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Production of Industrial Hemp in Kentucky

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PRODUCTION OF INDUSTRIAL HEMP IN KENTUCKY

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Abstract

Hemp, or *Cannabis sativa*, is a plant that can be used for many products, such as textiles, oils, and seeds. Currently, the four most important textiles in the United States' manufacturing industry are cotton, wood, silk, and linen. In the 1950s, the United States Government banned the production of hemp, as it was legislated into the marijuana policy of this industry. Because of this, the hemp crop was pushed out of the textile industry and replaced by cloth, linens, and textiles. Section 7606 of the Agriculture Act of 2014 declares the State Department of Agriculture's legalization of industrial hemp research in institutions and universities, (French, 2004) regulated by the state government. With a rise in hemp production in Kentucky, many universities became involved to create change in state research. The focus of this study was on the production of industrial hemp at Murray State University. This study aimed to gain a better knowledge of the production rate and viability of four varieties on industrial hemp. These four varieties were Futura 75, Santhica, Canda, and Delores. This research studied the yield, soil content, weather, and THC and CBD content so that farmers can develop a more tactical approach to grow this crop in the future. The study contained analysis on weather, soil, and THC and CBD levels for the hemp crops grown in 2014-2017 at Murray State University.

TABLE OF CONTENTS

List of Tables

Table of Figures

Chapter I

Introduction

Many positive benefits could arise from hemp production in the American market. Unfortunately, hemp has been labeled as a drug instead of a crop, and hemp production has been stunted in the United States since the US government banned its growth in the 1950s. In the US, the chemical, textile, and rope industries wanted to outlaw hemp production because it was competition (David, 2013). Therefore, these industries lobbied against hemp heavily, and it became outlawed due to its connection to marijuana.

Humans cultivated hemp for over 6000 years before it was introduced in the United States (David, 2013). Hemp has been grown across the world throughout time, from long-dead empires such as Prussia, to America and the rest of the world in 1937, to present day (Lane, 2016). Unfortunately, the association of hemp to marijuana was a major cause of the downfall of the hemp industry in the 1950s (Lane, 2016). In recent years, hemp has become a re-emerging industry in the United States.

The hemp plant grows to about 3-4 m tall, has several varieties, and prospers across several environments within America, Europe, and China. The cultivation of hemp in the past was done by hand and harsh diligent labor (David, 2013). Nowadays, the harvest of hemp is a mechanized process. The reintroduction of hemp growth can be beneficial for social and economic development in the United States, as this crop can be used as a source of fiber for textiles, rope, and other materials. This study explains how the benefits of processing hemp can be utilized using modern agricultural technology in the United States.

Many lawmakers are re-examining the growing process of hemp, its genetic identity, and its relationship to marijuana. Hemp can be used for many different things within the field of agriculture (Fine, 2014). Hemp can be processed into oils and other byproducts, such as rope and textiles. As an agricultural-based society, we need to investigate the properties of this plant, the economic impact it can have on the American agricultural system, and the benefits that its reintroduction can have on the textile industry (Lane, 2016). Hemp can economically revitalize some parts of the agricultural industry and provide many new jobs to farmers and those in the textile industries (Fine, 2014).

In 1937, the American government imposed a ban on cannabis in the continental United States akin to the prohibition that credited marijuana with its relationship to the psychological and physical effects on people (Lane, 2016). Lawmakers were racially profiling African-Americans in connection to marijuana, stating that it has a more intense effect on the African-American community (Lane, 2016). Hemp was put in this section of the law due to its genetic similarity to the marijuana plant. Several factors pushed the

American government to ban hemp. One example of this is that THC levels of hemp were thought to be high and thus a major factor in its psychological effects. However, textile representatives lobbied the United States Congress in the 1950s to ban cannabis in the United States because of other issues, such as production costs (Fine, 2014).

Currently, it is illegal to grow hemp or marijuana in the United States by the federal legislation. However, a new farm bill, the Agriculture Act of 2014, instigated a motion to allow the growth of hemp plants in several states (Lane, 2016). Through this, the production methods and benefits of the hemp crop can be studied in universities and colleges across the nation. Through this process, Mitchell McConnell and Rand Paul were major lawmakers pushing to allow the growth and study of hemp in several states, such as Kentucky. For the past four years, this farm bill has allowed the growth of hemp for educational purposes at the University of Kentucky, Murray State University, and Western Kentucky University. These Kentucky universities are studying and researching the effects of the hemp crop within the United States and Kentucky to show how a very useful crop can be produced in our economy (Williams, 2015). Several universities are studying the effects of pesticide use on the crop, while other universities are looking at the production and economic policies of hemp growth.

Hemp will likely play a significant role in the future of American agriculture. There is a possibility for the crop to develop into a promising industry. Overall, the general purpose of this research is to understand how to grow this crop more efficiently within the state of Kentucky. As a result, better tools can be developed for the production and research of hemp. This study will explore possible research tools regarding hemp production. In the United States, issues also need to be resolved in regards to measuring and determining prices for hemp output (Fine, 2014). This study aims to provide data on hemp production, hemp harvesting, and soil fertility, which will be helpful for future studies.

Statement of the Problem

This study investigated the production of industrial hemp, as it has been a significant industry in the past and was restricted throughout history. In modern day, hemp production is outlawed in the United States and its territories.

In the last few years, the production and study of hemp has been initiated within universities and research farms across the United States, if the state legislator and the state department of agriculture agrees. Many factors can affect industrial hemp, such as soil fertility and weather. The stability of industrial hemp is dependent on the environment, as it requires a temperate climate to grow. Particularly in the summer, growth of the crop is contingent on water content and the availability of water. Moreover, other environmental factors affect the yield and quality of industrial hemp, such as the presence of minerals in the soil. The use of minerals, either present in the soil or placed there by farmers, determines the sustainability of the crop. While farmers cannot control many environmental factors, such as temperature and humidity, they can manipulate other factors, such as the mineral levels in the soil. Different methods of managing the soil affect the ability to grow this crop within Kentucky's moderate climate.

Purpose of the Study

The purpose of the study was to evaluate how industrial hemp grows in Kentucky with controlled environmental conditions, such as soil fertility and mineral use. Moreover, other major issues within production have not yet been explored and could affect the data. The purpose of this study was to explore the best means to produce industrial hemp, which is helpful for future growers.

Research Objectives

Overall, the general objective of this research was to understand how influential factors, such as soil data and environmental issues of climate, affect industrial hemp growth in Kentucky. Moreover, the study attained a better understanding of the characteristics of this crop when grown in Kentucky. One objective of this research was to determine the correlation between weather and soil data on the THC and CBD contents of the crop. Another objective was to determine the correlation between annual weather data and its influence as an environmental factor for the yield of the crop. Another objective of this study was to develop soil data for this crop and explore the mineral needs for the crop to grow effectively.

Research Questions

The purpose of this study was to investigate the means of hemp production and other factors that affect hemp growth in Kentucky and the United States. In addition, this study developed information regarding the impact of minerals in the soil and environmental factors within Kentucky. Moreover, this study explored how to grow hemp so that it can become a major industry in the United States.

Is this crop affected by the weather and environmental conditions, such as temperature and mineral levels in the soil?

Can the development of new soil tactics resolve some of the problems that occur within the industrial hemp industry?

Can effective strategies be developed for growing this crop?

Does the yield correlate with soil fertility and weather conditions?

Is there a significance in mineral use in the soil that can affect the growing cycle of industrial hemp?

Operational Definitions

Hemp - A tall, widely cultivated Asian herb (*Cannabis sativa* of the family *Cannabaceae*, the hemp family) that has a tough bast fiber and is commonly used for fibers. The plant has many varieties, and the THC level must be 0.03% or lower to be considered hemp (C. indicia).

Chemical - The science that deals with the composition and properties of substances and various elementary forms of matter (C. Sativa).

Textile - Any cloth or goods produced by weaving, knitting, or felting (C. Sativa).

Scope of the Study

The scope of the study contained measurements of the soil data and climatic conditions at Murray State University. The study centered on four different varieties of hemp, which were Futura 75, Santhica, Canda, and Delores. This study evaluated weather data, yield data, climate data, and soil data. These results provided insight into how the crop is most efficiently grown and produced in the state of Kentucky. The study took place at Murray State University at West Farm and Pullen Farm. The results were analyzed and developed into data sets to be used for future studies. The study aimed to develop an understanding on how to measure soil and climate conditions as well as the effect of these on the hemp yield. The study gathered information on how to produce this crop and develop a better commercial industry for hemp.

Assumptions

One assumption made was that the plants grown from the seeds contained THC and CBD. If these seeds did not contain THC and CBD, it would skew the data of this study as the lack of THC and CBD would not be due to climactic and soil conditions but due to the seeds.

This study was contained to soil and climate research. The data collected in the fields on Murray State University farms was compared to determine whether there was a correlation between weather, climate conditions, and soil data and its effect on the yield of the crop. Overall, the limitations to this study are listed below:

1. There was not enough data gathered in the past to reach a long-term correlation, as the plant has only been grown for three years at Murray State University.
2. Data has been collected for the past four years.
3. There is a lack of mechanized machinery developed for this crop available in the United States.
4. Little information is available on how to increase industrial hemp production rates through the use of minerals in the soil in the United States.

Significance of the Study

Significance of this study was achieved by developing a foundation for soil data. This was completed by analyzing the climate and soil data and its effect on the yield data. Comparing climate data and yield data was an important element in gathering information for future studies on industrial hemp. This soil data was analyzed to discover necessary minerals for the optimal growth of the industrial hemp crop. This information could aid Kentucky's hemp industry in the future. The study will be continued in the future at Murray State University to further the research into hemp production. This study tracked weather, soil, and climate data and investigated the correlation between these and overall plant growth.

Chapter II

Review of Relevant Literature

Introduction

The purpose of this chapter is to present a review of the related literature for this research study. This review sheds light on the effectiveness of contextualized learning and the need for further study in this subject. The review is divided into the following sections: (1) Introduction; (2) History of Industrial Hemp; (3) Weed Control for Hemp; (4) The Difference between Hemp and Marijuana; (5) Hemp Economy; (6) Plant Characteristics; (7) Cultivation; (8) World Market Considerations; (9) Manufacturing Uses of Hemp; (10) Soil pH; (11) Viability of U.S. Cultivation and Processing Yields; (12) Theoretical Framework; (13) Summary.

History of Industrial Hemp

Hemp has been cultivated in several civilizations across the world in the last 4000 to 6000 years. Some of these civilizations include the Egyptian and Chinese as well as the Roman Empire (Fine, 2014). Over the ages, hemp has become an important crop for many industries and societies, as it is an important source in the production of textiles, rope, and other materials.

Throughout time, many empires across the world used hemp for various reasons. These uses included naval material and textile weaving. Moreover, the British Empire grew hemp in the American colonies in the 1640s (Fine, 2014). Hemp was first cultivated in New England and continued to be cultivated in the centuries after the United States gained its independence from Great Britain (Fine, 2014). The United States grew hemp for textiles and rope, maintaining an industry within the economy. George Washington also grew hemp on his farm (Lane, 2016).

Moreover, the first American-made jeans, created by Levi Strauss, were composed of hemp (Fine, 2014). The southern United States became a major producer of hemp because it had optimum climate and textile resources. Several states are ideal for hemp growth. These include Illinois, Kentucky, Missouri, and Virginia (Lane, 2016). In the late 1800s, these states were the primary hemp producers in the United States, until new laws and regulations against hemp growth were implemented (Lane, 2016).

Laws surrounding the cannabis plant, such as the Marijuana Tax Act of 1930, limited the production and sale of plants in the cannabis family in the early 20th century (Fine, 2014). This law also enabled the US Department of Treasury to tax profits made from the crop. During World War II, there were major producers of hemp in Illinois, Kentucky, and Virginia. These states manufactured the largest amount of hemp in the United States for the Allied forces in World War II.

In many parts of the United States, hemp continues to grow wild as a result of the industry during World War II. The industry created by the war efforts bred a highly competitive market for textile industry. The hemp industry grew in Kentucky, Tennessee, and many other states to aid the war effort. Farmers in Kentucky used to grow hemp on the sides of ditches and other unconventional places to increase hemp production for the war effort. Farmers in Austria-Hungary, Romania, Russia, Spain, Germany, France, and England also grew hemp for the war. This textile was very versatile and thus used to produce uniforms, rope, and other things for the Allied war effort (Lane, 2016). This crop was beneficial for the production of Allied clothing. Moreover, the Germans also used hemp for uniform textiles during World War II. Because of the cuts in production of cotton and other textile materials during this time, the German war effort used a substitute of hemp production. In many parts of Europe, the final years of World War II brought an increase in hemp production. At the close of World War II, 52,000 acres of hemp were being produced in Europe. Moreover, drumming production of hemp was 20% of the countries' production of textiles. Throughout the war, Germany and Italy were looking for an alternative way of producing textiles because of Allied blockades across Europe (Lane, 2016). Therefore, both the Axis and Allies greatly benefitted from the use of hemp in the war. After the war ended and production waned, competing textile industries began to lobby against the hemp industry in 1947 (Raney, 2006). These textile industries achieved their goal in outlawing the growth of plants within the cannabis family in the 1950s, which includes the hemp crop (Fine, 2014).

Textile industries lobbied to ban hemp production in the 1950s because of the threat it posed to other textile manufacturers, such as those of cotton. Regardless, it is clear that hemp can be greatly beneficial, as seen by its use in the world wars. Hemp can be very useful for local economies, although the ban on hemp growth remains to this day, even though many countries continue to grow hemp (Raney, 2006).

In the United States, this crop has not been commercially grown in 65 years. Between 2014 and 2018, there have been significant movements to legalize the growth of the hemp crop within the United States, the US Department of Agriculture, the Department of Agriculture in Kentucky, and most state governments (Raney, 2006). The support of senators Mitchell McConnell and Rand Paul has worked to reduce federal regulations on this crop. In 2014, Commissioner James Comer of the Department of Agriculture in Kentucky worked in Kentucky legislature to legalize hemp growth within the state of Kentucky. He achieved this, and now it is legal to grow industrial hemp with a permit and sell hemp products in the state of Kentucky. He became a congressman in 2017 and looked towards federal legislation to legalize industrial hemp as a commodity crop. However, there is still a lot of public uncertainty about this legislation as there are still taboos surrounding the growth of industrial hemp (Raney, 2006). The hemp trials in Kentucky promote cooperative development between the state and the federal government to determine the viability of this crop.

Weed Control for Hemp

Weed control is one of the many factors that can affect the growth of industrial hemp. Determining the best means of weed control is crucial for the future of this crop. As of 2017, there are no registered herbicides, pesticides, or fungicides labelled to treat industrial hemp in the United States (Bouloc, 2013). Many studies and farms found that the industrial hemp crop should be planted at a high seeding rate to prevent weed growth throughout the growing process, which is an organic solution for this problem. Having a higher seeding rate helps to maintain low populations of weeds because a denser hemp canopy prevents the sunlight from reaching the weeds, thus inhibiting weed growth (Bouloc, 2013). As of 2017, The US Department of Agriculture has not yet labeled anything for weed control, but it is likely that there will be new products developed to aid with pest and weed management for the industrial hemp crop (Bouloc, 2013).

The Difference between Hemp and Marijuana

There is a difference between the hemp and marijuana crop. While both of them are in the same species, *Cannabis*, there is a slight difference between marijuana and industrial hemp (Spalding, 2014). While they are of the same variety, the chemical makeup of hemp and marijuana differs slightly. The THC levels in marijuana range from 3% to 15%, while the federal law’s legal limit in the United States means that THC levels in industrial hemp must be less than 0.03%. This is covered in section 7606 of the

Agriculture Act of 2014. Farmers have modified industrial hemp over time through genetics and breeding to have lower THC levels (Spalding, 2014). Industrial hemp can be very beneficial for the economy, as it produces high yields for fabric and oil production. Most varieties can be seeded at a rate of 25% to 35% seeding dry matter (Spalding, 2014). Hemp is most beneficial when used for textile use and CBD oil, while many nations use marijuana for medicinal and recreational purposes (Spalding, 2014). Therefore, there is a difference between hemp and marijuana in both THC content and uses. This study only pertains to the production of industrial hemp.

Hemp Economy

Industrial hemp has been used for textiles and other purposes throughout world history. The development of the hemp economy first started on the North American continent in the early days of the British and Spanish colonies. They started to develop industries for this textile through the production of ropes, uniforms, and other products to trade throughout the world. The British Empire was the first to produce hemp on an industrial scale and used hemp products, specifically ropes, for their naval and trading vessels throughout the empire (Lane, 2016). This was very influential for the economy of the British Empire.

The industry continued to expand in the British colonies and farmers discovered more about this crop. Hemp grew well in America, and some of the founding fathers cultivated this crop in their farms. In the early 1800s, many Americans industrialists created large plantations to grow industrial hemp. One example of these American industrialists was Henry Clay, a senator from Kentucky. He grew industrial hemp for years on his farm in Lexington, Kentucky. Throughout the 1800s, the southern states continued to grow industrial hemp. This industry grew into one of the country's major industries, and its production rates were comparable to that of cotton and tobacco (Sankari, 2000). In this time, Kentucky was one of the major producers of hemp in the world. However, the biggest economy for growing hemp was in Russia. In modern times, Russia continues to grow hemp for textile use. In many parts of the world, hemp is a major economic force in the textile industry and CBD oil industry. The American hemp industry has the potential to grow into a significant economic force in the future, once legislators and members of society understand the economic benefits that can derive from this crop.

Plant Characteristics

The hemp and marijuana industry are vastly different as these two specific plants differ in some characteristics. However, laws and regulations surrounding marijuana have significantly affected the entire cannabis family. These two varieties of cannabis, hemp and marijuana, have different THC levels and induce different psychological effects because of the THC levels (Bourrie, 2003). Hemp plants can grow anywhere from 3 to 19 feet tall, and the seeds are less than a millimeter wide. The stem is woody, hard, and very stocky (Bourrie, 2003). The leaves have seven points and look exactly like a marijuana leaf.

However, the plants vastly differ by variety, and there are numerous varieties of hemp. Hemp generally has a lower amount of THC than marijuana (Bourrie, 2003). The THC level of hemp must be lower than 0.03% to be considered hemp. THC is the element that is largely responsible for many of the characteristics and psychological effects contributed to the consumption of marijuana. The hemp plant grows yearly in the summer and thrives in many parts of the South. This crop is both a subtropical plant and a temperate plant. Therefore, its growth is viable in the Midwest and parts of the South.

Cultivation

Cultivation depends upon the variety of the hemp crop. The conventional hemp crop can grow up to 12 feet. Most types vary in height; there are short and long stemmed varieties, and both varieties have been cultivated. In several parts of the world, such as Europe and China, hemp farming is sometimes done in the traditional way, by hand with a machete or a scythe. This is the most primitive way to cultivate this crop and was mostly used in the early 1940s before the industrialization of the hemp crop. Before mechanization, hemp was cultivated through intense manual labor (Sankari, 2000). Moreover, materials, machinery, and other plants can significantly affect cultivation. People in United States universities and companies started to develop new harvesting machinery and cultivation tools in 2013 and 2014.

Figure 1 below, dated to 1917, demonstrates how American agriculture was producing hemp through mechanized means for uniform production in World War I. In this period, Kentucky hemp markets were very important for the economy and very influential in the American society. In the early 1900s, it was important to develop new tools and mechanized machinery for hemp production to better supply the textile industry. At this time, hemp was only used for textiles and was not yet used for CBD oil. Studying the methods of early hemp production can be very influential in the development of modern methods. These pictures from 1917 demonstrate the types of tools and mechanized machinery that were used for industrial hemp.

Figure 1.0 The Harvesting of Hemp in 1917

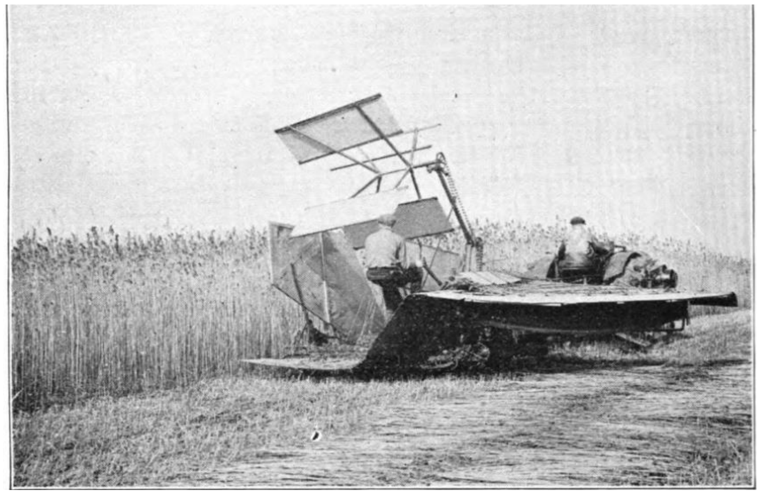


Figure 1.0 Humphrey, J (1919).*A modern hemp harvester,* Lexington. KY: University Kentucky Agricultural Experiment

Figure 1.1 Hemp Baler in 1917

Figure 1.1 Humphrey, J (1919). *The hemp gather- binder*, Lexington. KY: University Kentucky Agricultural Experiment

It is crucial to reflect on American agriculture of the past to see how hemp was grown, which will help to guide development of new machines and technologies. These photographs can be very beneficial for modelling new technology. American hemp production has fallen to the wayside due to the banning of hemp production, but there is hope that the hemp industry can be revitalized for the future of the American economy.

The hemp crop grows in 60-80°F or 13-22°C. These temperatures are the optimal range for growing a plant that will develop a complete structure. This crop can be cultivated in the Midwest and the South and harvested in the fall or summer, depending on when it is planted. Yield data for the hemp crop in the state of Kentucky has been used to better understand how to increase the efficiency of harvesting with a machine.

This study will grow four different varieties of the hemp crop within the state of Kentucky. The machines used in this study are being tested with the help of CV Science and the University of Kentucky (Williams, 2015). Cultivation in the past was a very difficult process because of the woody stems and the level of manual labor needed. Today, technology is in development that will lead to greater efficiency in cultivation, such as hemp combines and crop scouting.

World Market Considerations

Because of production rates in the 1800s, hemp became a major commodity in the world market. It was used extensively for paper, textiles, rope, and other goods (Bourrie, 2003). Around this time, hemp became a major cash crop because of low labor costs and minimal production expense. This crop then flourished in the market because of low market prices of goods and services relative to other products available at the time (Bourrie, 2003).

Many things, such as low labor costs and few production expenses, allowed hemp textiles in Asia and Central Europe to become competitive in the markets of rope and other textiles in the 1800s (Fine, 2014. In the last 60 years, the hemp textile industry in China has greatly benefited from the American market foregoing hemp production. However, the absence of the American market in the hemp industry has been disadvantageous on world economy. Hemp provides manufacturers with a myriad of materials that are very popular across the globe (Fine, 2014).

In addition to hemp's use in the textile industry, this crop is also used in paper production (Williams, 2015). Recently, American markets have been trying to introduce hemp products into the market system. To do this, private investors, such as CV Science, have provided research farms and materials across the nation in an attempt to discover the most efficient means of hemp production and the tools necessary for optimum growth. As hemp can flourish in many different environments, the long-term uses of hemp can be greatly beneficial to America's economy. The lack of hemp machinery can provide producers with economic incentives to trigger the production of saws and other tools, creating a niche in the market (Bourrie, 2003).

This plant can be also used in other areas, such as a feed supplement for cattle and other livestock. In relation to other feed supplements, large-scale hemp production is more feasible, less costly, and can be grown and harvested three times a year (Bourrie, 2003). Therefore, there is much potential for this crop to become an integral part of American agriculture.

Manufacturing Uses of Hemp

The development of materials in this industry has greatly improved in the past few years because of the availability of organic products within the world's economic market. As European markets never experienced a ban, they are vastly ahead of America in terms of manufacturing and production (West, 1996). The United States is not benefiting from the materials of this crop because hemp production has been banned for more than 60 years. In the United States, we obtain our materials from outside sources such as China, Europe, and South America, which is costly and inefficient (West, 1996).

Moreover, the biggest hemp commodity imported into the United States is hemp oil, which has been championed as a vitamin supplement. This has grown into a major manufacturing race for America. There is pressure to lobby for the legalization of hemp, but there are also many factors that still need to be considered for this controversial yet profitable crop (West, 1996). The United States is going to have difficulty producing profitable rates in the industry at first, unless they provide farmers with new technologies to manufacture it (West, 1996). People have an aversion to growing this crop because of its link to marijuana. Ultimately, this misinformation and prejudice will continue to impact the production of hemp in the American agricultural industry. The production of industrial hemp in the United States is going be a great feat, although manufacturing uses of this product will ultimately yield positive outcomes in industries such as clothing, rope, textiles, oils, and vitamins (West, 1996).

Figure 1.3 Hemp Factory in Kentucky

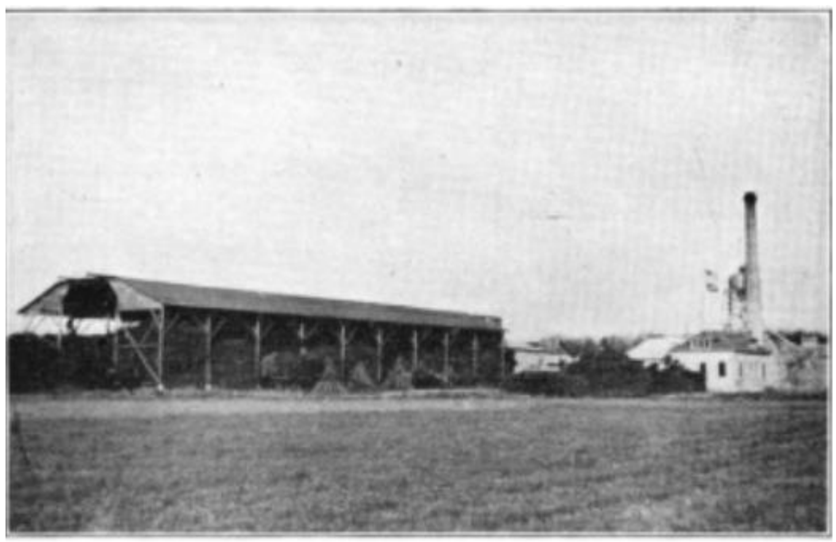


Figure 1.3 Humphrey, J (1919). *A Modern Hemp Mill Capable of Breaking, Cleaning, and Baling,* Lexington. KY :University Kentucky Agricultural Experiment

Figure 1.4 Outside View of an Industrial Hemp Factory

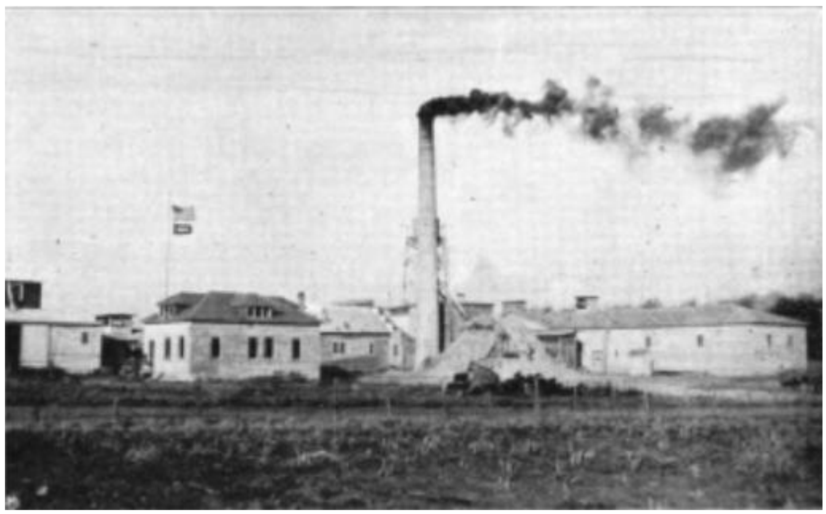


Figure 1.4 Humphrey, J (1919). *A Modern Hemp Mill Capable of Breaking Cleaning, and Baling*, Lexington. KY : University Kentucky Agricultural Experiment

Figure 1.5 Long Hemp Fiber as it Comes from the Scutcher

Figure 1.5 Humphrey, J (1919). *Long Hemp Fiber as it Comes From the Scutcher* Lexington. KY: University Kentucky Agricultural Experiment University Kentucky Agricultural Experiment

In Kentucky's past, industrial hemp has been grown for many uses and has aided in many wars. It has been very important for the textile industry as it was a great commodity in the past as an alternative to other fabrics, such as cotton. In the past, Kentucky's economy flourished under this crop.

Viability of U.S. Cultivation and Processing Yields

The actions of legislators in the state and national level who fought for the farm bill have provided an opportunity to investigate the viability of this crop. Research and development has taken place on university farms across seven states that have justified the growth of this crop.

This research opportunity has arisen in the state of Kentucky. Under the protection of Commissioner Comer, the hemp crop has been studied in the state on research farms. In 2013, Commissioner Comer added to the Kentucky state legislature an understanding that manufacturing this crop is beneficial to the economy. Kentucky is currently the forerunner of all hemp production in the United States (West, 1996). Internationally, countries such as France, the United Kingdom, and the Netherlands are major producers and cultivate hemp in large quantities. The United States can learn about the production and manufacturing of this crop from these and other successful hemp producing nations.

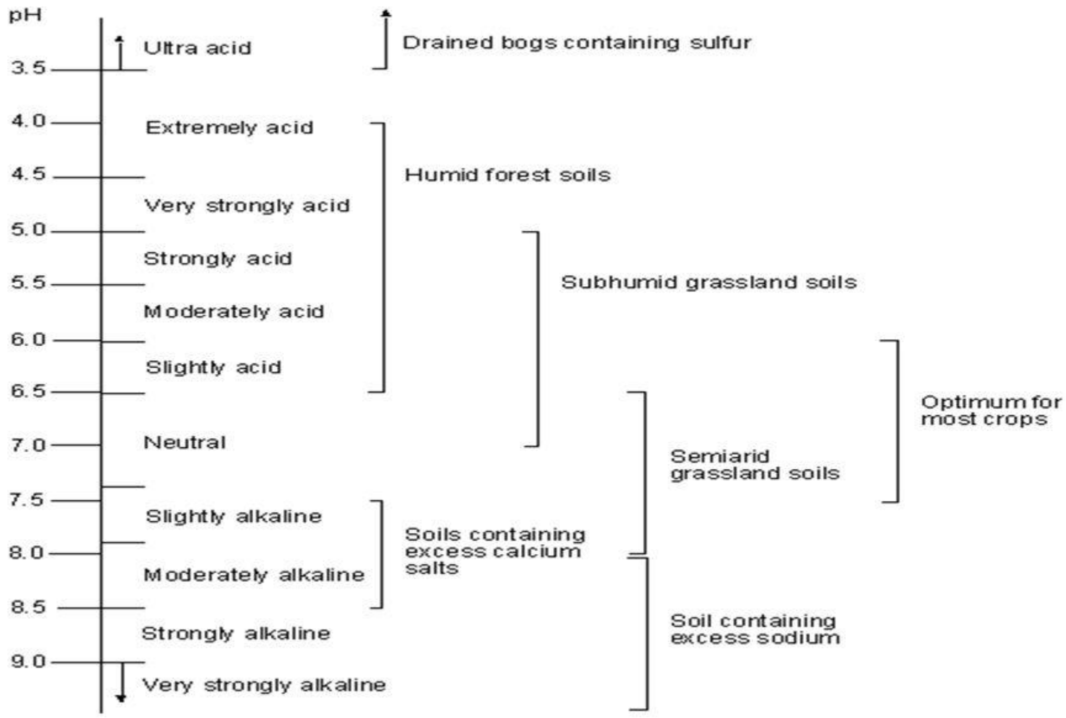
Another instance of prosperous hemp production is in Canada. Canada produces 800 pounds of hemp per acre annually, so the US should look to Canada for an understanding of how to cultivate hemp in North America. Within the US, people often look to Kentucky for information on the hemp crop and its uses. So far, the crop has only been manufactured in low quantities, a task that began in 2013 (West, 1996). Farmers were new to the cultivation of this crop and researchers did not have much modern information about this crop. It has not been grown in Kentucky or other states for such a long time that the crop has become a new and exciting prospect for Kentucky's agricultural system.

Many people expect large profits from hemp with regard to paper, rope, textiles, oil, and organic materials. People want the market to boom; however, it has been very difficult for Kentucky producers because the materials needed to create a more sustainable crop are not yet available (West, 1996). There is still a lot of information about hemp manufacturing that is out of date or unknown, so it will take some time for this crop to yield benefits for the economy. Over time, research and experimentation will determine how to improve manufacturing in Kentucky (West, 1996). Until then, manufacturers should study hemp production in Canada and other nations to determine the best way to move forward in the United States.

Soil pH

The feasibility of hemp greatly pertains to the quality and composition of the soil. There are many types of soils across the United States, and the level of nutrients in the soil affects the quality of the crop. One of the most important factors that influence the growth of a crop is soil (Michael, 1993). Unlike tobacco, hemp does not deplete the nutrients in the soil, so the soil remains fertile. Researchers should test many types of soil with this crop to determine the optimal soil conditions for hemp growth, and they sold investigate soil types such as clay loam, loam silt, and silt clay. These three types of soil are the most efficient to grow industrial hemp (Michael, 1993). The standard pH for growing industrial hemp in the United States is 5.8 to 6.0 (Michael, 1993).

Figure 1.6 Soil pH Ranges for pH Classes



Troth and Thompson (1993). *Soil pH Ranges for pH Classes and Associated Soil Conditions*. Washington, DC: National Soil Survey Manual.

Theoretical Framework

The study aimed to develop proper modes of production and provide insight for areas such as cultivation and harvesting. This production study focused on how to better the means of growing hemp in the state of Kentucky.

Summary

This literature review highlights the benefits that can accompany hemp production in the state of Kentucky. This review presents the production rates of hemp both in and out of the United States and explains how cultivation and other factors make hemp a greatly beneficial crop. However, there is still a lot of uncertainty about this crop. There are many tools and production tactics that will need to be developed before hemp production can be profitable. The skills and knowledge to grow hemp in the United States are still being constructed, which are vital to meet the demands of production. This literature review illustrates the many aspects of cultivation and the importance of different areas within the hemp industry. Over the last 65 years, farmers in the United States have not been growing industrial hemp on a large scale. However, in the past four years of production, researchers have learned about many processes that are crucial to understanding the benefits of industrial hemp growth for Murray State University and the state of Kentucky.

Chapter III

Methodology

Introduction

This chapter contains information on the four primary aspects researched in this study. The methods section provides statements about the different yields of the varieties of hemp, THC and CBD testing, weather data, and soil testing. The methodology is divided into the following sections: research design, subject selection, instrumentation, data collection procedures, data analysis procedures, and budget and time schedule.

Research Design

This study used a contained design. It showed the growth of four varieties of industrial hemp crops. The study also investigated whether weather affected the four varieties planted by measuring the data obtained from Western Kentucky University's mesonet and the weather station on Murray State University's West Farm, which is located near the test plots. This data was analyzed, compared to the data regarding the plant growth, and organized into a chart. This experiment was completed in four blocks of relationship design. The four varieties were planted in July 3, 2017 and harvested in mid-August. Weather data, yield data, THC and CBD content data, and soil data was collected throughout the growing process. Monthly soil testing was completed to compare the relationship between the yields. The objective of this study was to discover optimum conditions and methods to produce the hemp crop efficiently in Kentucky and the United States.

Variables

This experiment had many controlled variables. These included the varieties of hemp, the distance between plants, the soil depth, the soil inputs and outputs, and the means of harvesting. Using the same methods of growth and harvest across all varieties and test plots is important in understanding how to plant this crop in future studies and how to evaluate the effectiveness of the methods used. Soil data, climate data, yield data, and THC and CBD data were all gathered to determine their effect on the growth cycles of the crop.

Population

The design method was a chosen 200 pounds of each variety of seed. These varieties included Futura 75, Santhica, Canda, and Delores. Each variety of seed was distributed into one of four plots on both West Farm and Pullen Farm. Shipments of seeds arrived in 100-pound increments according to the regulations set by the Kentucky Department of Agriculture. West Farm's sample size was 2.4 acres and Pullen Farm's sample size was 1.4 acres. These test plots were seeded with four varieties: Futura 75, Santhica, Canda, and Delores. Soil testing on the West Farm included a sampling of 10 points around 2.4 acres.

Sampling Procedure

On June 3, the seeds were planted on West Farm and Pullen Farm at Murray State University. 200 pounds of each variety of hemp was planted. CV Science and Kentucky 21st Century provided the seeds and materials.

During the growing process, the researchers collected samples and measured crop growth every two days. Each variety of hemp was measured and a sample was collected. Soil outputs were tested once in the middle and once at the end of the growing cycle for each variety of hemp. On both West Farm and Pullen farm, researchers extracted soil samples of ten random spots around 2.4 acres by digging with a spade and mixing these samples in a five-gallon bucket. This process was repeated ten times. Once packaged, these samples were sent to Waters Agriculture laboratory in Owensboro, Kentucky. The results of these tests were sent back by email within a week.

Western Kentucky University's mesonet network of weather stations across Calloway County collected the weather data. This network provided soil temperature and moisture. Data was also collected from the weather station on the West Farm at Murray State University. These data sets spanned from May through September of 2014, 2015, 2016, and 2017.

When the crops were planted, seeding rate varied depending on the variety, which spanned between 45, 55, or 75 seeds per pound per acre on West Farm (see figure 3.1). Plot size was 8' by 20' for each of the four varieties. Yield samples were collected in 25-inch by 16-inch rows on Murray State University's West Farm. Within these rows, a measure was taken of 25 cm by 25 cm of each variety. Then, the bottom of the plant was clipped and the samples of each variety were dried. These varieties were Futura 75, Santhica, Canda, and Delores. These samples were thrashed and cleaned. Then, the seeds were measured and the stems were counted.

For THC and CBD sampling, multiple plants from each variety were clipped by hedge clippers in 12cm increments. Five to ten samples of each variety were taken in this way. Then, the samples were placed in paper bags and marked by variety, seeding rate, and the day they were clipped. The samples were then taken to the Murray State

University laboratory and dried for 48 hours in the dryer. After drying, the samples were thrashed by hand and put into a blender. These blended materials were put into a tube and sent to ElSohly laboratory to be tested for THC and CBD content. The results were sent back within two weeks by form of an email.

Instrumentation

Instrument Selection

In this study, the plots were separated by seed varieties. The method of research was chosen by digging average planting depths of 0.25 inches. The soil was pre-treated before planting, using (46-0-0) fertilizer. No herbicides and insecticides were applied to the soil. Instead, the crop was grown organically with a no-till method. However, a standard pretreatment of glyphosate was applied before planting. The plots were seeded with a drill seeder on the modified research plots. There was an average planting gap of 0.25 inches and an average planting depth of 0.25 inches. The four varieties were measured in the yield of the dry grains for the figure of dry matter of the yield implant. Both grain and fiber of the crop were harvested with the use of a combine. The yield sample was taken at the end of the growing cycle from the same randomly selected 1 m^2 area within each plot, avoiding plot edges. Grain was thrashed and cleaned by hand, dried by heated forced air to 9% moisture, and weighed. Grain data is expressed in pounds of dry grain/A. Stems for fiber yield determination were first counted to find plant densities. This data was expressed as the number of plants/A. The stems were subsequently dried by heated forced air for 48 hours and then weighed. Fiber yields are expressed as pound of dry matter (DM)/A.

Data Collection

The Kentucky mesonet was used to collect weather data. This data was taken from the weather stations in Calloway County and Trigg County. These weather stations measure wind speed, temperature, soil temperature, barometer, and air moisture. This data was synthesized through two-factor ANOVA tests and descriptive data sets. Soil was gathered with a bucket and a shovel from twelve coordinated points around West Farm and twelve coordinated points around Pullen Farm. Then, all of the samples from each farm were mixed together. The soil was then put into sample bags. This process was repeated two times on each farm, one in the middle of the growing process and once at the end of the growing process. Soil samples were sent from the West Farm and Pullen Farm to Waters Laboratory in Owensboro, Kentucky. About one week later, the information from the samples was received on a soil analysis report via email. This report included information regarding the levels of phosphorus, magnesium, calcium, soil pH, buffer pH, sulfur, boron, zinc, manganese, iron, and copper present in the soil samples. This data was analyzed using excel, descriptive data sets, and one-factor and two-factor ANOVA tests, depending on the type of data.

Upon receiving the results from ElSohly Laboratories about the THC and CBD content of the samples on West Farm and Pullen Farm, descriptive data sets and one-factor and two-factor ANOVA tests were used to analyze these results. The choice of test was dependent on the amount of data available. For these tests, significance was measured by whether the F-value > 2 and the p-value < 0.05.

Instrument of Study

Figure 1.7 Dryer

Figure 1.7 is the dryer that was used to dry the THC and CBD samples for processing. Each round of samples was dried for 48 hours in labelled paper bags.

Hemp Thrasher

The available wheat thrasher needed to be repaired for use on the industrial hemp. The thrasher was used to expedite the process of separating the seed from the stem and organic matter. An old wheat thrasher was used in this study because it was the most apt machine for the size of the seed. However, modifications needed to be made on the machine. For this thrasher to be used, the motor had to be replaced and an extension had to be added. This included adding a larger belt and a metal plate. Gasoline was used to power the machine, and oil was used to lubricate the engine. This study found that the thrashing method needs to be improved for use on industrial hemp. For example, the fan needs to be modified to a slower rotation to better separate the seed from the organic matter.

Figure 1.8 Hemp Thrasher

With the use of this machine, the process was much quicker and more efficient than hand thrashing. Seeds came out from the bottom slew and fell into an oil pan. Researchers tried hand thrashing, but this process was very difficult, tedious, and slow.

Figure 1.9 Finished Results of a Thrashed Sample of Futura 75

When each variety was thrashed, it was apparent by the quality of the stems which varieties are used for textiles and which are used for CBD content. Figure 1.9 shows the finished results of a thrashed sample of Futura 75, which is used for textiles and rope making. Futura 75, Santhica, Canda, and Delores were all thrashed successfully in the thrasher. In this process, the seed was separated from the organic matter, which can be seen in the figure below.

Figures 2.0 Resulting Seeds after Thrashing

Figure 2.0 shows resulting seeds after the process of thrashing. In this study, the seeds were effectively contained in an oil pan after being released from the thrasher. This oil pan prevented the seeds from mixing on the floor. Machine thrashing was proven more effective than hand thrashing. While the overall loss of seeds was greater with machine thrashing, the time-efficiency of this method makes it more economic, as labor for hand thrashing is costly. However, this machine must be modified in the future to make this process more effective. This thrasher was originally built for wheat, but this is the closest machine that could be used for the small hemp seeds, as there are not yet any effective machines on the market for hemp thrashing. Currently, this method works, but it needs more modifications to be efficient for hemp thrashing in the future on a large scale. This also provides information on how we could develop future modifications to benefit the hemp thrashing process. However, further research needs to explore possible

modifications for industrial hemp thrashing machines.

Figures 2.1 Seed Cleaner

Figure 2.1 above is a standard seed cleaner used for many different crops. It was created for a seed like soybean, but it was used for the industrial hemp seed. After thrashing, cleaning must be done to separate the seed from the organic matter. With this cleaner, the blower propels air upwards into the tube for five minutes on a timer. It has a fan on the bottom that blows the seeds upwards. The grain matter catches on the ridges, and the seeds catch at the top. The air can be vented, and this study used a quarter of an inch of venting. This machine was used for seed cleaning for all four varieties in the

2017 test plots, which were Santhice, Canda, Delores, and Futura 75.

Data Analysis

The data was analyzed using one-factor and two-factor ANOVA tests (SAS Institute, Cary, NC). Means were separated by F= protected LSD at $\alpha=0.02$. In addition, measures of variability in soil samples on the West Farm were analyzed in the form of standard deviation. The same methods of soil sampling were applied at Pullen Farm as at West Farm. However, organic and traditional fertilizer treatments were used at Pullen farm. The soil samples were sent to Waters laboratory in Owensboro, Kentucky. About one week later, the information from the samples was received in a soil analysis report via email. This report included information regarding the levels of phosphorus, magnesium, calcium, soil pH, buffer pH, sulfur, boron, zinc, manganese, iron, and copper present in the soil samples. These results were organized into bar graphs, line graphs, descriptive tables, scatterplots, and the stat pack on Excel. The data was then analyzed using excel, descriptive data sets, and one- factor and two-factor ANOVA tests, depending on the variety of the data. Upon receiving the results from ElSohly Laboratories about the THC and CBD content of the samples from West Farm and Pullen Farm, one-factor and two-factor ANOVA tests were used to analyze these results. The choice of test was dependent on the amount of data available. Within these tests, significance was measured by whether the F-value > 2 and whether the p-value < 0.05. Descriptive data sets were also used to analyze the data.

Time Schedule

This study was conducted over a five-month period, from July 9 to August 25, 2017. Hemp was planted and cultivated within the first three months of the study. During this time, the Murray State University farm managers managed the hemp fields. The next two months were dedicated to statistical analysis. This included collecting data on weather, soil, CBD, and THC content. Statistical analyses were completed in this two-month time frame. There was a budget for this research study and thus a limit on the amount of tests that could be carried out. The seeds were donated by CV Science and Murray State University equipment was used to plant the industrial hemp crop. The researchers at the Hutson School of Agriculture at Murray State University gathered THC, CBD, and soil samples. The soil samples were sent to Waters Agricultural Laboratory in Owensboro, Kentucky. The THC and CBD samples were sent to ElSohly Laboratories in Oxford, Mississippi.

Budget

The budget for this research study was $7,500, an amount donated by CV Science. However, the study used a total of $6,393.05. CV Science donated the seeds, and Murray State equipment was used to plant the industrial hemp crop. THC, CBD, and soil sampling was completed by the Hutson School of Agriculture at Murray State

University. The soil samples were sent to Waters Agricultural Laboratory in Owensboro, Kentucky. The THC and CBD samples were sent to ElSohly Laboratories in Oxford, Mississippi.

Table 1.0 The Research Budget

Budget of the Industrial Hemp Project			
DATE	**ITEMS/ TESTING**	**DETAILS**	**COST**
09/08/17	ElSohly Laboratories	Analysis of Samples	$ 1,200.00
09/14/17	Waters Agricultural Laboratory	Soil Testing	$ 60.00
09/27/16	Interaccount	Plastic	$ 99.98
04/19/17	Interaccount	Fertilizer	$ 1,323.32
04/19/17	Interaccount	Fertilizer	$ 356.75
04/19/17	Interaccount	Fertilizer	$ 389.76
04/17/17	Helena	Fertilizer	$ 1,368.91
02/15/17	ElSohly Laboratories	Hemp Testing	$ 300.00
09/18/17	Waters Agricultural Laboratory	Soil Testing	$ 110.00
09/17/16	Gary L. Brame Farms, LLC	Harvest Hemp Seed	$ 960.00
09/29/17	Interaccount	Agriculture Truck Mileage	$ 174.35
11/20/17	Interaccount	Torque	$ 49.98
		Total Cost	$ 6,393.05
08/22/17	Donation	CV Sciences	$ (7,500.00)

Table 1.0 above shows the itemized list of all expenses from this study. The total amount spent for this study was $6,393.05, which left an excess of $1,106.95. It is important to note that the dates correlate to the time in which the secretary filed these expenses and not when the purchases took place. The accountant in the Hutson School of Agriculture at Murray State University filed the purchases. On September 8, 2017,

$1,200 was put towards the analysis of samples at ElSohly Laboratories. On September 14, 2018, $60 was put towards the soil testing at Waters Agricultural Laboratory. On September 27, 2018, $99.98 was put towards the purchase of plastic, which was used in the process of drying the hemp for the yield sample. On April 19, 2017, three types of fertilizers were purchased, which costed $1,323.32, $356.75, $389.76, and $1,368.91. On April 17, 2017, a fertilizer known as Helena was purchased for $1,368.91. Moreover, on February 15, 2017, $300 was put towards hemp testing at ElSohly Laboratories. On September 18, 2017, $110 was used for soil testing at Waters Agricultural Laboratory. On September 17, 2017, $960 was spent to transport the combine and trucks to different farms for harvesting. Gary L Brame Farms, LLC, executed this task. On September 29, 2017, $174.35 was spent on the agricultural truck mileage to bring the seed to and from the farms. On November 20, 2017, $49.98 was spent on torque, which was necessary to fix the thrasher. All of these costs added up to $6,393.05.

Chapter IV

Results

Introduction

The results of the industrial hemp study contain soil sampling data, yield data, CBD and THC data, and weather data. This data was compared using correlations, scatterplots, and bar graphs. The results of this data will be influential for future studies, as the data provides information regarding the growth and production of industrial hemp within Kentucky.

Results for Objective

Upon studying the correlation between THC and CBD content in the crops and weather in the high periods of growth, there were no significant findings. After analyzing the four years of weather data, there was not enough evidence to suggest that weather or temperature affects the THC and CBD content of the industrial hemp crop. In studying the content of THC and CBD content over time, the p-values were insignificant. The soil data gathered here needs to be expounded upon in future studies, as this is the first year that results have been recorded on the soil. Because of the methods used, there was not enough time to gather sufficient data from the yield samples. For future studies, the methods of harvesting the hemp crop need to be further honed.

Climate Data

2014 Climate Data for Industrial Hemp

In 2014, there was not enough CBD and THC data to determine a relationship between temperature and THC and CBD content in the crop.

This section of the results investigated the effects of temperature and weather-related data on THC and CBD content to determine whether there was a correlation between the temperature and the levels of THC and CBD in the years of 2014-2017. Some of the data was incomplete, such as in the year of 2015, because data from that year was not recorded. In this year, there was not enough industrial hemp crop to test for THC and CBD content. Moreover, there were not enough data points to reach a conclusion in 2016, as the industrial hemp samples were only tested twice. Therefore, there are only data sets for 2014, 2016, and 2017.

Table 1.1 (below) discusses the mean, median, mode, maximum, minimum, and standard deviation of various factors on THC and CBD content. These factors include temperature, tetrahydrocannabinol (THC), wind speed (WSPD), relative humidity (RELH), and wind direction (WDIR). This chart illustrates the rates of the factors that affect the growth of industrial hemp. It is important to note that the sensors were broken for three months in Calloway County in 2014, so some data was not recorded.

Table 1.1

Overall Weather Conditions of 2014

	Mean	*Median*	*Mode*	*Minimum*	*Maximum*	*SD*
Temperature	78.73	79.73	0	56.97	0	7.39
WSPD	5.3842	5.2	6.23	1.19	13.04	2.403
RELH	62.46	63	53.1	31.7	0	14.22
WDIR	188.25	200.7	39.3	0.4	358.5	94.56

Note: Table 1.1 shows descriptive data, or mean, median, mode, minimum, maximum, and standard deviation of overall weather conditions of 2014. The mean temperature was 78.73 degrees Fahrenheit. The median temperature was 79.73 degrees Fahrenheit. The mode of the temperature was zero degrees Fahrenheit. The minimum temperature was 56.97 and the maximum was zero degrees Fahrenheit. The standard deviation for temperature was 7.39 degrees Fahrenheit. The mean WSPD was 5.3842 mph and the median was 5.2 mph. The mode for WSPD was 6.23 mph. The minimum for WSPD was 1.19 mph and the maximum was 13.04 mph. The standard deviation for WSPD was 2.403 mph. The mean for RELH was 62.46 percent. The median for RELH was 63 and the mode was 53.1 percent. The minimum for RELH was 31.7 and the maximum was zero percent. The standard deviation for RELH was 14.22 percent. The mean for WDIR was 188.25 percent. The median for WDIR was 200.7 and the mode was 39.3 perccent. The minimum for WDIR was 0.4 and the maximum was 358.5

percent. The standard deviation for WDIR was 94.56 percent.

Figures 2.2 2014 THC/TEMP

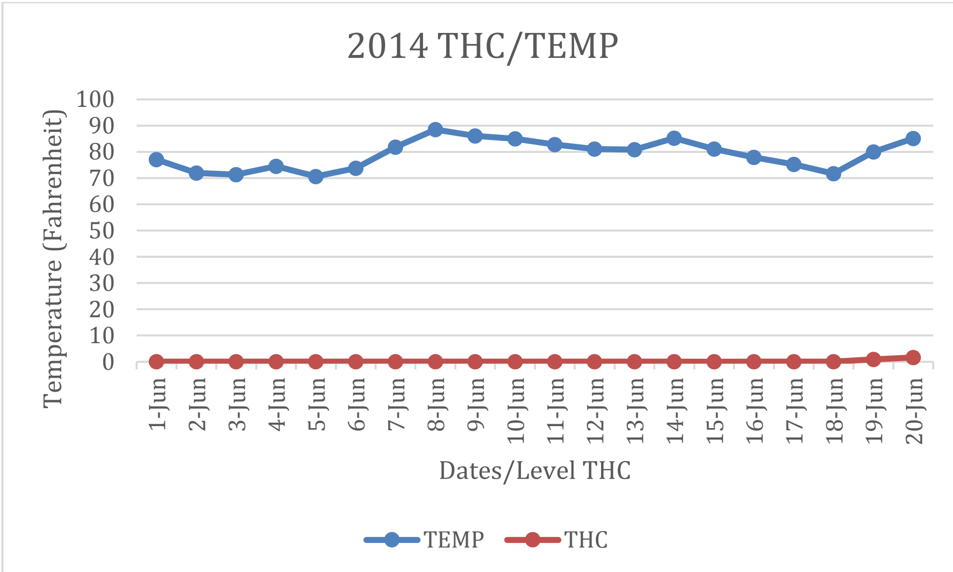


Figure 2.2 shows temperature results of THC over the span of June 2014, as June is the optimal time to grow industrial hemp. By this time, THC levels should be the highest. This figure also shows the temperature over the span of June 1 to June 20, 2014.

Figures 2.3 2014 CBD/TEMP

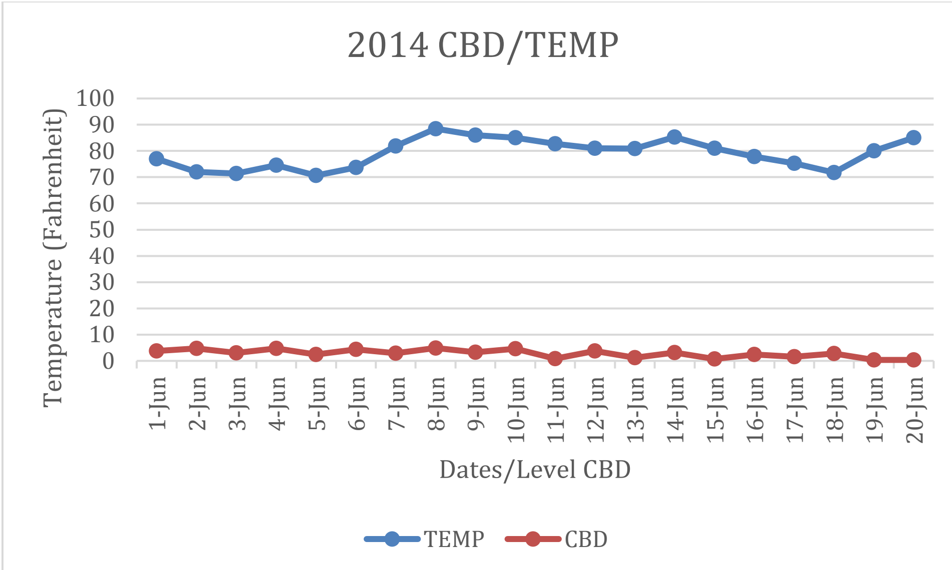


Figure 2.3 shows the temperature and CBD content of the crop from June 1 to June 20. This is the optimal time to grow hemp, so CBD levels should be at peak.

2015 Climate Data for Industrial Hemp

Climate data from 2015 cannot be studied because of insignificant testing in regard to THC and CBD. These results cannot be analyzed to reach a conclusion, as there are not enough data points from this year to complete statistical analyses tests.

2016 Climate Data for Industrial Hemp

In 2016, there was not enough CBD and THC data to conclude relationship between temperature and THC and CBD content.

Table 1.2 discusses the mean, median, mode, maximum, minimum, and standard deviation of various factors from the weather data gathered in 2016. These factors include temperature, wind speed (WSPD), relative humidity (RELH), and wind direction (WDIR). This chart illustrates the rates of the factors that affect the growth of industrial hemp

Table 1.2

Overall Weather Conditions of 2016

	Mean	*Median*	*Mode*	*Minimum*	*Maximum*	*SD*
Temperature	80.51	83.01	0	55.226	91.077	8.07
WSPD	4.86	4.605	4.59	0	95.4	12.83
RELH	63.91	65.2	65.2	55.22	95.4	12.83
WDIR	193.86	4.605	4.59	0	0	2.0216

Note. Table 1.2 shows the overall weather conditions of 2016. The mean temperature was 80.51 degrees Fahrenheit. The median temperature was 83.01 degrees Fahrenheit. The mode temperature was zero degrees Fahrenheit. The minimum temperature was 55.226 and the maximum was 91.077 degrees Fahrenheit. The standard deviation was 8.07 degrees Fahrenheit. The mean for WSPD was 4.86 mph. The median for WSPD was 4.605 mph. The mode for WSPD was 4.59 mph. The minimum for WSPD was zero and the maximum was 95.4 mph. The standard deviation for WSPD was 12.83 mph. The mean for RELH was 63.9% and the median was 65.2%. The mode for RELH was 65.2%. The minimum for RELH was 55.22% and the maximum was 95.4%. The standard deviation for RELH was 12.83%. The mean for WDIR was 193.86 and the median was 4.605. The mode of WDIR was 4.59. The minimum for WDIR was zero and the maximum was zero. The standard deviation for WDIR was 2.0216.

Figure 2.4 2016 THC/TEMP

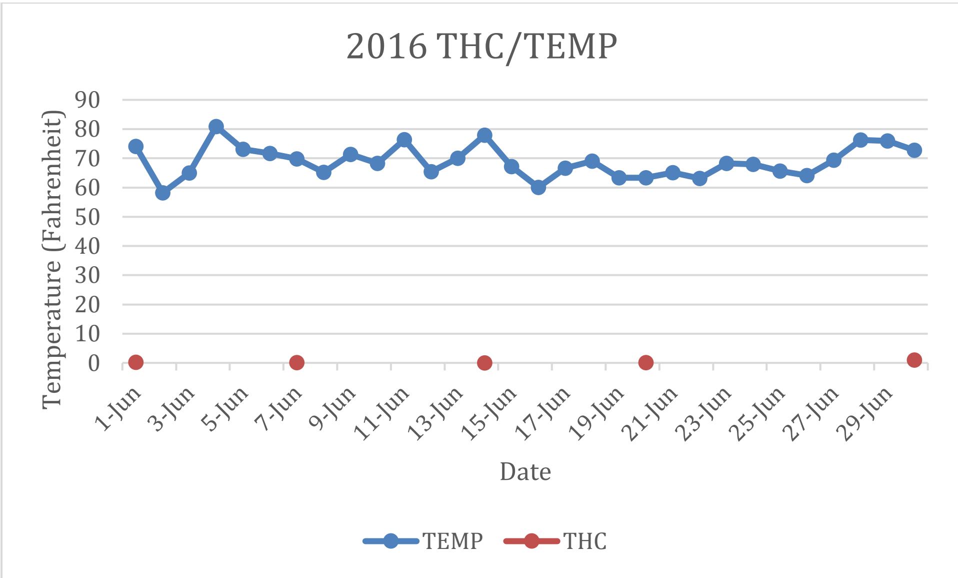


Figure 2.4 shows temperature and THC levels from June 1 to June 29, 2016. June is the optimal time to grow hemp, so THC levels should be at the peak.

Figure 2.5 2016 CBD/ TEMP

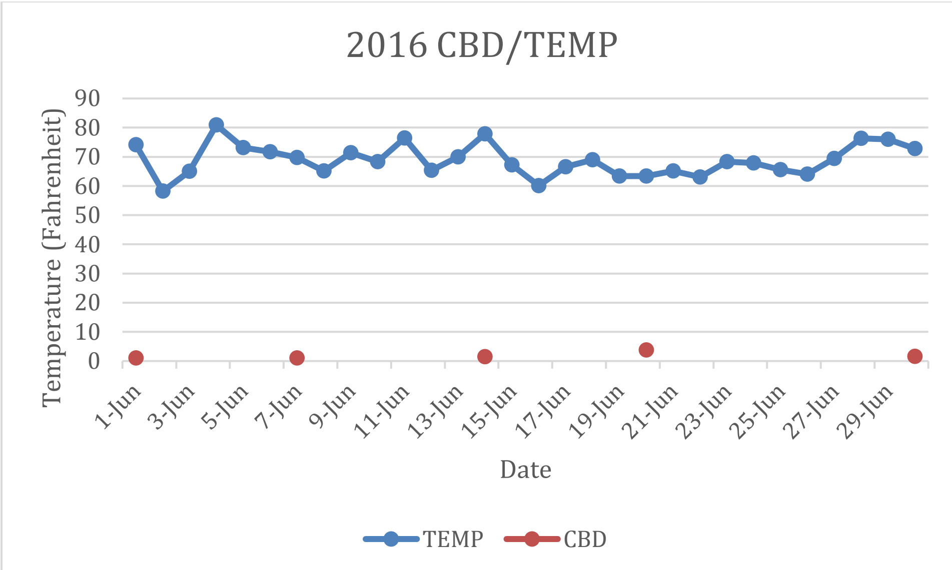


Figure 2.5 shows CBD and temperature between June 1 and June 29, 2016. This time is the optimal point of the year to grow industrial hemp, so CBD levels should be at peak.

2017 Climate Data for Industrial Hemp

In 2017, there was not enough CBD and THC data to determine a relationship between temperature and THC and CBD content.

Table 1.3 discusses the mean, median, mode, maximum, minimum, and standard deviation of various factors on THC and CBD content. These factors include temperature, wind speed (WSPD), relative humidity (RELH), and wind direction (WDIR). This chart illustrates the rates of the factors that affect the growth of industrial hemp.

Table 1.3

Overall Weather Conditions of 2017

	Mean	*Median*	*Mode*	*Minimum*	*Maximum*	*SD*
Temperature	72.5	72.97	70.48	41.24	93.17	9.11
WSPD	3.21	2.78	0	0	19.53	2.57
RELH	76.19	79.6	100	27.2	100	19.08
WDIR	159.69	169.2	70.48	360	93.175	9.11

Note: Table 1.3 illustrates data from 2017 regarding temperature, WSPD, RELH, and WDIR in terms of mean, median, mode, minimum, maximum, and standard deviation. The temperature was a mean of 72.5 degrees Fahrenheit, and the median of temperature was 72.97 degrees Fahrenheit. The mode of temperature was 70.48 degrees Fahrenheit and the minimum was 41.25 degrees Fahrenheit. The maximum of temperature was 93.17 degrees Fahrenheit. The standard deviation of temperature was 9.11 degrees Fahrenheit. There may be a correlation between THC and CBD levels and environmental factors, although there is not enough data to determine a correlation.

Figures 2.6 2017 THC/TEMP

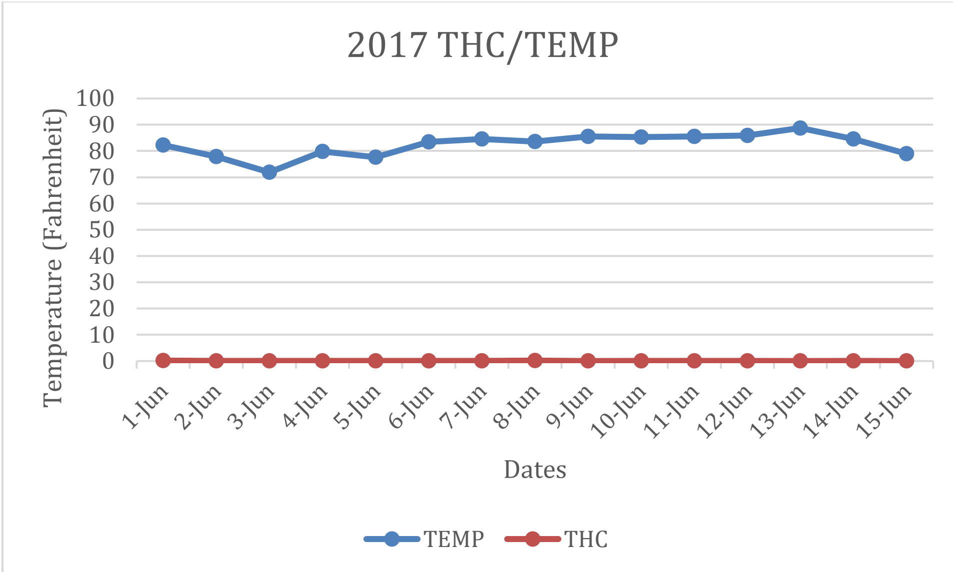


Figure 2.6 shows the THC levels and temperature for for June 1- June 15, 2017. This is the optimal time for growing industrail hemp, so THC levels should be at their peak.

Figures 2.7 2017 CBD/TEMP

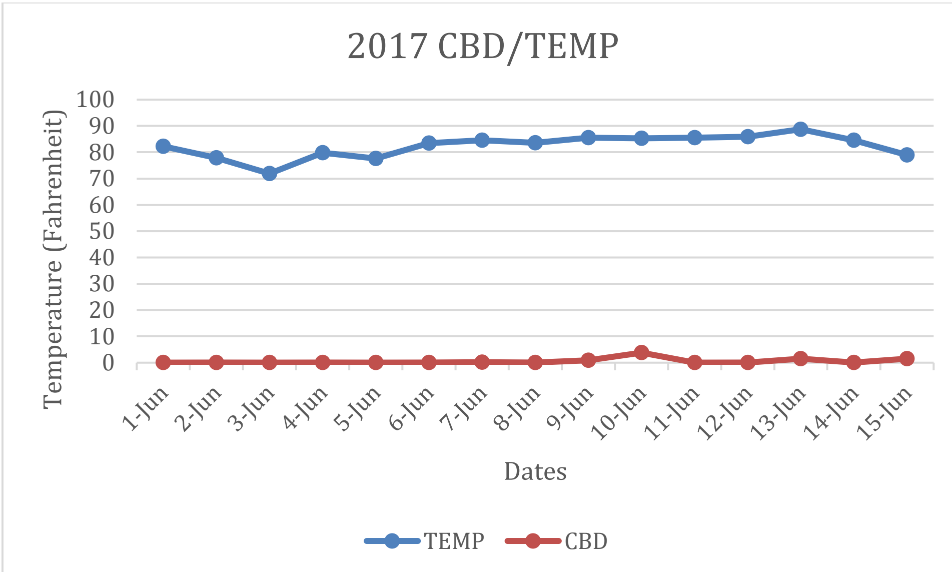


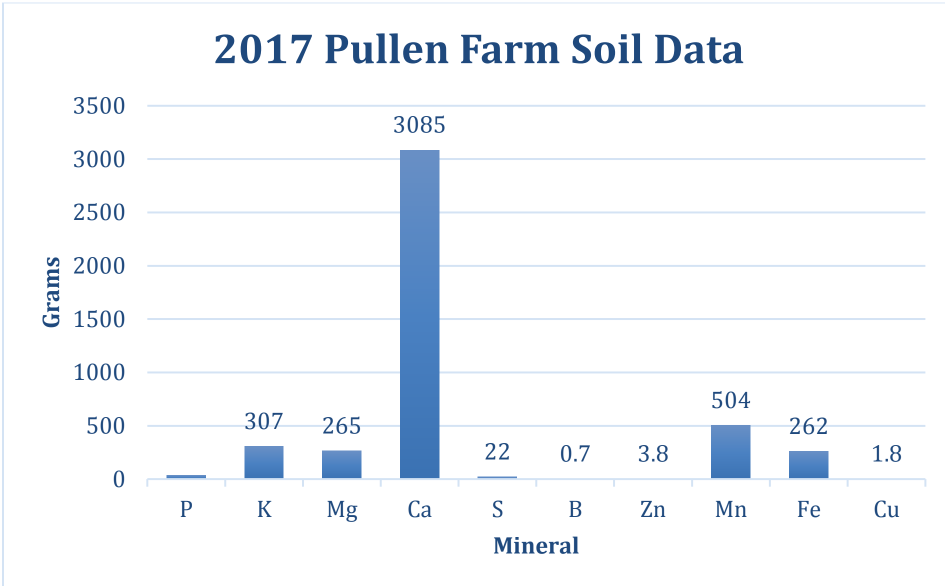
Figure 2.7 shows the CBD levels and temperature from June 1 to June 15, 2017. This is the optimal time of the year to grow industrial hemp, so CBD levels should be at their height.

Figure 2.8 Pullen Farm Test Plot

Futura 75 75Ib Acre	Santhica, 75Ib Acre	Canda 75Ib Acre	Delores 75Ib Acre
Border	Border	Border	Border
45Ib Acre	45Ib Acre	45Ib Acre	45Ib Acre

Figure 2.8 shows the four varieties that wer tested on the Pullen Farm test plot. The varieties of Futura 75, Santhica, Canda, and Delores were grown on this test plot. Selected organic and traditional fertilizers were used on these plots. These plot samples yielded information regarding THC and CBD content. However, there were not enough plants grown to create a significant yield sample. For soil testing, 13 samples were taken from 13 different sections of the test plot. The graph below shows the mineral contents of the soil, including soil pH, phosphorous, potassium, calcium, magnesium, sulfur, boron, zinc, manganese, iron, and copper.

Figure 2.9 2017 Pullen Farm Soil Data



The results in figure 2.9 show the soil data from 2017. The soil should be between 5.1 to 6.1 pH for optimum hemp growth (Bócsa, 1993). From the soil analysis, the soil from this plot contained 38 grams of phosphorous and 307 grams of potassium. The soil contained 265 grams of magnesium and 3,085 grams of calcium, which was the highest mineral content. It also contained 22 grams of sulpher and 0.7 grams of boron, which was the lowest mineral content. The soil contained 3.8 grams of zinc and 504 grams of manganese. Moreover, the soil contained 262 grams of iron and 1.8 grams of copper. The mineral amounts varied based on the history of the plot, specifically in crops grown on the plot in years prior. Minerals may need to be added to the soil when crops that deplete minerals have been grown on the plots. However, more data is needed on prior years regarding soil fertility and the results of this on industrial hemp growth.

There is not enough data from 2017 to reach conclusive results for Pullen Farm's soil content. It would be beneficial to have more intensive soil data spanning over a longer period to determine the effect of soil content on industrial hemp. Regardless, providing future studies with this soil data from 2017 will be very crucial for the future viability of this crop.

Figure 3.0 (pictured below) shows different variations of soil types and provides a brief summary of each type of soil. Soil maps are very crucial in understanding and predicting the development of the industrial hemp plant, which will affect the ways in which farmers grow hemp in the future. This study needs to be furthered to discover the benefits of different types of soil on different varieties of hemp. The plot at Pullen Farm was greatly ineffective for the growth and development of the hemp crop, as the weeds overtook the crop, making it difficult to collect samples for THC and CBD testing. The growth and development of the hemp crop on these plots failed to yield enough data to reach a conclusion for the soil samples. The thirteen soil samples that were taken from Pullen Farm yielded important information, but this aspect requires further study to gather more data.

Figure 3.0 below is a legend for reading the maps regarding the web soil survey. The series indicators, expressed with orange lines, identify the soil types. There are two maps to illustrate each soil type on both Pullen Farm and West Farm research plots. This legend explains the comprehensive symbols that may appear in the soil survey maps below.

Figure 3.0 Soil Map Legend

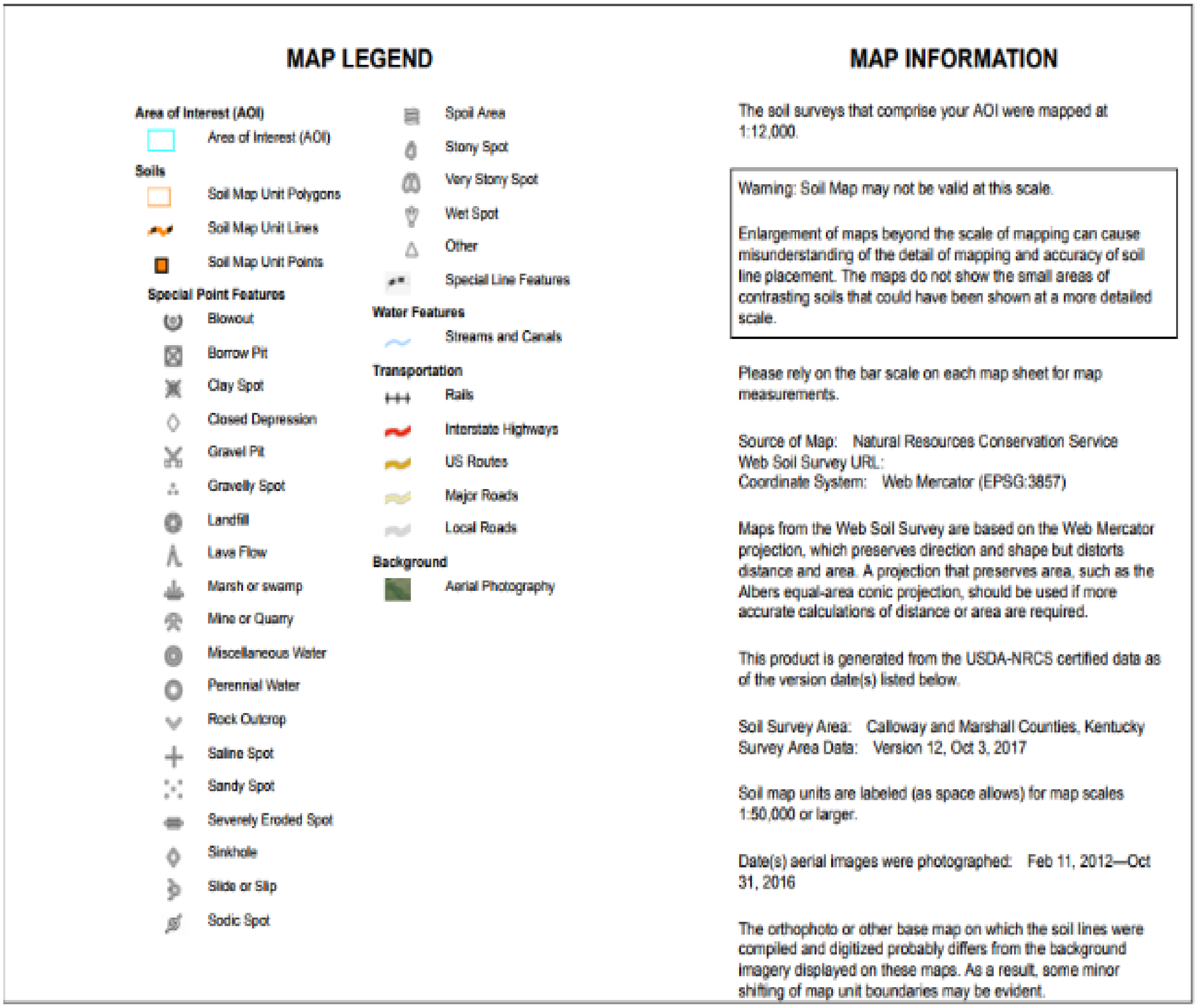


Figure 3.1 Pullen Farm Plot Soil Analysis

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
CwA	Calloway-Kurk complex, 0 to 2 percent slopes	0.1	17.5%
GrB2	Grenada silt loam, 2 to 6 percent slopes, eroded	0.3	82.5%
Totals for Area of Interest		**0.4**	**100.0%**

Figure 3.1 above shows data on the test plots and the types of soil present. This identifies the percentage of soil types that compose the test plot on Pullen Farm. There

was 17.5% of Calloway-Kurk complex at 0 to 2 percent slopes, or 0.1 acres in AOI. The map unit symbol for this type of soil is CwA. There was 82.5% of Grenada silt loam at 2 to 6 percent slopes, eroded, or 0.3 acres in AOI. The map unit symbol is GrB2. These different types of soil and their effects are still being investigated.

Soil pH can be very influential for any crop's growth, including industrial hemp. This is because industrial hemp requires 5.1-6.1 standard pH level for growth (Bócsa, 1993). If the pH level does not precisely match this, it will affect the growing process. For example, the pH at Pullen Farm was tested as 6.6 standard pH in some areas, and the crops did not grow optimally. At the West Farm, the soil was tested as 6.1 standard pH, and the crops grew very well. This suggests a correlation, although more research needs to be completed before causation can be established. Refer back to the literature review for the pH scale.

Table 1.4

Soil pH ANOVA Results (overall)

Hemp Farms	*150*	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
West Farm & Pullen Farm	150	0.5769	1	0.5769	6.9247	0.0207	0.4813
	150	1.0830	13	0.0833			

Note: Table 1.4 illustrates the soil pH for both West Farm and Pullen Farm. The test run was a one-factor ANOVA test. The SS for West Farm and Pullen Farm, between the two groups of data, was 0.5769 and 1.0830. The df for West Farm and Pullen Farm, between the two groups of data, was 1 and 13. The MS for West Farm and Pullen Farm, between the two groups of data, was 0.5769 and 0.0833. The F-value for the West Farm and Pullen Farm was 6.9247, which is significant. The P-value for the West Farm and Pullen Farm was 0.0207 at $P<0.05$, which is significant. The F-crit for West Farm and Pullen Farm was 0.4813.

Table 1.5

Soil pH in Plots

	Mean	*Median*	*Mode*	*Minimum*	*Maximum*	*SD*
West Farm	6.1	6.1	6.1	6.1	6.1	6.1
Pullen Farm	6.67	6.6	6.6	6.1	0	0.30042

Note. Table 1.5 shows the pH, mean, median, mode, minimum, maximum, and standard deviation of the soil in both West Farm and Pullen Farm. The mean of the soil pH at West Farm was 6.1, while the mean of the soil pH at Pullen Farm was 6.67. The median of the soil pH at West Farm was 6.1, while the median of the soil pH at Pullen Farm was 6.6. The mode of soil pH at West Farm is 6.1, while the mode of the soil pH at Pullen Farm was 6.6. The minimum of soil pH at West Farm and Pullen Farm was both 6.1. The maximum of soil pH at West Farm was 6.1, whereas the maximum of soil pH at Pullen Farm was zero. The standard deviation of soil pH at West Farm was 6.1, while the standard deviation of soil pH at Pullen Farm was 0.30042.

Figure 3.2 West Farm Plot

Futura 75 75Ib Acre Two Passes	Futura 75 75Ib Acre Two Passes	Futura 75 50Ib Acre Two Passes	Santhica 50Ib Acre Two Passes	Santhica 75Ib Acre Two Passes	Delores 75Ib Acre Two Passes	Delores 50Ib Acre Two Passes	Canda 50Ib Acre Two Passes	Canda 75Ib Acre Two Passes

Figure 3.2 shows how the four varieties, Futura 75, Santhica, Canda, and Delores, were planted. In 2017, the seeding rate varied between 50 and 75 pounds per acre. The four varieties were tested every two days for CBD and THC levels. Planting was repeated with two seeding passes for each variety. The buffer zone was used as a border to separate each row of the industrial hemp crop. It was found that the higher seeding rate was more efficient for keeping the weeds contained. When the hemp plant reached a certain height, the canopy caused a lack of sunlight to the weeds, which prohibited the growth of the weeds. The tall hemp plants prevented the growth of other weeds, as sunlight could not penetrate the canopy cover. There were no herbicides, pesticides, or fungicides used on this crop at West Farm; therefore, the use of over-seeding was the most successful method found for weed control. The samples taken on the soil and weather at this plot were compared with the levels of CBD and THC present in the crop.

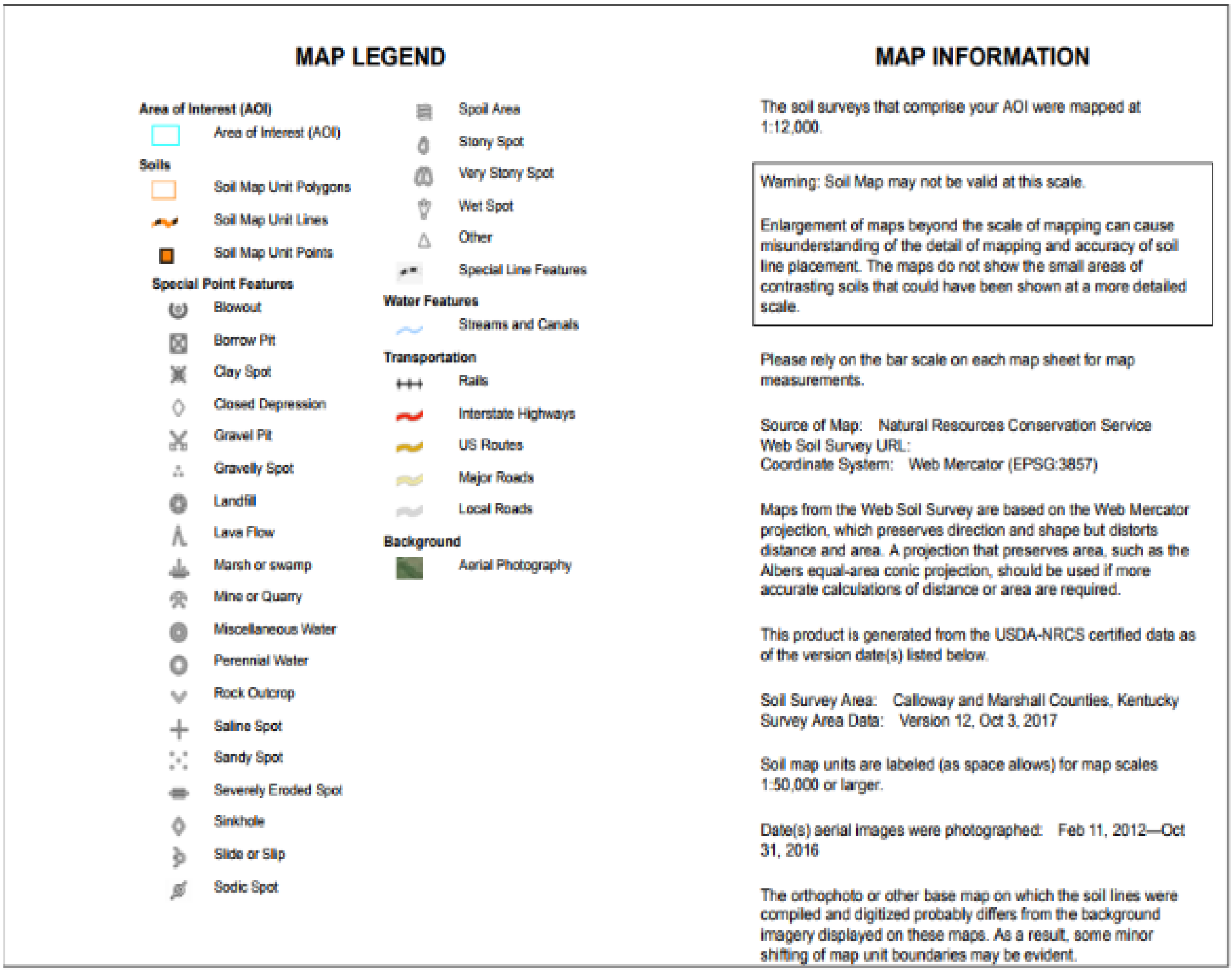
Figure 3.3 Industrial Hemp Crop of the Delores Variety

Figure 3.3 is a closer picture of the industrial hemp crop of the Delores variety, which is used for CBD oil production. This harvest was very effective as it only took 20 minutes to harvest two varieties, Delores and Canda, on the Murray State Agricultural Demonstration Day.

Figure 3.4 The First Stage of Growth of Industrial Hemp

Figure 3.4 shows the first stage of growth of the industrial hemp grown on Pullen Farm in 2017. The variety pictured above is Futura 75.

Figure 3.5 Soil Map Legend



MAP LEGEND

Area of Interest (AOI)
Area of Interest (AOI)
Soils
Soil Map Unit Polygons
Soil Map Unit Lines
Soil Map Unit Points
Special Point Features
Blowout
Borrow Pit
Clay Spot
Closed Depression
Gravel Pit
Gravelly Spot
Landfill
Lava Flow
Marsh or swamp
Mine or Quarry
Miscellaneous Water
Perennial Water
Rock Outcrop
Saline Spot
Sandy Spot
Severely Eroded Spot
Sinkhole
Slide or Slip
Sodic Spot
Spoil Area
Stony Spot
Very Stony Spot
Wet Spot
Other
Special Line Features
Water Features
Streams and Canals
Transportation
Rails
Interstate Highways
US Routes
Major Roads
Local Roads
Background
Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:12,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

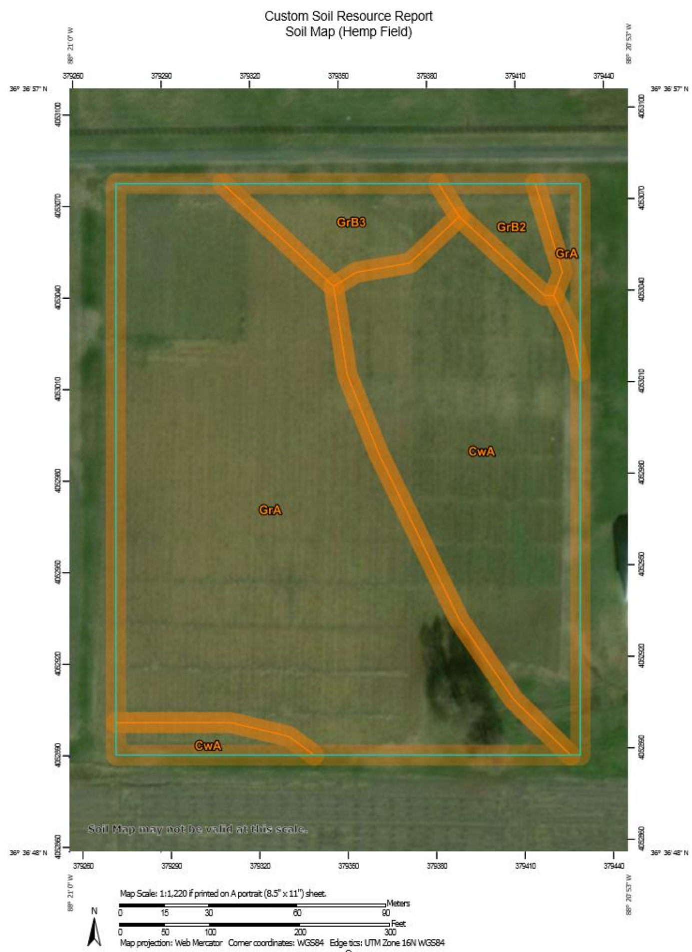
Soil Survey Area: Calloway and Marshall Counties, Kentucky
Survey Area Data: Version 12, Oct 3, 2017

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Feb 11, 2012—Oct 31, 2016

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Figure 3.6 West Farm Plot Analysis Map



Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
CwA	Calloway-Kurk complex, 0 to 2 percent slopes	2.3	32.1%
GrA	Grenada silt loam, 0 to 2 percent slopes	4.4	59.6%
GrB2	Grenada silt loam, 2 to 6 percent slopes, eroded	0.2	2.7%
GrB3	Grenada silt loam, 4 to 6 percent slopes, severely eroded	0.4	5.6%
Totals for Area of Interest		**7.3**	**100.0%**

Figure 3.6 shows the areas of different soil types on the industrial hemp plot at the West Farm. There was 32.1% of AOI of Calloway-Kirk complex at 0 to 2 percent slopes, or 2.3 acres in AOI. The map unit symbol for this is CwA. There was 59.6% of Grenada silt loam at 0 to 2 percent slopes, or 4.4 acres in AOI. The map unit symbol for this is GrA. There was 2.7% of AOI of Grenada silt loam at 2 to 6 percent slopes, or 0.2 acres in AOI. The map unit symbol for this is GrB2. There was 5.6% of Grenada silt loam at 4 to 6 percent slopes, or 0.4 acres in AOI. The map unit symbol for this is GrB3.

Delores and Canda are shorter varieties of the hemp crop, which are meant for CBD oil use. Futrell 75 and Santhica have a higher canopy rate, whereas Delores and Canda have a lower canopy rate. This was discovered by observing the crop growth over time on the West Farm. It was also found that the higher seeding rate was an effective method of weed control. These four varieties are meant for different purposes. Futrell 75 and Santhica are meant for textile use, while Delores and Canda are used to make CBD oil. Each variety can be used for multiple products.

Figure 3.7 The Growth of Different Varieties

Figure 3.7 shows the growth of different varieties at Murray State University's West Farm. This figure depicts the varieties of Futrell 75, Delores, Canda, and Santhica.

Figure 3.8 Hemp Harvesting at Murray State University

Figure 3.8 shows hemp harvesting at Murray State University's West Farm. This figure shows the combine harvesting of Delores and Santhica. This combine was modified to harvest industrial hemp.

Figure 3.9 The Combine after Harvesting the Industrial Hemp

Figure 3.9 shows a close-up picture of the combine after harvesting the industrial hemp on Murray State University's West Farm during Field Day.

Figure 4.0 2017 West Farm Soil Data

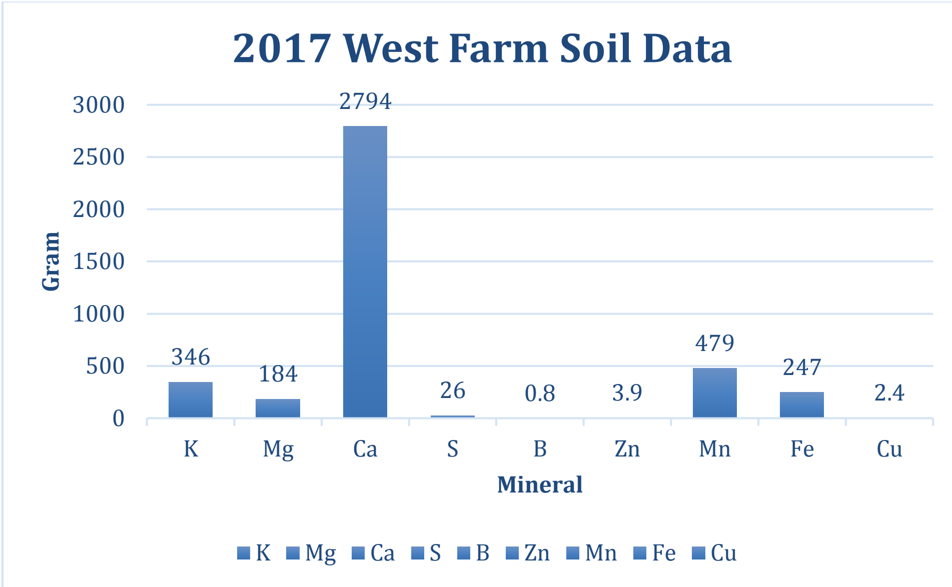


Figure 4.0 shows the mineral content of the West Farm soil at the test plot in 2017. The potassium value was 346 grams. The magnesium value was 184 grams. The calcium value was the highest at 2,794 grams. The Sulphur value was 26 grams. The boron value was the lowest at 0.8 grams. The zinc value was 3.9 grams. The manganese value was 479 grams. The iron value was 247 grams and the copper value was 2.4 grams.

THC and CBD Results

2014 THC and CBD Results

Table 1.6

THC and CBD 2014 ANOVA Results (overall)

Hemp Farms	*n*	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
West Farm & Pullen Farm	150	12.429	19	0.65421	0.5641	0.9085	1.86733
		85.069	2	42.5347	36.677	1.34E-9	3.2448
		44.068	38	1.15968			
Total	150	141.56	59				

Note: Table 1.6 shows the THC and CBD contents of the samples grown on West Farm and Pullen Farm in 2014. The test run was a two-factor ANOVA test. The total SS for the West Farm and Pullen Farm samples was 141.56. The total df for the West Farm and Pullen Farm samples was 59. The MS values were 0.65421, 42.5347, and 1.15968. The F values were 0.5641, which is insignificant at F>5, and 36.677, which is significant at F>5. The P-values were 0.9085 and 1.34E-9, which are insignificant at P<0.05. The F-crit values were 1.86733 and 3.2448.

Figure 4.1 West Farm 2014 THC

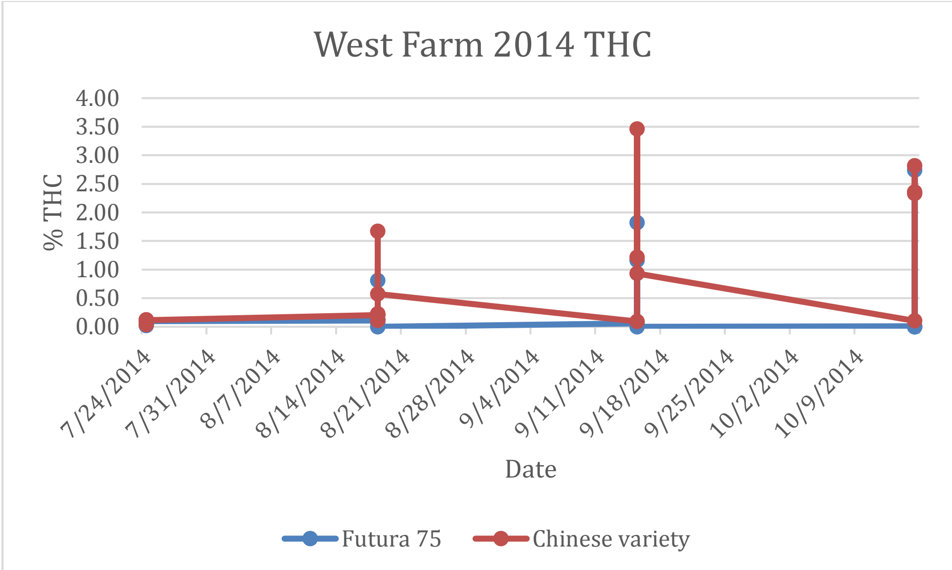


Figure 4.1 shows the growing cycle of Futura 75 and an unknown Chinese variety. This figure is from 2014, in which the crops yielded the highest THC value in four years of testing. This was the first year of testing, and the highest percentage of THC in the Chinese variety was 3.5%, which is over the legal limit of 0.03%. The highest percentage of THC in the Futura 75 crop was 1.82% THC, which is over the legal limit of 0.03%. Both of these values were recorded from September 18, 2014. In conclusion, Futura 75 produced much less THC than the Chinese variety in 2014.

Figure 4.2 West Farm 2014 CBD

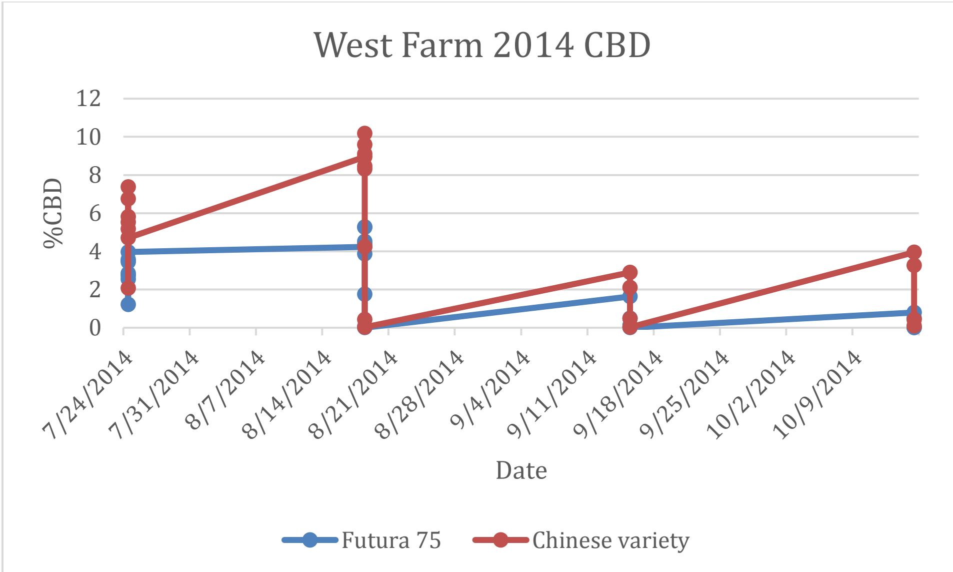


Figure 4.2 shows the CBD content of Futura 75 and the unknown Chinese variety in the year 2014. The highest percentage of CBD was on August 21, 2014, in which the Chinese variety had 10% and Futura 75 had 5% CBD content. This illustrates how the Chinese variety contained a higher percentage of CBD. Moreover, this figure highlights how CBD values had a peak point in the early to middle part of the growing cycle, on August 21, 2014, but then the values declined.

2015 THC and CBD Results

There was not enough data gathered in this year to create ANOVA charts or descriptive charts to analyze the THC and CBD contents. Moreover, the weather data cannot be analyzed, as this requires data regarding 2015 THC and CBD levels, which was not recorded.

2016 THC and CBD Results

Table 1.7

2016 THC and CBD Content of all Four Varieties (Overall)

THC & CBD 2016	*Mean*	*Median*	*Mode*	*Minimum*	*Maximum*	*SD*
THC	0.9225	0.075	0	0.04	0	0.0607
CBD	1.9725	1.53	0	1.02	0	1.2486

Note: Table 1.7 shows the combined values of the THC and CBD content of two varieties grown in 2016, Futura 75 and Fidora. The mean THC value of these two varieties was 0.9225, while the mean CBD value of these two varieties was 1.9725. The median THC value of these two varieties was 0.075, while the median CBD value of these two varieties was 1.53. The mode of both THC and CBD of these two varieties was zero. The minimum THC value of two varieties was 0.04, whereas the mean CBD value of these two varieties was 1.02. Moreover, the maximum THC and CBD content of these two varieties was zero. Furthermore, the standard deviation of the THC content of these two varieties was 0.0607, whereas the CBD content of these varieties was 1.2486.

Table 1.8

THC and CBD 2016 ANOVA Results (overall)

Hemp Farms	*n*	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
West Farm & Pullen Farm	150	9.9635	4	2.4908	4.6964	0.060262	5.192168
		2.6519	5	0.5303			
Total	150	12.615	9				

Note: Table 1.8 shows the THC and CBD contents of samples grown on West Farm and Pullen Farm in 2016. The test run was a one-factor ANOVA test. The total SS value was 12.615. The total df value was 9. The MS values were 2.4908 and 0.5303. The F-value was 4.6964, which is statistically insignificant at F>5. The P-value was 0.060262, which is statistically significant at P<0.05. The F-crit was 5.192168.

Figure 4.3 West Farm 2016 THC

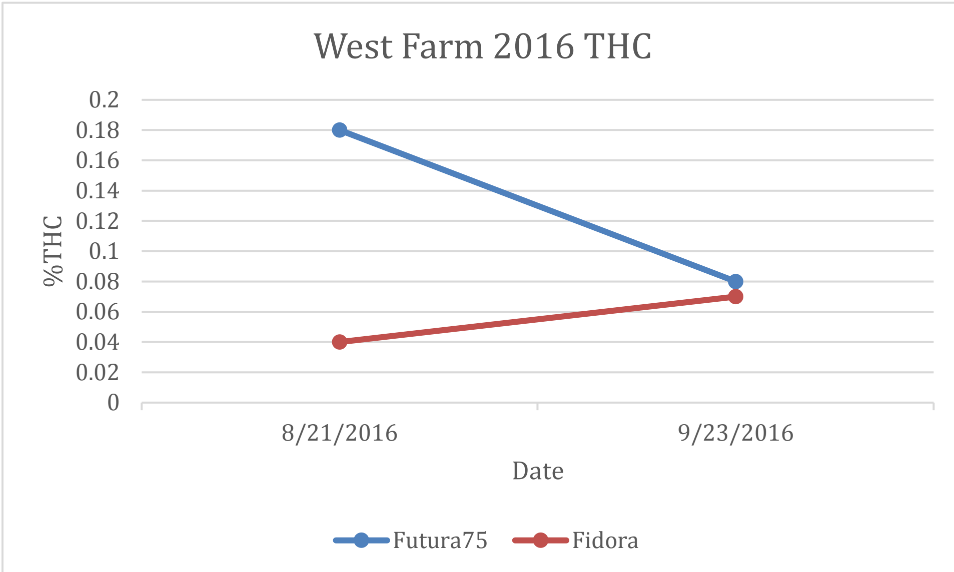


Figure 4.3 shows THC levels of two varieties of hemp, Futura 75 and Fidora, tested in summer of 2016. The levels of THC in these crops were only tested twice, once during the midpoint of the growing cycle and once at the end of the growing cycle. The graph illustrates how Futura 75 started at 0.18% and declined in THC content throughout the growing process, resulting in 0.08% THC content. Moreover, Fidora started at 0.05% THC and increased to 0.07% throughout the growing process. There was an increase in Fidora and a decrease in Futura 75 throughout the process. In the second test, the two varieties differed in THC levels. In the second sample, Futura 75 had 0.08% THC and Fidora had 0.07% THC.

Figure 4.4 West Farm CBD 2016

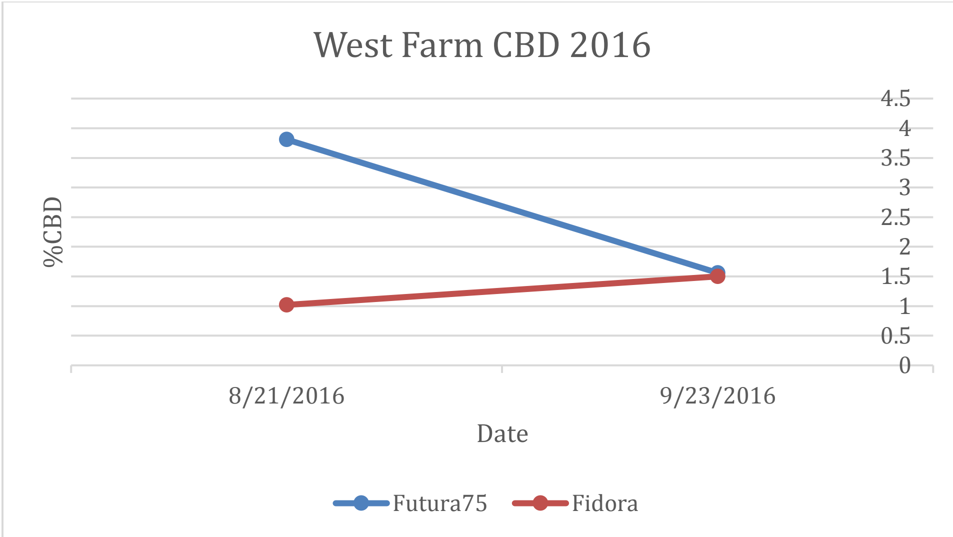


Figure 4.4 illustrates the CBD content of samples taken from two varieties, Futura 75 and Fidora. The first sample was taken in the middle of the growing process and the second sample was taken at the end of the growing process. Futura 75 had 3.81% CBD content in the first test, which was taken in the middle of the growing process. Throughout the growing process, the percentage of CBD oil decreased in Futura 75 to 1.56% CBD oil content in the second test, taken at the end of the growing process. In the middle of the growing process, Fidora had 1.02% CBD. Throughout the growing process, the CBD content raised to 1.5% in the second test, taken at the end of the growing process. By the end of the growing process, both varieties had similar CBD contents, as Futura 75 had 0.06% higher CBD content. However, this data from 2016 is inconclusive, as there was not enough testing of CBD content over the growing process to reach a conclusion.

2017 THC and CBD Results

Table 1.8

2017 THC and CBD content of all four varieties (overall)

THC & CBD 2017	*Mean*	*Median*	*Mode*	*Minimum*	*Maximum*	*SD*
CBD	0.047	0.027	0.01	0.01	0.18	0.0512
THC	0.07	0.0217	0.01	0.01	0.18	0.05

Note: Table 1.8 shows the mean, median, mode, minimum, maximum, and standard deviation of THC and CBD. The mean of CBD content was 0.047, whereas the mean of THC content was 0.07. The median of CBD content was 0.027, while the median of THC content was 0.0217. The mode of CBD and THC content was both 0.01. The minimum for CBD and THC content was both 0.01. The maximum for both THC and CBD content was 0.18. The standard deviation of CBD content was 0.0512, while the standard deviation of THC content was 0.05. This graph represents all of the data for CBD and THC content in all four varieties of the hemp crop from 2017.

Table 1.9

THC 2017 ANOVA Results

Hemp Farms	*n*	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
West Farm & Pullen Farm	150	3.3607	2	1.6803	59.457	0.001059	6.944272
		0.0917	2	0.0458	1.06233	0.03046	6.944272
		0.1130	4	0.0282			
Total	150	3.5655	8				

Note: Table 1.9 shows 2017 THC values from West Farm and Pullen Farm. The test was a two-factor ANOVA test. The total SS value was 3.5655. The total df value was 8. The MS values were 1.6803, 0.0458, and 0.0282. The F-values were 59.457, which has a high significance at F>5, and 1.06233, which has a low significance at F>5. The P-values were 0.001059 and 0.03046 at P<0.05, which is significant. The F-crit values were both 6.944272.

Table 2.0

CBD 2017 ANOVA Results

Hemp Farms	*n*	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
West Farm & Pullen Farm	150	3.3607	2	1.6803	59.457	0.001059	4.324555
		0.0917	2	0.0488	1.6233	0.304669	4.324555
		0.1130	4	0.02826			
Total	150	3.5655	8				

Note: Table 2.0 shows the CBD values of West Farm and Pullen Farm samples in 2017. The test ran above was a two-factor ANOVA test. The total SS value was 3.5655. The total df value was 8. The MS values were 1.6803, 0.0488, and 0.02826. The F values were 59.457, which has a high significance at F>5, and 1.6233, which has a low significance at F>5. The P-values were 0.001059, which is significant at P<0.05, and 0.304669, which is insignificant at P<0.05. The F-crit had two values of 4.324555.

Figure 4.5 Pullen Farm 2017 THC

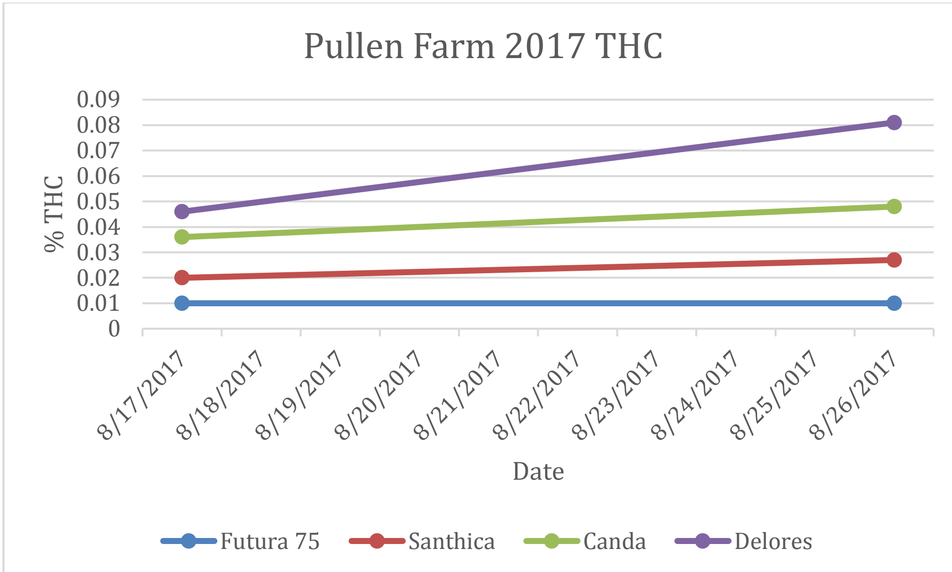


Figure 4.5 shows the rise in THC content in the varieties of Futura 75, Santhica, Canda, and Delores between the dates of August 17, 2017 and August 26, 2017. These tests were taken in the middle and at the end of the growing process. On August 17, 2017, Futura 75 had 0.01% THC content, Santica had 0.02% THC content, Canda had 0.38% THC content, and Delores had 0.048% THC content. On August 26, 2017, by the end of the growing process, Futura 75 had 0.01% THC content, Santhica had 0.029% THC content, Canda had 0.04% THC content, and Delores had 0.081% THC content.

Figure 4.6 Pullen Farm 2017 CBD

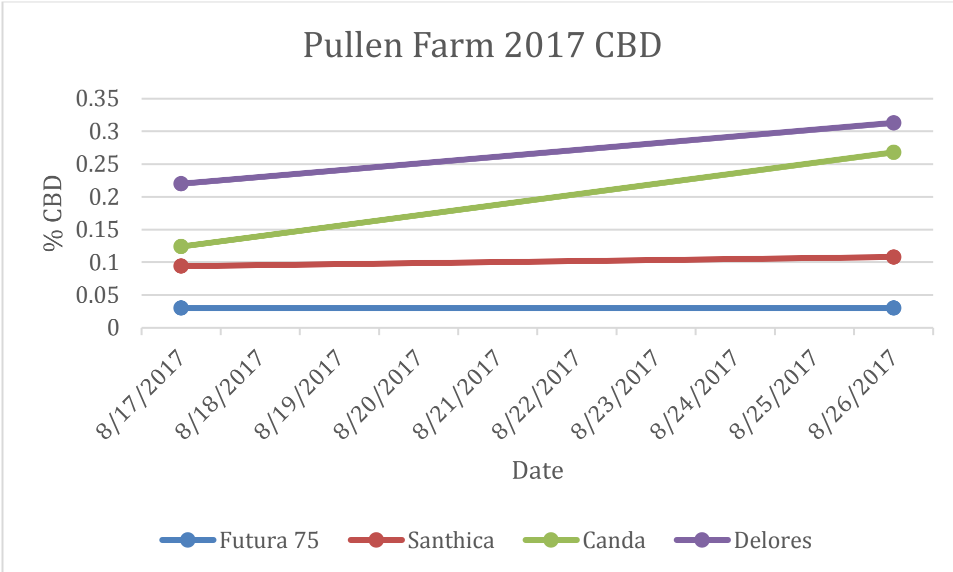


Figure 4.6 shows the CBD values between the two testing dates, August 17 and August 26 of 2017 for the varieties of Futura 75, Santhica, Canda, and Delores. These tests were taken in the middle and at the end of the growing process. On August 17, Futura 75 had 0.03% CBD content, Santhica had 0.1% CBD content, Canda had 0.13% CBD content, and Delores had 0.23% CBD content. By the end of the growing process, on August 26, Futura 75 had 0.03% CBD content, Santhica had 0.1% CBD content, Canda had 0.13% CBD content, and Delores had 0.23% CBD content.

Figure 4.7 West Farm 2017 THC

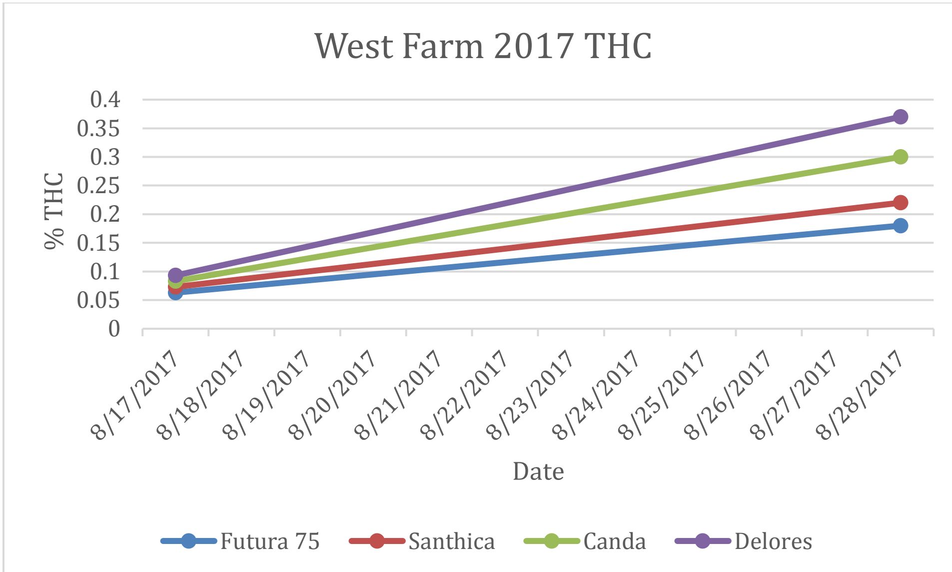


Figure 4.7 shows the rise of THC in the varieties of Futura 75, Santhica, Canda, and Delores between August 17 and August 28 of 2017 on the West Farm. These tests were taken in the middle and at the end of the growing process. On August 17, Futura 75 had 0.06% THC content, Santhica had 0.06% THC content, Canda had 0.08% THC content, and Delores had 0.1% THC content. On August 28, by the end of the growing process, Futura 75 had 0.18% THC content, Santhica had 0.21% THC content, Canda had 0.3% THC content, and Delores had 0.36% THC content.

Figure 4.8 West Farm 2017 CBD

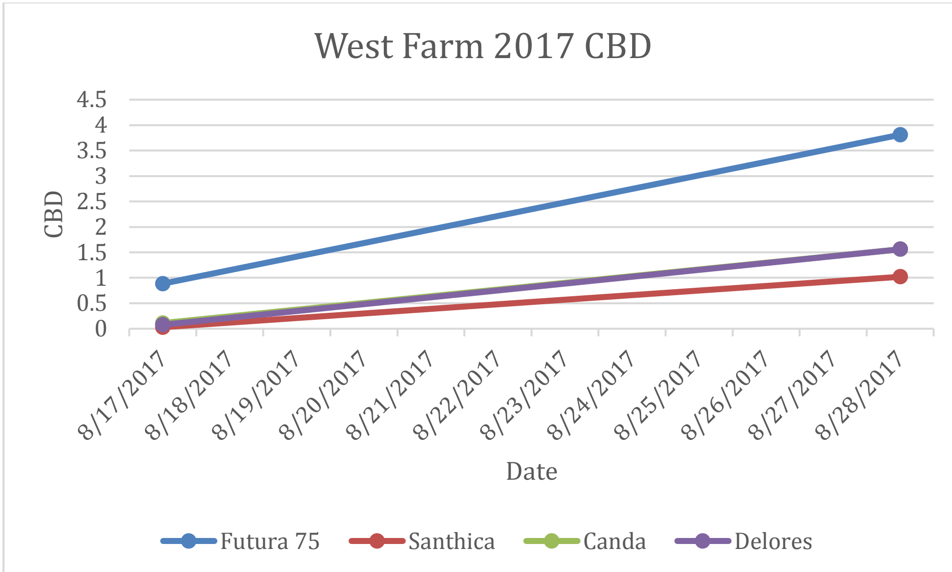


Figure 4.8 shows the rise in CBD on the West Farm in the crops of Futura 75, Santhica, Canda, and Delores. These tests were taken in the middle and at the end of the growing process. Delores and Santhica both had 0.08% CBD content and Futura 75 had 0.8% CBD content in the first testing on August 17. By the end of the growing process, on August 28, Santhica had 1.02% CBD content, Delores had 1.56% CBD content, and Futura 75 had 3.81% CBD content.

Yield Sample

The yield sample of 2017 was determined inconclusive. This is because there was a lack of time, manual labor, and funds to complete this part of the study. The four varieties of industrial hemp, Delores, Futura 75, Santhica, and Canda, were used in the yield sampling. A section of 25 centimeters for each variety was cut, and these samples were dried in a tobacco green house on the West Farm. This yield took two weeks to process and dry. After drying, the samples were collected in plastic tubs, which were then transported to the laboratory. At first, these materials were hand thrashed, but this procedure proved too labor intensive, and thus the task could not be completed. Then, mechanical thrashing was implemented. This method took many trials and errors to complete. Many parts of this machine had to be altered and repaired multiple times. A wheat thrasher was used to thrash the crop. Afterwards, the seeds were cleaned multiple times. At this point, it became clear that the seeds were too small to be separated from the materials via the seed-cleaning machine. Therefore, screens were implemented to separate the seeds from the organic matter, which proved successful for a period. After a certain point, the screens were no longer functioning, so the seeds had to be separated with the use of tweezers. At this point, there was no more time to complete this portion of this study. Therefore, to reach a conclusion on this yield sample, more time is needed to further investigate better means to execute the process of seed cleaning.

Conclusion

The results of this study were statistically insignificant. The soil analysis requires further investigation, while THC, CBD, and weather results were insignificant and thus require further study to obtain more data. To reach a conclusion, the process of yield sampling needs to be more efficient. This includes finding better means of thrashing and seed cleaning. The weather data did not yield any results, as there was a lack of data. This study concluded that there was no significant correlation established between the THC and CBD contents and the weather data. There was not enough data from past years to suggest a correlation between THC and CBD and weather data, so a conclusion cannot yet be reached.

Chapter V

Conclusions and Recommendations

Introduction

Hemp production is a very important domain to study in American agriculture and can be utilized to create textiles and oil. This was a difficult study, as much knowledge around the growth of this crop in the United States has been either lost or is underdeveloped in relation to other countries. However, there is potential for hemp to be revived into a major industry in the United States.

Industrial hemp can be used in many different ways, such as in the production of ropes, textiles, CBD oil, and other products. This 2017 study covered a great deal of literature and information on how industrial hemp is perceived by society and how research can change this perspective in the future. Legalization of hemp growth is necessary to produce industrial hemp and other types of marijuana throughout the Commonwealth of Kentucky, but there are many societal prejudices that must be overcome in order for hemp to become a major industry in Kentucky. Throughout the study, yield data, soil data, CBD and THC content, and weather data was explored. This research can provide data for future studies and answer questions about the viability of industrial hemp in the state of Kentucky.

Conclusion for Objective

2017 was the first year Murray State University recorded soil data for this industrial hemp project. The soil data gathered in this year was not sufficient to reach a conclusion, and there was not enough data to determine what minerals and inputs most benefitted the crop. However, this data will serve as a good basis of information for future studies. This research could also aid farmers to discover which elements of the soil affect industrial hemp growth, so analyzing the soil can be beneficial for the future of the industrial hemp crop.

Throughout the study, new ways to thrash and clean hemp using non-traditional equipment were explored. This study could serve as a basis for the development of new methods to harvest and produce industrial hemp, which will greatly benefit the industry. Technology for harvesting industrial hemp is slowly diffusing to the United States. To grow the crop more effectively, further research is needed to develop technology that is more efficient for the growth and production of industrial hemp.

From this study, it cannot be concluded whether the yield is correlated with soil fertility and weather conditions. This is due to the lack of data and time needed to complete the yield sampling. The soil data requires further years of research to reach a conclusion. A correlation cannot be established between yield and soil fertility or weather conditions. These aspects need to be explored further for a conclusion to be reached.

There is not enough data to conclude whether mineral content of the soil affects the growing cycle of the industrial hemp. This year of 2017 is the first year that data was gathered on the mineral contents of the industrial hemp plots at Pullen Farm and West Farm at Murray State University. To develop a conclusion, more research is necessary to explore mineral content in industrial hemp plots. To do so, more years of data need to be gathered and analyzed.

Recommendations for Future Research

There are several recommendations from this study for future research. One of these is to further analyze soil data more in-depth to understand which minerals are needed for Kentucky's industrial hemp crop to grow most efficiently. Soil data needs to be studied over multiple years in conjunction with hemp sampling data to determine mineral values and the effects of these on the crop. This would lead to more information regarding the optimum conditions for hemp growth. While soil information was collected for 2017, it is not possible to reach any conclusions based on this data alone. Instead, this data should be used as a starting point for future research.

Moreover, it is important to know the exact budget of the study and the costs of completing THC and CBD testing before beginning a project. It is also important to develop a sound method to collect hemp samples. In this study, all samples were collected and labelled efficiently, but the cost to test all of these samples greatly outweighed the budget. If the budget permits, the samples should be tested once a week throughout the growing process. When taking yield samples in the future, having the proper equipment is crucial. It would be beneficial to find a more efficient and less labor-intensive method of thrashing, cleaning, and drying than what was used in this study.

Another recommendation is to develop a more complete data pool from the Kentucky mesonet. This includes requesting more information, such as soil temperature. As of 2017, Calloway County does not have a soil temperature reader, although such device would be very beneficial to this research. Moreover, weather data should be gathered starting long before the study begins, as it takes a long time for the data to be received. Data should be gathered one month before growth and continue until one month after growth in order to reach accurate conclusions.

Recommendations for Practitioners

In soil testing, practitioners should develop a type of grid system for soil sampling. They should also develop a strategy to analyze the samples, and they should take these samples to a laboratory for analysis. The data gained from this study should be used as a basis to gather more information about the soil in relation to the hemp growth. There should be at least two rounds of testing completed, at the beginning of the summer and at the end of the summer. This will show what minerals the crops extracted from the soil.

Moreover, researchers should develop a new method for collecting the yield sample that is more efficient than the one used in this study. Researchers should focus on finding more effective machines, such as cleaners, thrashers, and dryers, to implement in industrial hemp production. This study took too long as there was a lack of labor, so future studies should have a minimum of five people working throughout the yield process.

Another recommendation is to gather mesonet data from May to August. This data should be gathered from Western Kentucky University. It takes time for the University to analyze the data and send it. After the growing season is complete, the weather data should be requested. Upon receiving this data, it is crucial to break down these data sets into times of the day to be analyzed. The researcher should focus on data sets stemming from optimal peaks of the day.

Conclusion

The soil data did not yield any conclusions. However, there needs to be more research done on this aspect. In 2017, this industrial hemp project was the first to study soil data at Murray State University and its effect on industrial hemp. To understand the importance of mineral use for the growth of industrial hemp, researchers should measure mineral content of the soil and its effect on industrial hemp. This is one of the most crucial aspects of industrial hemp growth, and it should be researched further.

In the past four years, industrial hemp has been grown at Murray State University. THC and CBD content was measured for the university records and for the state government records. This study investigated the relationship between CBD and THC content and temperature data, but found no correlation due to a lack of data. Overall, there has not been enough testing across the years to determine a correlation between the CBD and THC content of the hemp and the temperatures in which it was grown.

Moreover, the 2017 yield sample data was inconclusive because the methods used in thrashing and cleaning were not successful. Future studies should focus on finding more effective means to complete these tasks, as the methods used in this study were too labor-intensive to yield a significant sample. Therefore, this process needs to be investigated further to find a better method.

Furthermore, this study employed the use of data from THC and CBD testing throughout the four years of this industrial hemp project. The results from these past four years did not yield any significance in THC and CBD levels, so there is not enough data to reach a conclusion. In 2017, there was not enough funding to execute the necessary amount of tests to reach a conclusion. This field requires further research to find the peak points of hemp growth so that farmers are aware of the optimal time to harvest this crop for the greatest yield of THC and CBD.

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