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DEPARTMENT OF CROP SCIENCE

ASSESING THE IMPACT OF POULTRY MANURE APPLICATION RATES AND TIMING ON CABBAGE YIELD AND QUALITY.

A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS OF THE BACHELOR OF AGRICULTURAL SCIENCE HONOURS DEGREE IN CROP SCIENCE

DECLARATION

I, Annele Malandu, do hereby declare that this research project is a result of my original Research work undertaken by me, except where clearly and specifically acknowledged. It is being submitted in partial fulfillment of the Bachelor of Agricultural Science Honors Degree (Crop Science). It has not been submitted before for any degree or examination at any other university.

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I have supervised the research project for the above-mentioned, and I am convinced that the Research Project:

a) Can be submitted

Project Supervisor:

Signature Date: 18/09/2025

I certify that I have checked the Research project and I am satisfied that it conforms to the Department of Crop Science guidelines for project preparation and presentation. I therefore authorize the student to submit this dissertation for marking.

Chairperson______________________________Signature________________Date:

Official stamp/Date received in the Department of Crop Science office.

DEDICATION

To my loving family, whose love and support have fuelled my journey. Your sacrifices and encouragement mean the world to me.

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ABSTRACT

The shift with regards to sustainable agriculture has elevated interest in organic fertilisers like poultry manure, yet optimal application approaches for specific crop remain inferiorly understood especially in Zimbabwe. The research investigated the impacts of different poultry manure application rates and timing on cabbage yield and quality in Zimbabwe. The study adopted a randomized complete block design with five treatments: conventional fertilizer as the control, and four poultry manure treatments varying in quantity (300g and 400g) and application timing (one month and two months before transplanting). The parameters measured included leaf number, leaf length, and head weight at time of harvesting. There was highly significant difference ($p<0.001$) leaf number, leaf length and cabbage yield among the treatments, with the conventional fertilizer treatment consistently producing superior results across all parameters. Of the organic treatments, 400g of poultry manure applied two months before transplanting performed best suggesting the importance of both the quantity and timing in nutrient availability. The study concluded that while organic fertilizer can support cabbage production, careful consideration of application timing as well as rates is important for optimal yields. The recommendation that manure application done 2 months before planting at a rate of 400g per station was made.

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CHAPTER 1: INTRODUCTION

1.1 Background of the study

Animal manure has been used in vegetable production by many farmers over the years. As farmers search for sustainable and economical alternatives to chemical fertilisers, the use of organic fertilisers in vegetable production has gathered some momentum more so among smallholder farmers (Mapfumo *et al.*, 2021). Cabbage (*Brassica oleracea var. capitata*) is considered an essential vegetable crop in Zimbabwe and plays a pivotal role in family and national food security (FAOSTAT, 2023). It is vital to commercial agriculture with production estimated to exceed 250,000 metric tons annually. However optimal yields are often not achieved because of reduced levels of soil fertility and limited access to chemical fertilisers.

Poultry manure has emerged as a potential source of cheap organic fertiliser containing essential micro and macro nutrients needed for crop growth. Research has shown that poultry manure contains roughly 3-5% nitrogen 1.5-3.5% phosphorus and 1.5-3% potassium making it a potentially useful source of nutrients for use in vegetable production (Nyakudya *et al.*, 2020). Zimbabwe's growing poultry sector produces roughly 245,000 tons of manure annually (Zimbabwe Poultry Association, 2024). This presents an opportunity for sustainable nutrient cycling in agricultural systems.

Research conducted in different parts of sub-Saharan Africa have shown differing responses to poultry manure application in vegetable crops. In Zimbabwe's Highveld region, Masaka *et al.* (2023) reported a 40% increase in cabbage yields with applications of poultry manure at 5 ton/ha. Moyo *et al*. (2022) noted that incorrect timing and application rates could lead to nutrient losses to leaching and quite possibly, ground water contamination more so during high rainfall periods.

Mineralisation of poultry manure is dependent on the interaction of several factors such as soil temperature, moisture, and microbial activity (Chihombori *et al* 2021). Understanding these patterns is important for optimising timing of application to match nutrient release with crop demand periods. Studies conducted by Mutema *et al*. (2022) in Zimbabwe's communal areas has shown split application of poultry manure resulted in better use of nutrients by crops compared to single applications.

Several studies have been done on the use of poultry manure in vegetable production but there remains a knowledge gap pertaining to optimal application rates and timing specific to the different agro-ecological zones in Zimbabwe. Studies by Gandiya *et al*. (2023) revealed that quality parameters of cabbage such as head size, compactness, and nutritional content have all shown varying responses to organic fertilizer applications. Also, the economic implications of different application strategies need to be analysed in order to come up with practical recommendations for farmers.

The problems of soil fertility management in Zimbabwe are further complicated by the impact of climate change with increasing rainfall variability affecting nutrient availability and crop growth patterns (Climate Change Management Department, 2023). This makes it necessary to develop robust fertilizer management techniques that enhance both crop productivity and resilience. Understanding the relationships between fertilizer timing and quantities of application will be crucial for sustainable intensification of vegetable production and improved food security in Zimbabwe.

Smallholder farmers constitute 70% of Zimbabwe's workforce and often face the most challenges in accessing synthetic fertilisers (ZIMSTAT, 2024). The results of this study may have the most significance for them as a result. Furthermore, the results will add to the knowledge base on organic nutrient management in tropical vegetable production systems and contribute to the development of sustainable agricultural practices in Africa.

1.2 Problem statement

While poultry manure is readily available, cabbage farmers face the challenge of determining ideal application rates and timing of application to maximise crop yields and quality. Lack of standardised guidelines for use of poultry manure in cabbage production has resulted in inconsistent results. Many of the current practices are rooted in traditional knowledge as opposed to evidence based recommendations which results in either under-fertilisation resulting in poor yields or over-fertilisation resulting in nutrient losses to runoff and leaching and potential environmental issues. These knowledge gaps affect famers' ability to make informed decisions regarding manure management and affects the economic viability of organic vegetable production.

1.3 Justification

The majority of Zimbabwean farmers face challenges at one time or another with rising cost of chemical fertilisers and declining soil fertility. Although poultry manure is abundantly available, from the ever expanding poultry industry, there are limited evidence based application rates and timing of application recommendations for cabbage production under local conditions. The research findings will produce evidence based recommendations for smallholder farmers, possibly improving food security positions and cabbage enterprise profitability while enhancing soil health through sustainable soil management practices by using organic fertiliser correctly.

1.4 Objectives

1.4.1 Main objective

To assess the impact of different poultry manure application rates and timing on cabbage growth, yield, and quality parameters to develop ideal organic fertiliser recommendations for sustainable cabbage production.

1.4.2 Specific objectives

1. To evaluate the effect of poultry manure application rate and timing on cabbage leaf length under field conditions.
2. To evaluate the effect of poultry manure application rate and timing on cabbage leaf number under field conditions.
3. To determine the effect of poultry manure application rate and timing on cabbage yield under field conditions.

1.5 Hypothesis

1. Application rate and timing have significant effect on cabbage leaf length under field conditions.
2. Application rate and timing have significant effect on cabbage leaf number under field conditions.
3. Application rate and timing have significant effect on cabbage yield under field conditions.

CHAPTER 2: LITERATURE REVIEW

2.1 Cabbage production systems in Zimbabwe

In Zimbabwe, cabbage production has shown significant growth over the past decade with annual production in 2022 estimated at 250 000 metric tons (FAOSTAT, 2023). Cabbage is grown across all agro ecological regions with the highest production figures registered in natural regions II and III (Marongwe *et al*., 2022).

Many smallholder farmers have taken up cabbage production over the last decade accounting for approximately 65% of total production using mainly furrow irrigation systems (ZIMSTAT, 2024). Research by Musara *et al*. (2023) has shown that cabbage production contributes roughly 18% of household income for small scale vegetable fares and contributes significantly to food security.

Farmers from all walks of life have explored cabbage production with differing results. Production systems range from commercial production to subsistence farming with yields ranging from 15 to 65 tons per hectare (Chipfupa and Muvhunzi, 2024). Market analysis by Moyo *et al*. (2023) has shown that most of the cabbage produced in the country is consumed in urban markets taking as much as 70% while rural areas consume the remainder.

Research by Horticultural Development Council (2024) have revealed that adoption of improved varieties and improved management practices have seen a rise in yield per unit area by as much as 30%. However, Ncube and Dube (2023) noted that production among smallholder farmers remains plagued by challenges linked to access to inputs and technical knowledge.

2.2 Soil fertility management challenges in cabbage production

As with most other soil farming ventures, vegetable production is hampered by soil fertility decline. Research by Nyamangara *et al.* (2023) has shown that approximately 68% of agricultural soils contain less than 1.5% organic matter. The soil fertility situation is worsened by the fact that inorganic fertilisers are costly on the back of a 150% increase in fertiliser prices between 2020 and 2024 (Zimbabwe Fertiliser Manufactures Association, 2024).

According to Mapfumo *et al.* (2023), most smallholder farmers only apply 30% of the recommended fertiliser rates largely as a result of cost constraints. Some farmers do not apply any fertiliser at all because of cost and access issues. Continuous cultivation without nutrient replenishing has led to notable decline in yields as high as 25% over the last five year period (Chivenge *et al.*, 2022).

Lack of knowledge on fertility management has led to problems such as soil acidification. Mutema *et al*. (2024) discovered that pH fell from 6.2 to 5.2 over an 8 year period in intensively cultivated vegetable plots. According to the Zimbabwe Agricultural Research Institute (2023) roughly US$45 million in potential vegetable production value is lost annually to poor soil fertility management practices.

2.3 Characteristics of poultry manure

Different poultry production systems produce poultry manure with different characteristics. Research by Masaka *et al.* (2024) showed poultry manure from layer chickens to contain nitrogen ranging from 3.2% to 5.1%, phosphorus 1.5% to 3.2% and potassium 1.8% to 2.9%. Research by Gwandu *et al*. (2023) showed nitrogen levels in broiler manure to be between 4.5% and 6.2%. Nyakudya *et al.* (2023) noted that the carbon: nitrogen ratio averages 10:1 making it ideal for rapid mineralisation.

Physical properties of manure vary for many reasons. Fresh manure contains between 70% and 80% moisture whereas stored manure ranges between 30% and 40% (Poultry Research Institute, 2024). Moyo *et al.* (2024) demonstrated that covered storage of poultry manure reduced nitrogen losses by as much as 40% when compared with open storage.

Analysis of micronutrients undertaken by Mutema *et al.* (2023) showed notable zinc (290-450 ppm) and copper (165-280 ppm) contents. Proper handling and storage are important for maintaining nutrient value of manure (Zimbabwe Soil Fertility Consortium, 2023).

2.4 Mineralisation and nutrient release in poultry manure

Chihombori *et al.* (2024) showed that between 30% and 40% of nitrogen in poultry manure mineralises within the first 3 weeks under ideal conditions. Ideal soil temperatures for rapid mineralisation range between 25°C and 30°C (Marongwe *et al.*, 2023).

Moisture content is also a crucial factor affecting rate of mineralisation. Research done by the Soil Productivity Research Laboratory (2024) showed peak mineralisation occurring at 60 % to 70% moisture content. Mineralisation occurs more rapidly in soils with higher microbial populations.

Addition of manure often results in an increase in microbial populations with microbial activity increasing by as high as threefold within the first week of manure application (Nyamapfene *et al.*, 2023).

Changes in environmental conditions result in changes in the rate of mineralisation. Seasonal variations have been known to affect mineralisation. Matsika *et al*. (2024) noted a 25% higher rate of mineralisation in summer than in winter. Presence of soil enzymes such as urease and phosphatase influence nutrient availability notably (Zimba *et al*., 2023). It is important to understand these dynamics for optimal timing of application to match crop nutrient requirement.

2.5 Effects of poultry manure on soil properties

Poultry manure adds organic matter to the soil thus improving soil structure and fertility. Long term research by the University of Zimbabwe (2023) have shown that soil physical properties improve and the soil becomes better for crop production compared to untreated soil with addition of manure. Mudavanhu *et al*. (2024) states that, ”bulk density of soil decreased from 1.45g/cm³ to 1.28g/cm³ after 3 consecutive years of poultry manure applications at 5tons/ha”.

Water holding capacity increased by between 25% and 30% (Chimweta *et al*., 2023). A study done by Soil Research Institute (2024) showed that soil aggregation improved notably with average weight diameter increasing from 0.8mm to 1.2mm. Soil chemical properties showed positive changes with pH increasing from 5.2 to 6.4 in acidic soils by the end of the second year after poultry manure application.

According to Mutema *et al* (2024) cation exchange capacity improved by as much as 40%. Research conducted by Nyamangara *et al*. (2023) showed that organic carbon content increased from 0.8% to 2.1% after application of poultry manure at recommended application rates. Moyo *et al*. (2024) noted that salinity issues were reported in cases associated with excessive application.

2.6 Cabbage Nutrient requirements

Studies conducted by the Horticultural Research Centre (2024) showed that in order to achieve optimal yields, cabbage requires between 120kg and 150kg of nitrogen per hectare, 60kg to 80kg phosphorus per hectare and 120kg to 160kg potassium per hectare.

The uptake of nutrients by cabbage plants varies with growth stage. According to Dube *et al*. (2023), 70% of total nitrogen requirement is used during head formation. Phosphorus requirement is at its highest in the early stages of growth while potassium requirements peak during head development (Maseko *et al*., 2024).

Quality characteristics of cabbage plants are greatly affected by nutrient availability. Chitendo *et al*. (2023) established that crucial levels of nutrients in leaf tissue are 3.2%-3.8% for nitrogen, 0.3% -0.5% for phosphorus and 2.5% -3.0% for potassium. According to Macheka *et al*. (2024) head firmness is strongly linked to calcium levels and vitamin C content is associated with nitrogen availability.

2.7 Effects of poultry manure application to the environment

Using poultry manure in fields and landscapes has numerous benefits. Measurements of greenhouse gas emission done by Chikowo *et al*. (2024) proper timing of application reduces N_2O emissions by as much as 40%. Positive impacts of poultry manure application also include increased soil carbon sequestration with estimates ranging from 0.5-1.2tons carbon/ha/year increase.

Biodiversity research by Nyamangara *et al*. (2023) showed an increase in both earthworm populations and microbial diversity in manured soils.

Environmental impact studies by the Environmental Management agency (2024) have shown that the application of poultry manure while having its benefits also has drawbacks. Research conducted by Mutsvangwa *et al*. (2023) revealed that in areas of high application, nitrate levels in ground water increased from 5 to 15mg/L. Zimbabwe National Water Authority conducted a study which revealed phosphorus loading in water bodies in the proximity of heavily manured fields.

The challenge therefore lies in balancing out agricultural benefit and environmental protection.

2.8 Poultry manure as part of sustainable vegetable production systems

Integration of poultry manure into vegetable production systems may have benefits in both the financial sense and from an ecological perspective. Economic analyses done by the Agricultural Economics Research Institute (2024) showed that incorporating poultry manure into a vegetable production system can result in reduced fertiliser costs by as much as 40% to 60%.

Research conducted by Masuka *et al*. (2023) showed best management practices to include pre-plant application and split application during the growing season. According to,” Chivenge *et al*. (2024) combined use of poultry manure with synthetic fertilisers resulted in an increase in yields by as much as 25% when compared to either nutrient source alone”.

Adoption research done by Musara *et al*. (2023) showed major challenges to be transportation costs and labour requirements. Adoption rates among small holder farmers remains as low as 35% as a result of knowledge gaps and initial investment requirements (Moyo *et al*., 2023)

CHAPTER 3: MATERIALS AND METHODS

3.1 Study area

The research was carried out during the 2024/2025 summer cropping season at Ivordale Farm in Mashonaland Central Province near Juru Growth Point. It lies on an altitude of roughly 1273m above sea level on latitude of 17°40’12” South, longitude of 31°24’31” East. The farm is in natural region II and receives rainfall ranging between 700mm and 1000mm annually with temperatures as high as 28°C and above in the summer and as low as 5°C. The area is dominated by loamy-sand soils with the dominant soil colour being black.

3.2 Experimental design

The experiment was carried out in a Randomised Complete Block Design (RCBD) with five treatments replicated 3 times each. The following treatments were used:

Control: Compound C at planting (600kg/ha)

T1 : 400g poultry manure applied 1 month before transplanting

T2 : 400g poultry manure applied 2 months before transplanting

T3 : 300g poultry manure applied 1 month before transplanting

T4 :300g poultry manure applied 2 months before transplanting

3.3 Experiment Management

3.3.1 Land preparation and plot layout

Conventional land preparation was employed. Ploughing and discing was done using tractor drawn implements. Beds were marked each measuring one meter in width and five meters in length with a 60cm pathway separating beds. Planting stations were marked on the beds in two rows spaced 60cm between rows and 50cm within the rows. 10 planting stations were dug out to a depth of 30cm in each row. Treatment application was done at the prescribed times with treatments 2 and 4 applied on December 1 2024, followed by treatments 1 and 3 on January 1 2025, and finally control on February 1 2025.

3.3.2 Manure preparation

Poultry manure preparation was done between September and November 2024. The manure was gathered and piled then covered with black plastic to create the ideal environment for decomposition. The pile was turned on a weekly basis to encourage circulation of air and water was added to the pile in the process to keep it moist but not soggy.

3.3.3 Transplanting and irrigation

Transplanting of cabbage seedlings was done on February 1 2025. Soon after transplanting, all beds were mulched using spear grass (*Hoteropogon contortus*). For the first 2 weeks after transplanting, the plants were irrigated after every 2 days using a watering can with a rose attachment for gentle distribution. Once the seedlings were well established, the beds were flooded 2 times a week using a hosepipe.

3.3.4 Weed control

For control of weeds, Glyphosate was used on 29 November 2024, 27 December 2024 and 15 January 2025 for control of weeds that had emerged. After transplanting, weeds were removed by hand pulling whenever they were noticed.

3.3.5 Fertiliser application

Top dressing fertilizer of Ammonium Nitrate (34.5%) was applied first on 20 February 2025 at a rate of 5g per station. The second top dressing fertilizer of Calcium Ammonium Nitrate (27%) was applied on 19 March 2025 at a rate of 5g per station.

3.3.6 Pest and disease management

For control of soil pests. 5ml of Lambda cyhalothrin was mixed with 15l of water and drenched at a rate of 30ml per planting station 3 days after transplanting. 2 chemical combinations were used to control foliar pests and diseases. The first combination comprised of Nemesis (Emmermectin benzoate+acetamiprid) at 25ml (for chewing pests and sap sucking pests) and Tebuconazole (curative fungicide for fungal diseases) at 25ml in 16l of water was alternated every 7 days with the combination of Lambda cyhalothrin (for chewing pests) at 25ml and Dithane M45 (a preventive fungicide for control of diseases) at 50g in 16ml of water.

3.3.7 Data collection

Number of leaves were counted and Leaf length was measured and recorded on days 14, 30, and 45 after transplanting. Sampled heads' weight was measured and recorded on day 70 after transplanting.

3.3.8 Data analysis

The collected data was analysed using ANOVA in GenStat statistical software. The treatments means were separated using Fisher's Protected Least Significant Difference (LSD) test at 5% level of significance ($p \leq 0.05$).

CHAPTER 4: RESULTS

4.1 Effect of poultry manure application rate and timing on cabbage leaf length

There was highly significant difference ($p<0.001$) in cabbage leaf length among the different treatments across all the sampling periods (days 14, 30 and 45). At day 45, the control treatment produced the longest leaves (13.57cm) whereas T3 had the shortest leaves (11.72cm). this is illustrated on Figure 4.1 below.

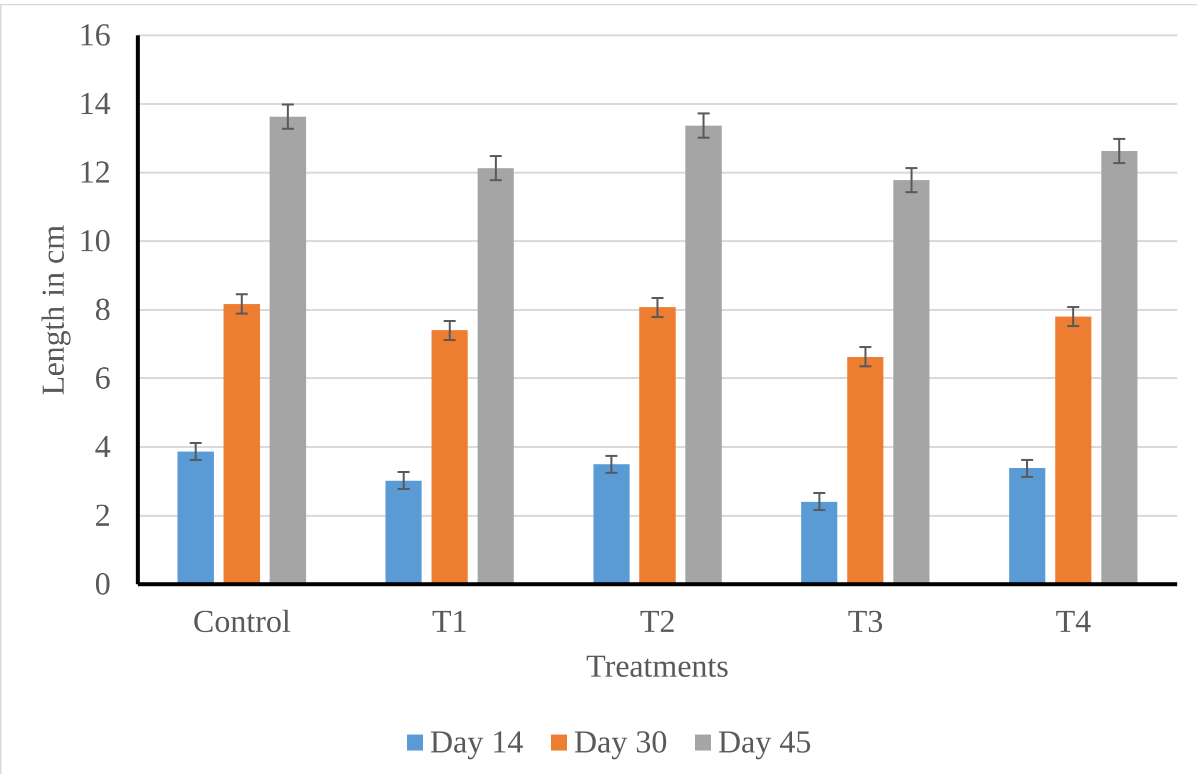

Figure 4.1: Effect of poultry manure application rate on cabbage leaf length

4.2 Effect of poultry manure application rate and timing on cabbage leaf number

There was highly significant difference ($p<0.001$) in cabbage leaf number among the different treatments across all the sampling periods (days 14, 30 and 45). At day 45, the control treatment produced the most leaves (17.333), whereas T3 had the lowest number of leaves (14.333). All the treatments had significant differences as indicated by the error bars (Figure 4.2).

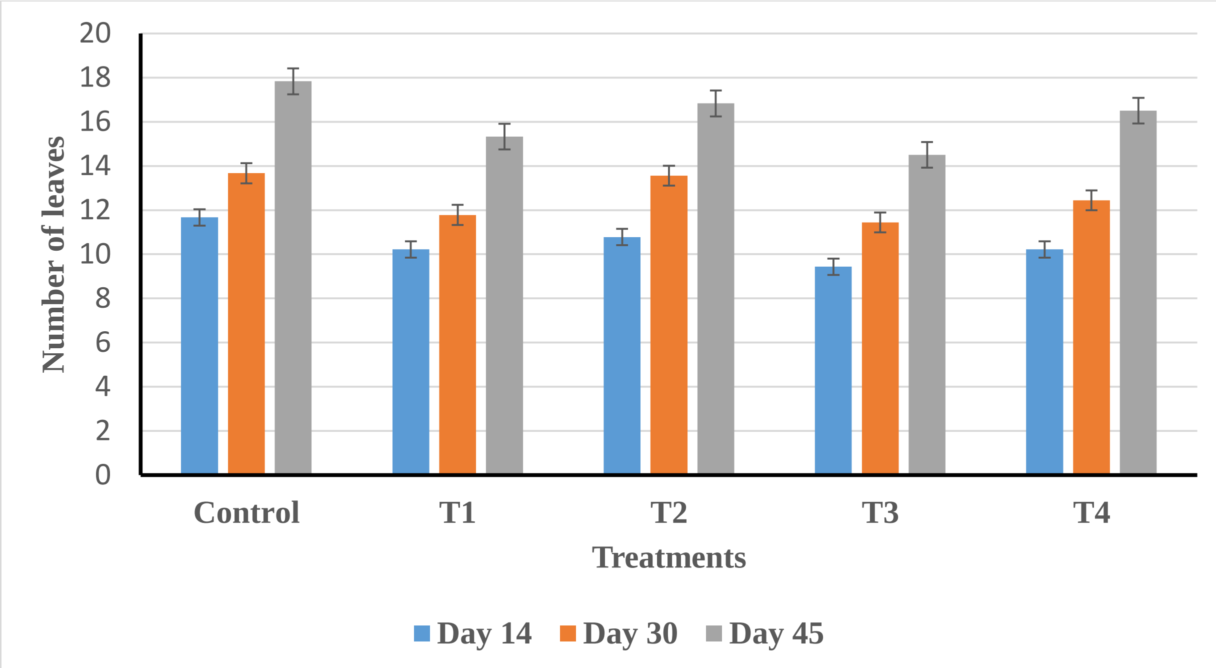

Figure 4.2: Effect of poultry manure application rate on cabbage leaf numbers

4.3 Effect of poultry manure application rate and timing on cabbage yield

There was highly significant difference ($p<0.001$) in cabbage yield among the different treatments in terms of weight, with the control treatment having the heaviest cabbages (4.643kg). Lowest yield was obtained from T1 and T3 which were statistically similar as shown in Figure 4.3.

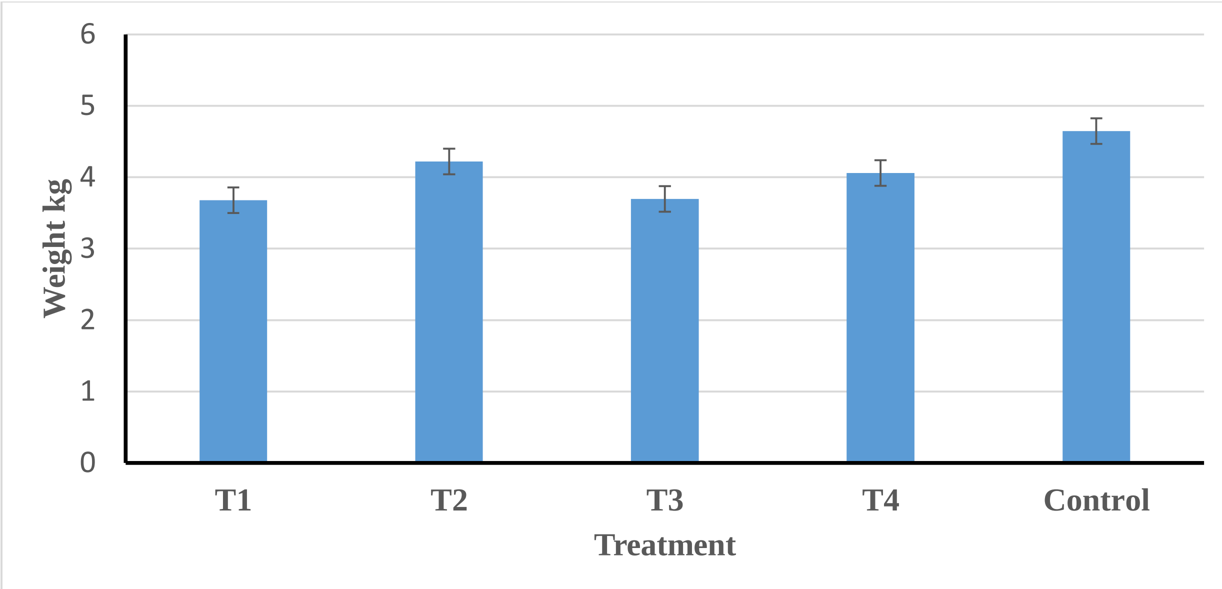

Figure 4.3: Effect of poultry manure application rate on cabbage

Block effects were not significant (0.759). The effects of the treatment were highly significant ($P<0.001$) but with a lower F-value (29.53) when compared with other parameters. The control treatment produced the heaviest cabbages (4.643kg) whereas T1 and T3 were the lightest and were statistically similar. The treatment SS (8.967) vs error SS (2.885) ratio was lower than that of other parameters but high enough to conclude clear treatment effects.

CHAPTER 5: DISCUSSION

The results highlighted the significance of the treatments on Leaf length, Leaf number and cabbage weight with several noteworthy patterns emerging from the data.

5.1 Effect of poultry manure application rate and timing on cabbage leaf length

The control treatment produced the longest leaves (13.567cm) consistently followed by T2 (400g of poultry manure applies 2 months before transplanting). This is consistent with observations made by Maseko *et al*., (2024) who noted that potassium and nitrogen are crucial for leaf development particularly during head development. This indicates that conventional fertilizer and earlier applied higher amounts of poultry manure promote better Leaf elongation. The lower leaf length realized in T3 (300g of poultry manure applied 1 month before transplanting) show that both timing and quantity of nutrient application are crucial for leaf development. The notable disparities between all treatments emphasizes the sensitivity of leaf length to nutrient management strategies. However, research done by Mudavanhu *et al*., (2024) showed that consistent manure application improves water retention and reduces soil compaction and this in turn supports better leaf development in the long term if applied and managed properly.

5.2 Effect of poultry manure application rate and timing on cabbage leaf number

Leaf number is a good indicator for vegetative vigour and nutrient sufficiency in cabbage. The pattern observed in leaf number was comparable to the leaf length results with the control treatment producing the highest number of leaves (17.333). This consistency across both leaf parameters suggests that the control treatment provides more readily available nutrients for vegetative growth. This outcome is consistent with findings by Chitendo *et al*., (2023) who noted that leaf development is closely correlated to nutrient sufficiency, especially nitrogen and phosphorus. The declining trend in leaf numbers from T2 (400g of poultry manure applies 2 months before transplanting) and T3 (300g of poultry manure applied 1 month before transplanting) supports the importance of both application timing and quantity in cabbage development. The slower release of nutrients in poultry manure treatments may be as a result of delayed mineralisation common under suboptimal moisture and microbial conditions (Chihombori *et al*., 2024). Moreover, Mutema *et al*., (2024) noted that soil acidification, common in intensively cultivated lands, can impede nutrient uptake, particularly in the early stages of growth. The highly significant nutrient effect indicates that leaf number is particularly responsive to nutrient management strategies.

5.3 Effect of poultry manure application rate and timing on cabbage yield

The results for cabbage weight showed a slightly different pattern with the control maintaining better results (4.643kg) but T1 (400g of poultry manure applied 1 month before transplanting) and T3 (300g of poultry manure applied 1 month before transplanting) showing statistical similarity. This indicates that while conventional fertilizers promote optimal weight gain, the timing of manure application may be more crucial than quantity for final cabbage weight. This is consistent with findings by Chivenge *et al*., (2022) who noted that up to 25% yield reductions may be experienced in systems where nutrient replenishment was not well timed. The significantly lower head weights in the manure treatments could be a reflection of suboptimal mineralisation or possibly, insufficient nutrient synchrony with cabbage crop demands, particularly during head formation when nitrogen is needed in higher quantities (Dube *et al*., 2023).

5.4 Integration of findings

The noticeably better performance of the control treatment across all parameters indicates that conventional fertilizers provide more consistent and readily available nutrients than poultry manure treatments (Dube *et al*., 2023). Among the poultry manure treatments T2 (400g of poultry manure applies 2 months before transplanting) consistently performed better showing that earlier application allows better nutrient mineralization and availability. The lower performance of reduced quantity applications i.e. T3 (300g of poultry manure applied 1 month before transplanting) and T4 (400g of poultry manure applied 1 month before transplanting) demonstrates that nutrient quantity is as important as timing.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

The research conclusively showed that timing and quantity of poultry manure application significantly influences cabbage growth and yield parameters even though conventional fertilizers produced optimal results. Organic alternatives can be viable when applied and managed properly. Earlier application (two months before transplanting) of higher quantities (400) g of poultry manure showed consistently better results than lower quantities applied later showing the importance of mineralization time for nutrient availability. We can conclude therefore that higher application rates of poultry manure when administered at optimal times will significantly increase the yield of cabbage compared to lower application rates in sub-optimal timing. Similarly, higher application rates of poultry manure when administered at optimal timing will significantly increase the length of leaves when compared to lower application rates and sub-optimal timing. High application rates of poultry manure when administered at optimal timing will significantly increase the number of leaves when compared to low application rates and sub-optimal timing.

6.2 Recommendations

Based on the research findings, the following recommendations can be drawn:

- Farmers making use of organic manures should apply said manure at least two months before transplanting to ensure adequate nutrient availability. Higher application rates such as 400g per planting station are preferable for optimal results.
- Future research can be ventured on examining the long-term effects of repeated use of poultry manure amendments as well as studying soil nutrient dynamics under different application regimes.
- Further researchers should also investigate combinations of organic and inorganic fertilizers to assess their impact both on cabbage yield as well as soil chemical and physical characteristics.

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Appendix

Appendix 1: ANOVA on Leaf length Day 14

Variate: Leaf_length_Day_14

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.03215	0.01607	1.32	
Block.*Units* stratum					
Treatment	4	3.84785	0.96196	78.95	<.001
Residual	8	0.09748	0.01219		
Total	14	3.97748			

Appendix 2: ANOVA on Leaf length Day 30

Variate: Leaf_length_Day_30

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.02311	0.01156	0.63	
Block.*Units* stratum					
Treatment	4	5.01007	1.25252	68.04	<.001
Residual	8	0.14726	0.01841		
Total	14	5.18045			

Appendix 3: ANOVA on Leaf length Day 45

Variate: Leaf_length_Day45

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.009333	0.004667	0.88	

Block.*Units* stratum					
Treatment	4	6.99438	1.748595	329	<.001
Residual	8	0.042519	0.005315		
Total	14	7.046232			

Appendix 4: ANOVA on Number of Leaves Day 14

Variate: Leaves_Day_14

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.17778	0.08889	3.69	
Block.*Units* stratum					
Treatment	4	9.14077	2.28519	94.92	<.001
Residual	8	0.19259	0.02407		
Total	14	9.51113			

Appendix 5: ANOVA on Number of Leaves Day 30

Variate: Leaves_Day_30

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.10371	0.05185	1.56	
Block.*Units* stratum					
Treatment	4	12.40001	3.1	93	<.001
Residual	8	0.26667	0.03333		
Total	14	12.77038			

Appendix 6: ANOVA on Number of Leaves Day 45

Variate: Leaves_Day45

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.04444	0.02222	0.23	
Block.*Units* stratum					
Treatment	4	22.91854	5.72963	59.5	<.001
Residual	8	0.77037	0.0963		
Total	14	23.73336			

Appendix 7: Cabbage head weight

Variate: Weight_kg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.055308	0.027654	6	
Block.*Units* stratum					
Treatment	4	1.971813	0.492953	106.94	<.001
Residual	8	0.036877	0.00461		
Total	14	2.063999			

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