UNIVERSITI MALAYSIA KELANTAN

Utilizing Wood Vinegar as an Effective Agent to Enhance the Growth Performance of Corn Plants

Anne Julia Binti Abdullah
J20A0417

A reported submitted in fulfilment of the requirements for the degree of Bachelor of Applied Science (Forest Resources Technology) with Honours

FACULTY OF BIOENGINEERING AND TECHNOLOGY
UMK

2024

DECLARATION

I declare that this thesis entitled “Utilizing Wood Vinegar as an Effective Agent to Enhance the Growth Performance of Corn Plants” is the results of my own research except as cited in the references.

Signature : ______________________

Student’s Name : Anne Julia Binti Abdullah

Date : 27/02/2024

Verified by:

Signature : ______________________

Supervisor’s Name : Dr. Boon Jia Geng

Stamp : DR. BOON JIA GENG
KETUA JABATAN
TEKNOLOGI BIO DAN SUMBER ASLI
FAKULTI BIOKEJURUTERAAN DAN TEKNOLOGI
UNIVERSITI MALAYSIA KELANTAN

Date : 27/02/2024

ACKNOWLEDGEMENT

First, I would like to thank God for their unending mercy and direction in helping me finish this thesis despite more obstacles and challenges during my journey of this final year project (FYP).

My gratitude has also been extended to Dr Boon Jia Geng, as an FYP supervisor, for guiding and assisting me throughout the whole process of my research.

I want to thank University Malaysia Kelantan for allowing me to gain experience in completing this challenging project.

I also want to express my gratitude to the laboratory assistant, Mr. Mohd Afifi Bin Suhaimi, for giving a lot of help and guidance throughout my project.

Most importantly, thanks to my family for their support and help during the initial process of planting corn to complete my project.

I would also love to thank all my friends who helped and struggled to complete this final-year project.

Finally, I would like to express my special appreciation to my one and only buddy, Siti Nurshazwani binti Aminuddin, for her unwavering support and for assisting me a lot during this journey.

Utilizing Wood Vinegar as an Effective Agent to Enhance the Growth Performance of Corn Plants

ABSTRACT

Using synthetic fertilizers and pesticides in corn cultivation has been linked to adverse environmental and human health effects. In addition, the excessive use of these chemicals has caused the deterioration of soil health and reduced crop productivity. Therefore, there is a need for alternative approaches to promote plant growth and increase crop yields without compromising environmental sustainability. Wood vinegar has been used in agriculture and livestock production. Wood vinegar is a natural by-product of wood pyrolysis. It contains various organic compounds that benefit plant growth, such as stimulating seed germination, increasing root growth, and increasing nutrient uptake. To enhance the effectiveness of wood vinegar, this research was carried out to evaluate the effect of wood vinegar on corn plant growth and compare the efficiency of corn plants with or without wood vinegar in improving growth performance while determining the most effective concentrations of wood vinegar for corn growth. This corn plant was undergoing the planting stage with different concentrations (0%,1%,3% and 5%) of diluted wood vinegar. To determine the efficiency according to the observation method. Different types of corn seeds are used as a sample for this testing: commercial sweet corn and coarse corn. The results showed that 3% of wood vinegar can be considered a suitable concentration in the planting stage. This research concludes that wood vinegar is the most suitable and effective agent to apply in plants to improve growth performance.

Keywords: Wood vinegar, Corn plants, Growth performance

Menggunakan Cuka Kayu sebagai Ejen Berkesan untuk Meningkatkan Prestasi Pertumbuhan Tanaman Jagung

ABSTRAK

Menggunakan baja sintetik dan racun perosak dalam penanaman jagung telah dikaitkan dengan kesan buruk terhadap kesihatan alam sekitar dan manusia. Selain itu, penggunaan bahan kimia ini secara berlebihan telah menyebabkan kemerosotan kesihatan tanah dan mengurangkan produktiviti tanaman. Oleh itu, terdapat keperluan untuk pendekatan alternatif untuk menggalakkan pertumbuhan tumbuhan dan meningkatkan hasil tanaman tanpa menjejaskan kelestarian alam sekitar. Cuka kayu telah digunakan dalam pertanian dan pengeluaran ternakan. Cuka kayu adalah hasil sampingan semula jadi daripada pirolisis kayu. Ia mengandungi pelbagai sebatian organik yang memberi manfaat kepada pertumbuhan tumbuhan, seperti merangsang percambahan benih, meningkatkan pertumbuhan akar, dan meningkatkan pengambilan nutrien. Bagi meningkatkan keberkesanan cuka kayu, kajian ini dijalankan untuk menilai kesan cuka kayu terhadap pertumbuhan tanaman jagung dan membandingkan kecekapan tanaman jagung dengan atau tanpa cuka kayu dalam meningkatkan prestasi pertumbuhan sambil menentukan kepekatan cuka kayu yang paling berkesan untuk pertumbuhan jagung. Pokok jagung ini sedang menjalani peringkat penanaman dengan kepekatan berbeza (0%,1%,3% dan 5%) cuka kayu cair. Untuk menentukan kecekapan dengan mengikut kaedah pemerhatian. Jenis benih jagung yang berbeza digunakan sebagai sampel untuk ujian ini: jagung manis komersial dan jagung kasar. Keputusan menunjukkan bahawa 3% cuka kayu boleh dianggap sebagai kepekatan yang sesuai dalam peringkat penanaman. Penyelidikan ini merumuskan bahawa cuka kayu adalah agen yang paling sesuai dan berkesan untuk digunakan dalam tumbuhan untuk meningkatkan prestasi pertumbuhan.

Kata kunci: Cuka kayu, Pokok jagung, Pertumbuhan

TABLE OF CONTENT

DECLARATION ..... **i**

ACKNOWLEDGEMENT ..... **ii**

ABSTRACT ..... **iii**

ABSTRAK ..... **iv**

TABLE OF CONTENT ..... **v**

LIST OF TABLES ..... **viii**

LIST OF FIGURES ..... **ix**

LIST OF ABBREVIATIONS ..... **xii**

LIST OF SYMBOLS ..... **xiii**

CHAPTER 1 ..... **1**

INTRODUCTION **1**

1.1 Background of Study 1

1.2 Problem Statement 3

1.3 Objectives 4

1.4 Scope of Study 4

1.5 Significances of Study 4

CHAPTER 2 ..... **6**

LITERATURE REVIEW **6**

2.1 Corn or maize (*Zea mays*) 6

2.1.1 The genetic and molecular mechanisms 7

2.1.2 The environmental factors that impact on corn growth. 9

2.1.3 Factors that affect corn growth. 10

2.1.4 The techniques that have been used to enhance corn growth. 11

2.2 Wood vinegar 12

2.2.1 The potential benefits of wood vinegar in agriculture. 13

2.2.2 The positive and negative aspect for corn cultivation. 14

2.2.3 The effectiveness in enhancing corn growth performance. 15

2.2.4 The challenges associated with the use of wood vinegar. 15

CHAPTER 3 17

MATERIALS AND METHODS 17

3.1 Materials 17

3.2 Methods 17

3.2.1 Sample preparation 17

3.2.2 Soil preparation 18

3.2.3 Seed treatment 19

3.2.4 Root application 20

3.2.5 Water application 21

3.2.6 Maintenance for corn growth 22

3.2.7 Effectiveness test for corn growth 23

CHAPTER 4 25

RESULTS AND DISCUSSION 25

4.1 The effect of wood vinegar on corn plant growth 25

4.2 The efficiency of corn plants with or without wood vinegar in growth performance. 29

4.2.1 Corn plant height 30

4.2.2 Stem diameter 34

4.2.3 Leaf length 38

4.2.4 Number of leaves 42

4.2.5 Number of damaged leaves 45

4.2.6 Corn yield 49

4.3 The most effectiveness concentrations of wood vinegar for corn development. 53

4.4 Soil pH 57

CHAPTER 5 59

CONCLUSIONS AND RECOMMENDATIONS 59

5.1 Conclusions 59

5.2 Recommendations 59

REFERENCES 61

APPENDIX A 67

APPENDIX B 68

APPENDIX C 69

LIST OF TABLES

Table 4.1(a): The commercial sweet corn growth performance in polybag 25

Table 4.1(b): The coarse corn growth performance in polybag.................................. 26

Table 4.1(c): The commercial sweet corn growth performance directly in the soil ... 27

Table 4.1(d): The coarse corn growth performance directly in the soil oil 28

Table 4.3(a): The effective concentration of commercial sweet corn in polybag....... 53

Table 4.3(b): The effective concentration of coarse corn in polybag 53

Table 4.3(c): The effective concentration of commercial sweet corn directly into the soil... 55

Table 4.3(d): The effective concentration of coarse corn directly into the soil 55

Table 4.4(a): Soil pH of corn plants in polybag 57

Table 4.4(b): Soil pH of corn plant directly into soil.. 57

LIST OF FIGURES

Figure 2.1: The corn plants (*Zea mays*) 7

Figure 2.2: The application of wood vinegar for corn plants.................................... 13

Figure 3.2: The wood vinegar 18

Figure 3.2: The oil palm effluent soil 19

Figure 3.2: The different type of seeds, commercial sweet corn and coarse corn 20

Figure 3.2: The root zone of corn plant in different type of seeds and planting treatments 21

Figure 3.2: The foliar feeding for corn plants 22

Figure 4.2(a): Height performance of commercial sweet corn with and without wood vinegar in polybags 30

Figure 4.2(b): Height performance of coarse corn with and without wood vinegar in polybags 31

Figure 4.2(c): Height performance of commercial sweet corn with and without wood vinegar directly into soil 32

Figure 4.2(d): Height performance of coarse corn with and without wood vinegar directly into soil 33

Figure 4.2(a): Stem diameter of commercial sweet corns with and without wood vinegar in polybags 34

Figure 4.2(b): Stem diameter of coarse corns with and without wood vinegar in polybags 35

Figure 4.2(c): Stem diameter of commercial sweet corns with and without wood vinegar directly into the soil 36

Figure 4.2(d): Stem diameter of coarse corns with and without wood vinegar directly into the soil..37

Figure 4.2(a): Leaf length of commercial sweet corn with and without wood vinegar in polybags 38

Figure 4.2(b): Leaf length of coarse corn with and without wood vinegar in polybags 39

Figure 4.2(c): Leaf length of commercial sweet corn with and without wood vinegar directly into the soil 40

Figure 4.2(d): Leaf length of coarse corn with and without wood vinegar directly into the soil..41

Figure 4.2(a): The growth performance of commercial sweet corn leaves with and without wood vinegar in polybags 42

Figure 4.2(b): The growth performance of coarse corn leaves with and without wood vinegar in polybags 42

Figure 4.2(c): The growth performance of commercial sweet corn leaves with and without wood vinegar directly into soil 43

Figure 4.2(d): The growth performance of coarse corn leaves with and without wood vinegar directly into soil 44

Figure 4.2(a): The leaves conditions of commercial sweet corn with and without wood vinegar in polybags 45

Figure 4.2(b): The leaves condition of coarse corn with and without wood vinegar in polybags 46

Figure 4.2(c): The leaves conditions of commercial sweet corn with and without wood vinegar directly into the soil 47

Figure 4.2(d): The leaves conditions of coarse corn with and without wood vinegar directly into the soil 48

Figure 4.2(a): Commercial sweet corn yield development with and without wood vinegar in polybags 49

Figure 4.2(b): Coarse corn yield development with and without wood vinegar in polybags 50

Figure 4.2(c): Commercial sweet corn yield development with and without wood vinegar directly into the soil 51

Figure 4.2(d): Coarse corn yield development with and without wood vinegar directly into the soil........ 52

LIST OF ABBREVIATIONS

N	Nitrogen	9
P	Phosphorus	9
K	Potassium	9
H	Height	25
SD	Stem diameter	25
L	Leaf length	25
NL	Number of leaves	25
DL	Number of damaged leaves	25
CY	Corn yield	25
WV	Wood vinegar	30
NWV	Non-wood vinegar	30

LIST OF SYMBOLS

°C	Temperature (Degree Celsius)	9
%	Percentage	53

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Cereal crops encompass numerous species cultivated largely for their edible grains. Every species exhibits distinct variations with distinctive attributes such as flavor, nutritional composition, and cultivation prerequisites. Among all the species of cereal crops, *Zea mays*, commonly known as corn, is the focused species in this research.

The corn crop (*Zea mays*) is primarily acknowledged as one of the most essential agricultural species, contributing significantly to the commercial sector. Corn or cereal plants are members of the *Poaceae* grass family. It is native to southern Mexico and has spread around the world. Corn plants are annual plants that grow best in warm climates. They can reach heights of up to 10 feet (3 meters) and have long, narrow leaves that grow alternately on the stem. The flowers of the corn plant are separate male and female structures, with the male flowers located at the top of the plant and the female flowers located lower down.

It is the most popular and extensively distributed staple crop in the world, and it is critical for sustainable agriculture and boosting growth performance. Corn is generally grown in areas with suitable soil and climatic conditions. In Malaysia, it is mainly grown in the states of Perak, Selangor, and Johor, as well as in some parts of Sabah and Sarawak. The crop is usually rotated with other crops, such as vegetables or legumes, to maintain soil fertility and reduce pest and disease problems. Corn is an essential food for livestock, and corn is used as a raw material in the industry and as fresh and processed food for human consumption.

However, the invasion of pathogenic bacteria such as *Xanthomonas campestris pv. zeae*, *Erwinia chrysanthemi* and *Clavibacter michiganensis* have become a threat to farmers and eliminated the corn population in cultivating corn crops. Since the incidents, many different approaches have been taken to evade the problems. Several ways are needed to produce healthier and stronger corn plants for their excellent growth performance. A practical method for studying the improvement of growth performance and overall health of maize plants involves the application of wood vinegar to the soil of maize crops.

As an agricultural agent, wood vinegar has recently gained attention because of its potential benefits in promoting plant growth and suppressing pests and diseases. Wood vinegar is also known as *pyrolignous acid*, a dark liquid produced by the destructive distillation (heating with a high temperature) of wood and other plant materials (Webster, 1913: de Guzman, 2009). It is one of the natural extracts from the woods used in agricultural activity and has been reported to have a beneficial effect on plant growth.

In a nutshell, this research aims to evaluate the effect of wood vinegar on corn plant growth. It will also compare the efficiency of corn plants with or without wood vinegar in improving growth performance. The outcomes of this research will help establish sustainable and ecologically friendly corn agricultural practices. Therefore, using wood vinegar as an agricultural agent may minimize the need for synthetic fertilizers and pesticides, improving soil health and lowering environmental pollution.

1.2 Problem Statement

Using synthetic fertilizers and pesticides in corn cultivation has been linked to adverse environmental and human health effects. In addition, the excessive use of these chemicals has caused the deterioration of soil health and reduced crop productivity. Therefore, there is a need for alternative approaches to promote plant growth and increase crop yields without compromising environmental sustainability. Wood vinegar has been used in agriculture and livestock production. Wood vinegar is a natural byproduct of wood pyrolysis. It contains various organic compounds that have been reported to have beneficial effects on plant growth, such as stimulating seed germination, increasing root growth, and enhancing the uptake of nutrients.

Additionally, wood vinegar has been shown to have insecticidal and fungicidal properties, making it a potential alternative to synthetic pesticides. It is typically applied to plants through foliar spray, soil drench, or irrigation. It can also be used as an amendment to improve soil structure and fertility because wood vinegar is a natural product, it is considered safe and environmentally friendly. Nevertheless, more studies are needed on the potential of wood vinegar as an effective agent to improve the growth performance of corn plants.

1.3 Objectives

The main objective of this research was:

1. To evaluate the effect of wood vinegar on corn plant growth.
2. To compare the efficiency of corn plants with or without wood vinegar in improving growth performance.
3. To determine the most effective concentrations of wood vinegar for corn growth.

1.4 Scope of Study

The scope of the study on the efficacy of wood vinegar in enhancing the growth performance of plants encompasses several factors, including the assessment of wood vinegar's impact on corn plants. This study assessed multiple characteristics of the growth of corn plants, including plant height, leaf area, root development, and yield. These measurements will provide insight into the effects of wood vinegar on various aspects of plant growth and productivity. This study included analyzing soil properties before and after applying wood vinegar—parameters such as soil pH. Therefore, the effectiveness of using wood vinegar on plants, especially corn plants, can be seen.

1.5 Significances of Study

This study can potentially increase agricultural productivity by improving the growth performance of corn plants. This can lead to higher yields and contribute to addressing global food security challenges. By using wood vinegar in agriculture, this study promotes sustainable practices. It allows for the effective use of waste materials.

Wood vinegar is a by-product of biomass pyrolysis and helps reduce environmental pollution. Wood vinegar is often considered a natural fertilizer because of its properties that promote plant growth. Investigating its effectiveness for corn plants explores its potential as an alternative to synthetic chemical fertilizers, thereby reducing reliance on potentially harmful substances and supporting organic farming practices. Higher crop yields and better quality can increase profitability, supporting agricultural livelihoods and the rural economy.

CHAPTER 2

LITERATURE REVIEW

2.1 Corn or maize (Zea mays)

Corn, also known as maize (Zea mays), is native to Mexico and Central America, where it was first domesticated (David Edwards, 2019). This is a cereal crop that is widely cultivated throughout the world (Ho Dinh Hai, 2016). It is a member of the grass family and is one of the most important staple crops in the world, used both as a food source for humans and animals and as a raw material for various industrial products. Corn is a tall, annual plant that grows to 10 feet (3 meters). It has long, narrow leaves and a single stalk that produces a cob covered in husks and contains rows of kernels. Each kernel is attached to a central stalk and can be yellow, white, or a mixture of both colours.

Corn is a versatile crop that can be used in many ways. It is a common ingredient in many food products, such as tortillas, chips, and cornmeal. It also used as animal feed and is an essential source of carbohydrates and protein for livestock. In addition, this plant is used in the production of ethanol. This biofuel is used as a gasoline additive and a raw material in producing many industrial products, such as starch, corn syrup, and bioplastics (M. K. Marichelvam et al. 2019).

Figure 2.1: The corn plants (*Zea mays*)

(Source: Chris Lee, 2023)

Corn, belonging to the *Poaceae* family, stands out due to its distinctive characteristic of producing substantial, succulent cobs enveloped by protective husks (Alma Pineyro-Nelson et al. 2017). Each ear contains rows of kernels, which are modified grass flowers. The kernels are attached to a central stalk or cob, also part of the flower structure. The *Poaceae* family is one of the most prominent flowering plants and includes many essential cereal crops such as rice, wheat, barley, and oats. Therefore, corn is now one of the world's most cultivated crops, including Malaysia. This is not only due to having many benefits from the plant but also because it can be used for economic resources and so on. The history of corn is a testament to the ingenuity and adaptability of human society and its importance to food security for years to come.

2.1.1 The genetic and molecular mechanisms

The genetic makeup of corn is complex. This is because corn has a relatively large genome, with an estimated 32,000 genes, and it is diploid, meaning it has two sets of chromosomes (2n=20) (Fusheng Wei et al. 2007). One of corn's most interesting genetic features is its high level of genetic variation (Miyassa Meriem Aci et al., 2018). This variation has been shaped by thousands of years of natural selection and human intervention, leading to the development of different varieties adapted to other environmental conditions and uses. Modern corn breeding has focused on developing hybrids created by crossing two genetically different parent lines (Flavio Breseghello et al., 2013). This process takes advantage of the high genetic variation in corn, allowing breeders to create hybrids with desirable characteristics, such as high yield, disease resistance, and drought tolerance.

However, this plant also has a molecular mechanism. It involves complex interactions between genes, proteins, and other molecules that regulate corn plants' growth, development and response to environmental stimuli. Genetic and environmental factors influence these mechanisms and involve various cellular and biochemical processes. One of the main molecular mechanisms of maize is gene regulation. Gene regulation is the process used to control the timing, location and amount in which genes are expressed. The process can be complicated and is carried out by various mechanisms, including through regulatory proteins and chemical modification of DNA (Julie Segre, 2023). Corn has a large and complex genome, with an estimated 32,000 genes (Fusheng Wei et al. 2007), and the expression of these genes is tightly regulated in response to internal and external signals. This regulation is mediated by various mechanisms, including transcription factors, epigenetic modifications, and small RNA molecules, which control gene activity at transcription, translation, and post-transcriptional processing levels.

Another important molecular mechanism of maize is hormonal signaling. Hormones such as auxin, cytokinin, and gibberellin play an essential role in controlling the growth (Yankun Zheng, 2021) and development of maize by regulating cell division, differentiation, and elongation and by coordinating responses to stress and other environmental factors. The molecular mechanism of corn also includes the biosynthesis and metabolism of complex molecules such as starch, protein, and secondary metabolites (Galvez Ranilla L. 2020). Maize is the primary starch source, synthesized in the grain during seed development. Enzymes involved in starch synthesis and degradation are regulated by a complex network of genes (Cho, Y. G., & Kang, K. K. 2020) and signaling pathways, which are influenced by various environmental and developmental signals.

2.1.2 The environmental factors that impact on corn growth.

The growth and development of maize is influenced by various environmental factors, which can affect yield and quality. Temperature, water ability, soil quality, light, pest and disease pressure are some factors. Corn is a warm-season crop that requires a certain amount of heat to germinate, grow, and mature. The optimal temperature for corn growth is 25 - 30°C during the day and 15 - 20°C at night (Muhammad Ahmed Waqas et al. 2021). Temperatures outside of this range can lead to reduced growth and yield.

Corn plants need enough water to grow and produce grain. The optimal water requirement for corn is about 1 inch per week during the growing season, with more water needed during the dry season. Water stress can result in reduced yield and quality. Corn requires well-drained soils that are rich in nutrients. Corn grows best in loam soils. For good germination of seeds, the soil needs to be 16°C or above (Lee Taylor, 2016). Soil fertility is a critical factor for corn growth, as the crop is a heavy feeder and requires adequate nitrogen (N), phosphorus (P), potassium (K), and other micronutrients. Corn needs enough sunlight to carry out photosynthesis and growth. Optimal light conditions for corn growth are around 12- 14 hours of sunlight daily. Shaded conditions or dim light can result in reduced corn growth and yield. Last, corn is susceptible to various pests and diseases, impacting growth and yield. Common corn pests include corn earworm, European corn borer, and armyworm, while common diseases include grey leaf spot, southern rust, and northern corn leaf blight.

2.1.3 Factors that affect corn growth.

Corn is a crop widely cultivated worldwide for its versatility and nutritional value, from water availability and drainage to nutrient access and root development. Various factors, including soil types, fertilization, and irrigation, influence the growth and development of corn plants. The soil type significantly affects corn growth and development. It has large particle sizes and low organic matter for sandy soils. These soils have low water-holding capacity and nutrient-holding ability, which can lead to drought stress in corn plants and limit the availability of essential nutrients such as nitrogen, phosphorus, and potassium. Clay soil is also one of the types because it has a small particle size and is high in organic matter. These soils have high water-holding capacity and heavy texture that can make it difficult for corn roots to penetrate, limiting their ability to access water and nutrients. Besides, loam soil has a balanced mixture of sand, silt, and clay particles. They have good water and nutrient-holding capacities, making them ideal for corn growth. At the same time, acidic soil has a pH below 7.0, which can limit the availability of specific nutrients such as phosphorus, calcium, and magnesium. Corn plants grown in acidic soils may exhibit stunted growth and poor yield. Saline soils are one of the types with high salt levels, which can limit the ability of corn plants to take up water and nutrients.

Besides, fertilization plays a crucial role in the growth and development of corn plants. Proper fertilization practices can significantly impact corn growth, yield, and overall plant health (Corn fertilization, 2023). Macronutrients are one of the examples that affect corn growth. This is because corn plants require three primary macronutrients in large quantities: nitrogen (N), phosphorus (P), and potassium (K) (Tamargo, 2019). These macronutrients play essential roles in various plant processes. Nitrogen promotes leafy growth and overall plant development. Phosphorus aids in root development, flowering, and fruit set. Potassium contributes to overall plant health, disease resistance, and stress tolerance.

Micronutrients also are one of them. Although required in smaller amounts, micronutrients are vital for corn growth. Examples of essential micronutrients include iron, zinc, manganese, copper, boron, and molybdenum. These nutrients are involved in the plant's enzyme activity, photosynthesis, and various metabolic processes.

Irrigation is a critical factor that can significantly impact corn growth (Huynh et al. 2019). Proper irrigation practices ensure that corn plants receive an adequate and consistent water supply, which is essential for their development, yield, and overall health. Water availability is a way in which irrigation can affect corn growth. Corn plants require sufficient water throughout their growth stages, especially during critical pollination and grain-filling periods. Insufficient water availability can lead to water stress, reduced photosynthesis, and stunted growth. Conversely, providing the right amount of water ensures optimal plant hydration and promotes healthy corn growth.

2.1.4 The techniques that have been used to enhance corn growth.

Several techniques have been used to increase corn growth. Among them is the method of genetic modification. Genetic engineering techniques have been used to develop genetically modified varieties of maize that exhibit enhanced growth characteristics. These modifications may include increased resistance to pests and diseases, increased tolerance to drought or temperature extremes, and increased nutrient uptake efficiency. In addition, fertilization is also one of the techniques. Fertilizers that contain nutrients such as nitrogen, phosphorus, and potassium can promote corn growth. Soil tests are conducted to determine nutrient deficiencies, and fertilizers are applied accordingly to meet plant needs.

Therefore, it can give a positive development to the growth of corn. Furthermore, intercropping corn withother crops in a rotation system can help improve soil fertility and reduce the development of pests and diseases specific to maize (Huss et al. 2022). Crop rotation allows better nutrient cycling and minimizes the risk of soil depletion.

2.2 Wood vinegar

Wood vinegar was also known as pyroligneous acid or wood acid. The hue of wood vinegar is dark brown, and it is produced via the destructive distillation of wood and other plants. It contains a complex mixture of organic compounds, including acetic acid, methanol, acetone, formaldehyde, and various phenols (Ortíz et al. 2014). German chemists were the first to explore *pyrroligneous acid.* Aside from that, this acid was consumed as a vinegar replacement. Wood vinegar may also cure wounds, ulcers, and other illnesses. (Agrawal et al. 2017). Salt may be created by neutralizing the wood vinegar acid with lye from the burned wood's ashes.

The composition of wood vinegar can vary depending on the type of wood used and the specific production process (Theapparat et al., 2018). Wood vinegar has been used for centuries in traditional medicine and agriculture due to its potential beneficial properties. It has often been used for ages as a sterilizing agent, deodorizer, fertilizer, and antimicrobial. It can enhance seed germination, root development, and overall plant health. Wood vinegar is also a natural pest repellent, as certain compounds can deter insects and other pests.

Figure 2.2: The application of wood vinegar for corn plants

(Source: Ahmad, 2015)

2.2.1 The potential benefits of wood vinegar in agriculture.

The natural byproduct known as wood vinegar, sometimes referred to as pyroligneous acid or liquid smoke, is obtained by pyrolysis, which involves burning wood or plant material. Agriculture has used it for various purposes, and it should benefit agriculture. Improvements to the land are one of them. This is because wood vinegar can improve the quality and fertility of the soil. It helps regulate soil pH, increase microbial activity, and increase organic matter. Therefore, this can result in better soil structure, nutrient availability, and water-holding capacity, leading to healthier and more productive soil for crop production, especially corn plants.

In addition, pest and disease management is also one of the benefits. Wood vinegar has natural pesticide and antimicrobial properties. It can act as a repellent, inhibiting the growth and activity of pests such as insects, nematodes, and fungi. Therefore, this fertilizer can help to reduce pest damage and control plant diseases. The presence of this wood vinegar can give good freshness and lead to healthier plants. Stress resistance is also among the benefits of agriculture. Wood vinegar can help increase plant resistance to environmental stress, such as drought, salinity, and extreme temperatures. Organic compounds found in wood vinegar can activate plant stress-responsive genes. Therefore, it can increase the plant's ability to withstand the weather and uncertain conditions and avoid dead trees.

2.2.2 The positive and negative aspect for corn cultivation.

The use of wood vinegar in corn cultivation is divided into two aspects, which are positive and negative. In terms of positive aspects, the use of wood vinegar can encourage the promotion of tree growth (Zhu et al. 2021). This is because wood vinegar contains organic compounds that can stimulate the growth of plants, including corn. Wood vinegar applied to corn plants can increase root development, nutrient absorption, and plant growth. Therefore, it will obtain a higher yield compared to other plants.

In addition, the use of wood vinegar can also improve the quality of the soil for corn cultivation. It helps regulate soil pH, increase microbial activity, and increase organic matter. Therefore, this can result in better soil structure, nutrient availability, and water-holding capacity, which is beneficial for corn crops. From a negative aspect, wood vinegar will suffer from a lack of Standardization (Aguirre et al. 2020). Wood vinegar products can differ in composition and concentration depending on the source material and production process. This lack of standardization can make it difficult to determine optimal application rates and potential effects on corn crops. It is advisable to consult with agricultural experts or conduct field tests before widespread use.

Furthermore, research on the use of wood vinegar is minimal. Despite its beneficial potential, however, more scientific research is still needed, specifically focused on using wood vinegar in corn cultivation. Therefore, more studies are required for precise effects, optimal application methods, and long-term implications for corn yield and quality.

2.2.3 The effectiveness in enhancing corn growth performance.

The efficiency of wood vinegar in boosting corn growth performance varies according to several aspects, including wood vinegar concentration, application method, soil conditions, climate, and corn variety. However, wood vinegar has shown potential benefits in promoting plant growth and improving soil quality. Therefore, it is also essential to consider wood vinegar's potential limitations or adverse effects, such as phytotoxicity, if used in excessive amounts or at high concentrations.

Natural fertilizers can improve corn growth by providing nutrients and increasing soil fertility. Compost is one of the natural fertilizers commonly used and has excellent potential for corn cultivation. Compost is a valuable natural fertilizer that improves soil structure. It increases nutrient availability and promotes microbial activity. Compost enriches the soil with organic matter when applied to cornfields, releasing nutrients slowly over time and leading to healthier corn crops and better yields. Increasing soil microbial activity can positively affect corn growth by increasing nutrient availability, improving soil structure and promoting overall soil health. Adding organic matter is one of the steps that can help increase soil microbial activity and benefit corn cultivation. Organic matter, such as compost, is applied to the soil. It can provide food sources for soil microorganisms. Organic matter supports microbial growth and activity, increasing nutrient cycling and improving soil structure. Adding organic matter to the soil before planting corn can increase the microbial population and positively impact the yield.

2.2.4 The challenges associated with the use of wood vinegar.

The use of wood vinegar in agricultural techniques has presented numerous obstacles. Among them is the need for greater standardization. The production method of wood vinegar and the resulting composition can vary significantly depending on the source material and the production process (Agrawal et al. 2017). This lack of standardization makes determining consistent concentrations of active compounds in wood vinegar easier. Variability in composition can impact its effectiveness and prevent reliable and reproducible results in agricultural applications.

In addition, experiencing the effects of change on different crops. The effectiveness of wood vinegar can produce different results when needed across different plant species and varieties. Some plants may respond positively to wood vinegar, while others may not benefit significantly or negatively. Furthermore, phytotoxic risks are also among the challenges faced in maize cultivation. Excessive use or high concentrations of wood vinegar can lead to phytotoxicity, causing harm to plants.

CHAPTER 3

MATERIALS AND METHODS

3.1 Materials

The raw materials that have been used in this study are wood vinegar that was obtained from a local supplier, oil palm effluent soil, and two different types of seeds, which are commercial sweet corn and coarse corn. The equipment used during this research consists of gardening implements, such as a hoe, garden fork for soil preparation and planting, watering can, planting polybag, measuring container, mixing container, pH testing kit, and sprayer.

3.2 Methods

There are numerous approaches for using wood vinegar as an efficient agent to enhance the growth performance of corn plants. It started with sample preparation, soil preparation, seed treatment, root application, foliar application, maintenance for corn growth, and effectiveness tests for corn growth.

3.2.1 Sample preparation

Wood vinegar was a sample substance received from a local supplier. The wood vinegar with a 50% concentration was good quality, free from impurities, concentrated, and diluted before use. The wood vinegar was mixed with water in an appropriate ratio of 1:200. This indicates that 2.5 ml of wood vinegar was combined with 500 ml of water. This dilution serves to prevent any potential harm to the plant. Wood vinegar has been stored in a clean, well-sealed container to preserve its quality and avoid contamination.

Figure 3.2: The wood vinegar

3.2.2 Soil preparation

Successful corn cultivation begins with thorough soil preparation through a comprehensive soil test to assess critical factors such as pH, nutrient levels, and soil structure. Then, the pH of the soil have been tested. If the soil pH is too acidic or alkaline, the optimal range have been adjusted for corn because corn plants prefer slightly acidic to neutral soil with a pH range of 6.0 and 7.5 (Slater, 2022). Following this, land clearing and plowing were made to remove debris, rocks, and weeds while breaking up the soil to create a loose, well-aerated seedbed. Secondary tillage using tools like harrows further refines the soil structure. Incorporating organic matter, such as compost or manure, enhances the soil's fertility, structure, and water retention capacity.

Fertilizers were then applied based on the soil test results, addressing the specific nutrient needs of corn, which commonly include nitrogen, phosphorus, and potassium. Once the soil was adequately prepared, planting at the recommended depth and spacing crucial for optimal germination and growth. Mulching has been employed to conserve moisture and suppress weeds, though its use depends on local conditions and cultivation practices. Throughout the growing season, regular monitoring of soil moisture and nutrient levels, along with consistent irrigation, plays a vital role in ensuring the health and productivity of corn plants.

Figure 3.2: The oil palm eluent soil

3.2.3 Seed treatment

Corn seeds have been soaked in a water solution for a short period, usually 1 to 2 hours, before planting. This treatment has help improved seed germination, strength, and early seedling growth (Kait, 2019). Seeds were treated with appropriate disinfectants to reduce the risk of seed-borne diseases. It was priming improved seed germination and early seedling growth. The seeds have been ensured to be completely submerged during priming. Treated seeds could dry completely before planting. The seeds were guaranteed to be completely dry before storing or planting to avoid potential spoilage or fungal growth.

Figure 3.2: The different type of seeds, which are commercial sweet corn and coarse corn

3.2.4 Root application

The timing and method of root application have played a crucial role in providing the necessary nutrients for corn throughout its lifecycle. After corn seeds have germinated and seedlings have emerged, phosphorus and potassium are often applied at the root zone to support root development, flowering, and overall plant resilience. A diluted wood vinegar solution have been applied directly to the plant's root zone.

A watering can has been used to spread the solution evenly around the base of the plant. Excessive application was avoided to prevent damage to the roots of the corn plant. Regularly monitoring soil conditions and plant nutrients was seen weekly to adjust root applications, ensuring that corn plants receive the proper nutrients at the right time for optimal yield and quality.

Figure 3.2: The root zone of corn plant in different type of seeds and planting treatments

3.2.5 Water application

Foliar feeding to corn plants involves spraying a water and wood vinegar solution directly onto the plant leaves. This method provided additional nutrients and other beneficial substances to corn plants and helped address nutrient deficiencies. Foliar application begins when the corn plant has developed and is actively growing. This usually occurs around the V4 to V8 growth stage.

The wood vinegar has been chosen and used for corn plants. This product is available through local suppliers. It is essential to achieve the correct concentration to avoid damage or ineffectiveness of the plant. Then, the response of the corn plant to leaf application was carefully observed. Any signs of nutrient deficiencies, stress or adverse effects have been monitored. The application frequency or nutrient concentration was adjusted based on observations of the corn plant.

Figure 3.2: The foliar feeding for corn plants

3.2.6 Maintenance for corn growth

The maintenance of corn growth involves a series of agronomic practices to provide optimal conditions for the plant's development and ensure a successful crop yield. The corn plant was ensured to get enough moisture through rain or regular watering. Then, the growth and development of corn plants have been observed in terms of vigor, shoot and root growth, and overall plant health.

Adequate and consistent moisture has been provided to corn plants, especially during critical growth stages such as germination, tillering, and ear development. Soil moisture levels and water have been monitored as needed; about 1 inch (2.5 cm) of water was aimed each week, including rain. Water deeply encourages profound root growth and avoids shallow watering, which causes a shallow root system. The corn planting area has been ensured to be weed-free, as these two plants compete for nutrients, water, and sunlight. Soil nutrient levels have been monitored through regular soil tests, and the appropriate fertilizers have been applied based on test results. Corn has a high nutrient demand, especially for nitrogen, phosphorus, and potassium.

Fertilizer was applied according to the set rate and time, considering soil fertility and plant needs. Corn plants were constantly monitored for pests and diseases. The common pests such as corn borers, armyworms and aphids and diseases such as rust, leaf blight and stalk rot have been monitored weekly. The maintenance of corn growth extends to carefully observing environmental conditions and adjusting practices accordingly to mitigate risks associated with extreme weather events or soil-related challenges. Then, the corn was harvested when the cobs reach maturity. Harvest timing was critical, ensuring the corn reaches maturity for optimal yield and quality. The harvest time depends on the variety of corn and its use. The moisture content of corn plants was monitored quickly to determine the optimal time to harvest.

3.2.7 Effectiveness test for corn growth

The effectiveness tests for corn growth involve systematic evaluations to assess the impact of various treatments or interventions on the development and productivity of corn plants. The effectiveness of wood vinegar has been measured for corn growth. The different treatment groups have been prepared with varying concentrations of wood vinegar, such as 0%, 1%,3% and 5%. In addition, a control group was included without wood vinegar treatment to see the effectiveness of the wood vinegar on corn plants. Each treatment group of plant corn seeds has been placed in a polybag and directly into the soil. The corn seeds used have been ensured of the same quality and quantity to maintain consistency.

A predetermined concentration of wood vinegar was applied to the soil around the corn plants in each treatment group. A consistent schedule has been followed for application, considering factors such as weekly frequency and amount of wood vinegar. All corn plants had uniform environmental conditions, including light, temperature, humidity and water availability. This ensures that any differences observed in growth will be attributed to the wood vinegar treatment rather than external factors. The growth of corn plants in each treatment group was continuously monitored. The parameters such as plant height, leaf number, stem diameter have been measured at predetermined intervals. Accurate measurements were taken carefully to ensure reliable data.

Then, the growth measures of different treatment groups were compared. The appropriate statistical methods, such as graph and table for specific data, are used to determine if there are significant differences in growth parameters between groups. Based on statistical analysis, the effect of wood vinegar on corn growth has been evaluated. There was a significant difference in growth parameters between the treatment groups, so the conclusion was made that wood vinegar affects corn growth. Also, the optimal concentration of wood vinegar that produces the best results has been identified for the next step in the corn growth system.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 The effect of wood vinegar on corn plant growth

The main observation of wood vinegar was carried out on the different planting methods and types of corn plants is commercial sweet corn and coarse corn through leaves, stems, and roots. Various aspects of corn plant growth were recorded in this phase, including plant height, stem diameter, leaf length, number of leaves, number of damaged leaves, and corn yield to evaluate the effect of wood vinegar on corn plant growth, as shown in Table 4.1.

Table 4.1 (a): The commercial sweet corn growth performance in polybag

Days of observation	Commercial sweet corn in polybag					
	H (cm)	**SD (cm)**	**L(cm)**	**NL**	**DL**	**CY**
20	96	5.0	82.00	11	0	0
30	105	6.0	83.67	11	4	0
40	124	6.9	94.67	15	5	0
50	138	7.0	104.00	10	3	1
60	171	8.9	123.00	17	3	2
70	183	9.1	127.33	17	4	2

Table 4.1 (b): The coarse corn growth performance in polybag.

Days of observation	Coarse corn in polybag					
	H (cm)	**SD (cm)**	**L (cm)**	**NL**	**DL**	**CY**
20	112	5.0	86.67	10	0	0
30	120	6.6	99.34	10	3	0
40	128	7.0	113.33	14	8	1
50	142	7.5	116.81	13	4	1
60	155	8.3	121.67	10	6	0
70	161	8.8	126.00	11	4	1

Referring to the data from different days of observation in Table 4.1 (a), the plant height was growth starting at 96 cm, the stem diameter was 5.0 cm, and the leaf length was 82.00 cm. There were 11 leaves, no diseases, and no corn yield yet at 20 days of corn performance. After 70 days, commercial sweet corn showed continuous improvement. It's getting bigger and higher until it reaches 183 cm, with a stem diameter of 9.1 cm and a leaf length of 127.33 cm. The number of leaves increased to 17 sheets. However, there are a few damaged leaves and effectively produce two corns.

Meanwhile in Table 4.1 (b), the coarse corn kind grows rapidly, reaching 112 cm after only 20 days of observations. Stem diameter: 5.0 cm, leaf length: 86.67 cm. Thus, there are ten leaves, no damage, and no corn has been produced. The coarse corn displayed delayed development beginning with the 40-day phase, as the tree's height only reached 161 cm on the 70th day of observation, compared to commercial sweet corn. The stem is 8.8 cm in diameter and has a leaf length of 126.00 cm. The number of leaves increases to 11. However, numerous damaged leaves have been eaten by insects, resulting in a single corn yield for this type of seed corn.

The collected results demonstrate that wood vinegar significantly impacts corn development, mainly when it is planted using the polybag technique. While the growth of commercial sweet corn exhibits greater consistency in daily observations compared to coarse corn, both varieties of corn are thriving and experiencing healthy growth. This occurs because of the reduction of weed competition. This can be especially advantageous during the initial phases of crop development. According to Elfarisna, (2000), plant height is significantly affected by shade; the higher the level of shade, the taller the plant. Plants that experience stress from low light intensity will increase plant height to increase light capture efficiency.

In short, this growing technique enables the creation of a regulated environment for corn plants within polybags. It allows better management of factors such as soil composition, drainage and sunlight exposure, and enough absorption of wood vinegar specific to each tree.

Table 4.1 (c): The commercial sweet corn growth performance directly into the soil

Days of observation	**Commercial sweet corn directly into soil**					
	H (cm)	**SD (cm)**	**L (cm)**	**NL**	**DL**	**CY**
20	94	5.0	74.33	11	0	0
30	108	5.6	86.67	11	0	0
40	124	6.3	94.00	13	1	2
50	145	7.4	113.33	15	2	4
60	168	8.0	127.67	15	0	5
70	185	9.6	131.00	17	1	7

Table 4.1 (d): The coarse corn growth performance directly into the soil

Days of observation	Coarse corn directly into soil					
	H (cm)	**SD (cm)**	**L (cm)**	**NL**	**DL**	**CY**
20	98	4.7	88.33	11	0	0
30	115	6.0	94.27	10	1	0
40	131	6.8	103.00	13	3	0
50	158	7.9	110.00	11	2	1
60	162	8.4	126.33	14	0	3
70	170	9.0	130.00	15	2	4

Based on the data collected on several observation days in Table 4.1 (c), the plant's height is 94 cm, the stem diameter is 5.0 cm, and the leaf length is 74.33 cm. At the 20-day mark of the corn performance, there were 11 leaves, no signs of illness, and no corn output. Commercial sweet corn exhibited consistent progress over 70 days. The plant maintains continuous growth until it attains a height of 185 cm, a stem diameter of 9.6 cm and a leaf length of 131.00 cm. The leaf count has risen to 17 sheets. Nevertheless, despite the presence of a broken leaf, the plant was able to yield a remarkable seven corns.

Moreover, the initial height of the corn plant in Table 4.1 (d), as seen on the 20th day, was 98 cm, which subsequently expanded to 170 cm by the 70th day of observation. Furthermore, it is accompanied by a stem diameter ranging from 4.7 cm to 9.0 cm and a leaf length ranging from 88.33 cm to 130.00 cm. Consequently, there is a substantial rise in the number of leaves, increasing from 11 to 15. The corn plants directly sown into the soil exhibit some leaf damage and yield four corns.

Apart from that, these two types of corn are interconnected in their growing process by being planted directly into the soil. Its drastic expansion indicates that planting directly in the soil allows the corn plant to interact with natural soil microorganisms and nutrients. This has further improved the aspects of corn development and soil-plant relationships that are more complex and potentially beneficial (Lingl & Enchen, 2024). Applying wood vinegar to corn plants enhances their structural integrity, promoting robust root and leaf development and facilitating high crop yield. Additionally, it serves as a preventive measure against potential harm caused by pests and diseases.

4.2 The efficiency of corn plants with or without wood vinegar in growth performance.

The primary objective was to compare the corn plant between applied and non-apply wood vinegar for its improved growth performance. It focused on critical parameters such as plant height, stem diameter, leaf length, number of leaves and damaged leaves, and corn yield. Its valuable insights into its potential as a sustainable and eco-friendly approach to optimizing corn production with wood vinegar or natural fertilizer application.

4.2.1 Corn plant height

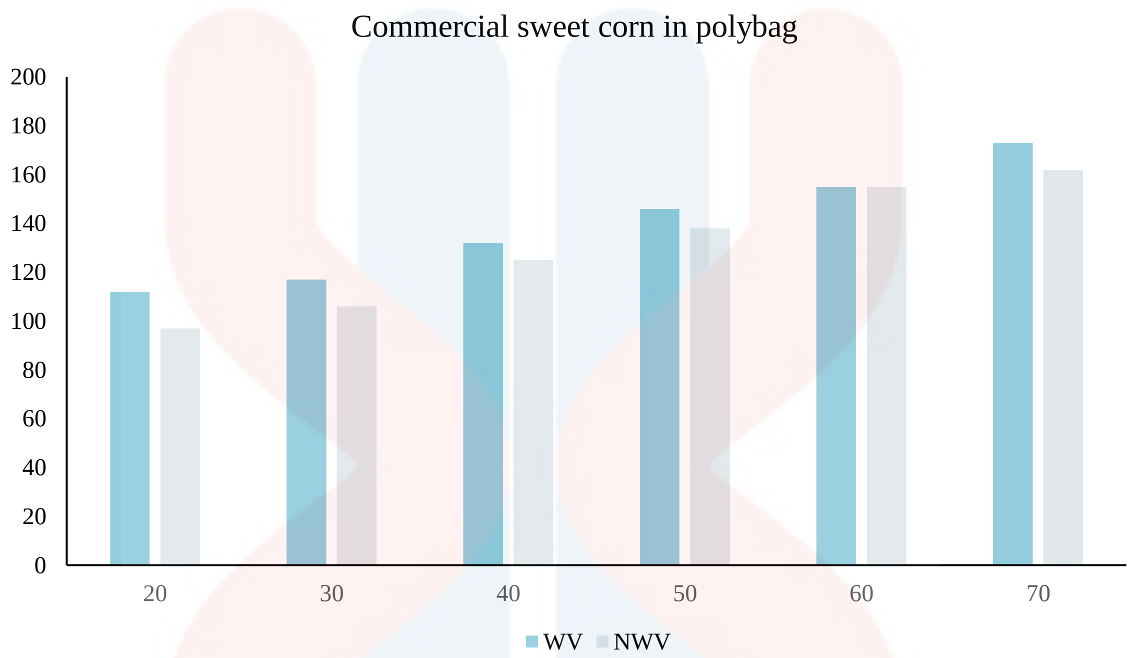

Figure 4.2 (a): Height performance of commercial sweet corn with and without wood vinegar in polybags

Applying wood vinegar to commercial sweet corn accelerated growth compared to the control group without wood vinegar. On 70 days, the sweet corn treated with wood vinegar reached a height of 173 cm, while the untreated group reached 162 cm. This indicates that wood vinegar has positively influenced the growth of commercial sweet corn, leading to taller plants throughout the observation period. Furthermore, commercial sweet corn grown in polybags without wood vinegar also showed stable growth. However, the final height of 162 cm on day 70 was slightly lower than that of the wood vinegar-treated group. Nevertheless, sweet corn showed resistance and consistent growth even without wood vinegar.

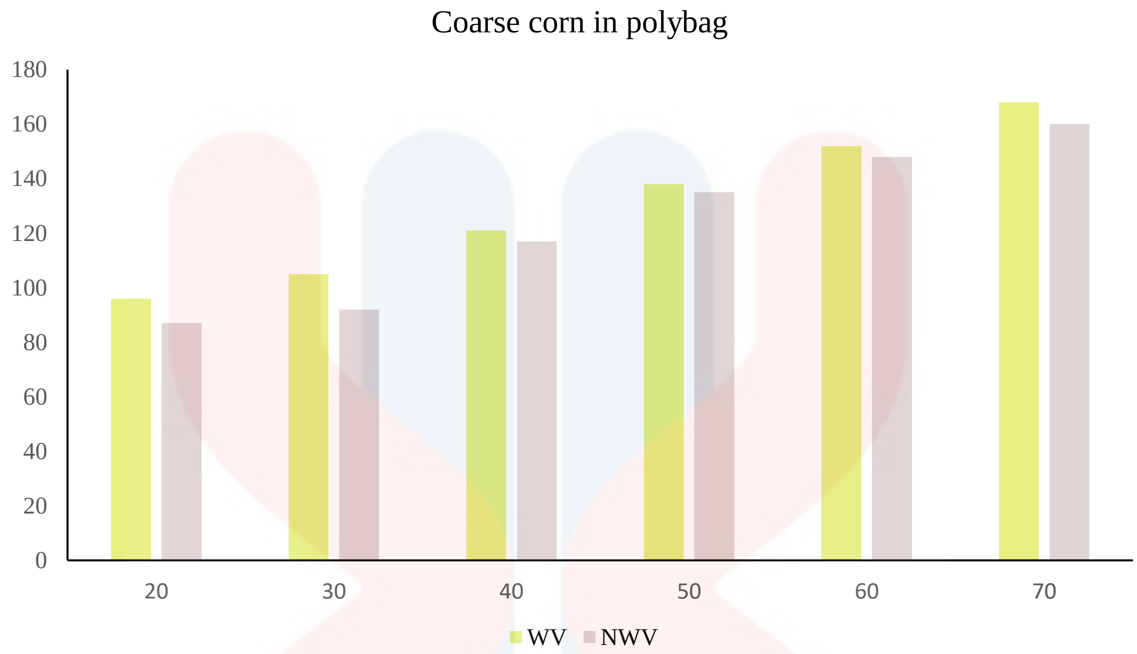

Figure 4.2 (b): Height performance of coarse corn with and without wood vinegar in polybags

Like commercial sweet corn, coarse corn treated with wood vinegar in Figure 4.2 (b), also accelerated growth. By 70 days, coarse corn treated with wood vinegar reached a height of 168 cm, while the untreated group reached 160 cm. This shows that wood vinegar positively affects coarse corn's growth, resulting in taller plants throughout the observation period. Meanwhile, coarse corn grown in polybags without wood vinegar also showed stable growth, reaching a final height of 160 cm on day 70. Although slightly inferior to the group treated with wood vinegar, the untreated coarse corn showed consistent growth and only suffered attacks by pest bacteria, resulting in decreased leaf quality.

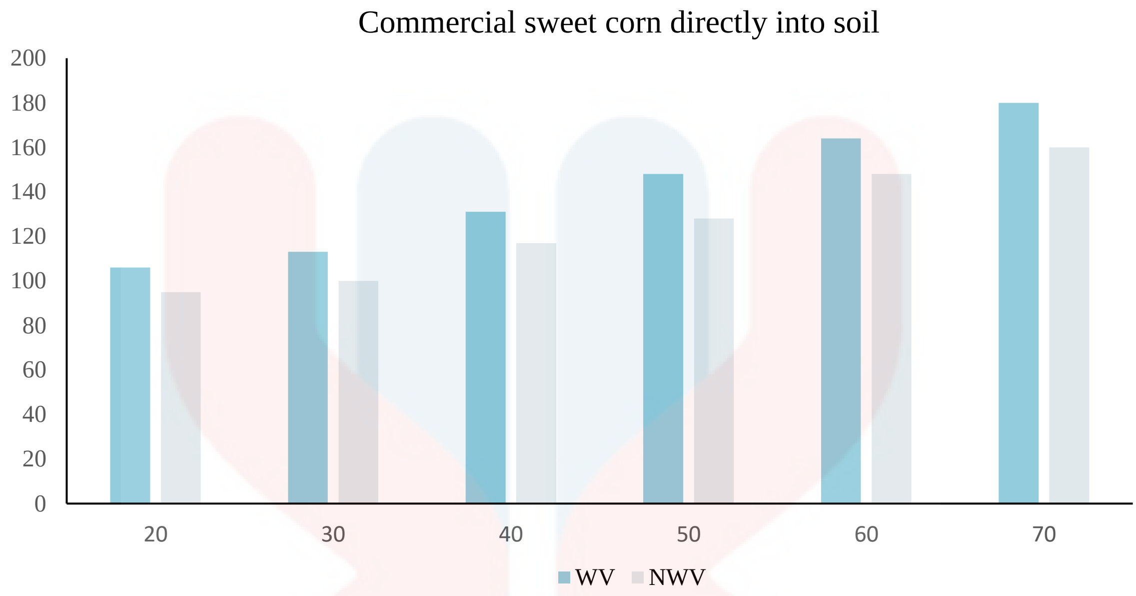

Figure 4.2 (c): Height performance of commercial sweet corn with and without wood vinegar directly into soil

Commercial sweet corn treated with wood vinegar and planted directly into the soil showed increased growth compared to the untreated group. By the 70th day, sweet corn treated with wood vinegar reached a height of 180 cm, while the untreated group reached 160 cm. This shows that wood vinegar positively affects commercial sweet corn's growth (Zhu et al., 2021), leading to better and perfect plants.

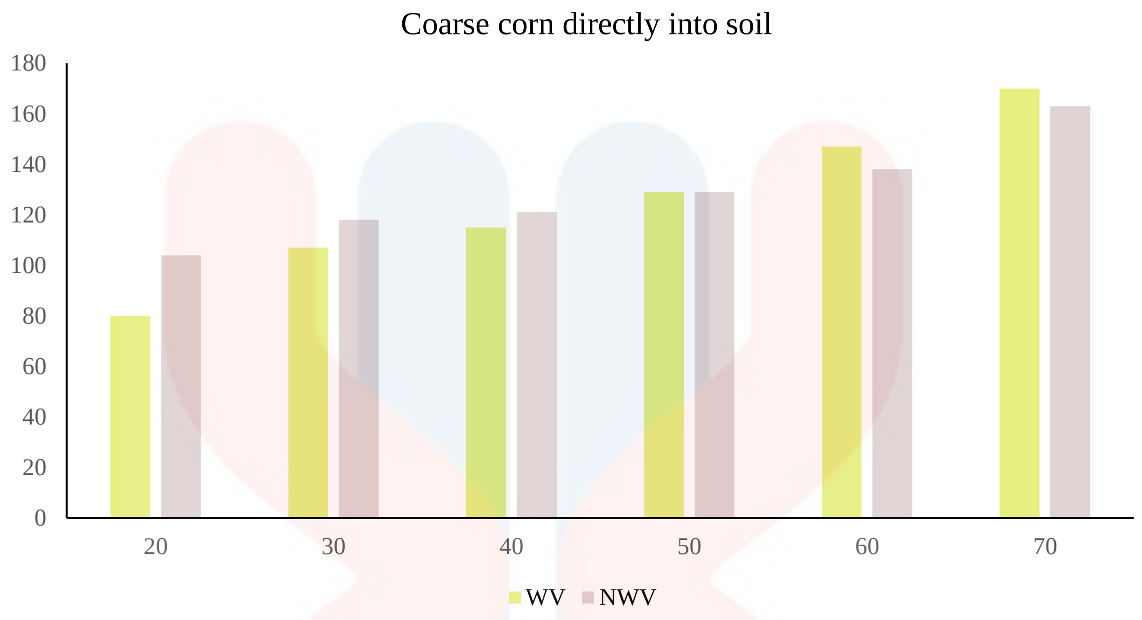

Figure 4.2 (d): Height performance of coarse corn with and without wood vinegar directly into soil

Commercial sweet corn treated with wood vinegar and planted directly into the soil showed increased growth compared to the untreated group. By the 70th day, sweet corn treated with wood vinegar reached a height of 180 cm, while the untreated group reached 160 cm. This shows that wood vinegar positively affects commercial sweet corn's growth (Zhu et al., 2021), leading to better and perfect plants.

The same goes for commercial sweet corn; coarse corn treated with wood vinegar and planted directly into the soil also showed improvement compared to the untreated group. On the 70th day, the corn treated with wood vinegar grew to a height of 170 cm, but the untreated group only reached 163 cm. These findings demonstrate that wood vinegar has a constant and advantageous impact on the development of rough corn, leading to increased plant height during the observation period.

In short, using wood vinegar positively affected the growth of commercial sweet corn and coarse corn grown in polybags and directly into soil. Although both types of corn showed stable growth even without wood vinegar, the treated group consistently outperformed the untreated group regarding final height. This suggests that wood vinegar can be an effective growth-promoting treatment for corn plantings, promoting taller and potentially more vigorous plants.

4.2.2 Stem diameter

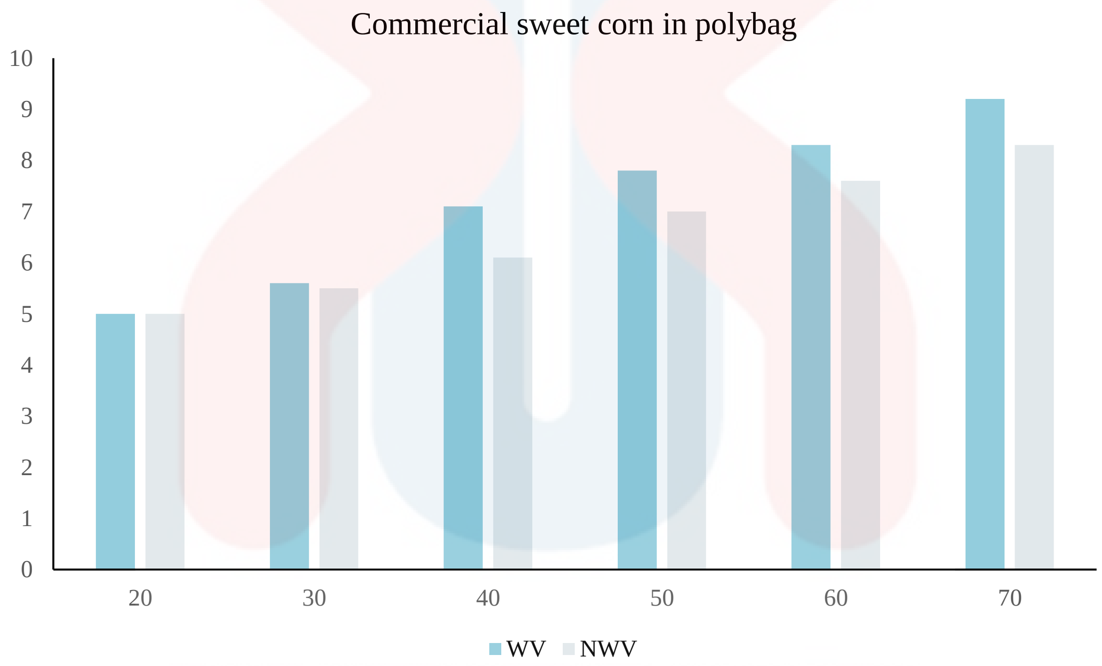

Figure 4.2 (a): Stem diameter of commercial sweet corns with and without wood vinegar in polybags

According to Figure 4.2 (a), commercial sweet corn treated with wood vinegar in polybags has consistently increased stem diameter throughout the observation period. By day 70, the diameter of wood vinegar-treated sweet corn stalks had reached 9.2 cm, showing significant growth from the initial diameter of 5.0 cm on day 20. Meanwhile, commercial sweet corn without wood vinegar also showed stable growth in stem diameter. However, the final diameter of 8.3 cm on day 70 was slightly lower than that of the wood vinegar-treated group.

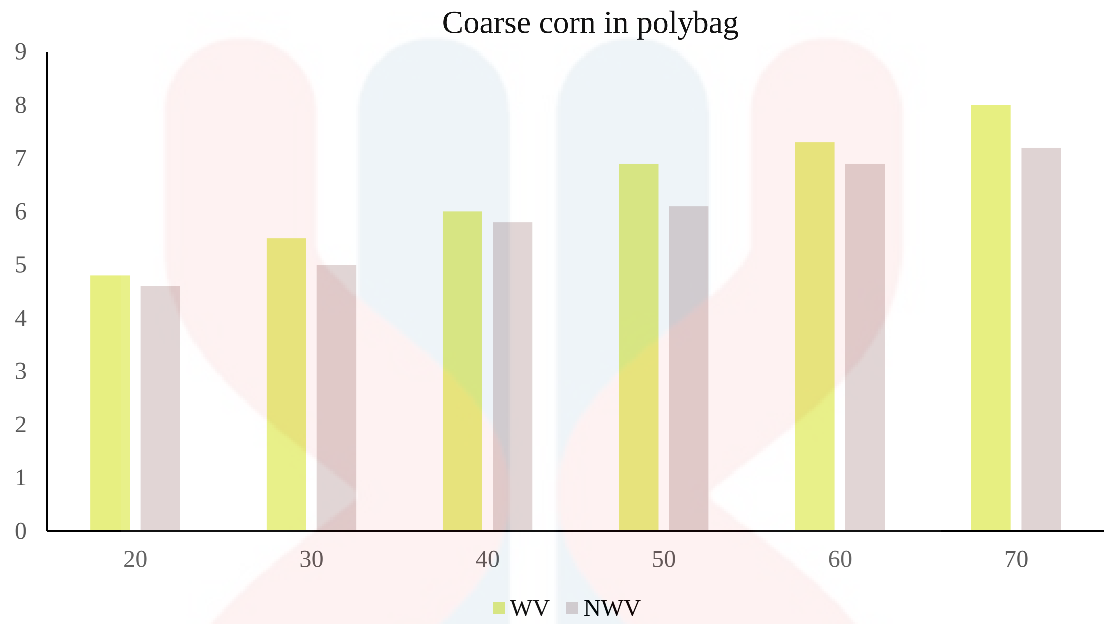

Figure 4.2 (b): Stem diameter of coarse corns with and without wood vinegar in polybags

Furthermore, coarse corn treated with wood vinegar in polybags also showed an equivalent increase in stem diameter throughout the observation period. This is because, by the 70th day, the diameter of the coarse corn stalks treated with wood vinegar reached 8.0 cm, showing significant growth from the initial diameter of 4.8 cm on the 20th day. The rough corn without wood vinegar also showed a stable growth in stem diameter. Although the growth was slightly slower, it reached a final diameter of 7.2 cm on the 70th day. Although slightly lower than the group treated with wood vinegar because of the lack of nutrients and fertilizer support for the growth of these plants (Mu et al., 2004).

Overall, wood vinegar positively affected the stem diameter growth of commercial sweet corn and coarse corn grown in polybags and directed into the soil, leading to thicker stems than the untreated group. Although both types of corn showed stable growth in stem diameter even without wood vinegar, the treated group consistently outperformed the untreated group in terms of final diameter due to enough nutrition and lighting for growth. During the growing season, corn plants must extract approximately nitrogen, phosphorus, potassium, magnesium, and sulfur to support a corn yield. Daily nutrient supply supports the demand to feed substantial growth in leaf and stalk structures. (Mark Jeschke, 2019). This shows that wood vinegar is an efficient agent for treatment to increase growth in corn cultivation.

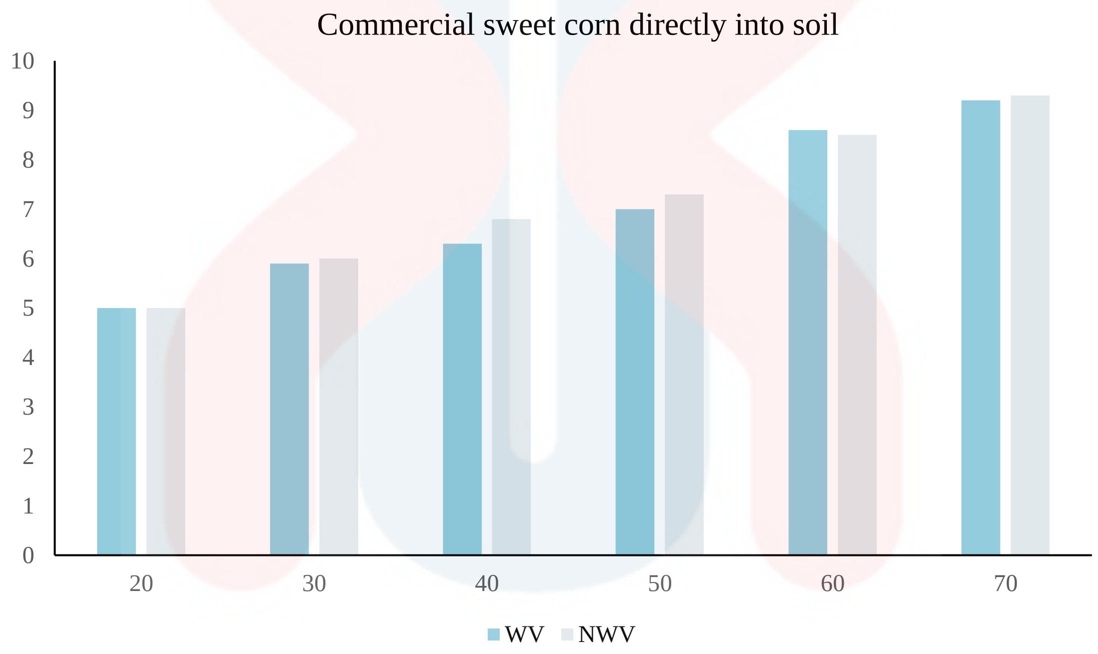

Figure 4.2 (c): Stem diameter of commercial sweet corn with and without wood vinegar direct in soil

As shown in Figure 4.2 (c), commercial sweet corn treated with wood vinegar and planted directly into the soil has consistently increased stem diameter throughout the observation period. By the 70th day, the diameter of the sweet corn stem reached 9.2 cm, showing significant growth from the initial diameter of 5.0 cm on the 20th day. According to Perera et al. (2023), wood vinegar contains organic compounds that stimulate root development, nutrient uptake, and plant growth. Wood vinegar has facilitated more robust stem growth in the sweet corn plant by promoting root expansion and nutrient absorption. Meanwhile, commercial sweet corn without wood vinegar also showed stable growth in stem diameter. However, the final diameter of 9.3 cm on the 70th day was lower compared to the group treated with wood vinegar.

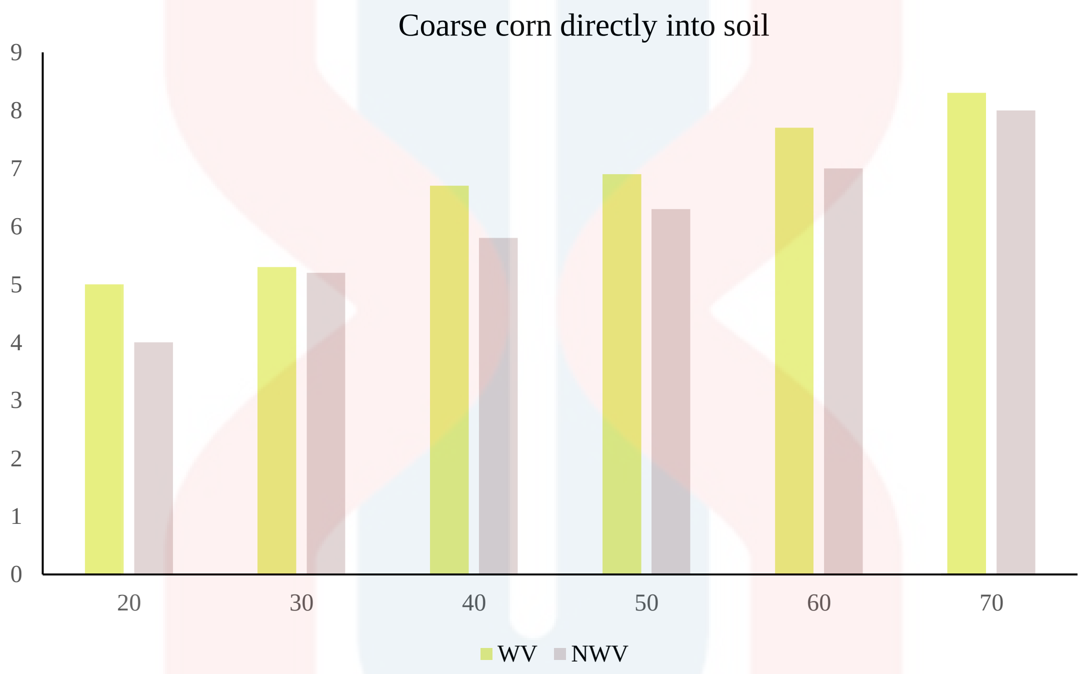

Figure 4.2 (d): Stem diameter of coarse corn with and without wood vinegar direct in soil

As shown in Figure 4.2 (d), commercial sweet corn treated with wood vinegar and planted directly into the soil has consistently increased stem diameter throughout the observation period. By the 70th day, the diameter of the sweet corn stem reached 9.2 cm, showing significant growth from the initial diameter of 5.0 cm on the 20th day. According to Perera et al. (2023), wood vinegar contains organic compounds that stimulate root development, nutrient uptake, and plant growth. Wood vinegar has facilitated more robust stem growth in the sweet corn plant by promoting root expansion and nutrient absorption. Meanwhile, commercial sweet corn without wood vinegar also showed stable growth in stem diameter. However, the final diameter of 9.3 cm on the 70th day was lower compared to the group treated with wood vinegar.

Coarse corn treated with wood vinegar also shows a consistent increase in stem diameter throughout the observation period. This is because the diameter of the coarse corn stalks treated with wood vinegar reached 8.3 cm, showing significant growth from the initial diameter of 5.0 cm on the 20th day. Without wood vinegar, the corn plant may have experienced slightly slower or less vigorous growth (Benedict Vanheems, 2024), and it only reached a final diameter of 8.0 cm on the 70th day.

Therefore, wood vinegar has affected the stem diameter growth (Zhu et al., 2021) of commercial sweet corn and coarse corn when planted directly into the soil, leading to thicker stems than in the untreated group. Although both varieties of corn grew steadily in stem diameter even without wood vinegar, the treated group regularly surpassed the untreated group in ultimate diameter and through growth.

4.2.3 Leaf length

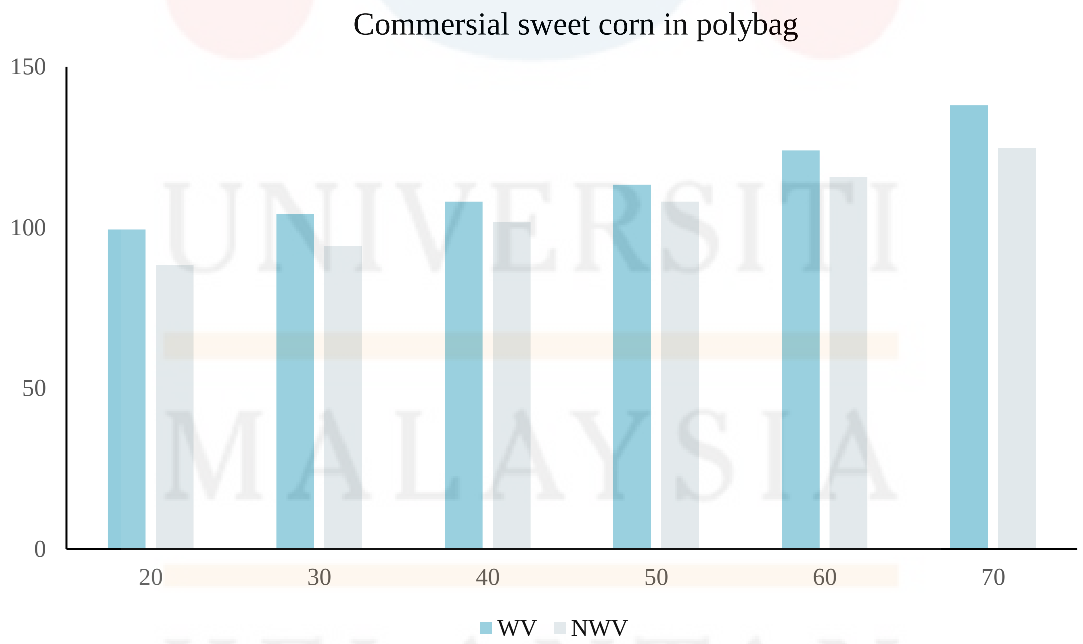

Figure 4.2 (a): Leaf length of commercial sweet corn with and without wood vinegar in polybags

Wood vinegar has been used to observe commercial sweet corn leaf length. The graph shows an increase in leaf length growth from 99.33 cm to 138.00 cm from day 20 to day 70. Sweet corn plants undergo significant vegetative growth during their developmental stages (Mimi et al., 2024). The increase in leaf length reflects the natural growth progression of the sweet corn plant as it matures over time. It has grown consistently and significantly throughout the observation period.

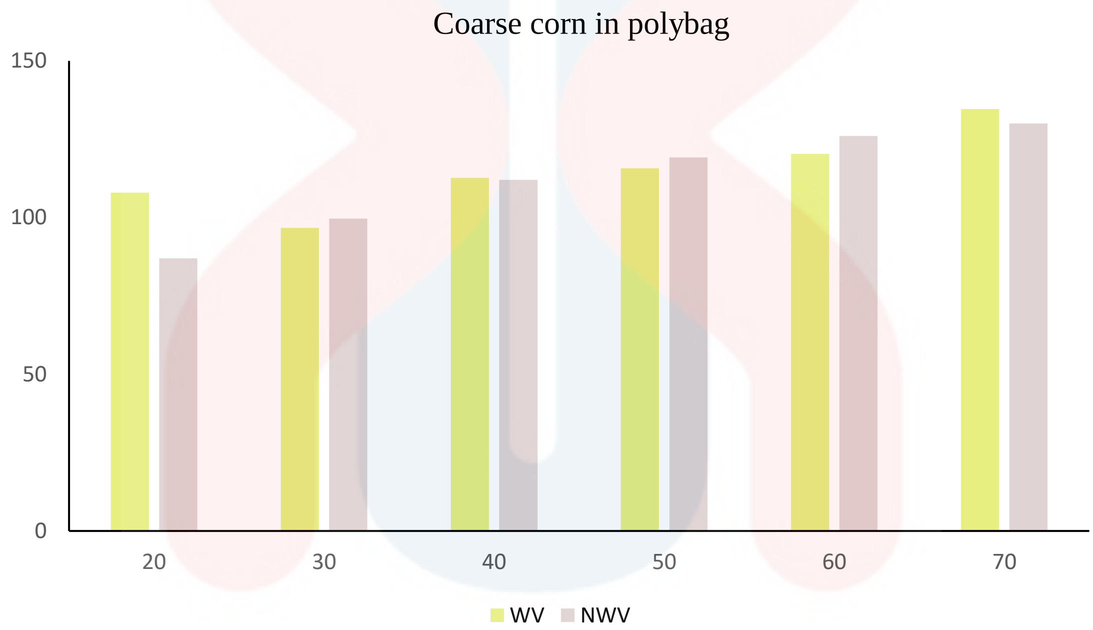

Figure 4.2 (b): Leaf length of coarse corn with and without wood vinegar in polybags

Meanwhile, coarse corn also showed growth in leaf length when treated with wood vinegar, although the growth trend appeared less significant than that of commercial sweet corn. From day 20 to day 70, leaf length increased from 108.00 cm to 134.67 cm, showing a significant but somewhat variable growth pattern throughout the observation period.

Comparing the growth of corn treated with wood vinegar with untreated corn, it was clear that commercial sweet corn and coarse corn experienced more incredible leaf length growth when wood vinegar was used (Furuno et al., 2004). In both cases, corn treated with wood vinegar consistently exhibited longer leaf lengths than untreated corn at each corresponding time interval, highlighting the growth-promoting effect of wood vinegar. In short, the wood vinegar used contributed to both corns grown in polybags, as evidenced by the increase in leaf length throughout the observation period. Although both types of corn showed increased leaf length when using wood vinegar, commercial sweet corn generally showed more consistent and significant growth than coarse corn. Therefore, this has shown that wood vinegar has a more significant effect in promoting the growth of commercial sweet corn when this planting is made.

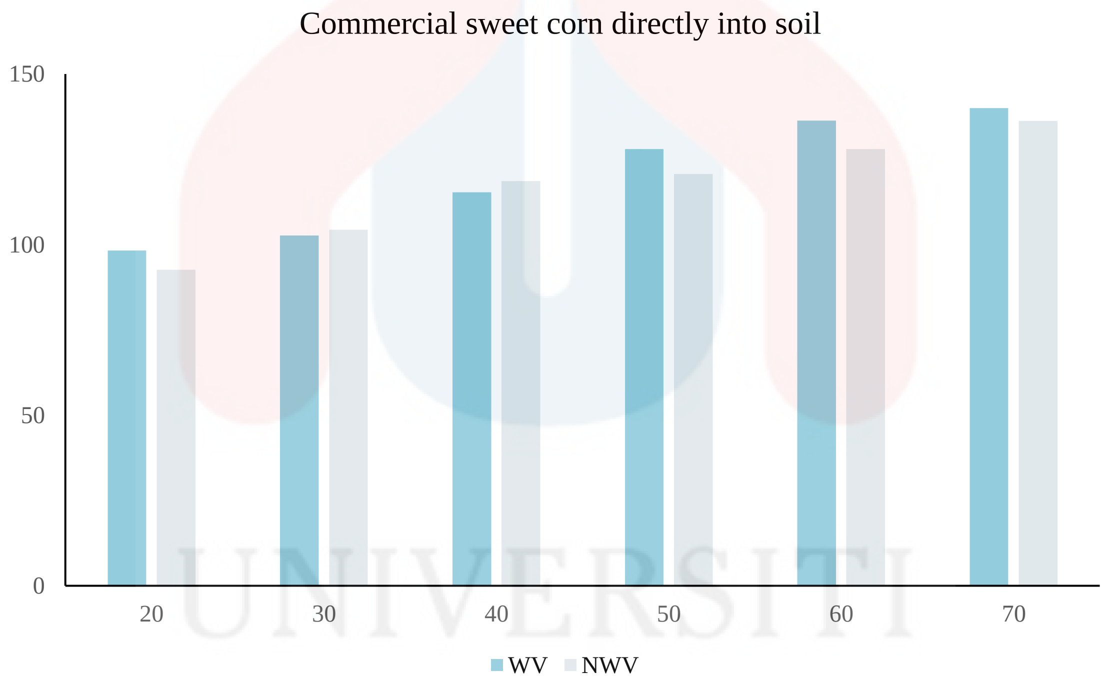

Figure 4.2 (c): Leaf length of commercial sweet corn with and without wood vinegar directly into soil

Commercial sweet corn plants planted directly into the soil showed consistent and significant growth in corn plant leaf length throughout the observation period after being treated with wood vinegar. From day 20 to 70, leaf length increased from 98.27 cm to 140.00 cm, indicating stable growth. This is because, according to Wang et al. (2019), wood vinegar contains bioactive compounds that can stimulate various physiological processes in plants, including cell elongation and division. These compounds may have acted as growth promoters (Steenackers et al., 2019), accelerating the growth rate of the sweet corn plants' leaves and ensuring consistent growth over the observation.

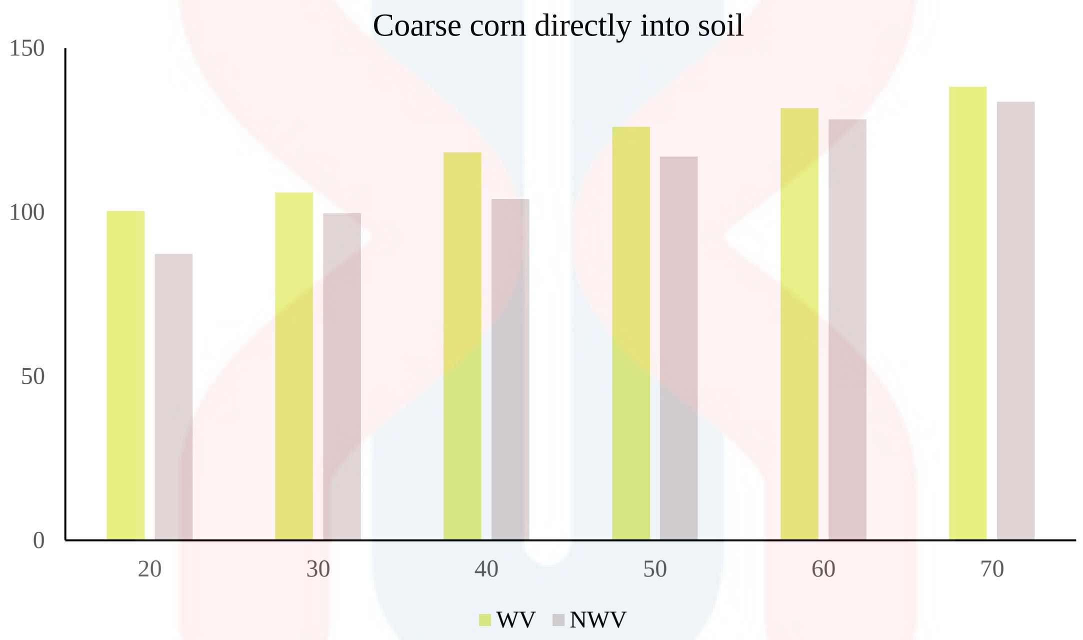

Figure 4.2 (d): Leaf length of commercial sweet corn with and without wood vinegar directly into soil

Meanwhile, growth patterns comparable to commercial sweet corn were seen in coarse corn after wood vinegar treatment, leading to longer leaves. The efficient growth of the leaf length from 100.33 cm to 138.27 cm from the 20th to the 70th day was seen. Therefore, it has been demonstrated that commercial sweet corn and coarse corn, when grown in soil treated with wood vinegar, exhibit much longer leaf lengths. Longer leaf lengths were consistently seen in corn treated with wood vinegar compared to untreated corn.

Therefore, using this wood vinegar has contributed to the growth of healthy and resistant corn in terms of growth (Liu et al., 2021). This has highlighted the potential of wood vinegar to promote leaf development in corn plants when planted directly into the soil.

4.2.4 Number of leaves

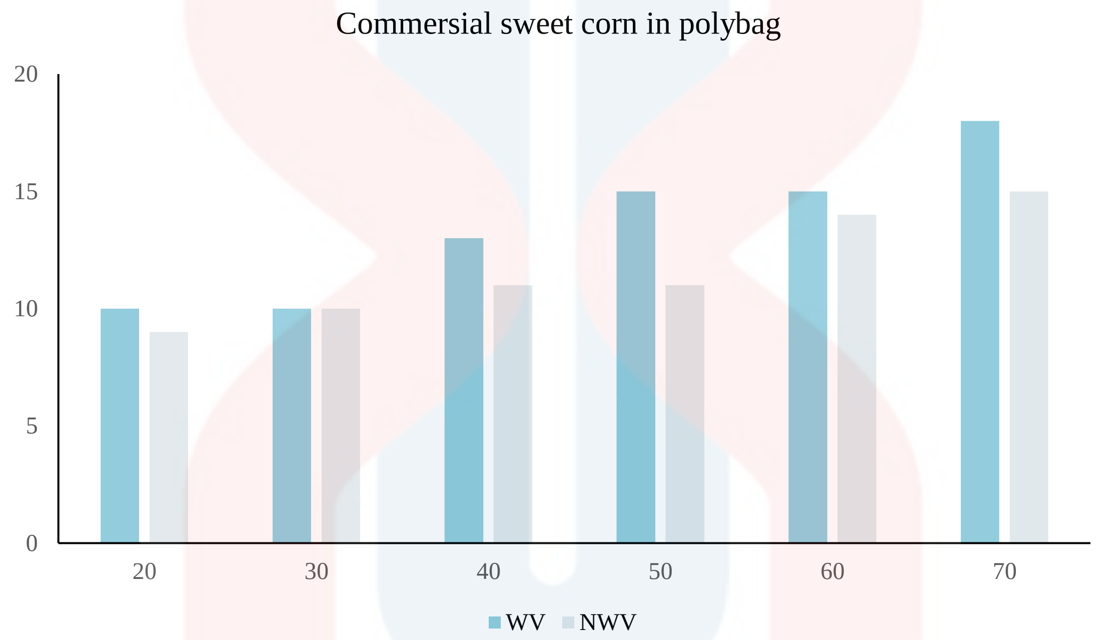

Figure 4.2 (a): The growth performance of commercial sweet corn leaves with and without wood vinegar in polybags

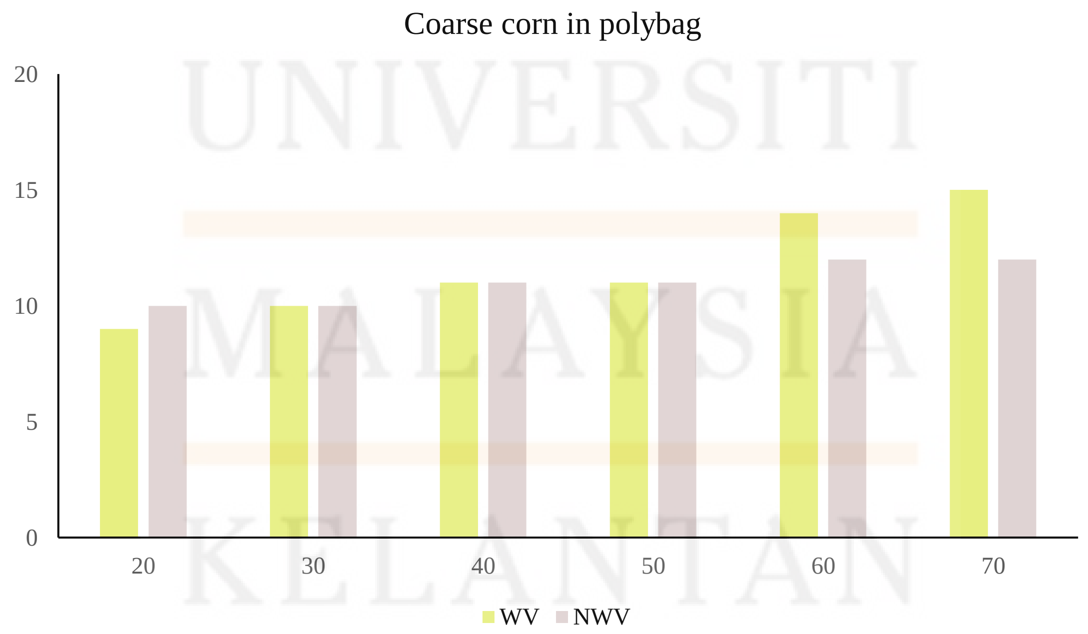

Figure 4.2 (b): The growth performance of coarse corn leaves with and without wood vinegar in polybags

As can be seen the Figure 4.2 (a), the number of leaves on commercial sweet corn treated with wood vinegar increased gradually throughout the observation period. There was a steady rise in the number of leaves, from 10 to 18, between days 20 and 70. As with coarse corn, it follows a similar development pattern to commercial sweet corn. There was a gradual rise in the number of leaves from 9 to 15, as seen throughout the observation in Figure 4.2 (b). According to Mungkunkamchao et al. (2013), corn plants exposed to wood vinegar grew more leaves than untreated corn. At each point, the corn treated with wood vinegar had more leaves than the untreated corn, proving that the vinegar had a growth-promoting impact.

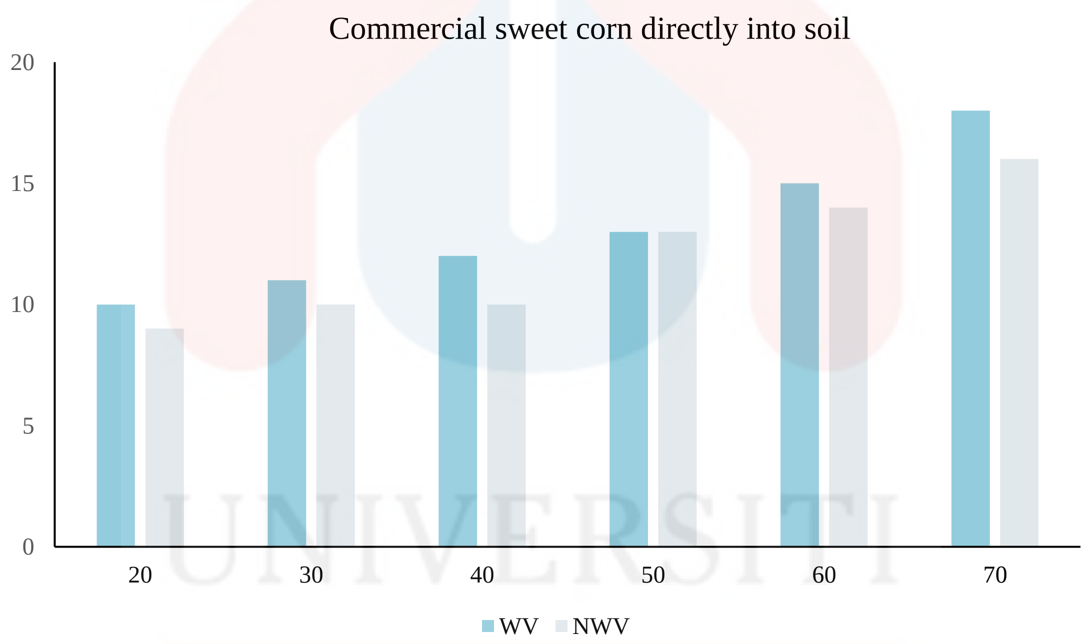

Figure 4.2 (c): The growth performance of commercial sweet corn leaves with and without wood vinegar direct in soil

From Figure 4.2 (c), the data indicates the number of leaves seen for commercially grown sweet corn and coarse corn, both when planted directly into the soil and with and without the application of wood vinegar, during a period of 20 to 70 days. Wood vinegar treatment resulted in a progressive rise in the leaf count of commercially grown sweet corn throughout the study.

From day 20 to day 70, the number of leaves increased from 10 to 18, indicating stable growth. This is because stable environmental conditions, such as optimal temperature, humidity, and light levels, may have also contributed to the gradual increase in the number of leaves (Ahmed et al., 2020) in commercial sweet corn treated with wood vinegar. Consistent environmental factors can support steady plant growth and development over time.

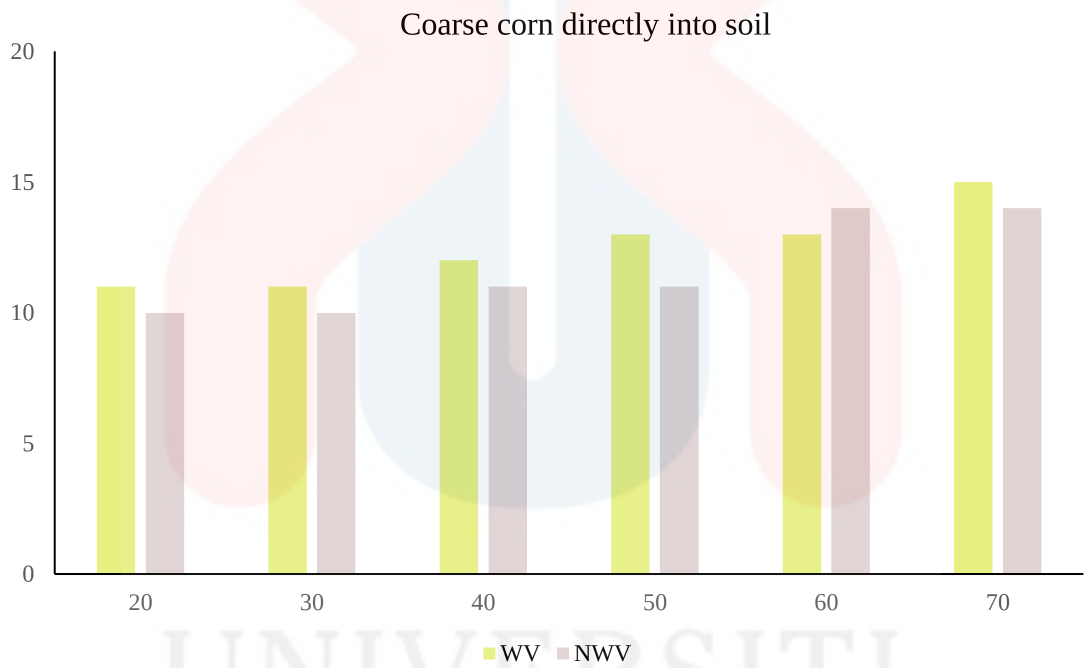

Figure 4.2 (d): The growth performance of coarse corn leaves with and without wood vinegar direct in soil

Furthermore, coarse corn exhibits a rise in quantity, displaying a growth pattern that resembles commercially cultivated sweet corn. The leaf count indicated a gradual rise, increasing from 11 to 15 on the 70th day of observation. However, data has been obtained that commercial sweet corn and coarse corn experience more excellent leaf development when wood vinegar is used. Corn treated with wood vinegar consistently showed a higher number of leaves than untreated corn at each time interval, as shown in Figure 4.2 (d).

The increase in the number of leaves during the observation proves that the application of wood vinegar contributes to the development of maize plants. On top of that, it's an antioxidant. Corn plants have compounds that can guard against diseases or provide therapeutic benefits. Some bioactive compounds mediate antioxidant action by scavenging free radicals. Because of this, wood vinegar can encourage the growth of corn plants' leaves when applied topically to soil.

4.2.5 Number of damaged leaves

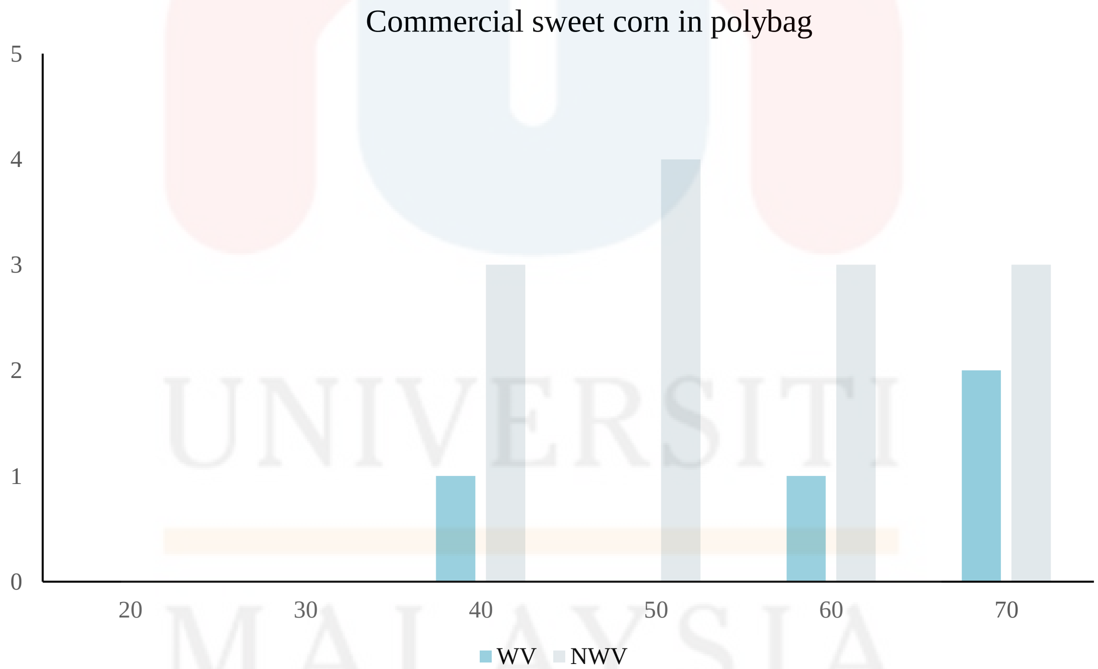

Figure 4.2 (a): The leaves conditions of commercial sweet corn with and without wood vinegar in polybags

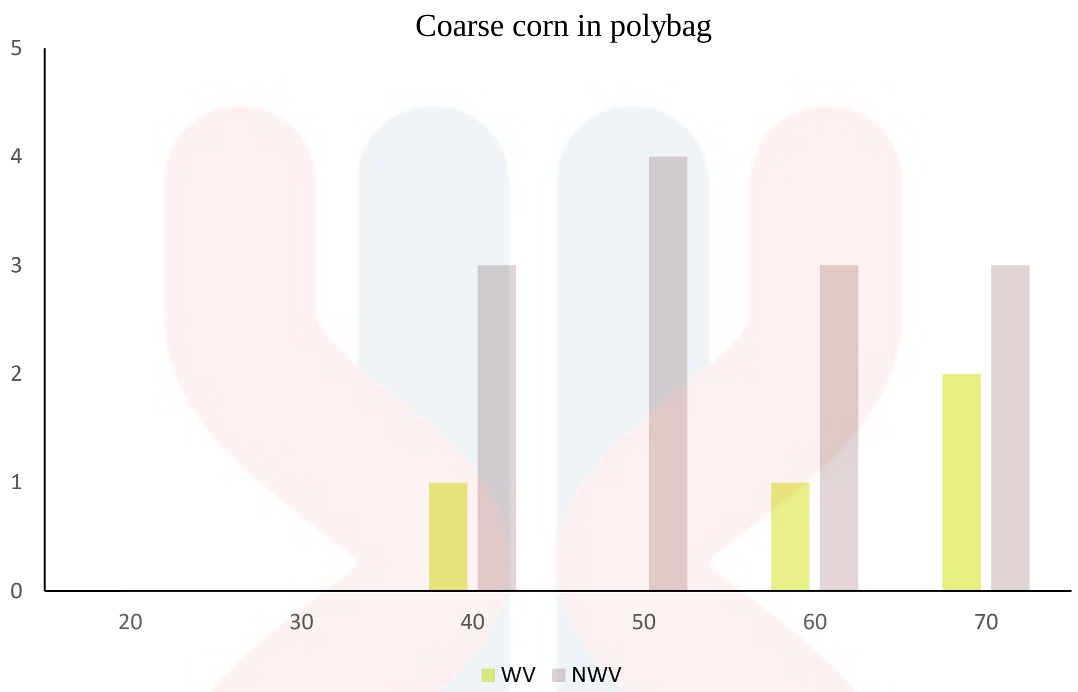

Figure 4.2 (b): The leaves conditions of coarse corn with and without wood vinegar in polybags

Throughout most observations, commercial sweet corn treated with wood vinegar showed minimal leaf damage in Figure 4.2 (a), with only one damaged leaf reported on day 50 and another on day 70. Like commercial sweet corn, coarse corn treated with wood vinegar also showed minimal leaf damage, with one damaged leaf reported on day 40, 1 on day 60, and 2 on day 70 as shown in Figure 4.2 (b). Wood vinegar contains organic compounds that enhance plant health and resilience against biotic and abiotic stressors (Mohd Amnan et al., 2023). Wood vinegar may have bolstered the plant's natural defense mechanisms when applied to commercial sweet corn, making it more resistant to leaf-damaging factors such as pests, diseases, and environmental stresses.

In contrast, commercial sweet corn not treated with wood vinegar showed slightly higher damaged leaves. Three damaged leaves were reported on both day 50 and day 70 and 2 on day 60. Meanwhile, coarse corn not treated with wood vinegar showed a significant decrease. This is because commercial sweet corn plants may have experienced nutrient deficiencies without the application of wood vinegar, which can weaken plant tissues and make them more susceptible to damage. According to John Sayer (2024), The older leaves of the corn plant may turn pale or yellowish-green when the plant is deficient in nitrogen.

Therefore, using wood vinegar helps reduce damaged leaves for both commercial sweet corn and coarse corn grown in polybags. Corn plants treated with wood vinegar generally exhibit more conductivity than those not treated with wood vinegar, thus increasing the protective effect of wood vinegar on leaf health.

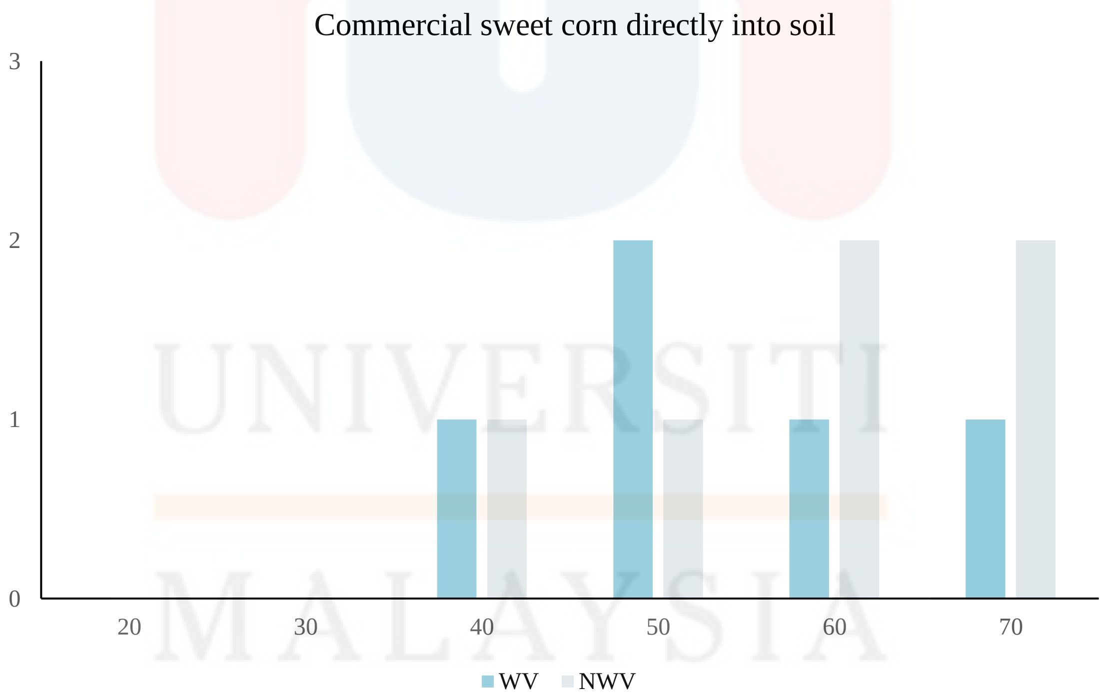

Figure 4.2 (c): The leaves conditions of commercial sweet corn with and without wood vinegar direct in soil

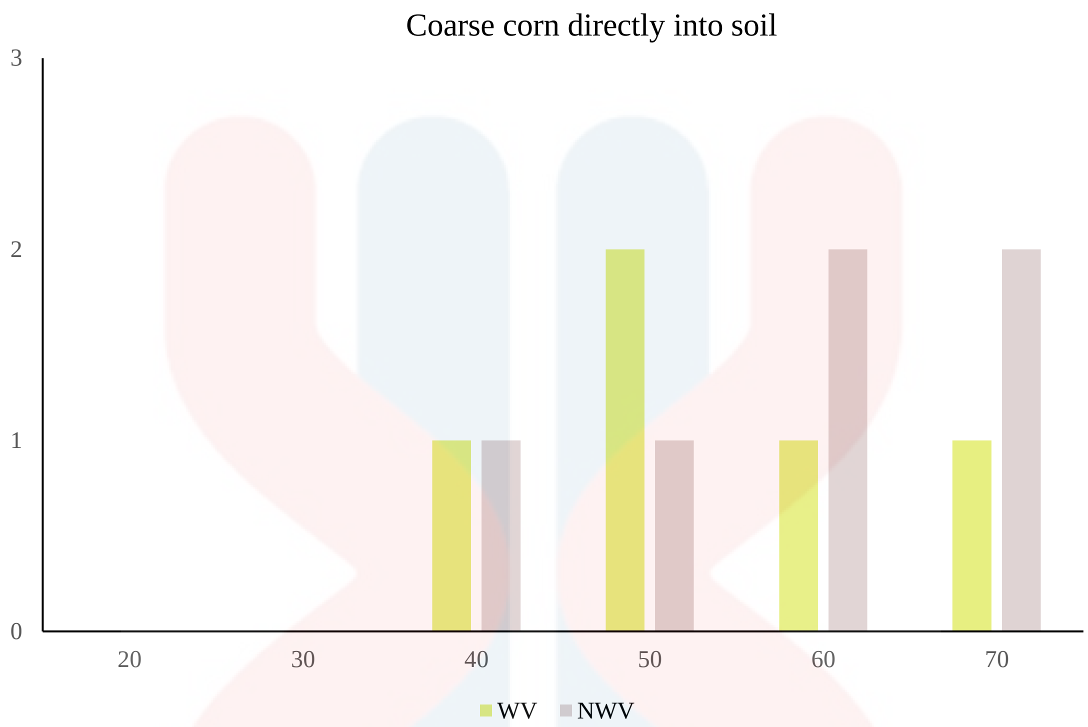

Figure 4.2 (d): The leaves conditions of coarse corn with and without wood vinegar direct in soil

Based on the data obtained in Figure 4.2 (c), commercial sweet corn showed minimal leaf damage throughout most of the observation period when treated with wood vinegar and planted directly into the soil. There was only one damaged leaf on the 60th day. This can be attributed to wood vinegar promoting plant growth and vigor by stimulating root development and enhancing nutrient assimilation (Zhu et al., 2021). Stronger, healthier plants are better equipped to withstand environmental challenges and recover from damage, resulting in minimal leaf damage. While, coarse corn treated with wood vinegar showed minimal leaf damage, with one damaged leaf reported on day 40, 2 on day 50, 1 on days 60 and 70 as shown in Figure 4.2 (d).

In contrast, commercial sweet corn and coarse corn untreated with wood vinegar showed a higher incidence of damaged leaves. Two damaged leaves were reported on both day 40 and day 70, and 1 on day 50 on sweet corn plants and one damaged leaf was reported on day 40 and day 50, and 2 on day 60th and 70th day for coarse corn crops. Therefore, the data show that wood vinegar can help minimize leaf damage in corn plants when planted directly into the soil. Protection and exploration of the potential use of wood vinegar as a natural way to increase plant resistance to environmental stress can be improved.

4.2.6 Corn yield

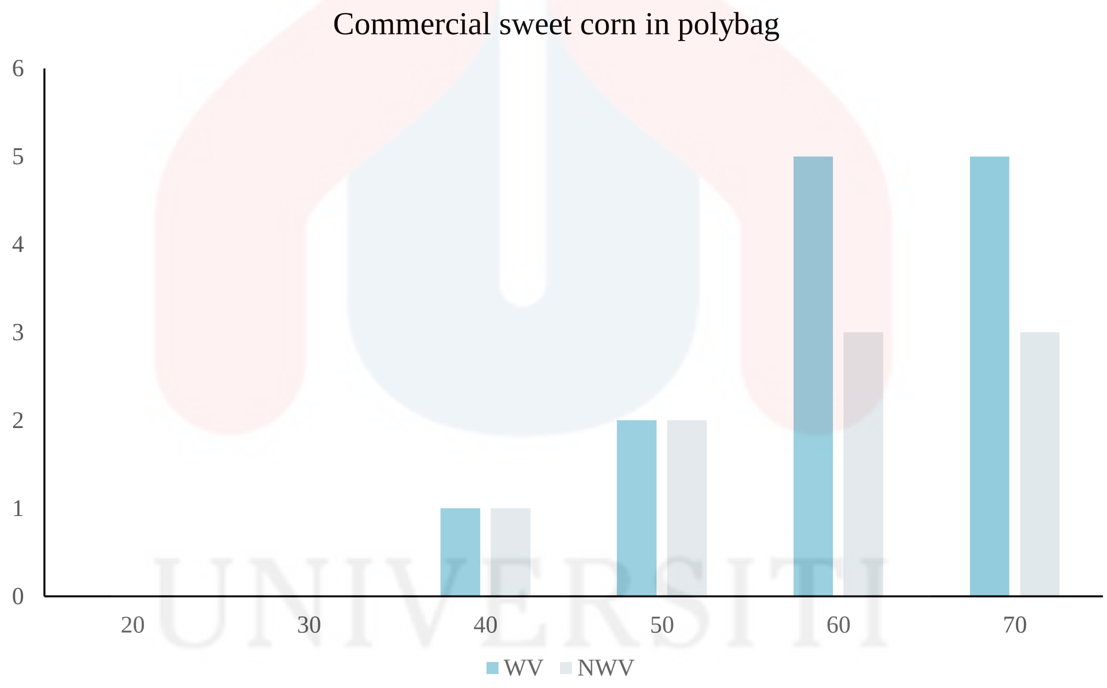

Figure 4.2 (a): Commercial sweet corn yield development with and without wood vinegar in polybags

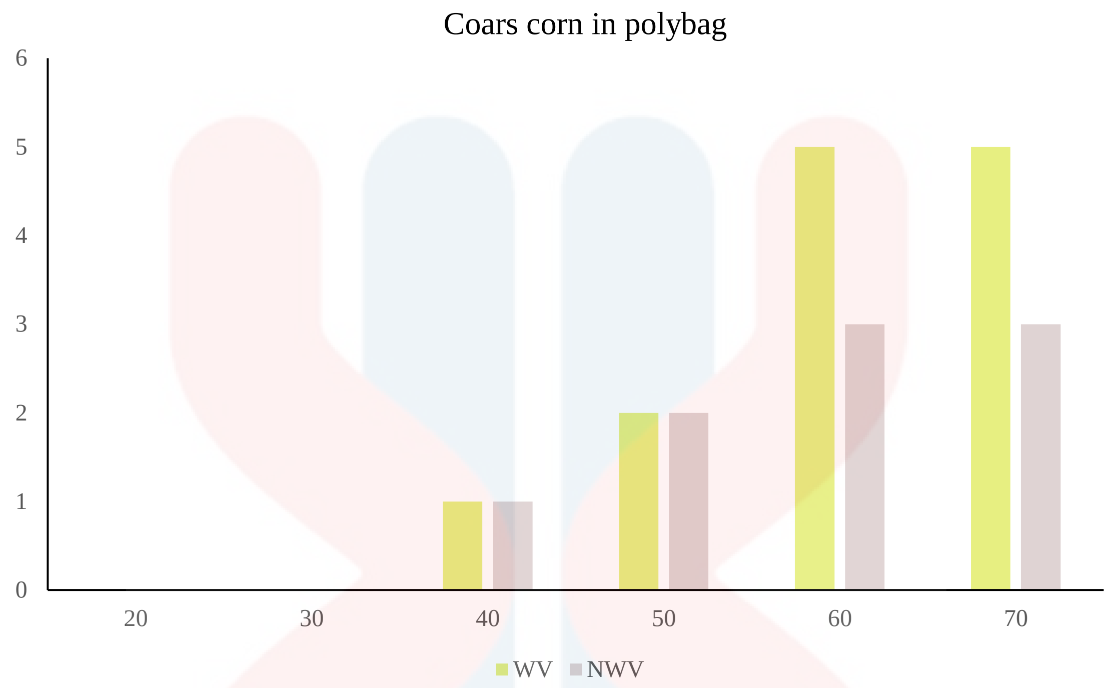

Figure 4.2 (b): Coarse corn yield development with and without wood vinegar in polybags

After being treated with wood vinegar and planted in polybags, it was found that commercial sweet corn showed a gradual increase in corn yield over 70 days of observation. The corn yield has increased from 1 on the 40th day to 3 on the 70th day. Meanwhile, coarse corn shows a variable corn yield throughout the observation period, with one result reported on the 30th day and the 70th day, and two results on the 70th day.

The amount of corn increases due to applying wood vinegar. Its enhanced plant immunity and resistance to diseases and pests. Treated corn plants may exhibit fewer infections and pest infestations, improving plant health and yield. In contrast, commercial sweet corn untreated with wood vinegar showed lower overall corn yield. No yield was reported on days 20, 30, 40, and 50; only one yield was reported on days 60 and 70, and coarse corn yielded only one.

From the analysis, both commercial sweet corn and coarse corn treated with wood vinegar showed higher corn yields compared to those not treated with wood vinegar. This shows that wood vinegar has positively affected corn production, promoting plant growth, increasing nutrient uptake, and improving overall plant health.

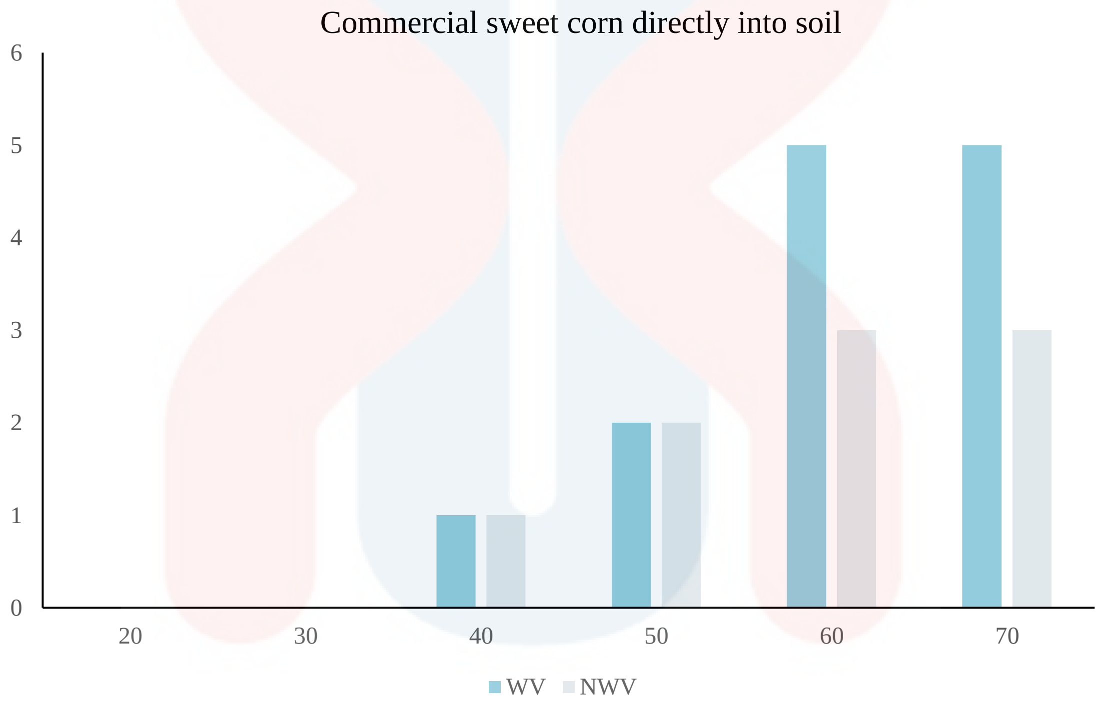

Figure 4.2 (c): Commercial sweet corn yield development with and without wood vinegar direct in soil

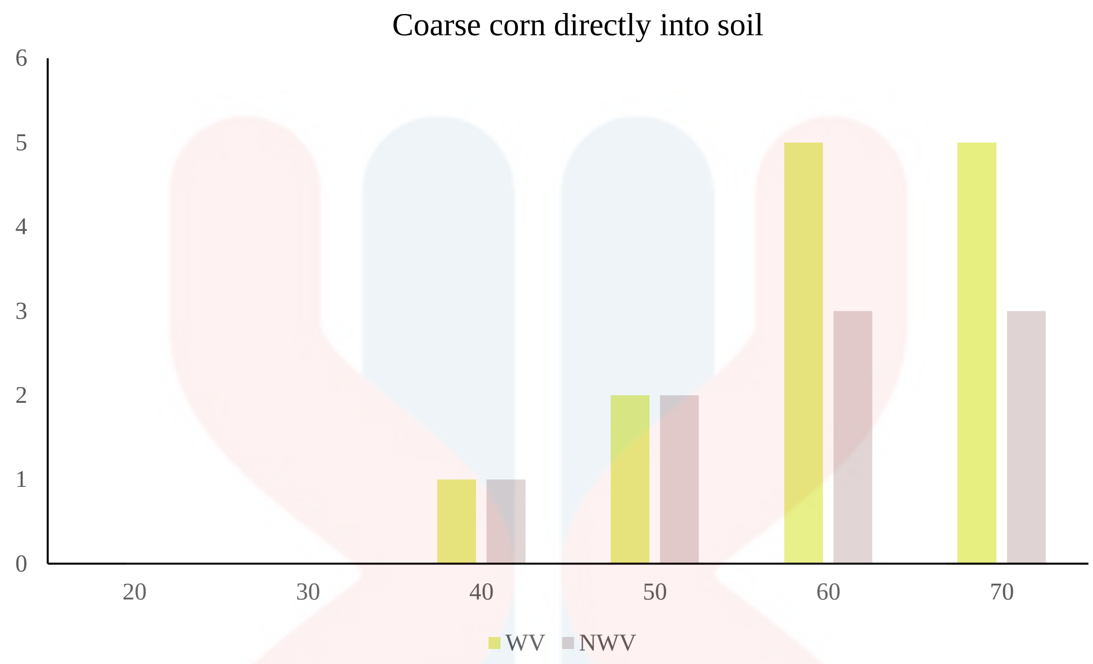

Figure 4.2 (d): Coarse corn yield development with and without wood vinegar direct in soil

Referring to the Figure 4.2 (c), the commercial sweet corn shows a significant increase in corn yield due to applying wood vinegar in planting directly into the soil. The corn yield significantly increased, from 1 unit on the 40th day to 7 units on the 70th day. Like the coarse corn, it exhibited a substantial rise in corn production, going from 1 on the 40th day to 5 on the 60th day and maintaining a steady level of 5 on the 70th day as shown in Figure 4.2 (d). This is because soil preparation is also essential in addition to applying wood vinegar. Soil can retain moisture better than polybags, especially during drought or dry weather. (Havranek & Benecke, 1978). Adequate soil moisture was essential for optimal plant growth and reproductive development in corn (Al-Kayssi, 2023). By planting directly into the soil, corn plants are better able to access moisture, which contributes to improved yield. On the other hand, commercial sweet corn and coarse corn not treated with wood vinegar showed a relatively low corn yield trend throughout the observation period, producing only 5 and 3 corn on day 70 compared to trees treated with wood vinegar.

The analysis indicates that applying a wood vinegar solution benefits the overall crop and corn production. Treated corn plants consistently demonstrate better yields compared to untreated plants. Hence, this wood vinegar is appropriate for application on corn plants, provided that the proper dosage is used to prevent plant damage and mortality resulting from excessive toxicity of the vinegar components.

4.3 The most effectiveness concentrations of wood vinegar for corn development.

Table 4.3 (a): The effective concentration of commercial sweet corn in polybag

Concentration (%)	**Planting in polybag**					
	Commercial sweet corn					
	H (cm)	**SD (cm)**	**L (cm)**	**NL**	**DL**	**CY**
0	99	4.8	88.27	8	5	0
1	131	5.6	116.33	10	3	0
3	178	7.2	124.00	14	2	1
5	180	8.6	136.00	17	0	4

Table 4.3 (b): The effective concentration of coarse corn in polybag

Concentration (%)	**Planting in polybag**					
	Coarse corn					
	H (cm)	**SD (cm)**	**L (cm)**	**NL**	**DL**	**CY**
0	115	5.0	96.00	9	4	0
1	130	5.8	108.27	10	4	0
3	163	6.3	121.00	13	3	1
5	172	7.2	130.66	15	1	1

The data analysis has been carried out from Table 4.3 (a), proving that a concentration of 3% wood vinegar consistently produces the best results (Idowu et al., 2023) for both sweet and coarse corn varieties in the polybag cultivation method. At this concentration level, the corn varieties exhibited significant increases in growth parameters, including plant height, stem diameter and leaf length. It has shown a robust response to the use of wood vinegar with no significant adverse effects.

Commercial sweet corn exhibits maximum growth stimulation when treated with a 3% concentration of wood vinegar, leading to taller plants with a larger stem diameter than lower concentrations. Furthermore, an increase in the number of new leaves was observed, indicating a boost in the plant's vegetative development. However, signs of leaf chlorosis were detected at a higher concentration of 5% of wood vinegar, resulting in a phytotoxic effect on corn plants. It was causing its growth to be disturbed in terms of pets and diseases for development.

Likewise, coarse corn has shown an extraordinary increase in growth at a concentration of 3% wood vinegar, as shown in Table 4.3 (b), through increased plant height, stem diameter, and leaf length. Furthermore, an apparent augmentation in the quantity of fresh leaves was noted at the 3% concentration, indicating enhanced vegetative growth without substantial adverse effects such as chlorosis. Although the higher concentration of 5% continued to promote growth, it also exhibited indicators of phytotoxicity with a high potential for the plant to remain fresh.

Therefore, the concentration of 3% wood vinegar has struck a compromise between enhancing growth and minimizing adverse effects on plant components. It is the most optimal choice for promoting the planting and development of commercial sweet corn and coarse corn in polybags.

Table 4.3 (c): The effective concentration of commercial sweet corn directly into soil

Concentration (%)	Planting directly into soil					
	Commercial sweet corn					
	H (cm)	**SD (cm)**	**L (cm)**	**NL**	**DL**	**CY**
0	120	5.4	88.99	9	3	0
1	153	6.8	108.27	11	1	1
3	161	7.3	127.66	15	2	2
5	183	8.0	134.27	17	3	4

Table 4.3 (d): The effective concentration of coarse corn directly into soil

Concentration (%)	Planting directly into soil					
	Coarse corn					
	H (cm)	**SD (cm)**	**L (cm)**	**NL**	**DL**	**CY**
0	110	5.0	96.00	10	3	0
1	148	5.6	107.27	10	2	0
3	157	6.0	124.33	13	3	1
5	169	7.0	130.00	14	1	2

Referring to data has shown the most effective concentration of wood vinegar for commercial sweet corn and coarse corn when applied directly to the soil, involving careful consideration of growth parameters and potential adverse effects. When researched and analyzed, it was found that the 1% concentration of wood vinegar stands out as the most suitable for both sweet corn and coarse corn when applied directly to the soil. Both varieties have shown a significant increase in growth parameters at this concentration level without signs of phytotoxicity or significant adverse effects. According to Lu et al. (2019), Vinegar is acidic, and in high concentrations, it can be harmful to plants. Therefore, this has made it a balanced choice to increase the growth of corn.

For commercial sweet corn, directly applying 1% wood vinegar to the soil produced favorable growth results, including increased plant height, stem diameter and leaf length as shown in Table 4.3 (c). The number of new leaves also showed a increase, indicating enhanced vegetative growth at this concentration. On the other hand, at higher concentrations of 3% and 5% wood vinegar, it has shown diminishing returns, with potential signs of leaf chlorosis observed, which has had a negative impact on plant health.

According to the Table 4.3 (d), the coarse corn has shown significant growth enhancement at a 1% concentration of wood vinegar. This concentration level leads to an increase in plant height, stem diameter, and leaf length, indicating robust vegetative growth. Furthermore, the number of new leaves significantly increased, indicating an overall plant improvement without substantial adverse effects. Higher concentrations of 3% and 5% wood vinegar showed reduced returns and suffered from phytotoxicity. Thus, by analyzing the data from the corn growth performance, the effectiveness of the 1% concentration has been confirmed to promote the growth of coarse corn directly in the soil.

In nutshell, a concentration of 1% wood vinegar appears to be the most suitable and effective to increase commercial sweet and coarse corn growth when applied directly to the soil. This has struck a balance between boosting growth and minimizing the negative impact on crops.

4.4 Soil pH

Table 4.4 (a): Soil pH of corn plant in polybag

Type of corns	Planting in polybag
	Soil pH
Commercial sweet corn	6.0
Coarse corn	5.0

Table 4.4 (b): Soil pH of corn plants directly into soil

Type of corns	Planting directly into soil
	Soil pH
Commercial sweet corn	6.2
Coarse corn	6

In polybag cultivation, the soil pH of commercial sweet corn is 6.0, which is in the optimum range (6.0 to 7.5) to provide a suitable environment for growth. Meanwhile, a soil pH of 5.0 for coarse corn crops is slightly lower than ideal. According to the journal (2023), maintaining soil pH in this optimal range is essential to ensure optimal growth and productivity. Since polybags have restricted root development and nutrient availability compared to direct planting in the soil, maintaining the appropriate pH levels has become even more critical to support healthy corn plant growth.

Similarly, when planting corn directly into the soil, as shown in Table 4.4(b), the pH of commercial sweet corn soil is in the optimum range of 6.2, while the pH of coarse corn soil is 6.0, which is also in the optimum range. This has allowed the environment to be more conducive and suitable for growth. Soil pH affects nutrient availability, microbial activity, and soil structure, affecting corn plant growth and development. (Ahmad et al., 2015). Therefore, frequent soil testing and appropriate pH management practices, such as liming to raise pH or adding sulfur to lower pH, may be necessary to maintain optimal soil conditions for corn cultivation.

Although corn plants can tolerate a range of soil pH levels, maintaining a slightly acidic to neutral pH range between 6.0 and 7.5 is typically ideal for both polybag and direct soil cultivation.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In a nutshell, the evaluation of wood vinegar at the planting stage showed a high increase in plant height, stem diameter, leaf length, number of leaves, amount of damaged leaves and corn yield. Applying wood vinegar offers several significant benefits to corn plants, enhancing their growth performance and overall health. Supplying essential nutrients and organic substances promotes healthy vegetative development. The theory states that wood vinegar boosts water and oxygen intake during the imbibition phase. Foliar sprays with wood vinegar decreased corn rot and disease infestations. Consequently, the plant's condition is influenced by the concentration of the wood vinegar solution; 1-3% was the most effective and appropriate concentration for corn plants because a higher concentration increases the soil's acidity, causing the plants to wither and not bear fruit. Thus, wood vinegar was preferable for continuous and optimum plant development.

5.2 Recommendations

Wood vinegar is an excellent organic fertilizer that can improve corn health, boost nutrient absorption, raise disease resistance, and encourage greater yields. I advocate using wood vinegar to enhance standard corn farming methods because of its numerous benefits. Wood vinegar has been found to boost maize seed germination rates and promote early vegetative development. Therefore, wood vinegar treatments in corn rely on the application technique and concentration.

I highly recommend the farmers to consider utilizing wood vinegar as a yield-boosting additive, primarily through seed treatment and foliar sprays during critical growth phases. Wood vinegar is a sustainable method for increasing maize yields while supporting environmental stewardship programs. Wood vinegar uptake and correct application regimens adapted to corn developmental biology might fuel the next jump in profitable corn output. I encourage on-farm testing combined with economic analysis to find optimal site-specific techniques that take advantage of wood vinegar's stimulation of germination, development, disease resistance, nutrient absorption, and production benefits reported in current studies. This is because adopting wood vinegar has the potential to catapult farms above current maize yield plateaus and into new economic heights. The wide range of reported growth enhancements and production benefits necessitates careful consideration as a cost-effective organic supplement.

REFERENCES

Agrawal, K. S., Sarda, A. V., Shrotriya, R., Bachhav, M., Puri, V., & Nataraj, G. (2017). Aceticacid dressings: Finding the Holy Grail for infected wound management. *Indian Journal of Plastic Surgery: Official Publication of the Association of Plastic Surgeons of India*, *50*(03), 273–280. https://doi.org/10.4103/ijps.ijps_245_16

Aguirre, J. L., Baena, J., Martín, M. T., Nozal, L., González, S., Manjón, J. L., & Peinado, M. (2020). Composition, ageing and herbicidal properties of wood vinegar obtained through fast biomass pyrolysis. *Energies*, *13*(10), 2418. https://doi.org/10.3390/en13102418

Ahmad, A., Mbofung, G. Y., Acharya, J., Schmidt, C. L., & Robertson, A. E. (2015). Characterization and Comparison of Clavibacter michiganensis subsp. nebraskensis Strains Recovered from Epiphytic and Symptomatic Infections of Maize in Iowa. *PloS One*, *10*(11), e0143553. https://doi.org/10.1371/journal.pone.0143553

Ahmed, H. A., Yu-Xin, T., & Qi-Chang, Y. (2020). Optimal control of environmental conditions affecting lettuce plant growth in a controlled environment with artificial lighting: A review. *Suid-Afrikaanse Tydskrif Vir Plantkunde [South African Journal of Botany]*, *130*, 75–89. https://doi.org/10.1016/j.sajb.2019.12.018

Al-Kayssi, A. A. (2023). Role of alternate and fixed partial root-zone drying on water use efficiency and growth of maize (Zea mays L.) in gypsiferous soils. *International Soil and Water Conservation Research*, *11*(1), 145–158. https://doi.org/10.1016/j.iswcr.2022.04.003

Alternative fuels data center: Ethanol production. (n.d.). Energy.gov. Retrieved May 23, 2023,from https://afdc.energy.gov/fuels/ethanol_production.html

Bacterial leaf streak. (2016, August 2). CropWatch. https://cropwatch.unl.edu/bacterial-leaf-streak

Bacterial leaf streak on sweet corn. (n.d.). Bayer.com. Retrieved May 23, 2023, from https://www.vegetables.bayer.com/us/en-us/resources/growing-tips-and-innovation- articles/agronomic-spotlights/bacterial-leaf-streak-on-sweet-corn.html

Benedict Vanheems, Grow perfect corn every time. (n.d.). GrowVeg. Retrieved February 7, 2024, from https://www.growveg.com/guides/grow-perfect-corn-every-time/

Breseghello, F., & Coelho, A. S. G. (2013). Traditional and modern plant breeding methodswith examples in rice (Oryza sativa L.). *Journal of Agricultural and Food Chemistry*, *61*(35), 8277–8286. https://doi.org/10.1021/jf305531j

Cho, Y.-G., & Kang, K.-K. (2020). Functional analysis of starch metabolism in plants. *Plants*, *9*(9), 1152. https://doi.org/10.3390/plants9091152

Corn fertilization. (n.d.). Msstate.edu. Retrieved May 23, 2023, from http://extension.msstate.edu/publications/corn-fertilization

Corn irrigation timing and water use efficiency. (n.d.). Krugerseed.com. Retrieved May 23, 2023, from https://www.krugerseed.com/en-us/agronomy-library/corn-irrigation-timing.html

Edwards, D. (2019, June 12). *The surprising history of maize*. Bright Maize. https://www.brightmaize.com/surprsing-history-maize/

Elfarisna. (2000a). *Adaptasi kedelai terhadap naungan: Studi Morfologi dan Anatomi*.

https://repository.ipb.ac.id/handle/123456789/4923

Gálvez Ranilla, L. (2020). The application of metabolomics for the study of cereal corn (Zea mays L.). *Metabolites*, *10*(8), 300. https://doi.org/10.3390/metabo10080300

Grenier , A.-M., Duport, G., Pagès, S., Condemine, G., & Rahbé, Y. (2006). The phytopathogen Dickeya dadantii (Erwinia chrysanthemi 3937) is a pathogen of the pea aphid. *Applied and Environmental Microbiology*, *72*(3), 1956–1965. https://doi.org/10.1128/AEM.72.3.1956-1965.2006

Havranek, W. M., & Benecke, U. (1978). The influence of soil moisture on water potential, transpiration and photosynthesis of conifer seedlings. *Plant and Soil*, *49*(1), 91–103. http://www.jstor.org/stable/42933570

How to improve seed germination, sprouting, seedling vigour, the rooting phase and plant health with microbial seed treatments. (n.d.). Explogrow.com.

Retrieved May 23, 2023, from https://www.explogrow.com/farming-with-microbes/how-to-improve-seed-germination-with-microbial-seed-treatments

Huss, C. P., Holmes, K. D., & Blubaugh, C. K. (2022). Benefits and risks of intercropping for crop resilience and pest management. *Journal of Economic Entomology*, *115*(5), 1350– 1362. https://doi.org/10.1093/jee/toac045

Huynh, H. T., Hufnagel, J., Wurbs, A., & Bellingrath-Kimura, S. D. (2019). Influences of soil tillage, irrigation and crop rotation on maize biomass yield in a 9-year field study in Müncheberg, Germany. *Field Crops Research*, *241*(107565), 107565. https://doi.org/10.1016/j.fcr.2019.107565

Idowu, O., Ndede, E. O., Kurebito, S., Tokunari, T., & Jindo, K. (2023). Effect of the interaction between wood vinegar and biochar feedstock on tomato plants. *Journal of Soil Science and Plant Nutrition*, *23*(2), 1599–1610. https://doi.org/10.1007/s42729-023-01227-1

John Sawyer, Nutrient Deficiencies. (n.d.). *Integrated Pest Management*. Iastate.edu. Retrieved February 7, 2024, from https://crops.extension.iastate.edu/files/article/nutrientdeficiency.pdf

Jon, M. (2019, July 6). How tall does corn grow? *GreenUpSide*. https://greenupside.com/how-tall-does-corn-grow/

Kait. (2019, August 21). Seed saving: How to save beetroot seeds. *Kaits Garden*. https://kaitsgarden.com/2019/08/21/seed-saving-how-to-save-beetroot-seeds/

Lee, C. (2021, August 20). *Maize vs corn: What's the difference?* Horticulture Magazine.https://horticulture.co.uk/maize-vs-corn/

Lingl., Z., & Enchen, J. (n.d.). *Effect of wood vinegar on seed germination and water implantation of corn*. Com.au. Retrieved February 6, 2024, from http://www.pyroligneousacid.com.au/wp-content/uploads/2019/01/Effect-of-Wood-Vinegar-on-Seed-Germination-Water-Implantation-of-Corn.pdf

Liu, X., Wang, J., Feng, X., & Yu, J. (2021). Wood vinegar resulting from the pyrolysis of apple tree branches for annual bluegrass control. *Industrial Crops and Products*, *174*(114193), 114193. https://doi.org/10.1016/j.indcrop.2021.114193

Liu, X., Zhan, Y., Li, X., Li, Y., Feng, X., Bagavathiannan, M., Zhang, C., Qu, M., & Yu, J. (2021). The use of wood vinegar as a non-synthetic herbicide for control of broadleaf weeds. *Industrial Crops and Products*, *173*(114105), 114105. https://doi.org/10.1016/j.indcrop.2021.114105

Lu, X., Jiang, J., He, J., Sun, K., & Sun, Y. (2019). Effect of pyrolysis temperature on the characteristics of wood vinegar derived from Chinese fir waste: A comprehensive study on its growth regulation performance and mechanism. *ACS Omega*, *4*(21), 19054–19062. https://doi.org/10.1021/acsomega.9b02240

Marichelvam, Jawaid, & Asim. (2019). Corn and rice starch-based bio-plastics as alternativepackaging materials. *Fibers (Basel, Switzerland)*, *7*(4), 32. https://doi.org/10.3390/fib7040032

Mark Jeshce, *Water and nutrient uptake during the corn growing season*. (2019, April 23). Pioneer.com; Pioneer. https://www.pioneer.com/us/agronomy/water-nutrient-uptake-corn.html

Mimi Broeske; VISUAL GUIDE. (n.d.). *University of Wisconsin*. Wisc.edu. Retrieved February 7, 2024, from https://ipcm.wisc.edu/wp-content/uploads/sites/54/2022/11/UW_CornDevGuide.pdf

MSU extension. (n.d.). MSU Extension. Retrieved May 23, 2023, fromhttps://www.canr.msu.edu/resources/how_to_grow_corn

Mohd Amnan, M. A., Teo, W. F. A., Aizat, W. M., Khaidizar, F. D., & Tan, B. C. (2023). Foliar application of oil palm wood vinegar enhances Pandanus amaryllifolius tolerance under drought stress. *Plants*, *12*(4), 785. https://doi.org/10.3390/plants12040785

Mu, J., Uehara, T., & Furuno, T. (2004). Effect of bamboo vinegar on regulation of germination and radicle growth of seed plants II: composition of moso bamboo vinegar at different collection temperature and its effects. *Journal of Wood Science*, *50*(5), 470–476. https://doi.org/10.1007/s10086-003-0586-y

Mungkunkamchao, T., Kesmala, T., Pimratch, S., Toomsan, B., & Jothityangkoon, D. (2013). Wood vinegar and fermented bioextracts: Natural products to enhance growth and yield of tomato (Solanum lycopersicum L.). *Scientia Horticulturae*, *154*, 66–72. https://doi.org/10.1016/j.scienta.2013.02.020

Nandi, M., Macdonald, J., Liu, P., Weselowski, B., & Yuan, Z.-C. (2018). Clavibacter michiganensis ssp. michiganensis: bacterial canker of tomato, molecular interactions and disease management. *Molecular Plant Pathology*, *19*(8), 2036. https://doi.org/10.1111/mpp.12678

Ortíz, I., & Quintero, R. (2014). Recent advancements in pretreatment technologies of biomass to produce bioenergy. In *Bioenergy Research: Advances and Applications* (pp. 57–69). Elsevier.

Perera, N., Nissanka, S., Dissanayake, C. L. W., & Gunarathne, D. S. (2023). Screening biomass for co-production of biochar and wood vinegar via slow pyrolysis. *2023 Moratuwa Engineering Research Conference (MERCon)*. https://doi.org/10.1109/MERCon60487.2023.10355452

Piñeyro-Nelson, A., Sosa-Peredo, D., González-Ortega, E., & Álvarez-Buylla, E. R. (2017). There is more to corn than popcorn and corn on the cob! *Frontiers for Young Minds*, *5*. https://doi.org/10.3389/frym.2017.00064

Pyroligneous acid (Wood Vinegar) - New Life Wood Vinegar USA. (n.d.). New Life Wood Vinegar. Retrieved May 23, 2023, from http://www.woodvinegarusa.com/pyroligneous- acid---wood-vinegar-.html

Sastry, K. S., Mandal, B., Hammond, J., Scott, S. W., & Briddon, R. W. (2019). Zea mays (cornor maize). In *Encyclopedia of Plant Viruses and Viroids* (pp. 2824–2853). SpringerIndia.

Slater, T. (2022, November 20). *Can you use black cow as A potting soil?* Arew. https://arew.org/can-you-use-black-cow-as-a-potting-soil/

Soliman, E. R. S., El-Shazly, H. H., Börner, A., & Badr, A. (2021). Genetic diversity of aglobal collection of maize genetic resources in relation to their subspecies assignments, geographic origin, and drought tolerance. *Breeding Science*, *71*(3), 313–325. https://doi.org/10.1270/jsbbs.20142

Steenackers, W., El Houari, I., Baekelandt, A., Witvrouw, K., Dhondt, S., Leroux, O., Gonzalez, N., Corneillie, S., Cesarino, I., Inzé, D., Boerjan, W., & Vanholme, B. (2019). cis-Cinnamic acid is a natural plant growth-promoting compound. *Journal of Experimental Botany*, *70*(21), 6293–6304. https://doi.org/10.1093/jxb/erz392

Tamargo, A. (2019, April 23). *Macronutrients in plants*. AGQ Labs USA.https://www.agqlabs.us.com/macronutrients-in-plants/

The importance of soil organic matter. (n.d.). Fao.org. Retrieved May 23, 2023, fromhttps://www.fao.org/3/a0100e/a0100e05.htm

Vicente, J. G., & Holub, E. B. (2013). Xanthomonas campestris pv. campestris (cause of black rot of crucifers) in the genomic era is still a worldwide threat to brassica crops: Xanthomonas campestrispv.campestris. *Molecular Plant Pathology*, *14*(1), 2–18.https://doi.org/10.1111/j.1364-3703.2012.00833.x

Wang, Y., Qiu, L., Song, Q., Wang, S., Wang, Y., & Ge, Y. (2019). Root proteomics reveals the effects of wood vinegar on wheat growth and subsequent tolerance to drought stress. *International Journal of Molecular Sciences*, *20*(4), 943. https://doi.org/10.3390/ijms20040943

Waqas, M. A., Wang, X., Zafar, S. A., Noor, M. A., Hussain, H. A., Azher Nawaz, M., & Farooq, M. (2021). Thermal stresses in maize: Effects and management strategies. *Plants*, *10*(2), 293. https://doi.org/10.3390/plants10020293

Wei, F., Coe, E., Nelson, W., Bharti, A. K., Engler, F., Butler, E., Kim, H., Goicoechea, J. L., Chen, M., Lee, S., Fuks, G., Sanchez-Villeda, H., Schroeder, S., Fang, Z., McMullen, M., Davis, G., Bowers, J. E., Paterson, A. H., Schaeffer, M., … Wing, R. A. (2007). Physical and genetic structure of the maize genome reflects its complex evolutionary history. *PLoS Genetics*, *3*(7), e123. https://doi.org/10.1371/journal.pgen.0030123

Zhu, K., Gu, S., Liu, J., Luo, T., Khan, Z., Zhang, K., & Hu, L. (2021). Wood vinegar as a complex growth regulator promotes the growth, yield, and quality of rapeseed. *Agronomy (Basel, Switzerland)*, *11*(3), 510. https://doi.org/10.3390/agronomy11030510

APPENDIX A

The parameters of corn plants elements with or without wood vinegar

Day	Types of corn seed	Planting in polybag					
		Apply wood vinegar					
		H (cm)	D (cm)	L (cm)	NL	DL	CY
20	Commercial sweet corn	112	5.0	99.33	10	0	0
30		117	5.6	104.23	10	0	0
40		132	7.1	108.00	13	0	1
50		146	7.8	113.33	15	1	2
60		155	8.3	124.00	15	0	2
70		173	9.2	138.00	18	1	3
20	Coarse corn	96	4.8	108.00	9	0	0
30		105	5.5	96.67	10	0	1
40		121	6.0	112.67	11	1	0
50		138	6.9	115.67	11	0	0
60		152	7.3	120.33	14	1	1
70		168	8.0	134.67	15	2	2

Day	Types of corn seed	Planting in polybag					
		Not apply wood vinegar					
		H (cm)	D (cm)	L (cm)	NL	DL	CY
20	Commercial sweet corn	97	5.0	88.33	9	0	0
30		106	5.5	94.27	10	0	0
40		125	6.1	101.66	11	0	0
50		138	7.0	108.00	11	3	0
60		155	7.6	115.66	14	2	1
70		162	8.3	124.67	15	3	1
20	Coarse corn	87	4.6	87.00	10	0	0
30		92	5.0	99.67	10	0	0
40		117	5.8	112.00	11	3	1
50		135	6.1	119.20	11	4	0
60		148	6.9	126.00	12	3	0
70		160	7.2	130.00	12	3	1

APPENDIX B

Day	Types of corn seed	Planting directly into soil					
		Apply wood vinegar					
		H (cm)	D (cm)	L (cm)	NL	DL	CY
20	Commercial sweet corn	106	5.0	98.27	10	0	0
30		113	5.9	102.66	11	0	0
40		131	6.3	115.33	12	0	1
50		148	7.0	128.00	13	0	3
60		164	8.6	136.33	15	1	5
70		180	9.2	140.00	18	0	7
20	Coarse corn	80	5.0	100.33	11	0	0
30		107	5.3	106.00	11	0	0
40		115	6.7	118.27	12	1	1
50		129	6.9	126.00	13	2	2
60		147	7.7	131.66	13	1	5
70		170	8.3	138.27	15	1	5

Day	Types of corn seed	Planting directly into soil					
		Not apply wood vinegar					
		H (cm)	D (cm)	L (cm)	NL	DL	CY
20	Commercial sweet corn	95	5.0	92.67	9	0	0
30		100	6.0	104.33	10	0	0
40		117	6.8	118.66	10	2	1
50		128	7.3	120.67	13	1	2
60		148	8.5	128.00	14	0	3
70		160	9.3	136.27	16	2	5
20	Coarse corn	104	4.0	87.33	10	0	0
30		118	5.2	99.67	10	0	0
40		121	5.8	104.00	11	1	1
50		136	6.3	117.00	11	1	2
60		148	7.0	128.33	14	2	3
70		163	8.0	133.66	14	2	3

APPENDIX C