfall being significant for 93% of the counties, respectively. He found that August also had a significant correlation with 85% of the counties corn yields, but it was not as significant as July. It is concluded, once again, that corn yields are increased with cooler and wetter conditions during the summer months and that precipitation outside of the critical months (July and August) does not have a high correlation with corn yield (Pathak, 2012).

The correlation of rainfall and temperature related to crop yield was analyzed throughout the Asunafo Forest, in Ghana (Peprah, 2014). The study looked at a wide range of different crops grown there such as maize, plantains, rice, yams and cococyam. The research tested the null hypothesis that there is no statistical significance between the correlation of rainfall, temperature, and crop yield over a 14-year time period (1995-2008). Annual rainfall range for the Asunafo Forest was from 168.8 mm (6.65 in.) to 1,737.9 mm (68.42 in.) and the annual temperature was from 22.7 degrees Celsius (81.9 degrees Fahrenheit) to 32.5 degrees Celsius (90.5 degrees Fahrenheit) (Peprah, 2014). The conclusion was made by Peprah (2014) that 83% of all rainfall cases showed that rainfall accounted for 0.0%-18.9% of variability in crop yield, as for the other 17% rainfall accounted for 40.9% crop yield variability. As for temperature, Peprah (2014) made the conclusion that "temperature recorded 67% acceptance of the null hypothesis in which temperature explained 4.2% – 10.7% crop yield variation in contrast to 33% rejection where 35.4% - 47.4% crop yield variability was due to temperature" (p.784) We can conclude that other factors have more explanation in crop yield variance. We also conclude that rainfall does not explain the larger portion of crop yield variation, temperature does.

Why might this research be important? It is commonly known that weather variables, specifically temperature and precipitation, play a key role in both apple and peach production nationwide. Lois Wright Morton et. al. (2017) take aim at identifying why these weather variables are one of the most crucial factors in decision-making for these production systems. In order to identify the significance of these variables, growers convened at the University of Massachusetts to further discuss how temperature and precipitation impact their production systems. During the meeting, a concept mapping process was implemented in order to gather individual challengeds as well as challenges that were common amongst the group. According to Morton et. al. (2017), this study identified that weather related management was the top concern for growers in the Northeast. Specifically in determining fruit thinning, disease threats, freezes near bloom, and crop load. All of these management decisions rely heavily on temperature and precipitation variations from year to year.

CHAPTER 3

DATA

Both the apple and peach yields were collected from two different locations on Flamm Orchards in Cobden, Illinois. The apple block that is being observed contains approximately 14.79 acres of the Red Delicious variety, on a spacing of 10'X20', and was first harvested in 1992 with the final harvest coming in 2017, making the orchard have a 25 year production lifespan. With each tree taking up approximately 200 square feet, it can also be recognized that there is 218 trees per acre and a total of 3,224 throughout the entire orchard. The reason that this orchard was selected is because of its long lifespan and also because it had the earliest harvest records on Flamm Orchards, dating back to 1992.

The peaches that are being observed is a block of approximately 11.84 acres of the Bounty variety with a spacing of 16'X22' and first harvested in 2005 with the final harvest coming in 2017, resulting in a 12 year production lifespan. It can be easily be noted that the lifespan of peaches falls much shorter than that of apples. Each tree takes up 352 square feet, meaning that there are 123 trees per acre and a total of 1,456 trees throughout the 11.84-acre orchard. This orchard was selected due to its location in relevance to the apple orchard that is being analyzed, as well as having the largest number of harvest records on file.

The weather data gathered for the regression analysis came from the National Climatic Data Center's (NCDC) location at the Carbondale Sewage Plant, Illinois. The location of the Carbondale Sewage Plant from the apple block is approximately 12.8 miles and 11.7 miles form the peach block. This was the closest available weather data that dated back long enough to account for the full lifespan of both orchards.

CHAPTER 4

METHODS

The methods used in this research follow closely with the conceptual framework of a previous study that aimed to analyze whether climatic variables of minimum and maximum temperature and precipitation had any significance, statistically, on influencing apple yield (Rather, 2018). This is a good model to follow because it is the most current and most closely related to this research topic.

The main purpose of this study is to determine if temperature (in March and April) and precipitation (in June, July, and August) have any statistical impact on peach and apple yields. As a result, the data will be analyzed across time. For this study, a multiple regression analysis has been run (Rather, 2018).

For the research done in this paper, a similar model has been formed that follows (Rather, 2018), which is a simple multiple regression model. This model is best suited for this research because it analyzes the relationships between one dependent variable and at least one independent variable. As stated previously, the dependent variables of this research are apple and peach yields, with the independent variables being temperature and precipitation. Since there are two different dependent variables, a multiple regression model had to be run on both apples and peaches. The equation for this multiple regression model can be seen as follows:

$$Y=\beta_0+\beta_1+\beta_2+\beta_3+\beta_4+\beta_5$$

Where Y is the dependent variable (apple and peach yield). In this model, each beta represents an independent variable. β_1 is the minimum temperature in March; β_2 represents the minimum temperature in April. As far as the precipitation variables, they are represented in the equation as follows; β_3= average precipitation in June, β_4= average precipitation in July, and β_5= average precipitation in August. The null hypotheses for the model states that X (independent variables) do not have any effect on the outcome of Y (dependent variables). Meaning that the relationship between the minimum temperatures in March and April, along with the average precipitation in June, July, and August, have no effect on the yield of apples or peaches. If the null hypothesis is rejected, then it can be concluded that X does play a role in determining the yields of apples and peaches Y. Through the implementation of this test, it will determine if these variables, in fact, do play a role in yield variances among apples and peaches. The software package EVIEWS was used to estimate this multiple regression model.

CHAPTER 5

RESULTS

The multiple regression analysis was ran to estimate the statistical impact of March and April minimum temperatures and June, July, and August average precipitation on the yields of apples and peaches. There was also a t-test ran in order to figure the statistical significance of each independent variable. The null hypothesis for the regression states that precipitation and temperature have no effect on the yields of apples or peaches. The temperature was measured in degrees Fahrenheit, with the precipitation being measured in inches. The statistical impact was that of what we had expected to find. Across the board for peaches and apples, as temperature rose from the minimum, there was an increase in yields. Also as precipitation rose in June and August, there was an increase in yields. However, for the month of July, there was a decrease in yields as precipitation rose.

When analyzing the results on peach yields, we can see an increase in yields while temperature rises from the minimum. In the month of March, for every one degree Fahrenheit increase in temperature from the minimum March temperature, bounty peach yields increased by 44.6 bushels (3.8 bu/acre). In April, a similar correlation was proven. For every on degree Fahrenheit increase in temperature from the minimum April temperature, bounty peach yields saw an increase in yields of 121.2 bushels (10.2 bu/acre). For precipitation, there was a similar trend. In June, for every one additional inch of rain above the average amount, bounty peach yields increased by 61.1 bushels (5.2 bu/acre). In July, a different result was found, for every one inch of rain above the average amount, bounty peach yields decreased by 10.9 bushels (.92 bu/acre). In August, there was a similar result to that of June, for every one inch of precipitation above the average, there was an increase in bounty peach yields of 86.02 bushels (7.3 bu/acre). These results can be seen in table 1.

Red Delicious apples saw a similar trend to that of the bounty peaches. In March, for every one degree Fahrenheit increase from the minimum temperature, there is an increase in Red Delicious yields of 139.4 bushels (9.4 bu/acre). In April, there was a slightly greater increase in yield. For every one degree Fahrenheit increase above the minimum April temperature, it can be concluded that Red Delicious yields will increase by 321.9 bushels (27.2 bu/acre). When looking at yield variances from precipitation in the month of June, it can be concluded that for every one additional inch of precipitation above the average, there is an increase in Red Delicious yields of 52.5 bushels (3.5 bu/acre). In the month of July, we conclude that for every one additional inch of rain above the average, Red Delicious yields decrease by 79 bushels (5.3 bu/acre). Finally, in August, for every one inch of rain above the average monthly amount, the Red Delicious saw an increase in yields of 278.2 bushels (18.9 bu/acre). Results for this regression are shown below in table 2.

There was an additional regression analysis ran, on both peaches and apples, without the precipitation variable. The reasoning for this is due to the lack of significance of the precipitation variable. One factor that could account for precipitation not being as significant is that Flamm Orchards implements irrigation, only to their apples, on extremely dry years. It is not typical in the operation, but if deemed necessary for tree survival than it must be done. Peaches aren't as effected by a lack of precipitation, so irrigation is not a factor for peach production at Flamm Orchards.

When looking at temperature alone, in the month of March, for every one degree Fahrenheit increase in temperature above the March minimum, bounty peach yields saw an increase in 27.5 bushels (2.3 bu/acre). In April, for every one degree Fahrenheit above the minimum temperature for the month, bounty peach yields increased by 106 bushels (9 bu/acre). These results can be found in table 3.

Red Delicious apples also saw an increase in yield for each additional degree Fahrenheit above the month's minimum temperature. In March, for every one degree Fahrenheit above the minimum temperature, Red Delicious yields increased by 131.6 bushels (8.9 bu/acre). In April, for every one degree Fahrenheit increase above the minimum temperature during the month, Red Delicious yields saw an increase of 291.8 bushels (19.7 bu/acre). This is displayed in table 4.

The null hypothesis that was formed, for the t-test, stated that March and April temperature and June, July, and August precipitation have no effect on the yields of apples and peaches. One would assume to reject this null hypothesis and accept the alternative, which states that March and April temperature along with June, July, and August precipitation do have an impact on apple and peach yields. We assume a 95% confidence level and a significance level of .05. The t-critical value for the peaches including both temperature and precipitation was 2.306 and for apples it was 2.080. For the regression with only the temperature variable, the t-critical value for peaches was 2.201 and for the apples it was 2.064. From looking at the t-statistics, all of them fall within the acceptance region of their respected t-critical value. This means that we accept the null hypothesis of March and April temperature and June, July, and August precipitation having no impact on apple and peach yields. Further meaning that temperature and precipitation in those months have no statistical impact on apple and peach yields.

As mentioned earlier, one explanation for precipitation not being relevant is due to the implementation of irrigation on extremely dry years for Apples at Flamm Orchards. It was still assumed to have a higher significance because the irrigation has only been added 4 years out of the last 30. As far as the spring minimum temperature not being statistically significant, that can be explained by a number of different variables. In order for the spring temperature to have an impact, the buds have to be coming out of dormancy and starting to lose their winter hardiness. For example, if the coldest temperature in the month of March or April happened before the buds started to lose their hardiness, then they wouldn't see much of an impact. The greatest impact can be seem a few days before flowering and the ten days following flowering. Typically if there isn't a freeze within the ten days after flowering, by then it is late enough in the spring that there won't be one. Another factor that could account for the lack of significance of spring minimum temperatures is the amount of buds to peach ratio. The trees put on such an extremely high number of buds every year. It is important to thin out fruit off of the trees in order for the fruit to reach an optimal size, it is recommended to remove about 80% of the fruit. A freeze has the ability to only take out a partial crop. If a spring freeze takes out, for example, 30% of the buds, the end yield won't be effected because those fruit would have to be taken off the trees at some point anyway.

CHAPTER 6

SUMMARY AND CONCLUSIONS

This research was conducted in order to identify the importance of temperature in March and April as well as precipitation in June, July, and August on peach and apple yields in Southern Illinois. The study focuses on bounty peach and red delicious apple orchards at Flamm Orchards, which is located in Cobden, Illinois. The weather data for this research was gathered from the Carbondale, Illinois sewage plant and the yield records were gathered from Flamm Orchards. A multiple regression analysis was used to determine the relationship between temperature and precipitation on these yields.

The two orchards were selected strategically in order to ensure the most accurate results from the multiple regression models. The apple orchard was selected based off of its extended lifetime of 25 years. This ensured a long number of years worth of data that could be studied. The peach orchard was also selected do to its life longevity. While not as long as the apple orchard, the peach orchard saw a lifespan of 12 years. Both of these orchards were the oldest orchards that Flamm Orchards had accurate harvest records for.

The analysis found that both temperature and precipitation do have a role in determining the yields of apples and peaches. Every variable accounted for an increase in yield for every one degree Fahrenheit increase in temperature and one-inch increase in precipitation, except for precipitation in the month of July. For every additional inch of rain above the average in this month, the yields actually decreased.

While the data did show that the two variables do account for some variation in yields, after running a t-test, we can conclude that statistically, these variables are not significant. The timing of both of these variables is so crucial on influencing yields that it is hard to say that it is statistically significant. The timing of a frost has to hit at the perfect time, and a degree or two can account for a huge difference. Precipitation also must be available during a small window of time for it to influence yield. It is during a time of the “final swell”, which is right before harvest when the fruit set on their final bulk size. The timing that both of these variables have that can influence yield is just so small of a window that it is difficult to say that they are statistically significant, according to the t-test’s that were ran.

A few things that should be considered for future research are the location of the orchards in relevance to the climatic reading location, orchards with and without deer fencing, and different pollination methods. The closest weather readings in relevance to the yield data were roughly 10 miles away. While this isn’t an extremely far distance, it is crucial to have an accurate reading at the location of the orchard, and not having that could influence the results slightly. Deer pressure is very heavy in the area of Flamm Orchards. It is actually so heavy that the farm has begun putting 6 foot, woven wire deer fencing around all of its orchards. This is a very effective way to keep the pests out of the orchards. As a result, it can be expected that the orchards with this method will see higher yearly yields. There are also two different pollination methods for apples practiced on the farm. Apples must be cross-pollinated with another apple in order for the pollination method to be complete. One method is inner planting crab apple trees every sixth tree in the orchard. Another method is planting four rows of one variety, followed by four rows of another. It would be expected for yields to increase with the second method, due to the extreme increase in the number of pollinators.

From this research, it is intended to benefit orchard growers in the Midwest in planning for expected yields during the months of which these variables come into play. It is often times difficult for orchard growers to predict yields because of the major role that weather plays in determining the end yield. With this analysis, it can give a basis that can be observed based on how the yields were affected to frosts in the spring and precipitation during the summer months.

Hopefully this will clear up uncertainty of future yields for these producers, and give them a better idea of what to expect during harvest.

TABLES

TABLE 1 Temperature and Precipitation on Peach yields

Dependent Variable: PEACH_BU
Method: Least Squares
Date: 03/24/19 Time: 08:52
Sample (adjusted): 2005 2017
Included observations: 13 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-2014.636	6356.771	-0.316928	0.7605
MAR_MIN_TEMP	44.55126	93.14868	0.478281	0.6470
APR_MIN_TEMP	121.1794	147.1037	0.823768	0.4372
JUN_PRECIP	61.13502	256.5898	0.238260	0.8185
JUL_PRECIP	-10.90936	165.6679	-0.065851	0.9493
AUG_PRECIP	86.01922	265.9667	0.323421	0.7558

R-squared	0.119565	Mean dependent var	2967.462
Adjusted R-squared	-0.509317	S.D. dependent var	1209.855
S.E. of regression	1486.359	Akaike info criterion	17.75008
Sum squared resid	15464842	Schwarz criterion	18.01083
Log likelihood	-109.3755	Hannan-Quinn criter.	17.69649
F-statistic	0.190123	Durbin-Watson stat	1.477860
Prob(F-statistic)	0.956973		

TABLE 2 Temperature and Precipitation on Apple yields

Dependent Variable: APPLE_BU
Method: Least Squares
Date: 03/24/19 Time: 08:51
Sample: 1992 2017
Included observations: 26

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-4096.449	7140.220	-0.573715	0.5726
MAR_MIN_TEMP	139.4013	123.6276	1.127590	0.2728
APR_MIN_TEMP	321.9258	203.9262	1.578639	0.1301
JUN_PRECIP	52.48757	257.5794	0.203772	0.8406
JUL_PRECIP	-78.98148	300.8761	-0.262505	0.7956
AUG_PRECIP	278.1511	462.9375	0.600839	0.5547

R-squared	0.160379	Mean dependent var	8517.581
Adjusted R-squared	-0.049526	S.D. dependent var	3500.203
S.E. of regression	3585.832	Akaike info criterion	19.40654
Sum squared resid	2.57E+08	Schwarz criterion	19.69687
Log likelihood	-246.2851	Hannan-Quinn criter.	19.49015
F-statistic	0.764053	Durbin-Watson stat	1.448029
Prob(F-statistic)	0.586333		

TABLE 3 Temperature only on Peach yields

Dependent Variable: PEACH_BU
Method: Least Squares
Date: 03/26/19 Time: 10:28
Sample (adjusted): 2005 2017
Included observations: 13 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-804.8363	3665.410	-0.219576	0.8306
MAR_MIN_TEMP	27.46972	51.09263	0.537645	0.6026
APR_MIN_TEMP	105.9999	104.1789	1.017479	0.3329

R-squared	0.096806	Mean dependent var	2967.462
Adjusted R-squared	-0.083833	S.D. dependent var	1209.855
S.E. of regression	1259.548	Akaike info criterion	17.31407
Sum squared resid	15864602	Schwarz criterion	17.44444
Log likelihood	-109.5414	Hannan-Quinn criter.	17.28727
F-statistic	0.535909	Durbin-Watson stat	1.512702
Prob(F-statistic)	0.601043		

TABLE 4 Temperature only on Apple yields

Dependent Variable: APPLE_BU
Method: Least Squares
Date: 03/26/19 Time: 10:27
Sample: 1992 2017
Included observations: 26

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-2324.312	5752.829	-0.404029	0.6899
MAR_MIN_TEMP	131.5797	105.3494	1.248983	0.2242
APR_MIN_TEMP	291.7931	176.1041	1.656936	0.1111

R-squared	0.142856	Mean dependent var	8517.581
Adjusted R-squared	0.068321	S.D. dependent var	3500.203
S.E. of regression	3378.519	Akaike info criterion	19.19643
Sum squared resid	2.63E+08	Schwarz criterion	19.34159
Log likelihood	-246.5536	Hannan-Quinn criter.	19.23823
F-statistic	1.916643	Durbin-Watson stat	1.448046
Prob(F-statistic)	0.169872		

REFERENCES

Avila, A., J. Farias, H. Pinto, and F. Pilau. 2013. “Climatic Restrictions for Maximizing Soybean Yields.” *A Comprehensive Survey of International Soybean Research-Genetics, Agronomy and Nitrogen Relationships.* 17:367-375.

Bakshi, P. 2015. “Impact of meteorological parameters on growth and quality of peach (Prunus persiaca) cv. Early Grande under subtropical condition. *Indian Journal of Agricultural Sciences.”* 3:131-136.

Fereres F and Goldhamer D A. 1990. Deciduous fruits and nut trees. (In) Irrigation of Agricultural Crop, pp. 987–1 017. Stewart B A and Nielsen D R (Eds). American Society of Agronomy Madison, WI.

Lopez, G., R. Johnson, and T. DeJong 2007. “High Spring temperatures decrease peach fruit size.” *California Agriculture* 61: 31-34

Morton, Lois Wright, Daniel Cooley, Jon Clements and Mark Gleason. 2017. Climate, Weather and Apples. Sociology Technical Report 1046. Department of Sociology, Iowa State University, Ames, Iowa. 16 pp.

Pathak, T. 2012 “How July Temperatures and Precipitation Correlate to Corn Yields” Unpublished, University of Nebraska-Lincoln.

Peprah, K. 2014. “Rainfall and Temperature Correlation with Crop Yield: The Case of Asunafo Forest, Ghana.” *International Journal of Science and Research (IJSR)* 3:784-789.

Rather, P. 2018. “Impact of Climate Variability on Apple Production in Shopian District, Jammu and Kashmir.” *International Journal of Trend in Scientific Research and Development (IJTSRD).* 2:1511-1520.

Sanders, D., I. Altman, and N. Ferraro. 2014. "Technological Advances in Soybean Yields: A Disaggregated Approach" *Agribusiness An International Journal.* 30:207-221.

Tannura, Michael A, et al. 2008. "Weather, technology, and Corn and Soybean Yields in The Corn Belt " *Marketing and Outlook Research Reports*. Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, February 2008.

Westcott, P.C., and M. Jewison 2013. *Weather Effects on Expected Corn and Soybean Yields.* Washington DC: U.Ss Department of Agriculture, ESCS For. Agr. Econ. Rep. 2013, April.

APPENDIX

DEER FENCING IMPACT ON RED DELICOUS APPLES

As noted in the above research, deer fencing has the potential to also play a factor in the yields of apples in the Southern Illinois region. Deer populations are extremely high in most of the Southern Illinois area, adding another hurdle to the production of apples. Most of the damage from deer is seen in the early stages of tree growth. While damage is seen most frequently early in the tree growth stages, it is also important to note that damage can also occur when fruit is mature and hanging freely on the tree.

The data collected for this analysis was also gathered from Flamm Orchards in Cobden, Illinois. Flamm Orchards has been continuously implementing new ways to limit deer pressure on their fruit trees. They have found the most effective to be putting fence up. The fence is 6" tall, woven wire, and is put up around the entire border of an orchard or field. The block without deer fencing being the same block of Red Delicious apples that was observed in the above section of this paper on temperature and precipitation. It is approximately 14.79 acres on a 10'X20' spacing (218 trees per acre), first harvested in 1992 and final harvest in 2017. The red delicious orchard with deer fencing is located just west of the orchard without fencing. This orchard is a approximately 7.3 acres also on a 10"X20" spacing (218 trees per acre), it was first harvested in 2001 and is still in production today. Due to the difference in years or harvest between the two orchards, when running the regression model, only the harvest records from 2001-2017 were taken into consideration.

The methods used for this analysis was identical to that used above when analyzing precipitation and temperature on apple and peach yields. The method used follows the conceptual framework of a multiple regression analysis. This method is best fit for the analysis because it looks at one independent model and one dependent model. The dependent model is red delicious apple yields and independent model is deer fencing. The null hypothesis formed states that X (independent variable) has no effect on Y (dependent variable). Thus meaning that deer fencing has no effect on the yields of red delicious apples in southern Illinois. Through the use of the software package EVIEWS, we found the difference in yields between the orchard with and without fencing, then running a trend between the two in order to prove the null hypothesis is false.

As stated previously, the null hypothesis formed states that deer fencing will have no impact on the yields of red delicious apples in southern Illinois. The statistical impact that we expected to find was proven true. That is that deer fencing does impact the yields of red delicious apples in southern Illinois. From the calculation of the t-critical value, we can determine if we will reject or accept the null hypothesis. The t-critical value is 2.31 for a two-tailed test, with the t-value (as seen in table 5) being -6.020805, which falls in the rejection area, so we will reject the null hypothesis. Deer fencing does have a statistical impact on red delicious yields in southern Illinois. We can also see that the trend is -721.6, proving that over time yields decreased in the orchard without fencing compared to the orchard with fencing. With an R-squared value of .71, this tells us that deer fencing accounts for 71% of the variability in red delicious yields.

This additional research was conducted in order to give Flamm Orchards some feedback on how effective their fencing methods actually were. It is also intended to show growers a potential option if deer pressure is an issue in their operation. Using deer fencing around the red delicious orchard did prove to be a very significant variable when determining the yields. One thing to consider when determining if fencing is an appropriate method of resistance is the orchards location. If there isn't any area surrounding the orchard for deer to feel covered (woods, bedding ground), then the deer fencing probably won't be as effective because the deer pressure isn't as heavy. It is also important to remember that there are other variables that account for the variance in apple yields; some include pollination methods, fertilization programs, and pruning techniques.

TABLE 5 (Apple Regression with and without fencing)

Dependent Variable: DIF
Method: Least Squares
Date: 09/20/19 Time: 14:21
Sample (adjusted): 2001 2017
Included observations: 17 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	9655.128	1124.372	8.587127	0.0000
@TREND	-721.6447	119.8585	-6.020805	0.0000

R-squared	0.707318	Mean dependent var	3881.971
Adjusted R-squared	0.687805	S.D. dependent var	4332.976
S.E. of regression	2421.023	Akaike info criterion	18.53190
Sum squared resid	87920293	Schwarz criterion	18.62992
Log likelihood	-155.5211	Hannan-Quinn criter.	18.54164
F-statistic	36.25010	Durbin-Watson stat	1.754714
Prob(F-statistic)	0.000023		

VITA

Graduate School
Southern Illinois University

Parker L. Flamm

Parker.flamm@gmail.com

Southern Illinois University Carbondale
Bachelor of Science, Agbusiness Economics, December 2018

Research Paper Title:
Impact of Temperature and Precipitation on Apple and Peach Yields in Southern Illinois

Major Professor: Dr. Dwight Sanders