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FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCE
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Comparative Evaluation of Organic Foliar Fertilizers (Vermiwash, Rabbit Urine and Nutriplant Organic Plus) on Growth and Yield of Green Peppers (*Capsicum annuum* L.) variety: California Wonder.



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APPROVAL FORM

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DECLARATION

I, TARIRO SITHOLE, registration number B221779B, do hereby declare that this dissertation is my own original work and has not been copied from any source without due acknowledgement of the source.

DEDICATION

I dedicate this dissertation to my family, friends and Hartzel Central primary school in appreciation of their support and encouragement throughout the whole project period.

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ABSTRACT

Green pepper (*Capsicum annuum* L.) production is often limited by declining soil fertility and the high cost of inorganic fertilizers. This study evaluated the effects of vermiwash, rabbit urine, and Nutriplant Organic Plus Fertilizer (NOPF) on the growth, yield, and economic performance of green peppers under open-field conditions. The field experiment consisted of five treatments which includes rabbit urine (T1), vermiwash (T2), rabbit urine plus vermiwash (T3), NOPF (T4), and an untreated control (T5). Data were taken on plant height, leaf area, fruit number, fruit weight, and profitability. Analysis of the data indicated statistically significant differences ($P < 0.001$) among treatments for all evaluated growth and yield parameters. NOPF consistently produced the highest plant height (79.2 cm), leaf area (45.74 cm²), fruit number (51.76 fruits per plant), and fruit weight (20.07 kg per plant). The combined application of rabbit urine and vermiwash ranked second in all growth and yield parameters and produced the highest net profit of \$40.10 due to its low production cost and high yield response. The control treatment exhibited the least values for all assessed parameters. Economic analysis showed that although NOPF produced the highest yield and revenue, its profitability was reduced by higher input costs. The study concluded that NOPF is the most effective treatment for maximizing growth and yield of green peppers, while the combined application of rabbit urine and vermiwash is the most cost-effective option for smallholder farmers. Therefore, the use of organic nutrient sources enhances sustainable green pepper production and improve farm profitability.

Key words

Green pepper

Capsicum annuum L.

Organic fertilizer

Vermiwash

Rabbit urine

Nutriplant Organic Plus Fertilizer (NOPF)

Growth and yield

Economic performance

Small holder farmers

Sustainable production

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LIST OF ABBREVIATION

ANOVA – Analysis of Variance

CV – Coefficient of Variation

H_0 – Null Hypothesis

H_1 – Alternative Hypothesis

K – Potassium

LSD – Least Significant Difference

N – Nitrogen

NOPF – Nutriplant Organic Plus Fertilizer

NPK – Nitrogen, Phosphorus and Potassium

P – Phosphorus

pH – Potential of Hydrogen

RCBD – Randomized Complete Block Design

SED – Standard Error of Difference

WAP – Weeks After Planting

CHAPTER ONE

Introduction

1.1 Research background

Green pepper (*Capsicum annuum* L) is a high-value horticultural crop widely cultivated in Zimbabwe for both local consumption and export (Agroleaner, 2023). The primary source of origin for green pepper is believed to be South America. They have been domesticated in Latin America several millennia ago and was introduced in Europe in the 15th century after which they were domesticated in quite a number of countries around the world (Liu *et al.*, 2013)

Green pepper cultivation frequently faces challenges such as inadequate nutrient availability, increased production expenses, and soil degradation due to the use of synthetic fertilizers ref. Recently, there is increasing attention toward organic foliar fertilizers, which offer a more affordable, environmentally conscious, and sustainable alternative for enhancing crop performance ref. To get higher produce with high quality, soil health management is a critical factor. Due to high demand in organic produce most farmers are now venturing into organic farming of various produce.

According to Jamir *et al.*, (2017), vermicompost, rabbit urine, poultry manure, cow dung and crop residue are the most organic manure commonly used in horticultural crop. Recently, there is increasing attention toward organic foliar fertilizers, which offer a more affordable, environmentally conscious, and sustainable alternative for enhancing crop performance. According to Sisay, (2025), organic fertilizers have no residual effect, they are non-toxic to plant and animals, they improve the soil texture, allowing water to be held longer in the soil and increase the bacterial and fungal activity in the soil.

According to Said *et al.*, (2018), rabbit urine contains essential nutrients such as nitrogen, potassium and phosphate for plant growth. “It has been suggested for increased agronomic parameters and yield of vegetable crops as one of the least expensive forms of fertilizer”, (Indabo & Abubakar, 2020). As highlighted by Mmbaga *et al.*, (2024), rabbit urine is reported to be better than other livestock urine and other organic fertilizers and it speeds growth of crops when applied in a suitable amount. As stated by Yetunde *et al.*, (2022) Organic fertilizer, such as rabbit

urine, which is inexpensive to get through rabbit rearing (cuniculture), are essential to minimizing crop production costs. In general, the application of organic fertilizer improves root system and plant stems better than chemical fertilizers.

Another organic fertilizer that has been tested and has produced positive results in the production of horticultural crops is vermiwash. According to Awadhpersad *et al.*, (2021), the by-product of the vermicomposting process, which is termed vermiwash is a brownish coloured substance that is formed due to the movement of water in the vermicomposting units through the burrows formed by the earthworms. According to Jaybhaye & Bhalerao., (2015), the vermiwash also contains enzymes and secretions of earthworms and would stimulate the growth and yield of crops. It is very useful as a foliar spray. The use of vermiwash is eco-friendly and it improves the quality of the agricultural produce.

Nutriplant Organic Plus Fertilizer (NOPF), is a certified organic fertilizer produced by Green World company. According to Sakumona *et al.*, (2023) NOPF is composed of both micro nutrients and macro nutrients, containing multiple small molecules of amino acids, peptides, and chitosan chelate with trace elements. In reference to Enemali *et al.*, (2023), Green World NOPF (Nutriplant Organic Plus Fertilizer) are known to be available and advertised to possess the ability to increase the growth, thickness, resistance to plant diseases and increases the amount of yield per plant. According to Sakumona *et al.*, (2023), “NOPF promotes the growth of plant roots, stems and leaves, renews soils, boosts soil nutrients, retains flowers and fruits, improves the quality and flavour of the harvestable parts of crops significantly, enhances the drought resistance, infertility resistance, diseases and insect pest resistance of plants, helps the seeds germinate faster and stronger, improves soil structure and enhances the bioactivity of the soil.”

This research aims to promote eco-friendly farming, reducing production cost for farmers and enhancing green pepper production to cater for high market demand for both local and export market.

1.2 Problem statement

Green pepper production in Zimbabwe continues to face challenges such as limited nutrient availability, high costs of agricultural inputs, and environmental risks linked to chemical fertilizers. Smallholder farmers lack knowledge on the affordable, effective and sustainable foliar fertilizers that can enhance their green pepper production. Although organic foliar fertilizers like vermiwash, rabbit urine, and NOPF present sustainable and affordable alternatives, there is a lack of comparative field-based research evaluating their effectiveness in improving the growth and yield of green peppers. This study aims to assess the effectiveness of these organic inputs on the production of green peppers, California wonder under open field.

1.3 Research objectives

1.3.1 General Objective

- To evaluate the effectiveness of vermiwash, NOPF and rabbit urine as organic foliar fertilizers in enhancing the growth and yield performance of green peppers (*Capsicum annuum*), California wonder variety under open field conditions.

1.3.2 Specific Objectives

- To compare the effects of vermiwash, rabbit urine and NOPF on vegetative growth parameters (plant height, leaf area) of green peppers over a 10-week growing period.
- To assess the impact of vermiwash, rabbit urine and NOPF on yield components (fruit number, fruit weight) of green peppers at harvest maturity.
- To evaluate the cost-effectiveness of using vermiwash, rabbit urine and NOPF in green pepper production systems.

1.4 Research hypotheses

Null Hypothesis (H_0):

Application of vermiwash, rabbit urine and NOPF as organic foliar fertilizers has no significant effect on the growth and yield of green peppers (*Capsicum annuum*) compared to untreated plants.

Alternative Hypothesis (H_1):

Application of vermiwash, rabbit urine and NOPF as organic foliar fertilizers significantly enhances the growth and yield of green peppers (*Capsicum annuum*) compared to untreated plants.

CHAPTER TWO

Literature Review

2.1 Introduction

In Zimbabwe, green pepper (*Capsicum annuum L*) is a very important horticultural crop, consumed locally and for international marketing. Despite its great significance, farmers constantly face issues concerning cost of production and environmental depreciation associated with inorganic fertilizer application. For instance, Zohoungbogbo *et al.*, (2024) report that national output of green chilli and pepper increased from about 18,500 tonnes in 2018 to roughly 34,400 tonnes in 2021, showing greater adoption of enhanced agronomic practices. By 2024, production reached approximately 35,200 tonnes—the highest level recorded to date.

In Africa, Zimbabwe also took part in the capsicum trade. Past records illustrates that green pepper exports were valued at around US\$16.7 million in 2002, underscoring the crop's contribution to foreign currency earnings and its strong market prospects. At the same time, scholars such as Ummyiah *et al.* (2017) stated that organic farming offers a sustainable pathway forward, one that equilibrate production with environmental protection.

2.2 Nutrient Requirement for Green Pepper production

According Wang *et al.*, (2018), green pepper requires well-balanced nutrients especially nitrogen (N), phosphorus (P) and potassium (K) for optimal vegetative growth and fruiting. In addition, micronutrients like Boron (B) for flower and fruit set, Zinc (Zn) for enzyme activation, Manganese (Mn), Iron (Fe) and Copper (Cu) are necessary for overall plant metabolism for green pepper production. In line with Chikowo *et al.*, 2015, inadequate or excessive use of synthetic fertilizers negatively affects crop performance, fruit quality and soil microbial activity. Organic foliar fertilizers offer a sustainable method that enhances nutrient uptake efficiency, especially during critical growth stages.

2.3 Vermiwash as a foliar fertilizer

According to Das *et al.*, (2014), vermiwash is a liquid extract obtained by allowing water to percolate through vermicompost inhabited by earthworms. Conversion of biodegradable matter

into enriched compost is possible with the use of earthworms and this technology known as vermicomposting. Vermiwash contains plant growth regulators (e.g., auxins and cytokinin), enzymes, and beneficial microbes that stimulate plant development. Recent studies have confirmed its effectiveness in enhancing vegetative growth and yield in various crops. For example, vermiwash has been shown to improve leaf expansion, chlorophyll content, and fruit set in solanaceous crops like tomatoes and peppers, (Gudeta *et al.*, 2021). In line with Kaur *et al.*, (2015), the nutrients in the vermiwash solution circulates to all parts of the plants in the natural ecosystem. Foliar application allows for rapid nutrient absorption, bypassing soil-related limitations such as poor structure and nutrient fixation.

2.4 Rabbit urine as a foliar fertilizer

According to the research by Ekwere *et al.*, (2023), rabbit urine contains higher concentration of nitrogen due to its forage-based intake and drinking little water. Under nutrient testing, rabbit urine revealed that it contains 3.56% potassium, 2.11% phosphorus and 2.36% nitrogen. The Ph range for the rabbit urine is 8-9 which alkaline, and it neutralize the acid in the soil, (Said *et al.*, 2018). There is a significant increase of biomass when the correct dilution of rabbit urine is applied in the production of crops like spinach, oats and desmodium.

Rabbit urine is also widely known as a natural biopesticide, providing protection against harmful pest and pathogens. Kemunto et al. (2022) illustrated its role as a biofertilizer, improving seed viability in cinnamon (*Cinnamomum burmannii* L.) and improving growth and yield in pagoda (*Brassica narinosa* L.) and tomato. This double function of being a nutrient source and a pest deterrent makes rabbit urine an affordable, multifunctional input that is valuable for smallholder farmers who are after eco-friendly agricultural practices.

2.5 Nutriplant Organic Plus Fertilizer as a foliar fertilizer

Nutriplant Organic Plus Fertilizer (NOPF) is an organic foliar fertilizer made from hydrolyzed poultry feathers, (Sakumona et al., 2023a). Macro and micronutrients as well as amino acids, peptides and chelated trace elements were used in the fortification of NOPF to improve its nutrient absorption and enhance plant tolerance to stress. NOPF, contains 4% nitrogen, 3% phosphorus, and 3% potassium, together with 100 g/L of amino acids and 20 g/L of trace

elements such as zinc, iron, manganese, and copper. Further evidence from Sakumona et al., (2023b) in Zambia illustrated that NOPF significantly improve the growth and yield of green beans compared to untreated plots. Its performance was also on par with conventional inorganic fertilizers, pointing to its potential as a sustainable option for vegetable production systems. These research highlight NOPF's promise in reducing dependance on inorganic inputs while maintaining productivity.

2.6 Research gap

Green pepper production largely depends on inorganic fertilizers to maximize optimal growth and productivity. However, the increasing costs of these inorganic fertilizers, negative environmental impacts and the increase in the preference for organically produced crops has driven the innovation of sustainable alternatives including vermiwash and rabbit urine. Despite these promising findings, comparative studies on vermiwash, rabbit urine and NOPF in green pepper production remain limited. This study aims to fill that gap by evaluating their effectiveness on growth and yield of green pepper under open field conditions, supporting ongoing efforts to improve organic fertilizer usage in crop production.

CHAPTER THREE

Methodology And Experimental Design

3.1 Study site

The study was laid out in Mutasa District, Manicaland province at Old Mutare Mission, in the eastern part of Zimbabwe. According to Mungandani *et al.*,2012, The area lies approximately 18.898° S latitude and 32.724° E longitude at an altitude of around 1.200- 1.400 meters above sea level. This altitude contributes to a relatively cool moist condition. The temperature ranges between 9°C – 28°C. The site lies in the Agro-ecological region 1. In this region an annual rainfall of 1000 mm and above is experienced. The soils are loamy to clay-loam with pH ranging between 5.5 – 6.5. The experiment was conducted from 28th November 2025 to 28th February 2026.

3.2 Experimental design

The randomized complete block design (RCBD) was used to test how vermiwash and rabbit urine contributes to the growth and yield of green peppers (*Capsicum annuum*) in open field conditions. Five treatments were applied and these were: vermiwash foliar spray, rabbit urine foliar spray, mixture of rabbit urine and vermiwash, certified organic foliar fertilizer (Nutriplant Organic Plus Foliar Fertilizer) (NOPF) and a control group with no foliar application. Replication of each treatment was done three times to ensure reliable comparisons. Each plot measuring 2 meters by 3 meters. Each plot contained 18 green pepper plants, spaced 60cm inter-row and 45cm in-row. A buffer zone of 1 meter was maintained between plots to prevent overlap of treatments.

3.2 Experimental layout

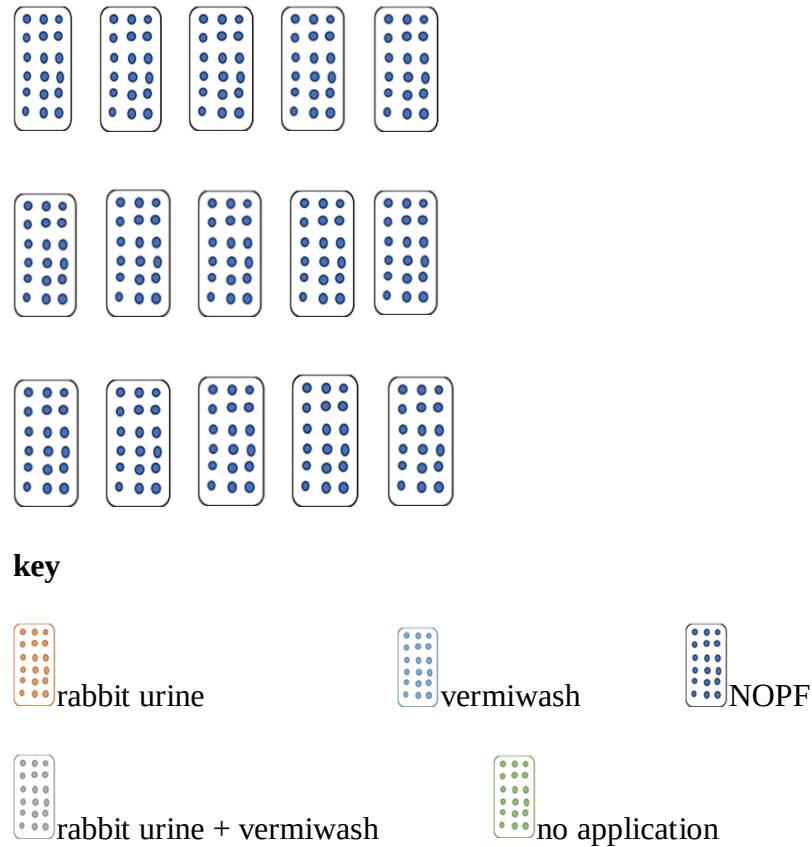


Fig 3.1: representing layout of treatments

Table 3.1: Treatment structure

TREATMENT	DESCRIPTION
Treatment 1	1:10 rabbit to water ratio
Treatment 2	1:10 vermiwash to water ratio
Treatment 3	1:20 rabbit to water and 1:20 vermiwash to water ratio
Treatment 4	Nutriplant Organic Plus Fertilizer at a rate of 10 ml as to 10 l of water
Treatment 5	No foliar application

3.3 PREPARATION OF CONCERNTRATIONS

3.3.1 Rabbit urine preparation

One part of rabbit urine was mixed with 10 parts of water (1:10 ratio). The mixture was left to sit for 24 hours to allow sediments to settle. For the prevention of clogging of the nozzles of the hand sprayer, solution filtration was done.

3.3.2 Vermiwash preparation

1kg of vermiwash was mixed with 1kg of sugar in 10 litres of water. The mixture was left to ferment for 24 hours, after which it was filtered to remove solids. A ratio of 1:10 was used to dilute the vermiwash and sugar solution before spraying.

3.3.3 Mixture of rabbit urine and vermiwash preparation

Rabbit urine was mixed at a ratio of 1:20 and vermiwash was mixed at a ratio of 1:20. The two solutions were mixed and applied to plants.

3.3.4 Nutriplant Organic Plus Fertilizer preparation

NOPE 10ml was diluted with 10 litres of water. The mixture was stirred thoroughly to ensure the fertiliser dissolved completely. After mixing the solution was then applied on plants.

3.4 Experimental procedure

3.4.1 Seedling acquisition

Seedlings were bought from Freshpicks Nursery in Ruwa. The seedlings were well hardened to enhanced and overall survival rate. The average length of the green pepper seedlings was 150mm with an average leaf number of 7 per plant.

3.4.2 Land preparation

The land was cleared, removing weeds and debris. Manual ploughing was done using a hoe and a pick to a depth of 20 to 30cm. Land levelling was done so as to create a fine tilth. 15 Raised beds were created measuring 3m by 2m. The beds were 1m apart for pathway and to reduce edge effects on treatments. All beds were drenched with copper oxychloride to prevent fungal diseases.

3.4.3 Transplanting of seedlings

Seedling transplant was done on the 28th of November 2025. The seedlings were watered before planting. Seedlings were planted using a spacing of 0.45 in-row and 0.65 inter-row. Planting stations were marked and dug hole which were slightly larger than the seedling's root ball. 5 grams of N: P: K (10:20:10) was mixed with soil and the placed the seedlings in the hole. The seedlings were planted at the same depth as the seedling tray which was about 2cm. after transplanting the plants were watered thoroughly.

3.4.4 Top dressing

Two weeks after transplanting, top dressing of foliar fertilizers was applied. All treatments were applied accordingly. A hand sprayer was used for all treatment application and thoroughly cleaned before applying another treatment to prevent biased results. All treatments were applied in two weeks intervals.

3.5 Rabbit urine

1 litre of rabbit urine was diluted with 10 litres of water. Fine mist nozzle hand sprayer was used to apply the rabbit urine solution. Full coverage of the foliage with the rabbit urine was done for each plant. About 2 litres of the diluted rabbit urine was used on a single application, the remaining solution was kept in a tightly closed container for next application.

3.6 Vermiwash

Vermiwash was diluted with water at a rate of 1: 10 Only 2 litres of the dilution was used for the 3 beds. Also, a hand sprayer with a fine mist nozzle was used. The leaves were fully covered but not dropping off. An air-tight closed container was used to store the remaining solution.

3.7 Rabbit urine + vermiwash

0.5 litres of rabbit urine were diluted with 10 litres of water. 0.5 litres of vermiwash were diluted with 10 litres of water. The two diluted treatments were mixed and applied to the plants using a hand sprayer with fine nozzle to ensure full and even application.

3.8 Nutriplant Organic Plus Fertilizer

2 ml of NOPF was diluted with 2 litres and applied to the plants evenly. The recommended dilution rate is 10ml NOPF as to 10 litres of water. A fine nozzle was used for spraying.

3.9 Crop Protection

3.9.1 Weed management

Physical weed management method was used. The beds were weeded carefully using a hoe making sure not to disturb or damage the plant roots or stem. Sometimes hand pulling method was used to remove weeds from the beds, this was done so as to reduce soil disturbances. Weeding was mostly done every 2 to 3 weeks so as to reduce resource competition.

3.9.2 Disease management

Early morning scouting was done regularly so as to identify pest and diseases before doing much damage to the plants. Damping off was one of the diseases that affected the plants at an early stage. Mancozeb was drenched and sprayed to pepper plants to mitigate and control damping off. Also, Leaf miner was identified in the field. Acetamiprid was applied at an appropriate rate to control leaf miner. Aphids were also identified in the green pepper plants which were spread from the nearby vegetable beds was treated using dimethoate.

3.10 Data Collection

3.10.1 Plant height (cm)

Plant height was measured bi-weekly from week two till week fourteen. Random selection of five plants and tagging was done. The tagged plants were continuously measured. The plants were measured from the base up to the shoot apex of the plant using a measuring tape. The average height was recorded in centimetres.

3.10.2 Leaf area (cm²)

Leaf area was measured from week two up to week ten after planting on two week-intervals. Three leaves were selected from tagged plants and measured. The leaves were measured from the base to the tip and also the maximum width of the leaf was measured.

The formula for calculating leaf area used was:

$$\text{Leaf area (cm}^2\text{)} = \text{leaf length (cm)} \times \text{leaf width (cm)} \times 0.75$$

Where 0.75 is the common correctional factor used for pepper leaves.

3.10.3 Fruit number per plant

Fruit number was recorded during the first, second and third harvest. All marketable fruits harvested were counted manually. The mean number of fruits per plant was calculated for each treatment.

3.10.4 Fruit weight (kg)

The harvested fruits from the sampled plants were taken and weighed. A digital scale was used to weigh the fruits. The total weight of the fruits per plant was determined by adding the weights from all harvests and recorded in kilograms (kgs)

3.10.5 Economic analysis

Economic performance of each treatment was evaluated using total production costs, total yield, revenue, and net profit. Net profit was determined using the formula:

Net Profit = Total Revenue – Total Production Cost

United States Dollar currency was used for all economic calculations.

3.10.5 Statistical analysis

The GenStat statistical software was used to analyse all the collected data using Analysis of Variance (ANOVA). Treatment means were separated using the Least Significant Difference (LSD) test at a 5% level of significance. Differences were considered significant when $P \leq 0.05$.

CHAPTER FOUR

Results

4.1 Growth Parameters

4.1.1 Effects of vermiwash, rabbit urine and NOPF on plant height of green peppers

Table 4.1 represents the mean plant height of green peppers measured from week 2 up to week 14 under five treatments: rabbit urine (T1), vermiwash (T2), rabbit urine plus vermiwash (T3), NOPF (T4), and control treatment (T5). The statistical analysis showed highly significant differences among treatments at all sampling periods ($P < 0.001$). NOPF (T4) consistently produced the tallest plants at every growth stage. The combination of rabbit urine and vermiwash (T3) showed the second-best results. Single application of rabbit urine and vermiwash gave intermediate rabbit urine slightly higher than vermiwash from 4 weeks after planting.

Table 4.1.1: effects of vermiwash, rabbit urine and NOPF on plant height of green peppers

Treatment	Plant height 2 WAP	Plant height 4 WAP	Plant height 6 WAP	Plant height 8 WAP	Plant height 10 WAP	Plant height 12 WAP	Plant height 14 WAP
T1	15.067 ^b	21.900 ^c	30.57 ^c	41.77 ^c	48.900 ^c	58.167 ^c	66.300 ^c
T2	14.333 ^c	20.567 ^d	29.23 ^d	38.57 ^d	47.867 ^d	57.200 ^d	64.533 ^d
T3	15.067 ^b	23.067 ^b	32.17 ^b	43.37 ^b	54.467 ^b	65.500 ^b	73.500 ^b
T4	16.300 ^a	24.800 ^a	35.33 ^a	48.13 ^a	59.400 ^a	70.900 ^a	79.200 ^a
T5	13.200 ^d	18.367 ^e	25.10 ^e	33.50 ^e	42.400 ^e	50.267 ^e	56.867 ^e
Grand mean	14.913	21.740	30.48	41.07	50.607	60.407	68.080
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SED	0.1776	0.1623	0.453	0.411	0.3011	0.2503	0.3116
LSD	0.4096	0.3742	1.044	0.947	0.6944	0.5773	0.7186
CV%	1.5	0.9	1.8	1.2	0.7	0.5	0.6

Based on the range test $P < 0.05$, means with the different letters on each column are significantly different from each other

4.1.2 effects of vermiwash, rabbit urine and NOPF on leaf area of green peppers

Table 4.1.2 represents the leaf area of green peppers measured from week 2 up to week 10 under five treatments: rabbit urine (T1), vermiwash (T2), rabbit urine plus vermiwash (T3), NOPF (T4), and control treatment (T5). Differences among treatments were highly significant at all sampling periods, with P-values ≤ 0.002 . Leaf area increased progressively with plant age across all treatments from grand mean of 13.77 cm² at 2 weeks after planting to 39.31 cm² at 10 weeks after planting. NOPF (T4) shows the largest leaf area at every growth stage. Rabbit urine plus vermiwash (T3) shows the second largest leaf area with 43.10 cm² at 10 weeks after planting. Single application of rabbit urine (T1) and vermiwash (T2) showed intermediate leaf areas with rabbit urine outperforming vermiwash.

Table 4.1.2 effects of vermiwash, rabbit urine and NOPF on leaf area of green peppers

Treatment	2 WAP	4 WAP	6 WAP	8 WAP	10 WAP
T1	14.11 ^b	21.53 ^b	27.69 ^c	34.72 ^c	40.15 ^c
T2	12.88 ^c	18.46 ^c	23.54 ^d	31.98 ^d	38.23 ^d
T3	16.10 ^a	23.80 ^a	31.27 ^b	37.80 ^b	43.10 ^b
T4	16.11 ^a	23.93 ^a	33.03 ^a	40.14 ^a	45.74 ^a
T5	9.63 ^d	14.98 ^d	18.68 ^e	24.53 ^e	29.31 ^e
Grand Mean	13.77	20.54	26.84	33.84	39.31
P-value	<0.001	<0.001	0.002	<0.001	<0.001
SED	0.59	0.90	2.34	1.83	1.97
LSD (5%)	1.36	2.08	5.39	4.22	4.54
CV (%)	5.30	5.40	10.70	6.60	6.10

Based on the range test $P < 0.05$, means with the different letters on each column are significantly different from each other

4.2: Yield parameters.

4.2.1 Impact of vermiwash, rabbit urine and NOPF on fruit number of green peppers at harvest maturity

Table 4.2. presents the mean number of fruits per plant recorded at the first, second, third harvests for green peppers under five treatments: rabbit urine (T1), vermiwash (T2), rabbit urine plus vermiwash (T3), NOPF (T4), and control treatment (T5). The analysis of variance showed highly significant differences among treatments at all harvests ($P < 0.001$). Fruit number increased from the first harvest with grand mean of 40.13 to the second harvest with grand mean of 52.1 and then declined at third harvest with grand mean of 31.33 for all treatments. NOPF (T4) consistently produced the highest fruit number across all three harvests. The combined application of rabbit urine plus vermiwash (T3) was second-best. Single application of rabbit urine (T1) and vermiwash (T2) gave intermediate results. Rabbit urine outperformed vermiwash at every harvest. The control treatment (T5) had the lowest fruit number at all harvests.

Table 4.2 Impact of vermiwash, rabbit urine and NOPF on fruit number of green peppers at harvest maturity

Treatment	First harvest	Second harvest	Third harvest
T1	41.67 ^c	54.0 ^c	32.33 ^c
T2	38.33 ^d	49.70 ^d	29.33 ^d
T3	45.33 ^b	61.70 ^b	35.67 ^b
T4	49.33 ^a	66.30 ^a	39.67 ^a
T5	26.00 ^e	29.00 ^e	19.67 ^d
Grand mean	40.13	52.1	31.33
P-value	<0.001	<0.001	<0.001
SED	1.687	3.59	1.065
LSD (5%)	3.889	8.29	2.455
CV (%)	5.1	8.4	4.2

Based on the range test $P < 0.05$, means with the different letters on each column are significantly different from each other

4.2.2 Impact of vermiwash, rabbit urine and NOPF on yield components fruit weight of green peppers at harvest maturity

Table 4.3 shows the mean fruit weight per plant at harvest maturity for green peppers under five treatments: rabbit urine (T1), vermiwash (T2), rabbit urine plus vermiwash (T3), NOPF (T4), and control treatment (T5). The effect of treatment on fruit weight was highly significant ($P < 0.001$). NOPF (T4) showed the highest mean fruit at 20.07 kg per plant, followed by the combined application of rabbit urine plus vermiwash (T3) with 18.17 kg per plant. Single applications of rabbit urine (T1) and vermiwash (T2) produced intermediate yields of 16.13kg and 14.67 kg per plant respectively. The control treatment (T5) recorded the lowest fruit weight of 9.03 kg per plant.

Table 4.3 impact of vermiwash, rabbit urine and NOPF on yield components fruit weight of green peppers at harvest maturity

Treatment	Mean fruit weight kgs
T1	16.13 ^c
T2	14.67 ^d
T3	18.17 ^b
T4	20.07 ^a
T5	9.03 ^e
Grand mean	15.61
P-value	<0.001
SED	0.530
LSD (5%)	1.222
CV (%)	4.2

Based on the range test $P < 0.05$, means with the different letters on each column are significantly different from each other

4.3: Cost-effective assessment using vermiwash, rabbit urine and NOPF in green pepper production systems

The table 4.4 shows that the combined application of rabbit urine and vermiwash (T3) was the most cost-effective treatment, giving the highest net profit of \$40.10 with relatively low input

cost. While NOPF (T4) produced the highest yield, its profitability was limited due to high input cost. Rabbit urine (T1) performed well economically due to its low input cost and moderate yield response. Vermiwash (T2) was less cost-effective because of its higher cost per unit and lower yield compared to rabbit urine (T1). All the produce was sold at the same price of \$0.80 per kg. All other costs like transport cost, packaging, labour were held constant for easy evaluation of the income.

Table 4.4 Showing economic analysis of using vermiwash, rabbit urine and NOPF in green pepper production systems

Treatment	Treatment quantity	Cost per unit	Total cost	Total yield	Cost per kg	Revenue	Net Profit
T1	Rabbit urine (1litre)	\$2.00/ litre	\$2.00	48.4kg	\$0.80	\$38.72	\$36.72
T2	Vermiwash (1kg)	\$5/ kg	\$5.00	44kg	\$0.80	\$35.20	\$30.20
T3	Rabbit urine (0.5litre)	\$1.00/ litre	\$3.50	54.5kg	\$0.80	\$43.60	\$40.10
	Vermiwash (0.5kg)	\$2.50/ kg					
T4	NOPF (100mls)	\$10/ 100ml	\$10.00	60.2kg	\$0.80	\$48.16	\$38.16
T5	Control			27.1kg	\$0.80	\$21.68	\$21.68

CHAPTER FIVE

Discussion

5.1: Vegetative growth parameters.

5.1.1 Effects of vermiwash, rabbit urine and NOPF on vegetative growth parameters plant height of green peppers

Nutriplant Organic Plus Fertilizer performed better than rabbit urine, vermiwash, rabbit urine plus vermiwash, and control treatment. The constant increase in plant height under NOPF treatment may be due to the presence of amino acids and bioactive compounds that stimulate metabolic processes and improve nutrient uptake efficiency. According to (Fernandez & Brown, 2013), foliar-applied nutrients are rapidly absorbed through leaf stomata and cuticles, making them immediately available for plant growth and development. The plants treated with NOPF showed a plant height mean of 79.2 cm which was the highest of all treatments.

The combination treatment of rabbit urine and vermiwash produced the second highest plant height. According to Kurnianta et al., 2021, The combined effects of nitrogen-rich rabbit urine and plant growth hormones contained in vermiwash led to the vigorous increase in plant height. The results showed a synergistic interaction between rabbit urine and vermiwash. The combined treatment performed better than each being used separately.

The least results were shown in all parameters for the control treatment throughout the experiment. There were no foliar applications like other treatments. The green pepper plants depended only on available soil nutrients which were not enough to support vegetative growth fully. According to Ganeshamurthy et al., 2015, nutrient deficiency reduces chlorophyll formation, photosynthesis and protein synthesis, thereby limiting stem elongation and plant development.

5.1.2: Effects of vermiwash, rabbit urine and NOPF on vegetative growth parameters leaf area of green peppers

NOPF produced leaves with the highest mean leaf area. NOPF contains nitrogen, magnesium, and iron which play important roles in chlorophyll formation and photosynthetic activity, which promote rapid leaf expansion and canopy development (Mao *et al.*, 2022). The rapid increase of

leaf area from week 2 to week 10 indicates that NOPF provided a continuous supply of essential nutrients throughout the vegetative growth stages of green pepper plants.

Rabbit urine plus vermiwash showed the second highest leaf area. Ganeshnauth *et al.*, 2015 reported that vermicompost-based treatments produced pepper plants with maximum chlorophyll content and faster growth rates. Rabbit urine is rich in nitrogen, potassium and calcium which drives rapid expansion in leaves, (Indabo and Abubakar., 2020). The combination of these produces higher leaf area than when they are used separately.

The control treatment showed very small leaf area from week 2 up to week 10. This generally shows that the available soil nutrients were insufficient for leaf expansion.

5.2: Yield parameters

5.2.1: Impact of vermiwash, rabbit urine and NOPF on fruit number of green peppers at harvest maturity.

NOPF produced the highest yield of green peppers. NOPF supplied nutrients in a more balanced, readily available, and sustained manner throughout the crop growth cycle. Green pepper is a heavy feeder that requires adequate nitrogen, phosphorus, potassium, calcium, magnesium, and micronutrients for vegetative growth, flowering, fruit set, and fruit enlargement.

Rabbit urine plus vermiwash recorded the second highest yield recorded for this experiment is rabbit urine plus vermiwash. According to Ekwere *et al.*, (2023), the combined application of rabbit urine and vermiwash generally produces higher green pepper yield than the sole application of either rabbit urine or vermiwash. The results may be due to that the mixture provides a more balanced supply of nutrients, growth-promoting substances, and beneficial microorganisms to plants.

Rabbit urine produced the third-highest yield in the study. Previous research by Adekiya *et al.*, (2020) has shown that organic liquid fertilizers with high nitrogen content can markedly enhance plant height, flowering, and fruit formation in vegetable crops. However, when rabbit urine is used as the sole nutrient source, imbalances may occur because it contains relatively low levels of phosphorus and fewer beneficial microorganisms.

Vermiwash, on the other hand, recorded the fourth-highest yield. Pathma and Sakthivel., (2012) noted that vermiwash stimulates microbial activity in the rhizosphere, promoting nutrient

mineralization and improving soil fertility. Nonetheless, its comparatively lower concentration of major nutrients than rabbit urine can restrict yield potential, particularly in nutrient-demanding crops such as green pepper.

The control treatment produced the least yield. The available nutrient in the soil was insufficient for the peppers to yield better.

5.2.2: Impact of vermiwash, rabbit urine and NOPF on yield components fruit weight of green peppers at harvest maturity

NOPF treatment showed the highest fruit weight. The superior performance of NOPF may be attributed to its balanced nutrient composition and rapid foliar nutrient absorption, which enhanced photosynthesis, assimilate translocation, and fruit development. According Havlin *et al.*, 2016, balanced nutrient availability improves flower retention, fruit set, and fruit enlargement, resulting in heavier fruits.

The combined application of rabbit urine and vermiwash produced the second-highest fruit weight per plant, indicating a synergistic effect between the two organic nutrient sources. Rabbit urine is rich in nitrogen and potassium, which promote vegetative growth and carbohydrate synthesis, while vermiwash contains growth-promoting hormones, enzymes, micronutrients, and beneficial microorganisms that enhance nutrient uptake and plant metabolism (Pathma & Sakthivel, 2012). The combination therefore improved nutrient availability and physiological efficiency more effectively than the sole application of either rabbit urine or vermiwash.

Rabbit urine alone produced a higher fruit weight per plant than vermiwash alone. This difference may be due to the relatively higher nitrogen content in rabbit urine, which supports vigorous vegetative growth and increased photosynthetic activity. Increased leaf development enhances carbohydrate production, which is later translocated to developing fruits, thereby increasing fruit weight, (Indabo & Abubakar., 2020). Similar findings were reported by Adekiya *et al.*, (2020), who observed improved growth and yield of pepper under organic nutrient applications rich in nitrogen.

The control treatment produced the lowest mean fruit weight per plant because plants depended solely on the natural fertility of the soil, which was likely inadequate to support optimum fruit

development. According to Taiz & Zeiger., (2014), Nutrient deficiencies reduce chlorophyll formation, photosynthetic activity, and assimilate partitioning to fruits, ultimately resulting in smaller and lighter fruits.

5.3: Cost-effectiveness of using vermiwash, rabbit urine and NOPF in green pepper production systems.

The combined application of rabbit urine and vermiwash (T3) achieved the highest net profit of \$40.10, even though it did not produce the greatest yield. This treatment resulted in a total harvest of 54.5 kg and revenue of \$43.60, with a relatively modest input cost of \$3.50. The superior profitability of T3 can be attributed to the complementary interaction between rabbit urine and vermiwash, which enhanced nutrient availability and overall crop performance while keeping production expenses low.

NOPF (T4) produced the highest total yield of 60.2 kg and the highest revenue of \$48.16. However, its net profit (\$38.16) was lower than that of T3 because of its relatively high input cost of \$10.00 per 100 ml. This suggests that although NOPF was highly effective in increasing yield, its profitability was reduced by the higher cost of the product.

Rabbit urine alone (T1) generated the second-highest net profit of \$36.72 from a total yield of 48.4 kg. The profitability of rabbit urine may be explained by its very low production cost and its relatively high nutrient content, particularly nitrogen, which promotes vegetative growth and fruit development. The low input cost enabled farmers to obtain substantial economic returns despite producing lower yields than T3 and T4.

Vermiwash alone (T2) produced a total yield of 44 kg and a net profit of \$30.20, which was lower than rabbit urine alone and the combined treatment. Although vermiwash improves soil biological activity and plant physiological processes, its lower nutrient concentration and higher cost per unit may have reduced its economic efficiency when applied alone.

The control treatment (T5) recorded the lowest yield (27.1 kg), revenue (\$21.68), and net profit (\$21.68). The poor performance of the control indicates that the natural soil fertility alone was insufficient to support optimum green pepper production. Nutrient deficiencies likely reduced vegetative growth, flowering, and fruit development, resulting in lower marketable yield.

CHAPTER SIX

Conclusion And Recommendations

6.1 Conclusion

The study illustrated that vermiwash, rabbit urine, and NOPF significantly influenced the growth and yield performance of green peppers. NOPF consistently produced the highest plant height, leaf area, fruit number, and fruit weight due to its balanced nutrient composition and rapid nutrient availability. The application of rabbit urine and vermiwash combined together produced high quality and quantity and also illustrating its cost effectiveness by producing the highest net profit because of its low input cost and good yield response. The least performance was recorded for the control treatment in all measured parameters, proving that nutrient supplementation is of outmost importance for optimum green pepper production. Rounding off, the study demonstrated that both NOPF and the combined use of rabbit urine and vermiwash can improve green pepper productivity under open field conditions.

6.2 Recommendations

Farmers are recommended to use NOPF for maximum growth and yield of green peppers where financial resources are available. However, for smallholder farmers seeking a more affordable and profitable option, the combined application of rabbit urine and vermiwash is recommended due to its high economic return and lower input cost. Further studies should also be conducted to evaluate the long-term effects of these organic nutrient sources on soil fertility and green pepper quality under different environmental conditions.

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APPENDIX

Appendix 1: Analysis of variance

Variate: plant_height_at_2_WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	0.08133	0.04067	0.86	
block.*Units* stratum					
treatment	4	17.35733	4.33933	91.68	<.001
Residual	8	0.37867	0.04733		
Total	14	17.81733			

Appendix 2: Analysis of variance

Variate: Plant_height_at_4_WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	1.34400	0.67200	17.01	
block.*Units* stratum					
treatment	4	71.71600	17.92900	453.90	<.001
Residual	8	0.31600	0.03950		
Total	14	73.37600			

Appendix 3: Analysis of variance

Variate: Plant_height_at_6_WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	0.2680	0.1340	0.44	
block.*Units* stratum					
treatment	4	170.7173	42.6793	138.87	<.001
Residual	8	2.4587	0.3073		

Total	14	173.4440
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Appendix 4: Analysis of variance

Variate: Plant_height_at_8_WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	0.2613	0.1307	0.52	
block.*Units* stratum					
treatment	4	357.6667	89.4167	353.19	<.001
Residual	8	2.0253	0.2532		
Total	14	359.9533			

Appendix 5: Analysis of variance

Variate: Plant_height_at_10_WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	0.0253	0.0127	0.09	
block.*Units* stratum					
treatment	4	509.9760	127.4940	937.46	<.001
Residual	8	1.0880	0.1360		
Total	14	511.0893			

Appendix 6: Analysis of variance

Variate: Plant_height_at12_WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	1.00133	0.50067	5.33	
block.*Units* stratum					
treatment	4	762.51600	190.62900	2027.97	<.001
Residual	8	0.75200	0.09400		

Total	14	764.26933
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Appendix 7: Analysis of variance

Variate: Plant_height_at_14_WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	0.9880	0.4940	3.39	
block.*Units* stratum					
treatment	4	883.5507	220.8877	1516.39	<.001
Residual	8	1.1653	0.1457		
Total	14	885.7040			

Appendix 8: Analysis of variance

Variate: LA_at_2_WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	0.5637	0.2818	0.54	
block.*Units* stratum					
treatment	4	86.7503	21.6876	41.44	<.001
Residual	8	4.1872	0.5234		
Total	14	91.5012			

Appendix 9: Analysis of variance

Variate: LA_at_4_WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	2.322	1.161	0.95	
block.*Units* stratum					
treatment	4	174.954	43.739	35.80	<.001

Residual	8	9.774	1.222
Total	14	187.050	

Appendix 10: Analysis of variance

Variate: LA_at_6_WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	0.297	0.149	0.02	
block.*Units* stratum treatment	4	408.770	102.193	12.48	0.002
Residual	8	65.503	8.188		
Total	14	474.570			

Appendix 11: Analysis of variance

Variate: LA_at_8_WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	11.978	5.989	1.19	
block.*Units* stratum treatment	4	438.676	109.669	21.88	<.001
Residual	8	40.104	5.013		
Total	14	490.758			

Appendix 12: Analysis of variance

Variate: LA_at_10_WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	12.924	6.462	1.11	
block.*Units* stratum					

treatment	4	472.576	118.144	20.36	<.001
Residual	8	46.418	5.802		
Total	14	531.918			

Appendix 13: Analysis of variance

Variate: Fruit_number_first_harvest

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	22.533	11.267	2.64	
block.*Units* stratum					
treatment	4	951.067	237.767	55.73	<.001
Residual	8	34.133	4.267		
Total	14	1007.733			

Appendix 14: Analysis of variance

Variate: fruit_number_second_harvest

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	292.93	146.47	7.56	
block.*Units* stratum					
treatment	4	2511.73	627.93	32.40	<.001
Residual	8	155.07	19.38		
Total	14	2959.73			

Appendix 15: Analysis of variance

Variate: fruit_number_third_harvest

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	5.733	2.867	1.69	

block.*Units* stratum					
treatment	4	688.000	172.000	101.18	<.001
Residual	8	13.600	1.700		
Total	14	707.333			

Appendix 16: Analysis of variance

Variate: harvested_fruit_weight_kg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	0.4053	0.2027	0.48	
block.*Units* stratum					
treatment	4	212.4440	53.1110	126.15	<.001
Residual	8	3.3680	0.4210		
Total	14	216.2173			

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