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BOOSTING SPINACH GROWTH WITH WOOD VINEGAR FOR ENVIRONMENTALLY FRIENDLY FARMING

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DECLARATION

I, Muhamad Rabbani Bin Mohd Ayub, hereby declare that this thesis titled "Boosting Spinach Growth with Wood Vinegar for Environmentally Friendly Farming" is my original work. The content presented in this thesis is the result of my own research and has not been submitted, in whole or in part, for any other degree or qualification.

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Boosting Spinach Growth with Wood Vinegar for Environmentally Friendly Farming

ABSTRACT

This study studies the use of wood vinegar to promote spinach growth for ecologically friendly agriculture. Wood vinegar, a biomass pyrolysis byproduct, contains organic chemicals that boost plant development. The study evaluated plant development with wood vinegar, synthetic fertilizer, and no treatment over 26 days. Each treatment's soil pH was also assessed. Wood vinegar neutralizes soil pH at 6.4. Synthetic nutrient-treated soil had a pH of 5.2, whereas the untreated control group had 6.2. Plant area, height, and leaf count were compared to the untreated control to assess wood vinegar and synthetic nutrient benefits. These results illuminate how these treatments affect plant development and offer agricultural uses. Wood vinegar, synthetic nutrients, and no treatment were given to the control groups. To observe dynamic changes, plant growth was assessed on days 3, 7, 14, 18, 22, and 26. Data analysis shows huge trends in all indices. Growth was consistently better with wood vinegar than with synthetic nutrients or the untreated control group. On day 3, wood vinegar-treated plants had an area of 0.84 cm^2, a height of 2.4 cm, and 2 leaves. Plants treated with synthetic nutrients had a 0.72 cm^2 area, 2.1 cm height, and 2 leaves, whereas the untreated control group had a 0.77 cm^2 area, 2.2 cm height, and 2 leaves. The growth gap widened throughout the research. On day 26, wood vinegar-treated plants had a 71.07 cm^2 area, 14.6 cm height, and 8 leaves. Plants given synthetic fertilizers had a 65.0 cm^2 area, 13.8 cm height, and 7 leaves, whereas the untreated control group had 58.8 cm^2, 12.5 cm height, and 7 leaves. In sustainable agriculture, treatment selection may be based on their combined impact on plant physiology and soil conditions.

Keywords: spinach, soil pH, wood vinegar, synthetic nutrients, no growth treatment,

Menggalakkan Pertumbuhan Bayam dengan Cuka Kayu untuk Pertanian Mesra Alam

ABSTRAK

Kajian ini mengkaji penggunaan cuka kayu untuk menggalakkan pertumbuhan bayam untuk pertanian mesra ekologi. Cuka kayu, produk sampingan pirolisis biojisim, mengandungi bahan kimia organik yang meningkatkan pembangunan tumbuhan. Kajian itu menilai perkembangan tumbuhan dengan cuka kayu, baja sintetik, dan tiada rawatan selama 26 hari. pH tanah setiap rawatan juga dinilai. Cuka kayu meneutralkan pH tanah pada 6.4. Tanah yang dirawat dengan nutrien sintetik mempunyai pH 5.2, manakala kumpulan kawalan yang tidak dirawat mempunyai 6.2. Luas tumbuhan, ketinggian dan bilangan daun dibandingkan dengan kawalan yang tidak dirawat untuk menilai cuka kayu dan faedah nutrien sintetik. Keputusan ini menerangkan bagaimana rawatan ini mempengaruhi pembangunan tumbuhan dan menawarkan kegunaan pertanian. Cuka kayu, nutrien sintetik, dan tiada rawatan diberikan kepada kumpulan kawalan. Untuk melihat perubahan dinamik, pertumbuhan tumbuhan dinilai pada hari 3, 7, 14, 18, 22, dan 26. Analisis data menunjukkan arah aliran yang besar dalam semua indeks. Pertumbuhan secara konsisten lebih baik dengan cuka kayu daripada dengan nutrien sintetik atau kumpulan kawalan yang tidak dirawat. Pada hari ke-3, tumbuhan yang dirawat dengan cuka kayu mempunyai keluasan 0.84 cm^2, ketinggian 2.4 cm, dan 2 helai daun. Tumbuhan yang dirawat dengan nutrien sintetik mempunyai luas 0.72 cm^2, ketinggian 2.1 cm, dan 2 daun, manakala kumpulan kawalan yang tidak dirawat mempunyai luas 0.77 cm^2, ketinggian 2.2 cm, dan 2 daun. Jurang pertumbuhan melebar sepanjang penyelidikan. Pada hari ke-26, tumbuhan yang dirawat dengan cuka kayu mempunyai keluasan 71.07 cm^2, ketinggian 14.6 cm dan 8 daun. Tumbuhan yang diberi baja sintetik mempunyai keluasan 65.0 cm^2, tinggi 13.8 cm, dan 7 daun, manakala kumpulan kawalan yang tidak dirawat mempunyai 58.8 cm^2, tinggi 12.5 cm, dan 7 daun. Dalam pertanian mampan, pemilihan rawatan mungkin berdasarkan kesan gabungannya terhadap fisiologi tumbuhan dan keadaan tanah.

Kata kunci: bayam,pH tanah, cuka kayu, nutrien sintetik, tiada rawatan pertumbuhan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

WV	Wood Vinegar
SN	Synthetic Nutrients
NT	No treatment
A	Area of leaves
H	Height of spinach
NL	Number of leaves

LIST OF SYMBOLS

cm	centimeter
cm^2	square centimeter
ml	milliliter

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The need for increased food production is directly related to the rising global population. In order to meet this need, farmers increasingly turn to synthetic inputs like chemical fertilizers and pesticides. Their use, however, has led to environmental problems such soil depletion, water contamination, and biodiversity loss. This has led to a push for environmentally responsible farming methods that reduce chemical use and promote long-term productivity.

Among these methods is using wood vinegar as a fertilizer. The organic chemicals in wood vinegar, a result of wood pyrolysis, are beneficial to plant development. The gases released during the pyrolysis and carbonization of biomass are condensed and separated to yield wood vinegar, an organic liquid. It's a concoction of numerous organic substances. (Mungkunkamchao, et. al. 2013)

Researchers have shown that rice, cucumbers, and tomatoes all benefit from wood vinegar's ability to stimulate growth and enhance yields. Charcoal manufacture yields a liquid byproduct called wood vinegar, also called pyroligneous acid. It's full of organic components that boost plant development and harvest, such acetic acid, methanol, and phenol. Wood vinegar is safe for use in organic farming because of its fungicidal and insecticidal characteristics.

Leafy green vegetables like spinach (*Spinacia oleracea*) are great sources of several essential elements, including iron, calcium, and vitamins A and C. Nevertheless, soil nutrient availability, water availability, pests, and illnesses may all have an impact on growth and productivity. Wood vinegar has been applied to plant leaves as a foliar fertilizer and used to control plant growth in modern agriculture. D. Mohan & P. Pittman et. al. 2006. As a result, there is a pressing need for environmentally friendly methods of maximizing spinach production with little usage of artificial fertilizers and pesticides. However, studies on the effects of wood vinegar on spinach development are few. Thus, the purpose of this research is to assess how wood vinegar influences spinach's development and productivity.

1.2 PROBLEM STATEMENT

The issue is that traditional agricultural practices frequently rely on synthetic fertilizers and pesticides, which can harm the environment and human health. Furthermore, some farmers may be unwilling to embrace more sustainable agricultural techniques owing to fears about lower crop yields or higher expenses.

The appropriate concentration and effectiveness of wood vinegar in boosting the growth of spinach are yet unclear, despite the growing interest in using wood vinegar as an organic fertilizer for sustainable agriculture. The benefits of wood vinegar on plant growth have been demonstrated in prior research, however there is no agreement on the optimal dose for optimizing crop yields with minimal environmental impact. To fix this problem, farmers need to switch to a method that reduces their impact on the environment while yet increasing their crop yields. Wood vinegar could be used to encourage more spinach to grow. Therefore, more research is required to understand the effects of various concentrations of wood vinegar on spinach growth, as well as the benefits and threats to the environment that may result from its usage in agriculture.

1.3 OBJECTIVE

1. To assess the increase in spinach crop yield resulting from the application of wood vinegar as a fertilizer.

2. To compare the effects of wood vinegar with synthetic nutrients and no treatment on spinach.

1.4 EXPECTED OUTCOMES

Wood vinegar can provide essential nutrients such as nitrogen, phosphorus, and potassium which are necessary for spinach growth. Dilution rates of wood vinegar and the application of biochar along with wood vinegar can also play a significant role in enhancing spinach growth. Spraying wood vinegar on spinach can lead to increased photosynthesis, osmotic adjustment, and antioxidant enzymes, which can improve spinach's resistance to adverse conditions such as low temperature stress. Wood vinegar is an effective and environmentally friendly way to boost spinach growth. It is a natural and organic alternative to synthetic fertilizers, which can be harmful to the environment. By using wood vinegar, farmers can reduce their reliance on chemical fertilizers and promote sustainable agriculture

1.5 SCOPE STUDY

The study focuses specifically on the use of wood vinegar as a growth-promoting agent for spinach plants. It investigates the effects of wood vinegar on spinach growth parameters, such as plant height, leaf area, biomass, and nutrient content.

1.6 SIGNIFICANT OF STUDY

The method of boosting spinach growth with wood vinegar is significant for environmentally friendly farming as it provides a cost-effective and eco-friendly way to promote crop growth and enhance stress resistance. Wood vinegar is a natural extract from woods that is non-toxic and biodegradable, making it a great choice for organic farming. Using wood vinegar in combination with biochar can further improve soil health, promote plant growth, and increase crop yields. Farmers can also use wood vinegar to nourish seeds for germination, facilitate composting, and enrich soil fertility. However, it should not be used with alkaline chemicals. Overall, wood vinegar has various benefits for organic farming and can potentially reduce farm input costs while improving production results.

Chapter 2

Literature Review

2.1 The study of Spinach Growth

Spinach is a leafy green vegetable that is consumed often all over the world due to the numerous health advantages that are associated with its consumption. It is essential to have an understanding of the processes involved in the growth of spinach as well as the elements that have an effect on it in order to optimise planting practises, boost yield, and enhance plant quality. The growth of spinach is affected by a number of elements, including the kind of soil, temperature, amount of accessible water, and amount of available nutrients. In recent years, an increasing number of individuals have begun to adopt environmentally friendly agricultural practises that promote sustainable agriculture and place restrictions on the use of synthetic chemicals. This pattern is being driven by an increase in people's understanding of the significance of protecting the environment.

One such practice is the use of wood vinegar as a natural fertilizer to boost spinach growth. Wood vinegar is a byproduct of the process of making charcoal from wood and contains various organic compounds that can promote plant growth. Studies have shown that the application of wood vinegar can increase the yield and quality of spinach crops.

2.1.1. Nutrient requirements of spinach

In most cases, these nutrients come from either the soil or the fertilisers that are applied to it. It is essential to keep in mind that the particular nutritional requirements of plants might change based on the species of plant, the development stage, and the circumstances of the environment. Spinach must be able to provide a number of necessary nutritional requirements for normal and healthy growth and development. The majority of the nutritional solution is composed of potassium (K), nitrogen (N), phosphorus (P), calcium (Ca), magnesium (Mg), and sulphur (S), in addition to many other micronutrients. When producing vegetables for commercial purposes, the electrical conductivity (EC) of the nutrient solution is almost often employed as the major

controlling element in determining how much of each nutrient is applied to the soil. Calcium and magnesium are the two key nutrients that are necessary for the growth and development of spinach plants. It is crucial to steer clear of excessive nitrogen since it has the potential to cause fires to break out at the leaf tips. Hydroponic spinach takes about 40-50 days to grow, and fast-growing systems may see a finished spinach harvest in as little as 35 days. Once harvested, hydroponic spinach can be stored in resealable containers lined with paper towels to absorb any moisture. Spinach is full of nutrients that aid in bone and blood health, including carotenoids, vitamin C, vitamin K, folic acid, iron, and calcium. (Kris Gunnars, et al, 2023). It is also rich in iron, vitamins C and E, potassium, and magnesium, and can help support immune function and aid the digestive system (Marie Lorraine Johnson, et al, 2023).

2.1.2 Factors that affect spinach growth

To boost spinach growth with wood vinegar for environmentally friendly farming, it's important to consider several factors that can affect spinach growth. (Zhu et al., 2022) Spinach prefers well-draining soil with good nutrient content, consistent moisture, at least 6 hours of sunlight per day, and cool temperatures. Wood vinegar can provide essential nutrients such as nitrogen, phosphorus, and potassium, which are necessary for spinach growth. However, it's crucial to monitor growth and conduct experiments to compare its effects with synthetic nutrients. (Keiji Jindo et al., 2022) Dilution rates of wood vinegar and the application of biochar along with wood vinegar can also play a significant role in enhancing spinach growth. (Zhu et al., 2022) Moreover, spraying wood vinegar on spinach can lead to increased photosynthesis, osmotic adjustment, and antioxidant enzymes, which can improve spinach's resistance to adverse conditions such as low temperature stress. By following these steps, farmers can effectively boost spinach growth in an environmentally friendly way.

2.1.1.1 Soil types

Enhancing spinach growth with wood vinegar can be beneficial on many types of soil. Sandy soil has larger particles and a low water holding capacity. Wood vinegar can help improve water retention in sandy soils by promoting soil aggregation and increasing the soil's ability to hold moisture. Additionally, the nutrient content of wood vinegar can provide additional nutrients to support the growth of spinach in nutrient-poor sandy soil. Within the context of a particular

ecosystem, soil health refers to how well the soil is able to carry out the environmental activities for which it was designed. These functions include fostering plant development, controlling the flow of water, recycling waste materials, safeguarding living species, and moderating the chemical make-up of the atmosphere. (Brady, et al. 2017). In addition to the usage of wood vinegar, it is essential to take into account other soil fertility parameters, regardless of the kind of soil present. These factors include nutrient levels, the amount of organic matter present, and soil compaction. Conducting a soil test to determine nutrient deficiencies and pH levels can help adjust the use of wood vinegar and ensure balanced nutrient supplementation.

2.1.1.2 Pest and disease control

Spinach growth can be influenced by various factors such as nutrient availability, light, water, temperature, and soil quality. Spinach requires high levels of moisture and if rainfall is inadequate, 2.5 cm (1 in) of water should be applied every 7-10 days. Spinach is vulnerable to various diseases and pests such as damping off, downy mildew, cutworms, wireworms, flea beetles, slugs and snails, and aphids. (Carroll, 2012) To tackle these issues, gardeners can take various measures such as using traps, sprays, or insecticidal soaps, planting quality seeds, avoiding overwatering and overcrowding, and spacing plants at recommended distances. Spinach diseases can be managed by using fungicide-treated seeds, planting resistant varieties, avoiding saturated soils, and avoiding planting spinach successively in the same location. Wood vinegar has been studied for its potential to enhance crop growth and yield. It can act as a plant growth regulator and increase root growth.

2.2 Wood Vinegar as a Plant Growth Stimulant

When wood is heated in the absence of oxygen, an organic liquid known as wood vinegar is produced. Its high concentration of key minerals including nitrogen, phosphate, and potassium makes it a powerful plant growth stimulator. Wood vinegar contains essential minerals for plant growth and can be used as a fertiliser, particularly for leafy greens like spinach.

To boost spinach growth with wood vinegar, several factors need to be considered. Spinach prefers well-draining soil with good nutrient content, consistent moisture, at least 6 hours of sunlight per day, and cool temperatures. Therefore, it is important to ensure that the soil is well-draining and has sufficient nutrients to support the growth of spinach

2.2.1 Wood vinegar

Wood vinegar is a natural by-product of charcoal production that is gaining popularity in natural farming as an essential farming input. It is a liquid extract obtained through the process of biomass pyrolysis (Luis et al., 2020). Wood vinegar is also known as pyroligneous acid or liquid smoke and is produced by condensing the vapor released during the burning of wood. It is used in agriculture and animal fodder. Wood vinegar has various applications, including as a fertilizer, growth-promoting agent, and plant growth regulator. It can also aid in improving soil quality, eliminating pests, controlling weed growth, and boosting crop defenses against disease.

2.2.2 Chemical composition of wood vinegar

Wood vinegar is a liquid extract obtained through the process of biomass pyrolysis, a natural by-product of charcoal production. The chemical composition of wood vinegar varies depending on the type of wood used in the pyrolysis process. The compositions of the pyroligneous acids were analyzed qualitatively and quantitatively, and 23 components were identified, with acetic acid being the major component (Yongyuth Theapparat et al., 2015). It has been studied for its potential to enhance crop growth and yield, act as a plant growth regulator, and increase root growth. Additionally, wood vinegar has been used as a natural herbicide agent for controlling weeds.

2.2.3 Mechanisms by which wood vinegar promotes plant

Vinegar made from wood has organic acids and phenols, which are natural antioxidants and can affect plant physiology. These phenols and organic acids can improve plant resilience by promoting growth and development despite harsh conditions. Superoxide dismutase (SOD), catalase (POD), peroxidase (CAT), and other free radical scavengers are all part of a complex antioxidant system that plants have evolved to tolerate environmental stress (Zhu et al., 2022). Plants have improved their resistance to stress thanks to this system. As the first line of defence in membrane protection, SOD is in charge of converting ROS into H2O2, which is then broken down into water and oxygen by POD and CAT. Abiotic stresses cause plant cells to collect a wide range of organic and inorganic substances (including proline, soluble sugar, and soluble protein) for the goal of osmotic correction. The osmotic potential of the cell is reduced, and the stress is relieved as a result.

2.3 Effects of Wood Vinegar and synthetic nutrients on Spinach Growth

Wood vinegar, also known as pyroligneous acid, is a natural byproduct of the carbonization process of wood. It contains various plant nutrients and organic compounds that can improve soil fertility and promote plant growth. When used as a fertilizer, wood vinegar can enhance the absorption of nutrients, increase root growth, and improve plant resistance to pests and diseases. On the other hand, synthetic nutrients are artificially made chemical compounds that are designed to provide specific nutrients to plants. They can be highly effective in promoting plant growth and yield, but they may also have negative impacts on soil quality and the environment if overused. In terms of spinach growth, the effectiveness of wood vinegar and synthetic nutrients may depend on various factors, such as soil type, climate, and application method. Generally, a balanced combination of both natural and synthetic nutrients can provide optimal growth conditions for spinach. However, it is important to use them in moderation and follow proper application guidelines to prevent any negative effects.

2.4 Environmental Benefits of Using Wood Vinegar in Farming

Wood vinegar, also known as pyroligneous acid, is a byproduct of the process of producing charcoal. It is an organic liquid that contains various beneficial compounds such as acetic acid, methanol, and acetone. Using wood vinegar in farming for boosting spinach growth can offer several environmental benefits.

2.4.1 Reduction in the use of synthetic fertilizers and pesticides

Using wood vinegar as a natural alternative to synthetic fertilizers and pesticides is becoming increasingly popular among farmers and agricultural researchers. Wood vinegar contains biologically active compounds that can act as plant growth regulators, similar to gibberellin, and enhance nutrient uptake, seed germination, and stress resistance. It has been studied for its potential to enhance crop growth and yield, act as a plant growth regulator, and increase root growth. Wood vinegar can be an effective fertilizer in hydroponic systems and can improve soil quality, and has shown potential as a bio-stimulant for crops, increasing biomass and fruit production without adverse effects on the environment or non-target organisms (Fedeli et al., 2022). However, synthetic fertilizers may still be more effective in providing quick feed with higher nutrient levels.

2.4.2 Potential for improved soil health

Wood vinegar has been found to be effective in improving soil quality. It contains biologically active compounds that act as plant growth regulators and enhance nutrient uptake, seed germination, and stress resistance. These compounds also promote plant defense mechanisms against stress (Idowu et al., 2023). Wood vinegar can be used as a fertilizer, growth-promoting agent, and plant growth regulator. It has a compound effect of promoting crop growth similar to plant growth hormones (Zhu et al., 2021). However, it is worth noting that while wood vinegar has positive effects on soil health, synthetic fertilizers may still be more effective in providing quick feed with higher nutrient levels.

2.4.3 Reduction in water pollution

Wood vinegar can also contribute to the reduction of water pollution (Plant Use, 2023). Since it is biodegradable and non-toxic, it does not have any adverse effects on the environment or non-target organisms, unlike synthetic fertilizers and pesticides. Additionally, by reducing the dependence on chemical fertilizers and pesticides, the use of wood vinegar in agriculture can help prevent water pollution caused by the runoff of these chemicals into water bodies.

Chapter 3

Materials and Method

3.1 Materials

3.1.1 Spinach Seeds

Spinach seeds serve as the base material for this investigation. Aquire spinach seedlings from online seed retailers and garden centers. Typically, small and spherical in shape, these seeds exemplify the capacity to produce verdant foliage that is closely associated with nutrient-dense leafy vegetables. By diluting wood vinegar and applying it to the seedlings, spraying it directly onto the plant, or incorporating it into the soil, it can be utilized. It is hypothesized that this methodology facilitates enhanced absorption of nutrients, encourages the development of roots, bolsters the vitality of the plant, and contributes to the overall health of the plant. As necessary, adjustments are made to the concentration and frequency of use during this procedure.

3.1.2 Wood Vinegar

Wood vinegar is produced through the pyrolysis process, which involves heating wood or plant material in the absence of oxygen. Pyroligneous acid, commonly referred to as wood vinegar, is a chemical consisting of a combination of organic acids, phenolic compounds, and several other volatile substances. Effect of pyrolysis heating rate on the chemical composition of wood vinegar from Eucalyptus urograndis and Mimosa tenuiflora. (de Medeiros et.al, 2019). Production requires the breakdown of organic matter in the wood, followed by the subsequent condensation of steam to obtain the distinctive liquid state of wood vinegar. The wood vinegar used is obtained from a nearby producer, Forest Bio Energy Sdn Bhd. Spray 100ml of wood vinegar with a concentration of 5% mixed with 400ml of water in a ratio of 1:4 (Akkus et.al., 2023). This ratio is used to promote the reproduction of spinach plants.

3.1.3 Synthetic Nutrients

synthetic nutrients for spinach may vary depending on various factors, such as soil nutrient levels, specific nutrient deficiencies, and the growth stage of the spinach plants. It is essential to conduct soil testing and consider the nutritional needs of the crop before applying synthetic nutrients to ensure they are used efficiently and effectively. A common synthetic fertilizer for

spinach might have an NPK ratio of approximately 10-10-10, which means it contains equal parts nitrogen, phosphorus, and potassium. However, this is a general-purpose fertilizer, and the actual ratio used would depend on the specific requirements of the soil and the crop.

3.2 Method

A controlled experiment was undertaken to assess the impact of wood vinegar in comparison to synthetic nutrients on the development of spinach. The experiment will consist of three cohorts of spinach plants: one cohort subjected to wood vinegar treatment, another cohort receiving synthetic nutrients, and a control cohort devoid of any foreign compounds. Plants are observed to assess their growth rate, leaf colour, and general health. Results are documented and compared to ascertain the relative efficacy of each therapy. The experiment was replicated several times to assure precise results.

3.2.1 Selecting and preparing the spinach growing area

The effectiveness of spinach planting depends on choosing and preparing the planting space. choosing a well-drained spot with at least six hours of sunshine will provide a fruitful environment. Soil health is improved by adding organic matter and fertilisers, while debris clearing and appropriate planting encourage spinach development. Strategic row spacing, raised bed design, and sunshine exposure help create a successful arrangement. Spinach requires constant watering, such as drip irrigation. Crop rotation, row cover, and organic mulches strengthen spinach plants. Understanding temperature, companion planting, and spacing criteria helps create the perfect spinach growth environment within a wider agricultural research and practice framework.

3.2.2 Seed Preparation

Select healthy spinach seeds for planting. Before sowing the seeds, soak them in the diluted wood vinegar solution for a short period, usually around 10-15 minutes. (Zhu et al., 2021). A disciplined approach to seed preparation ensures optimum germination and plant growth. Baba seeds are utilised because they are carefully selected for purity, germination rate, and growing adaptability. Seeds should be stored in a cold, dry, airtight container to avoid moisture and pests. To control diseases and pests, seed treatment with hot water or fungicides is essential. The selection of a proper seed sowing media or germination combination, 2cm sowing depth, and temperature and humidity management all help germination. Next comes seedling transplantation, meticulous record keeping, and continuous monitoring.

3.2.3 Regular Watering

Water spinach plants regularly to maintain proper moisture levels in the soil. it is better to water the spinach in the morning or early evening, allowing the leaves to dry before nightfall. It is important to keep the soil moist but avoid waterlogging. Adequate watering helps plants absorb nutrients and promotes healthy growth. Additionally, periodically add diluted wood vinegar to the irrigation water, usually every 2-3 weeks. (Zhu et al., 2021). Spinach needs wet soil. Daily, insert your finger into the soil 1-2 inches deep to check for dryness. Spinach requires constant hydration. Water when the top two inches of soil feel dry. Apply water gently and thoroughly until the bottom drainage hole empties. This promotes deep rooting. Polybag spinach needs watering every 1-3 days, depending on environment. In hot temperatures, water more. Use 1/2–1 inch of water every watering session. Watering often and lightly causes weak roots. Wet leaves are more vulnerable to fungal infections, so water in the morning. The polybag should include drainage holes at the bottom to remove excess water. Record the date, flow, wetness, and inches utilised after each watering. Combining this data with observed water consumption quantity and duration gives standardised parameters for spinach's water demands for optimum production without excess.

3.2.4 Plants Growth Use

In addition to the root infusion, the use of wood vinegar leaves can be beneficial. Prepare a solution of diluted wood vinegar by mixing it with water. (Plant Use, 2023). Using a suitable spray bottle or sprayer, apply the diluted wood vinegar solution to the spinach leaves, ensuring thorough coverage. This foliar application allows plants to directly absorb the nutrients and growth-promoting substances found in wood vinegar through their leaves. Before planting, dilute wood vinegar greatly. Spray 100ml of 5% wood vinegar with 400ml water in a 1:4 ratio. About 2-3 weeks after planting spinach, sprinkle wood vinegar on the leaves in the morning or afternoon. Apply the diluted solution freely to leaves, stems, and soil. A 500ml water spray bottle with an even pattern works. Freshen the wood vinegar spray every 7-10 days. It works via plant respiration and enzymes. Wood vinegar boosts spinach chlorophyll and leaf density. It also boosts disease resistance. The right polybag spacing and plant air movement are stressed. If necessary, prune older or crowded leaves. Spray spinach with wood vinegar for optimal hydration and fertilizing.

This helps plants. To improve your process across generations, record application dates, dilution rates, and spinach responses.

3.2.5 Soil pH

The ideal soil pH for growing spinach ranges between 6.0 and 7.0. Spinach prefers slightly acidic to neutral soil conditions. (Growing Spinach and Swiss Chard in Home Gardens, 2022). Spinach soil pH is controlled to optimize growth and nutrient availability. The next processes begin with a thorough soil test to establish the planting area's pH. Spinach pH is 6.0–7.0 on a pH meter. Tools like soil testers provide reliable data. Fertilizers and compost maintain soil pH and structure. Organic mulches increase soil health and drip watering decreases surface-induced pH fluctuations. Detailed spinach pH, amendment, and growth data guide management and planting.

3.2.6 Measure and Number of leaves

Using a ruler or tape measure, carefully measure the length of each leaf from base to tip to measure the length and width of the leaf. (Get Busy Gardening, 2022). Be sure to measure along the center or midrib of the leaf for consistency. The spinach leaf count technique must be methodical and standardized to reliably evaluate vegetative development. Occasionally pick average-sized leaves and measure length and breadth using 2 of 6 representative spinach plants from each polybag group. Attach ties or stakes to these plants. Define a spinach "leaf". To prevent recounting, gently unfold each leaf and use a pointer or pen to count the leaflets. Choose medium-sized mature leaves on indicated plants. Leaf length and breadth are measured in cm using a ruler. Each plant's leaf count and measurements are entered in the data book. Measure every week or two. Stretch each leaf carefully and count from base to tip. We determined the average number of leaves and plant size in each polybag group. Count or size decreases over time may suggest environmental stresses require repair. Graph weekly leaf counts and size data to track crop progress. Record data independently for each cluster to compare cultivars/varieties. To optimize leaf development and plant quality, coordinate manufacturing techniques depending on findings. Keep a data diary and evaluate it to improve spinach output.

3.2.7 Height Measurement

Height might reflect spinach variety, growth circumstances, and vitality. Height over time is measured using 2 of 6 sample trees from each polybag cluster. Mark this plant sample. Measure height in cm or inches using a ruler. Measure spinach from the soil line from the base to the highest leaf. To size bent leaves, gently straighten and hold them upright. Weekly or biweekly height measurements monitor progression. Spinach leaves wilt and vary height during the day, so measure at a regular time. Find the average plant height for each polybag group. Growth curves are made by plotting average height over time. Note development plateaus or decreases that may indicate environmental stress. Track varieties individually and compare growth trajectories. Height data should be used to adjust output to meet growth goals. Record all measurements and utilize the data to enhance spinach harvests.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 To assess the increase in spinach crop yield resulting from the application of wood vinegar as a fertilizer.

To assess the impact of wood vinegar fertilizer on spinach yield increases, it is imperative to devise and execute a comprehensive experimental investigation. The subsequent primary stages delineate a methodical strategy for assessing the impact of wood vinegar on the yield of spinach, as illustrated in (Table 4.1.1).

Treatment	Soil pH
Wood vinegar	6.4
Synthetic Nutrients	5.2
Non treatment	6.2

Table 4.1.1: pH level of the soil

To attain optimal spinach growth via environmentally sustainable agricultural practices, it is imperative to take into account soil pH and employ wood vinegar strategically. For optimal nutrient availability, soil pH should be maintained between 6.0 and 7.5 when cultivating spinach. With its mild acidic nature, wood vinegar has the potential to enhance soil pH, thereby creating an optimal environment for the growth of spinach plants. The soil pH of 6.4, which was achieved through the application of wood vinegar, falls within the range of mildly acidic to neutral conditions that are generally conducive to the growth of spinach. This pH value falls within the optimal range of 6.0 to 7.5, which is ideal for spinach cultivation. Wood vinegar has the capacity to not only preserve but also elevate soil acidity to a level that is conducive to the growth of spinach plants. In contrast, synthetic nutrient application results in a pH of 5.2 in the soil. Although some plants might be able to thrive in a mildly acidic environment, the current pH level of this setting may be suboptimal for spinach. Vigilant monitoring of acidity levels is critical, as an extended period of low pH can lead to nutrient imbalances and negatively impact the spinach plant's overall health. The pH of the soil was recorded as 6.2 in the absence of any intervention, a value that falls

within the permissible range for spinach. This suggests that the soil's inherent conditions are already optimal for the growth of spinach, and further interventions may necessitate meticulous deliberation in order to prevent unintended consequences. In brief, the application of wood vinegar as a treatment for soil pH in spinach cultivation seems to yield favorable results, ensuring that the pH remains within the intended range. Nevertheless, the introduction of synthetic nutrients has resulted in a rise in acidity, potentially necessitating remedial actions to restore spinach to its ideal growing conditions. The pH of untreated soils remained within the permissible range, underscoring the criticality of evaluating soil conditions prior to treatment implementation. Regular monitoring and alterations of the soil pH will be crucial in order to achieve optimal growth conditions for spinach.

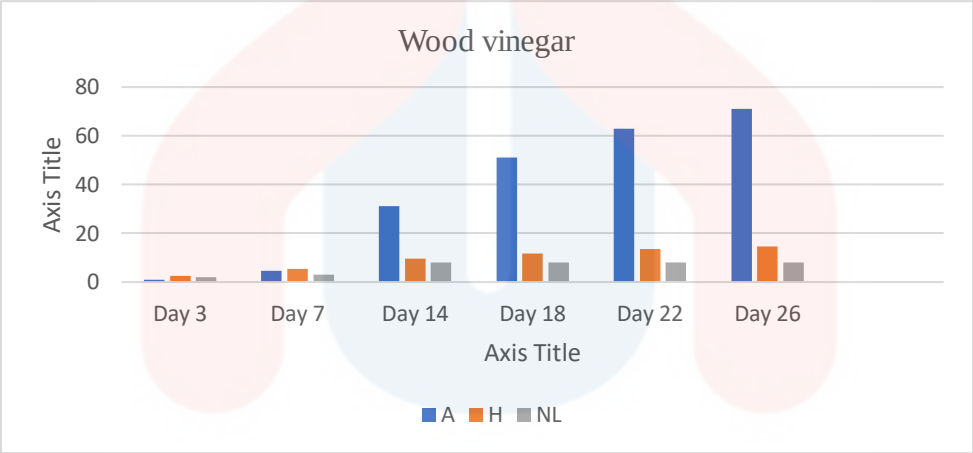

figure 4.1.2: spinach trees grown using wood vinegar

The growth parameters of spinach plants during 26 days are illustrated in Figure 4.1.2. The data demonstrates the progression of leaf area, plant height, and leaf count. The developmental trajectory spanning from Day 3 to Day 26 exhibits a dynamic and harmonious progression. Early on, particularly between Days 3 and 7, there was a notable surge in both the leaf area and plant height, which served as indicators of the commencement of a period of accelerated growth. Subsequently, spinach plants maintained a consistent leaf count of eight from Day 14 to Day 26, indicating an ongoing equilibrium between leaf expansion and new leaf production.

Day 26 saw a further increase in leaf area, which measured 71.07 cm^2, which is indicative of vigorous foliage development. Simultaneously, the plant exhibited vertical growth, as evidenced by its increase in height from 2.4 cm on Day 3 to 14.6 cm on Day 26, which demonstrated a

consistent and robust upward trend. A sustained tally of eight leaves starting from Day 14 signifies an optimal equilibrium between the production of leaves and the overall development of the plant.

The combined observations indicate that spinach plants exhibit a synchronized growth pattern characterised by discrete periods of accelerated development succeeded by a state of consistent equilibrium. A consistent leaf count indicates that the plant has implemented an efficient resource allocation strategy to facilitate leaf expansion and ongoing new leaf production. In summary, the data collected indicates that wood vinegar exhibits potential as a beneficial agent in the cultivation of spinach. However, in order to maximise its impact on plant development, it is imperative to engage in ongoing monitoring and refinement of the application strategy.

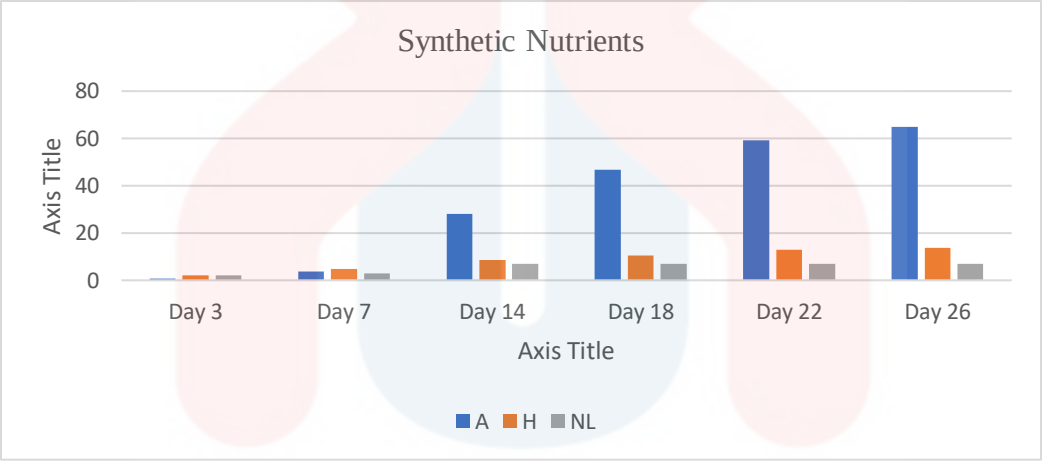

Figure 4.1.3: spinach with synthetic nutrients

The utilization of synthetic nutrients during the spinach cultivation depicted in Figure 4.1.3 yields substantial beneficial outcomes across multiple facets of plant development, as supported by the data collected over 26 days. The substantial and consistent increase in leaf area, which commenced at 0.72 cm^2 on Day 3 and reached 65.0 cm^2 on Day 26, serves as evidence that the synthetic nutrient regimen effectively promotes robust leaf development. In a similar vein, the steady progression of plant height, which commenced at 2.1cm and culminated at 13.8cm on Day 26, indicates a positive and sustainable growth pattern. This further establishes the effectiveness of synthetic nutrients in facilitating vertical expansion and overall plant development.

Nonetheless, the intriguing characteristic of the plant sustaining an even number of leaves (7) starting from Day 14 instigated a more thorough analysis of resource distribution within the

organism. This phenomenon suggests that synthetic nutrients may have an impact on resource efficiency by diverting nutrient resources toward the growth of established leaves as opposed to the development of new foliage. Potential effects of this allocation strategy on the productivity and overall structure of spinach plants are possible.

The observed enhancements in leaf area and plant height serve as evidence that synthetic nutrients establish conducive environments for growth. However, the consistent number of leaves necessitates ongoing surveillance and possible modifications to nutrient application methods to guarantee the most efficient allocation of resources and harmonious growth of the plant. To optimize the advantages of synthetic nutrients in the cultivation of uncooked spinach while mitigating potential obstacles, this fine-tuning is vital.

When examining the enduring viability of synthetic nutrient utilization, it is critical to prioritize the incorporation of environmentally conscious practices, including nutrient amendments and cover crops. The objective of this nutrient approach is to enhance plant health, reduce ecological harm, and advance a resilient and well-balanced agricultural nutrient system. In conclusion, the data indicate that synthetic nutrients have a beneficial impact on the growth of spinach. However, for sustainable and effective nutrient management in agriculture, constant vigilance, adaptation, and nutrient approaches are required.

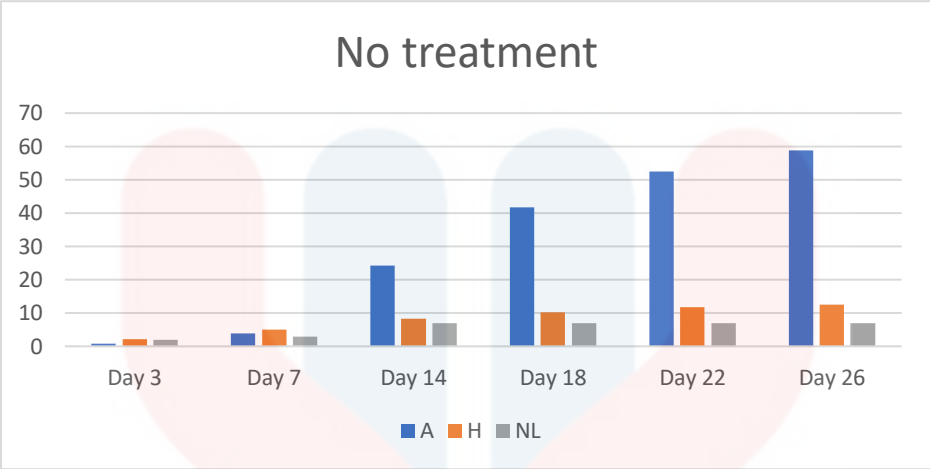

Figure 4.1.4: spinach with no treatment

The data from figure 4.1.4 about non-treatment conditions in spinach cultivation for a duration of 26 days provide significant knowledge regarding the intrinsic growth patterns and robustness of spinach plants in the absence of any external intervention. Leaf area, plant height, and leaf count measurements collectively offer an all-encompassing depiction of the organic growth of spinach while subjected to the monitored conditions. The progressive augmentation of leaf area, commencing at 0.77 cm^2 on Day 3 and culminating at 58.8 cm^2 on Day 26, underscores the plants' inherent capacity to augment their leaf canopy in the absence of external interventions. The spinach plant's overall health and vitality are enhanced by the efficient utilisation of available resources, as indicated by its gradual and consistent growth.

Similarly, the steady progression of the plant's height, which grew from 2.2cm on Day 3 to 12.5cm on Day 26, signifies a growth trajectory that is both natural and sustainable. The vertical growth of the plants under non-treatment conditions demonstrated their intrinsic capacity to flourish in the absence of external influences.

The observation that the quantity of leaves remains consistent at seven starting from day fourteen is significant. The observed stability suggests that spinach plants effectively manage the growth and development of new leaves, thereby demonstrating an inherent resource allocation efficiency that enhances the overall resilience of the plant.

The non-treatment method is consistent with sustainable and eco-friendly agricultural practices. By reducing reliance on external inputs and synthetic compounds, it promotes an environment

more conducive to the natural growth of spinach. This methodology is especially pertinent in fostering biodiversity and soil health, thereby making a contribution to an agricultural ecosystem that is ecologically sustainable and holistic.

In summary, the findings regarding the absence of any treatment in spinach farming demonstrate the plant's capacity to flourish autonomously, as evidenced by its substantial leaf area and plant height growth, in conjunction with an effective allocation of resources. This methodology adheres to the tenets of sustainable agriculture, placing emphasis on the feasibility of cultivating spinach successfully with limited external intervention.

4.2 To compare the effects of wood vinegar with synthetic nutrients and no treatment on spinach

A systematic experimental design was employed to examine the comparative impacts of wood vinegar, synthetic nutrients, and no treatment on the growth of spinach. The investigation spanned a duration of 26 days. The objective of this research endeavour was to clarify the effects of the three cultivation methods on crucial parameters, namely leaf area, plant height, and leaf count.

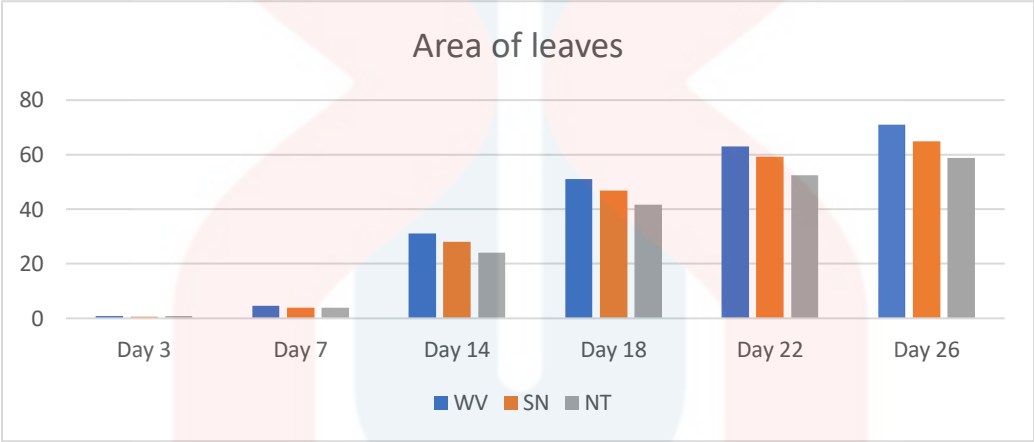

Figure 4.2.1: Area of leaves

The leaf area (cm^2) measurements for spinach plants exposed to wood vinegar treatment, synthetic nutrients, and untreated conditions for a duration of 26 days are presented in Figure 4.2.1. These data offer significant insights into the relative impacts of the various cultivation methods utilized. During the observed days, the application of wood vinegar resulted in a marginally greater leaf area in comparison to the synthetic nutrient. Furthermore, both treatments exhibited a substantial improvement in growth quality when compared to the untreated conditions.

Spinach plants subjected to the wood vinegar treatment exhibited a consistent and noteworthy growth in leaf area, as evidenced by measurements spanning from 0.84 cm^2 on Day 3 to 71.07 cm^2 on Day 26. In a similar vein, the treatment involving synthetic nutrients resulted in substantial leaf area development, spanning from 0.72 cm^2 on Day 3 to 65.0 cm^2 on Day 26. On the contrary, the

leaf area of the untreated condition increased at a more progressive rate, from 0.77 cm^2 on Day 3 to 58.8 cm^2 on Day 26.

A comparative analysis revealed that synthetic nutrients and wood vinegar were both effective in stimulating the growth of spinach leaf area; however, wood vinegar consistently exhibited a marginally superior impact. The results of this study emphasise the possible advantages of utilising external intervention to promote the growth of spinach. Among these alternatives, wood vinegar stands out as a viable and ecologically sustainable choice. Although synthetic nutrients did make a substantial contribution to the expansion of leaf area, they consistently lagged behind wood vinegar, indicating a growth-promoting effect that was comparatively weaker but noteworthy. On the other hand, the leaf area of spinach plants increased more gradually under the No Treatment condition, highlighting their inherent capacity for growth in the absence of any external intervention.

The results of this study highlight the considerable potential of Wood Vinegar as a potent growth promoter in the context of spinach farming. This has significant ramifications for the implementation of sustainable agricultural methods. By illuminating the subtle effects of various cultivation techniques on leaf area, comparative analysis contributes to the comprehension of the most effective strategies for promoting spinach growth. In summary, the findings of this study provide support for the hypothesis that Wood Vinegar, when compared to the other conditions assessed, has the potential to significantly increase the leaf area expansion of spinach plants.

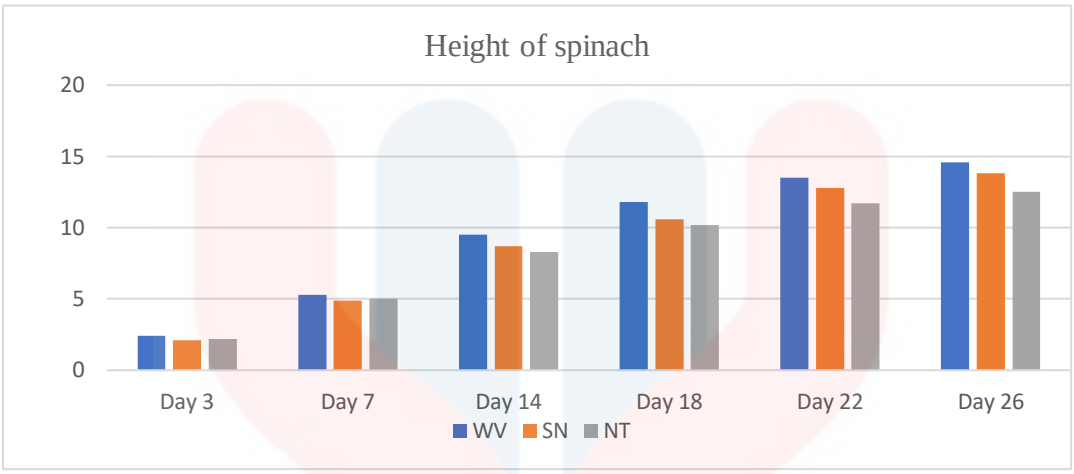

Figure 4.2.2: Height of spinach

An exhaustive analysis of the vertical growth of spinach plants over 26 days, as depicted in Figure 4.2.2, demonstrates a discernible pattern in the impact of each treatment (wood vinegar, synthetic nutrients, and untreated conditions) on plant height. During the entire period of observation, wood vinegar consistently demonstrated a more pronounced impact, resulting in greater quantities of spinach plants in comparison to conditions unadulterated with synthetic nutrients and those treated with synthetic nutrients.

Spinach plants demonstrated consistent growth in height during the wood vinegar treatment, with measurements ranging from 2.4 cm on Day 3 to 14.6 cm on Day 26. Additionally, synthetic nutrients facilitated vertical expansion, albeit to a lesser degree; during the same period, plant heights varied from 2.1 cm to 13.8 cm. When left untreated, the height of spinach plants increased at a more gradual rate, fluctuating between 2.2 cm and 12.5 cm over 26 days.

In comparison to synthetic nutrients, wood vinegar consistently demonstrated superior performance, underscoring its efficacy in stimulating the vertical development of spinach. Furthermore, the growth observed in untreated conditions was surpassed by both treated conditions, highlighting the favorable impact of the external intervention on the height of the plants.

The results indicate that wood vinegar functions as an exceptionally efficient growth promoter, presenting a potentially advantageous and ecologically sustainable substitute for augmenting the

erect development of spinach. Additional investigation into the subtle distinctions between synthetic nutrients and wood vinegar may aid in the enhancement of cultivation methodologies, the optimization of yields, and the promotion of sustainable approaches in the realm of spinach cultivation.

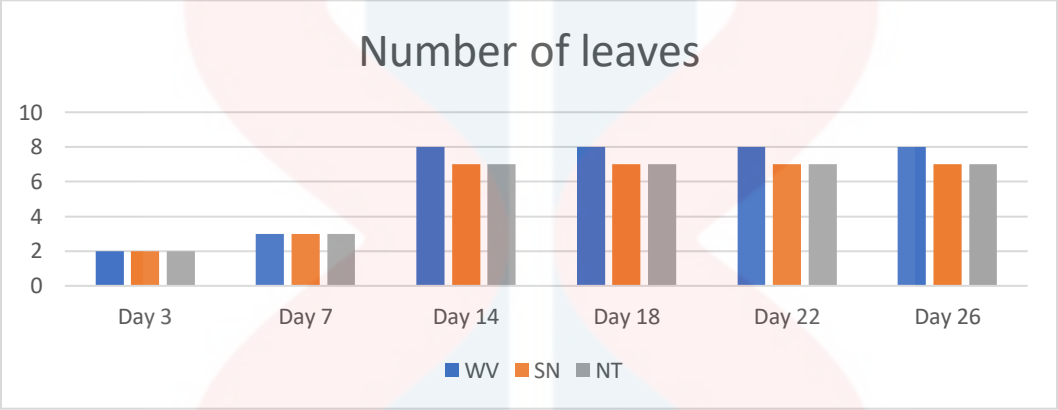

Figure 4.2.3: Number of leaves

The analysis of the leaf count in spinach plants treated with wood vinegar and synthetic nutrients, as compared to the control condition without treatment, over 26 days, is depicted in Figure 4.2.3. The results indicate a discernible trend in leaf production that is impacted by the implementation of this particular cultivation method. The data indicated that leaf development was positively impacted by both wood vinegar and synthetic nutrient therapies, although wood vinegar may have had a more pronounced effect.

Spinach plants subjected to wood vinegar treatment consistently retained eight leaves beginning on Day 14. This finding suggests that wood vinegar exerts a sustained influence on leaf production. As opposed to the no-treatment and synthetic nutrient treatment conditions, the number of leaves remained constant at seven beginning on Day 14. While the number of leaves observed in the untreated condition was surpassed by both treated conditions, the wood vinegar treatment consistently maintained a greater leaf count.

The results of this study indicate that wood vinegar exerts a substantial impact on the promotion of ongoing leaf development in spinach plants. The observation of consistent leaf production in

both treated conditions provides further evidence for the beneficial impact of external intervention on this particular facet of spinach growth.

In summary, the data underscore the efficacy of synthetic nutrients and wood vinegar in promoting consistent leaf production, although wood vinegar may exert a marginally more pronounced impact. The provided information enhances comprehension regarding the impact of various planting methodologies on the leaf arrangement of spinach plants. Consequently, it offers valuable insights that can be utilized to maximize planting strategies, thereby augmenting spinach cultivation's productivity and sustainability.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

In conclusion, the Wood Vinegar experiment on spinach growth shows promise for ecologically friendly farming. Compared to Synthetic Nutrients and No Treatment, Wood Vinegar consistently promotes leaf area expansion, vertical growth, and sustained leaf output. Wood Vinegar is eco-friendly and might replace synthetic fertilizers in sustainable agriculture. The study shows that Wood Vinegar may promote spinach growth, outperforming Synthetic Nutrients and natural growing conditions. Wood Vinegar may boost production and reduce chemical inputs in crops. The eco-friendliness of Wood Vinegar matches the increased focus on sustainable and organic farming. Wood Vinegar's favorable effect on spinach growth and environmental advantages make it a great choice for farmers seeking sustainable, efficient agricultural output. However, further study and field experiments are needed to improve application techniques and understand the long-term impacts on soil health and crop output to fully assess its potential in sustainable spinach agriculture.

5.2 RECOMMENDATION

Wood Vinegar's efficacy in spinach growth suggests an eco-friendly agricultural method. We advocate adding Wood Vinegar to crop management strategies to promote spinach growth naturally and sustainably. To maximize spinach growth advantages, Wood Vinegar research should optimize application methods, concentrations, and frequency. Thorough field testing in various agricultural settings will confirm the effectiveness and help determine Wood Vinegar's scalability in real-world farming. Educational outreach programs are needed to promote Wood Vinegar's benefits as an ecologically friendly growth stimulator among farmers. Additionally, academics, agronomists, and farmers may collaborate to promote sustainable agriculture. Market access, legislative lobbying, continual monitoring, and adaptive management will enable Wood Vinegar's effective incorporation into ecologically friendly agricultural techniques. Wood Vinegar's potential in crop rotation systems and interactions with other crops will improve agricultural production and sustainability as we study it. These guidelines use Wood Vinegar to grow spinach sustainably and promote ecological balance and resilience in agriculture.

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APPENDIX A

Figure A.1: the process of planting spinach seedlings in polybags

Figure A.2: soil pH measurement process

Figure A.3: wood vinegar used to spray spinach

Figure A.3: spinach used in this study

APPENDIX B

Spinach with Wood vinegar

Days	leaf length	leaf width	number of leaves	Height of spinach
Day 3	1.2cm	0.7cm	2	2.4cm
Day 7	3.6cm	1.3cm	3	5.3cm
Day 14	6.9cm	4.5cm	8	9.5cm
Day 18	8.8cm	5.8cm	8	11.8cm
Day 22	9.7cm	6.5cm	8	13.5cm
Day 26	10.3cm	6.9cm	8	14.6cm

Spinach with Synthetic Nutrients

Sample/day	leaf length	leaf width	number of leaves	Height of spinach
Day 3	1.2cm	0.6cm	2	2.1cm
Day 7	3.2cm	1.2cm	3	4.9cm
Day 14	6.7cm	4.2cm	7	8.7cm
Day 18	8.5cm	5.5cm	7	10.6cm
Day 22	9.4cm	6.3cm	7	12.8cm
Day 26	10.0cm	6.5cm	7	13.8cm

Spinach with No treatment

Sample/day	leaf length	leaf width	number of leaves	Height of spinach
Day 3	1.1cm	0.7cm	2	2.2cm
Day 7	3.2cm	1.2cm	3	5.0cm
Day 14	6.2cm	3.9cm	7	8.3cm
Day 18	8.5cm	4.9cm	7	10.2cm
Day 22	9.2cm	5.7cm	7	11.7cm
Day 26	9.8cm	6.0cm	7	12.5cm

$$length \times width = Area$$

APPENDIX C

Entire spinach tree data

Days	Wood vinegar			Synthetic Nutrients			No Treatment		
	Area (cm^2)	Height of spinach	number of leaves	Area (cm^2)	Height of spinach	number of leaves	Area (cm^2)	Height of spinach	number of leaves
Day 3	0.84	2.4cm	2	0.72	2.1cm	2	0.77	2.2cm	2
Day 7	4.68	5.3cm	3	3.84	4.9cm	3	3.84	5.0cm	3
Day 14	31.05	9.5cm	8	28.14	8.7cm	7	24.18	8.3cm	7
Day 18	51.04	11.8cm	8	46.75	10.6cm	7	41.65	10.2cm	7
Day 22	63.05	13.5cm	8	59.22	12.8cm	7	52.44	11.7cm	7
Day 26	71.07	14.6cm	8	65.0	13.8cm	7	58.8	12.5cm	7