BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCE

DEPARTMENT OF CROP SCIENCE

EFFECTS OF INTEGRATED FERTILIZER MANAGEMENT COMPARED TO THE USE OF INORGANIC FERTILIZERS ON THE GROWTH AND YIELD OF CABBAGE.

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A DISSERTATION TO BE SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT OF THE BACHELOR OF SCIENCE HONOURS DEGREE

(CROP SCIENCE)

APPROVAL FORM

The undersigned certified that they have supervised and recommend to Bindura University of Science education for acceptance of dissertation entitled **Effects of integrated fertilizer management compared to the use of inorganic fertilizers on the growth and yield of cabbage** submitted in partial fulfilment of the Bachelor of Science Honours Degree in Crop Science.

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ABSTRACT

The integration of systemic fertilizer with various organic fertilizers can be an alternative source of nutrient management in cabbage production. However, there is limited information available on the effect of integrated fertilizer management using different combinations on growth and yield of cabbage. A field experiment was conducted to evaluate the effects of integrated fertilizer management on the growth and yield of cabbage. A total of four treatments were assessed in a randomised complete block design with a single factor and the treatments were replicated four times. The treatments include the integration of 25% compound C + 25% AN + 50% chicken manure, 15% compound C +15% AN+ 70% chicken manure, 50% compound C + 50% AN and 100% chicken manure. Data was analysed using Genstat 18th edition and the comparison of treatment means was done using Least Significant Difference (LSD) at 5% significant level. The results showed that the treatment with the integration of 25% compound C + 25% AN + 50% chicken manure recorded the highest measurements in all growth and yield parameters whilst the treatment with 100% chicken manure recorded the least in terms of plant height (28.98 cm), number of loose leaves(10,85) ,head circumference (28.27 cm) and head weight (805g). Farmers are advised to consider the integration of systemic fertilizer with organic fertilizers as they are cheap and easily accessible by farmers, thereby reducing production cost.

KEY WORDS: Integrated fertilizer management, cabbage, production cost, fertilizers

DEDICATION

I dedicate this dissertation to my family and friends in appreciation of their continued support throughout the whole project period.

ACKNOWLEDGEMENTS

I want to express my gratitude to the Almighty God for his grace, everlasting love and provisions throughout the research period. Special thanks to my fellow colleagues for their selfishness and support. My Sincere gratitude goes to Mr Kondo and Mr Macheche from Teryden farm for their guidance. I also want to thank my family and friends for their spiritual and moral support throughout the period.

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ACRONYMS AND ABBRIVIATIONS

AN	: Ammonium Nitrate
ANOVA	: Analysis of Variance
IFM	: Integrated Fertilizer Management
FAO	: Food and Agriculture Organizations of the United States
GPS	: Global Positioning System
LSD	: Least Significance Difference
%	: Percentage
RCBD	: Randomized Complete Block Design

LIST OF MEASUREMENTS

cm	: Centimetres
g	: Grams
ha	: hectares
kg/ha	: kilograms per hectare
km	: kilometres
m	: metres
mm	: millimetres

Chapter 1

1. Introduction

1.1 Background

Cabbage (*Brassica oleracea*) is a form of leaf vegetable which is grown globally including African countries like Zimbabwe (FAO, 2009). According to Ayres, (2019), cabbage is believed to have originated from Europe and has been widely grown for over 2500 years as a vegetable food crop. It is believed that cabbage (*brassica oleracea*) was introduced to the Africans by European colonialist in the sixteenth century (Daniel and Muindi, 2023). It is a very popular vegetable amongst urban and rural people in Zimbabwe. According to Nyamande (2014), cabbage can be cooked as a side dish in restaurants, hotel and homes or it can be consumed raw as salads. Cabbage is of economic importance through their nutritional value as it contains large amount of minerals, vitamins A, B and K, carotenoids, iron, magnesium and dietary fibre (Ayres, 2019). It is also a cash crop for smallholder farmers in Zimbabwe.

In Zimbabwe, cabbage is generally grown throughout the year and it can grow best in cool and humid environments. However, its production in Zimbabwe is being affected by the gradual increase in prices of fertilizers which is expensive for smallholder farmers. This has resulted in reduction in final yield and productivity due to increase in cost of production. Farmers are failing to purchase fertilizer due to high cost and consequently, they combine with natural fertilizers which can be accessed easily (Gumindoga, Ruponga and Sakwa, 2024). Besides increase in cost of production, there are some other factors which hinder cabbage production in Zimbabwe such reduction in soil fertility and fluctuating climatic conditions.

On the other hand, organic fertilizers like poultry manure, cow dung and compost manure can be used in cabbage production because they are very affordable and readily available for smallholder farmers. However, the use of organic fertilizers on its own cannot be very effective as it might not meet the amount of nutrients required by the plants due to slow release of nutrients and relatively low nutrient content (Rut *et al.*, 2021). There is therefore the need for integrated fertilizer management (IFM). The integration of organic and inorganic fertilizers ensures appropriate supply of all the essential nutrients necessary for long term soil and crop productivity and therefore, this will reduce the need for chemical fertilizers

(Shirichena, Sup and Madzingaidzo, 2022). The mixture of natural and chemical fertilizers is effective as inorganic fertilizers delivers nutrient like nitrogen, phosphorus and potassium rapidly whilst organic fertilizers improves soil structure, water retention and boost microbial activity. The use integrated method has been proven to reduce over reliance on inorganic fertilizers, increases nutrient use efficiency (Mucheru-Muna *et al.*, 2010).

1.2 Problem statement

There is little information on integrated fertilizer management techniques that combine organic and inorganic inputs to boost yield at a low cost. There is also a major knowledge gap on the best combination of integrated fertilizer management that helps to reduce production cost.

1.3 Justification

This investigation is crucial for developing a sustainable and affordable solution to the rising problem of high fertilizer costs that smallholder cabbage producers must deal with. The study also intends to determine the best combinations of inorganic and organic inputs that not only reduce input prices but also improves soil health that has been harmed by the excessive use of inorganic fertilizers by exploring integrated fertilizer management techniques. The results of this study will assist government and extension officials in developing fertilizer policies and training initiatives that are grounded by scientific evidence, as well as in giving farmers useful advice on the most economical combination of inorganic and organic fertilizers. Ultimately, this study will contribute to Zimbabwe's efforts to promote ecologically friendly farming methods, enhancing the livelihoods of farmers sand improve food security.

1.4 Objectives

1.4.1 Main Objective

To investigate the potential effects of integrated fertilizer management compared to the use of inorganic fertilizers on the growth and yield of cabbage.

1.4.2 Specific objectives

1. To evaluate cabbage's growth performance under integrated fertilizer management.
2. To assess the effects of integrated fertilizer management versus the use of inorganic fertilizers on cabbage yield

1.5 Hypothesis

1. H1: Integrated fertilizer management have a positive effect on the growth of cabbage.
2. H1: The use of integrated fertilizer management has a great effect on the yield of cabbage.

Chapter 2

2 Literature review

2.1 Origin of cabbage

Cabbage (*brassica oleracea*) is a common agricultural food crop which is a member of cruciferous or brassicacae family. It is an indigenous crop to Western Europe and Northern shore of the Mediterranean region(Chaurasia, 2015). It was derived from the wild, green, non-heading varieties of *Brassica oleracea var sylvestris* (Moamongwe, 2005). According to Ayres, (2019), cabbage is among the ancient vegetables which have been grown for more than 2 500 years.

In over 90 countries around the world, cabbage has been produced for its head (Ram, Lata and Shar, 2009). According to Sarker *et al.*, (2002), the top producers of cabbage worldwide are China, Japan, Germany, South Korea and South Africa. In Africa, cabbage was brought by European colonialists in the 60th century (Daniel and Muindi, 2023). According to Chauvin, Mulangu and Porto, (2012), the top five cabbage growing countries in Africa which have dominated throughout this time include Ethiopia, Egypt, Niger and South Africa, with Ethiopia having 12% of Africa's overall production.

2.2 Importance and nutritional content of cabbage

Cabbage is one of the vegetable crops that is commonly produced around the world and is valued for its nutritional and economic importance. It is a staple crop in many places because of its resistance to different of agro climatic conditions and it contributes greatly to the vegetable production industry as it is the primary source of revenue for many small and commercial farmers(Cervenski *et al.*, 2022). Cabbage has a high yielding potential, short production cycle and is adaptable to both organic and inorganic production methods making it to be favoured by farmers (Adhikari *et al.*, 2023)

In the food processing industry and fresh markets, cabbages are also in high demand. According to Moreb *et al.*, (2020), this cruciferous vegetable has been proven to be helpful in minimizing the risk of cancerous diseases and other chronic disease like cardiovascular diseases, cataracts and diabetes because of its nutritional composition which includes a variety of antioxidants and phytochemical like carotenoids, glucosinolates, phenolic compounds and vitamins E and C. Cabbage is important in a balanced diet because it is great provider of the essential nutrients. According to Daniel and Muindi, 2023, raw cabbage contains 92% water, 6% carbohydrates 1% protein and some negligible fats. Cabbage contains 2% fibre, vitamin A, C and K and mineral ions that are crucial for human nutrition and health, including calcium, iron, sodium, zinc, magnesium, phosphorus and potassium (Daniel and Muindi, 2023).

2.3 Ecological requirements of cabbage

According to Ayres, 2019, cabbage is regarded as a cool season crop, emerging at an optimal soil temperature of 4 degrees Celsius and an ideal temperature of 18 to 35 degrees Celsius. Cabbage can tolerant temperatures as low as -3 degrees Celsius without incurring any damage (Daniel and Muindi, 2023). It requires about 400mm of water (Ayres, 2019). On the other hand, over the growth season, crop water consumption increases and reaches its peak at head maturity close to the end of the growing season. If crops receive less than 380mm of soil moisture they wilt an d limp whereas those that receives more than 500mm develop root rot which destroys them (Daniel and Muindi, 2023). Therefore water conservation method are vital for ensuring adequate soil moisture in areas that are vulnerable to excessive evaporation and constructing drainage canals which help to remove excess water from heavy rains because cabbage is susceptible to floods.

Cabbage crop requires a lot of nutrients for its growth and therefore it is known to be a heavy feeder. It grows well in loamy soils with good drainage and has an effective rooting depth of about 600mm (Ayres, 2019). Cabbage requires the right nutrients such as nitrogen, potassium and phosphorus. On the other hand, too much nitrogen can cause to loose head formation and decay. (SeedCo Cabbage Production Guide, 2019), recommend 400kg of ammonium nitrate and 600 to 1000 kg of compound fertilizer per hectare for the production of cabbage. In order to avoid the leaching of nutrients at once, ammonium nitrate should be applied in three splits, between two to eight weeks after transplanting. Manure of about 10 to 20 tonnes and chicken litter of 2 to 5 tonnes per hectare is also recommended for the production of cabbage, but they need to be well decomposed and composted in order to avoid root burn (SeedCo Cabbage Production Guide, 2019). Cabbage also requires enough light for it to grow and carry out photosynthesis. Absents of sufficient light reduce the production of carbohydrates and thereby causing stem elongation an etiolation (Daniel and Muindi, 2023).

2.4 Effects of organic fertilizers on cabbage production

The use of organic inputs such as compost manure, chicken manure and cow dung manure is very crucial in cabbage production as it helps to maintain soil fertility and crop productivity. The application of chemical fertilizers in crop production have some negative effects on soil health whereas organic do not cause such (Akhter, 2016). (Tindall, 2000) states that use of inorganic fertilizers help to improve crop quality and production in addition to soil productivity. It also helps to improve water retention and thereby increasing soil biological activity, nutrient mobilization and soil structure (Belay, 2021). The utilization of organic fertilizers is of great importance as they can result in better plant growth, higher yields and produce of high quality with enhanced flavour and nutritional value. Vegetable grown using organic fertilizers often have high vitamins and minerals as compared to those grown using inorganic inputs.

Furthermore, organic fertilizers help to reduce the need for systemic fertilizers, thereby promoting sustainable farming, decreasing the chances of soil degradation and reducing environmental contamination. However, because of its slow release of nutrients and generally low nutrient content, the use of inorganic inputs alone is not enough to meet the crop's nutrient requirements (Rut *et al.,* 2021).

2.5 Effects of inorganic fertilizers on cabbage production

Inorganic fertilizers are manufactured by industries and are also known as systemic fertilizers (Utomo M., Sbrina, T., Lumbanraj, 2016). Inorganic fertilizers have a major impact of crop yield and quality. They are often referred to as N.P.K fertilizers which contain concentrated forms of vital nutrients like nitrogen (N), phosphorus (P) and potassium (K) (Lin, 2023). Systemic fertilizers such as nitrogen based formulations encourage the vegetative growth and heard formation (Mbungua et al 2020). Plants often lack nitrogen which is a very crucial macro nutrient therefore proper fertilization is essential for the best production of cabbage. According to Mengel and Kirkby, (2000), plants absorbs nitrogen informs of NO_3^- and NH_4^+. Plants with low nitrogen content may have pale green leaves and may result in slow growth. Increase in plant height stem diameter, leaf area, leaf number, fresh and dry shoot mass have been linked with nitrogen treatment(Zhang and Zhao, 2009).

(Lin, 2023) states that inorganic inputs gives plants readily accessible nutrients that promote fast growth and development because they are quickly absorbed by the roots. This helps to reduce nutrient shortages and encourages optimal yield. However, smallholder farmers are finding it increasingly difficult to afford systemic fertilizers as prices are rising whilst they have limited resources (Concepts and Geremew, 2020). This has an impact on adoption rate and productivity. According to Zimbabwe Farmers Union, 2022, the prices of agricultural inputs have increased significantly especially the prices of nitrogenous fertilizers.

2.6 Compatibility of inorganic and organic fertilizers

In order to increase agricultural yields and sustainable soil fertility, integrated fertilizer management may be the best alternative strategy (Rut *et al.,* 2021). This approach combines organic fertilizers with inorganic fertilizers for enhancing soil with immediate nutrient supply (Paramesh *et al.,* 2023). The combination of inorganic and organic inputs can enhance crop yield and nutrient utilization efficiency. For instance, integrated fertilizer management produces faster growth rate, larger cabbage heads and more marketable yields (Sarker et al., 2002). Organic components helps to improve soil structure, fertility, microbial activity and sustains productivity over time while systemic fertilizers ensures timely supply of nutrients and encourages rapid development. According to (Concepts and Geremew, 2020), integrated fertilizer management meet the needs of plants whilst promoting sustainable agriculture. Despite the benefits, the effectiveness of integrated fertilizer management varies depending on crop nutrient requirements and application rate.

CHAPTER 3

3.1 Materials and Methodology

A field experiment trial was conducted at Tambawadya primary school garden in Chikangwe Karoi. Chikangwe is a suburb of Karoi which is about 2 kilometres east of the city centre. Karoi is in Hurungwe district of Mashonaland west province. Its GPS coordinates are -16.8033927 and 29.6977442. It is found in Zimbabwe's natural region 2a which is characterized by a moderate annual rainfall of 750 to 1 000 mm and generally climatic conditions are conducive for agriculture. Temperatures in Karoi are moderate, with temperature ranging between 15 and 25 degrees Celsius and the annual rainfall typically begin in November and last through March or April. The region is characterised by sandy loam soils (Ministry of Lands, Fisheries, Agriculture, Water and Rural development, 2021)

3.2 Experimental design

The experiment was set up in a randomized complete block design so as to reduce the impact of field variability. The blocking factors include the slope of the land and shade from trees. There are four treatments which were replicated four times. This guarantees the results' statistical correctness and dependability. There were four treatments which were replicated four times. These include the treatment with 25% compound C + 25% Ammonium nitrate + 50% chicken manure, 15% compound C + 15% Ammonium nitrate + 70% chicken manure, 50% compound C + 50 % Ammonium nitrate and a treatment with 100% chicken manure. A 3m x 3m plot was used. Each plot had a total of 36 plants, with a cabbage seedling spacing of 50cm x 50cm.

3.3 Land preparation

Land preparation was done 4 days before transplanting so as to clear all the weeds and unwanted materials from the land. Digging was done using a hole and lumps were broken using a hole so as to come up with a fine tilth. Due to the advanced stage of weeds, slashers were used to clean the field .3m x 3m beds were constructed and a garden liner was used to ensure that the beds were aligned and of consistence size. A garden rake was used to level the beds. Making and holing out of planting stations was done using a hole.

3.4 Planting

Cabbage planting was done soon after marking of planting stations. Aco Lambda was applied before planting through drenching in order to control cutworms. Planting was done on the 21th of January 2025 at a spacing of 50 cm x 50 cm. When planting, the seedlings were placed vertically. A late maturity, Lunaria Cabbage variety which is a hybrid was planted. Watering was done soon after transplanting using a watering cane so as to reduce the rate of transpiration shock.

3.5 Fertilizer management

Basal fertilizer was applied before planting together with chicken manure using different rates and then incorporated into the soil so as to avoid the placement of seedlings directly on fertilizer and manure on the day of planting. Basal fertilizer, compound C was applied at the rate of 800kg/ha as recommended by SeedCo. The amount of compound C applied was determined by the treatments. The rate of two tonnes of chicken manure per acre was applied. Ammonium nitrate was applied in three slits as top dressing from week three after transplanting and using the rate of 100kg/ha.

3.6 Water management

Cabbage production was done in the rain season. Therefore watering was done when there were no rains, during some dry spell periods. Watering was done using a watering cane. This was done to ensure that the soil was always moist throughout the research period.

3.7 Weed management

Weeding was done through hand hoeing and hand pulling. This was done so as to reduce competition for nutrients and water between weeds and the desired cabbage. Weeds were destroyed because they can also harbour pest.

3.8 Pest and disease control

On the day of cabbage planting lambda was applied through drenching so as to prevent the infestation of cutworms. A weekly time table was designed on the spraying of insecticides and fungicides so as to prevent diseases and pest infestations. Insecticides such as lambda and super dash (accetamiprid + emamectin benzoate) were applied as preventatives together with fungicides such as dithane M45 and copper oxychloride. Scouting was done regularly in order to monitor pest and diseases infestation.

3.9 Data collection

Data was gathered by taking measurements randomly from chosen plants.

3.9.1 Growth parameters

Plant height

The height of cabbage was measured using a metre ruler from the base of the stem, which is at the soil surface, to the top of the canopy which is the highest portion of the plant. This was carried at two weeks interval from the second week following transplanting until the eighth week. Plant height measurements were documented in centimetres (cm).

Number of loose leaves

This was done by counting the number of fully developed leaves. Counting of leaves was done manually. This was done at two weeks interval from second week after transplanting up to week eight.

3.9.2 Yield measurements

Head circumference

Head circumference of randomly selected cabbage heads was measured using a tape measure.

Head weight

The weight of cabbage heads with unfolded leaves was obtained by measuring the weight of randomly selected plants. Weighing was done using an electronic scale and the weight was expressed in grams.

3.10 Data analysis

The data was analysed with ANOVA using GENSTAT 18th edition. Comparison of treatment means was done using the Least Significant Difference (LSD) at 5% significance level. The plotting of graphs was done using Microsoft excel.

Chapter 4

4 Results

4.1 Growth parameters

4.1.1 Plant Height

Analysis of variance for plant height revealed significant effects from week 2 through to week 8 with all weeks showing p- values<0.05 (table). Across all the weeks treatment 1(25% compound C + 25% Ammonium nitrate + 50% Chicken manure) consistently recorded the tallest plants reaching 38.45 cm by week 8 whereas treatment 4 with 100% chicken manure hand the shortest plants measuring 28.98cm by week 8. Differences between all the treatments were statistically significant.

Table 3 Mean plant height

Plant height (cm) at different weeks				
Treatment	Week 2	Week 4	Week 6	Week 8
25% compound C + 25% Ammonium nitrate + 50% chicken manure	9.27a	22.575a	31.01a	38.45a
15% compound C + 15% Ammonium nitrate + 70% chicken manure	8.27b	19.835b	28.00b	36.60b
50% compound C + 50 % Ammonium nitrate	8.25b	17.975c	25.17c	34.75c
100% chicken manure	7.77c	14.825d	21.71d	28.98d
P value	0.003	<0.001	<0.001	<0.001
SED	0.285	0.2075	0.574	1.195
LSD (5%)	0.644	0.4693	1.298	2.704

4.1.2 Number of loose leaves

Analysis of variance for number of loose leaves showed significant treatment effects from week 2 through week 8 with all weeks showing p-values≤0.002 (table). The highest number of leaves across all the weeks was seen in treatment 1(25% compound C + 25% Ammonium nitrate + 50% chicken manure) reaching a peak of 16,48 leaves at week 8 while treatment 4 (100% chicken manure) only managed 10.85 leaves at week 8. The Differences between all treatments was statistically significant.

Table 4 Mean number of loose leaves

Treatment	Number of loose leaves at week			
	2	4	6	8
25% compound C + 25% Ammonium nitrate + 50% chicken manure	4.05a	9.10a	14.10a	16.48a
15% compound C + 15% Ammonium nitrate + 70% chicken manure	3.70ab	7.70ab	13.35a	15.65a
50% compound C + 50 % Ammonium nitrate	3.05b	7.30ab	12.05b	14.95a
100% chicken manure	2.75b	6.55b	9.90c	10.85b
P value	<0.001	0.002	<0.001	<0.001
Sed	0.1768	0.462	0.316	0.510
LSD (5%)	0.3999	1.045	0.715	1.155

4.2 Yield

4.2.1 Head circumference

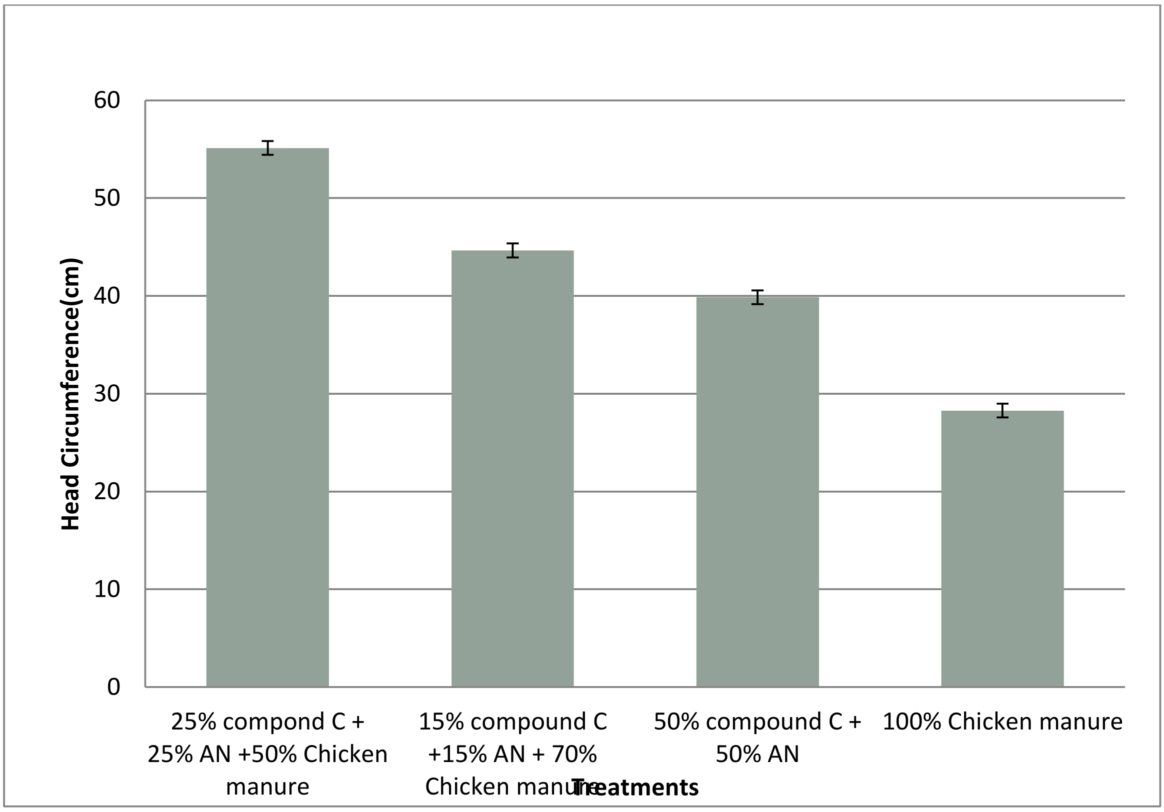

Figure 1 Mean head circumference

All the treatments had a highly significant effect on head circumference ($p<0.001$) with treatment 1(25% compound C + 25% Ammonium nitrate + 50% chicken manure) producing the largest head circumference (55.12cm) and treatment 4 (100% chicken manure) having the smallest circumference (28.27 cm). There were significant differences among all the treatment.

4.2.2 Head weight

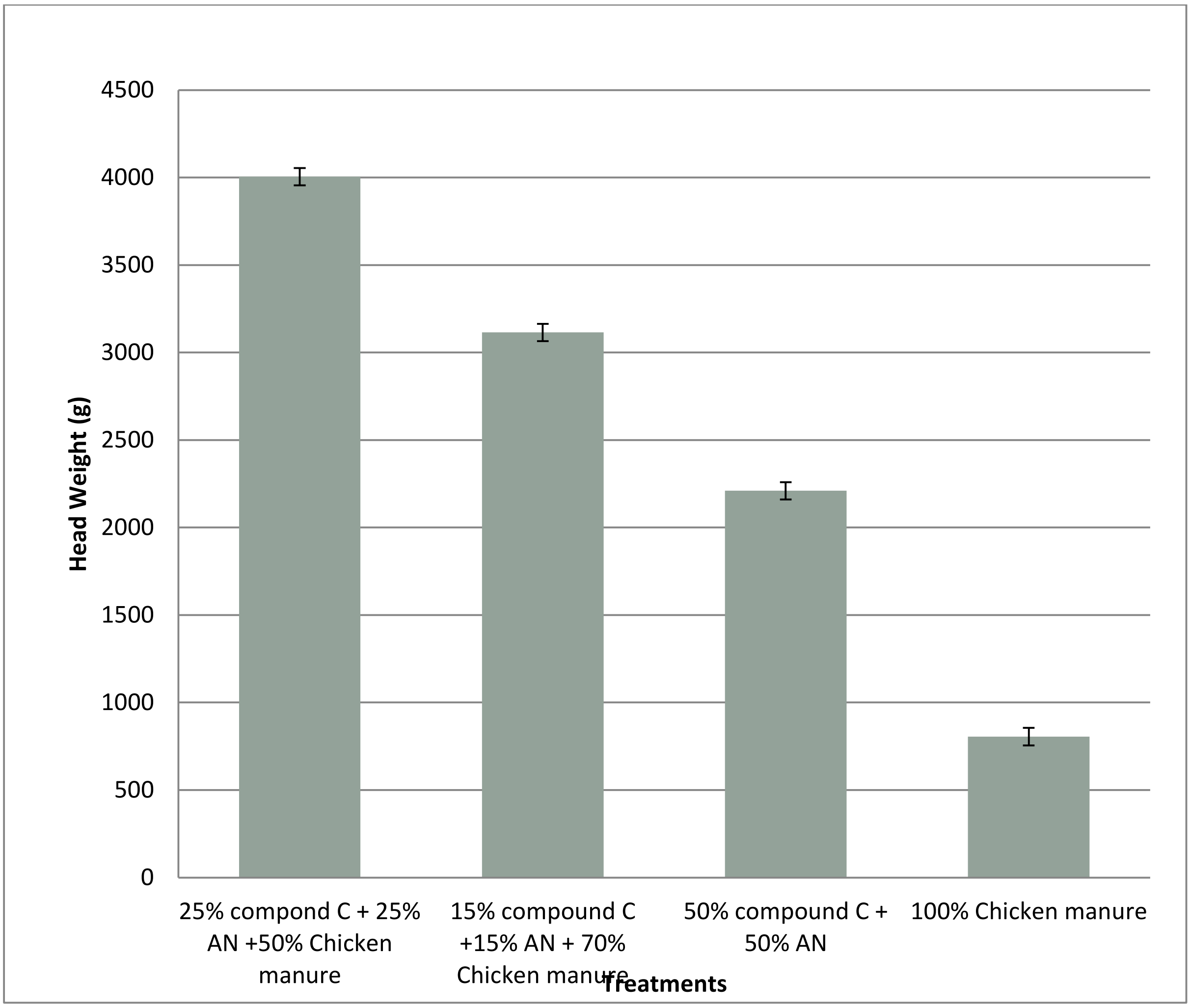

Figure 2 Mean head weight

The difference between treatment effects significantly influenced head weight ($p<0.001$) as detailed in table 4.6. The heaviest heads were seen in treatment 1(25% compound C + 25% Ammonium nitrate + 50% chicken manure) weighing 4005g while treatment 4 (100% chicken manure) hand the lightest heads at 805g. All the different treatments were significantly different from each other.

Chapter 5

5. Discussion

5.1 The effects of integrated fertilizer management on the growth of cabbage.

5.1.1 Plant height

The results showed that the different treatments significantly affected plant height across all sampling weeks with treatment 1(25% compound + 25% Ammonium nitrate + 50% chicken manure) consistently giving the tallest pants and treatment 4 (100% chicken manure) having the shortest. This trend is consistent with the existing studies which highlight the crucial role of having nutrient availability in promoting vegetative growth as well as elongation (Mengel and Kirby, 2001; Zhang *et al*., 2009). The superior performance in treatment 1 can be attributed to a more efficient nutrient supply probably through integrated fertilization which has been shown to optimize growth and development parameters such as height by providing both immediate and sustained nutrient availability (Concepts and Geremew, 2020; Paramesh *et al.*, 2023)

Cabbage is a heavy feeder and requires ample nitrogen for optimal development and benefits from balanced regimes (SeedCo, 2019). It is likely that with treatment 4 (100% chicken manure), insufficient nutrients impeded cell elongation and leaf expansion leading to reduced plant height (Daniel and Muindi, 2023) the findings are in sync with documented sensitivity of cabbage growth to nitrogen as well as overall soil fertility status which are crucial for maximizing canopy development (Ayres, 2019). This study therefore reinforces the importance of sufficient nutrient management in cabbage cultivation to improve early and sustained growth stages.

5.1.2 Number of loose leaves

The number of loose leaves was notably different among the different treatments with the highest counts recorded in treatment 1 (25% compound C + 25% Ammonium nitrate + 50% chicken manure) indicating enhanced vigour. These results are in line with Sharma (2019) who noted that organic fertilizer improved nutrient availability and soil structure thereby promoting healthier and more abundant leaf production in cruciferous crops. The positive influence of organic amendments on leaf development are well documented often attributed to increased microbial activity as well as nutrient mobilization (Belay, 2021).

Conversely the lower leaf count seen in some treatments may be a reflection of limited nutrient uptake or imbalanced fertilization which can impede photosynthesis capacity and retard leaf expansion (Daniel and Muindi, 2023). The notable differences seen between the different treatments also supports the assumption that the combination of organic and chemical fertilizers enhances vegetative growth more effectively than sole applications (Rut *et al.,* 2021;Concepts and Geremew, 2020). These findings are consistent with the understanding that the leaf numbers is a key factor of crop vigour and productivity potential more so in cabbage where a robust leaf canopy is necessary for maximizing head development(SeedCo Cabbage Production Guide, 2019).

5.2 The effects of integrated fertilizer management on cabbage yield.

5.2.1 Head circumference

Significant treatment effects were seen with head circumference measurements. Treatment 1 (25% compound C + 25% Ammonium nitrate + 50% chicken manure) yielded the largest heads and treatment 4(100% chicken manure) had the smallest heads. These results are consistent with the recognized importance of nitrogen and other macronutrients in head formation and vegetative development (Mbungau et al., 2020; Mengel and Kirby, 2001). Sufficient nutrient supply especially through combined organic and inorganic fertilizer is known to improve cell division and enlargement in cabbage heads thus increasing their size (Concepts and Geremew, 2020; Rut *et al.,* 2021)

The smaller head circumference s seen in treatment 4 (100% chicken manure) are likely a reflection of deficiencies or imbalances that compromise head compactness and and size as excess nitrogen can lead to loose head formation and low quality output (SeedCo Cabbage Production Guide, 2019). This observation is in sync with outcomes that balanced fertilizer applications not only improve yield but also enhance the physical quality of cabbage heads which is important for market acceptance and consumer preference (Paramesh *et al.*, 2023). Therefore, this study emphasises the importance of exact nutrient management to optimize cabbage head size as well as overall cabbage quality

5.2.2 Head weight

Analysis of variance showed a similar trend for head weight to that of circumference with significant differences between the different treatments being seen with the heaviest heads recorded under treatment 1 (25% compound C + 25% Ammonium nitrate + 50% chicken manure). The strong positive effect of integrated fertilizer management on biomass accumulation is well documented as it enables both rapid nutrient uptake as well as sustained nutrient release essential for optimal yield (Rut *et al*., 2021; Paramesh *et al.*, 2023). The enhanced head weight observed indicate improved photosynthetic capacity and assimilate partitioning in line with the nutritional benefits of synthetic fertilizers combined with organic amendments (Belay, 2021; Lin, 2023)

Treatment 4's (15% compound C + 15% Ammonium nitrate + 70% chicken manure) notably low head weight shows limited nutrient availability which limits growth and biomass accumulation consistent with reports that nutrient deficiencies directly reduce yield components in cabbage (Daniel and Muindi, 2023). These findings are in sync with broader literature that sufficient fertilizer regimes particularly those balancing immediate and slow releasing nutrients are important for maximizing both yield and crop quality in cabbage (Sarker *et al.*, 2002; Mengel and Kirby, 2001). This places emphasis on the agronomic advantage of integrated fertilizer strategies in improving cabbage cultivation efficiency.

Chapter 6

6. Conclusions and Recommendations

6.1 Conclusions

The results from this study demonstrated that the combined application of inorganic and organic fertilizers was very effective in increasing cabbage production without deteriorating the soil and with minimum cost incurred. The results hold considerable promise for lowering the use of systemic fertilizers without lowering cabbage production. There were high significant effects that were observed on the growth and yield of cabbage which was influenced by integrated fertilizer management. The treatment with the combination of 25% compound C + 25% ammonium nitrate + 50% chicken manure proved to be a good combination for the production of cabbage. Therefore l conclude that the best combination of organic and inorganic fertilizers with balanced nutrient sources appeared to be effective on the growth of cabbage by incurring minimum cost.

6.2 Recommendations

1. The researcher recommends farmers to adopt integrated fertilizer management for the economic productivity of cabbage at without deteriorating the soil and incurring less cost.
2. Farmers are recommended to adopt the integration of 25% compound C + 25% ammonium nitrate + 50% chicken manure as it has performed well as compared to other treatments, however there is need for research on the combinations of inorganic and organic fertilizers.
3. Smallholder farmers are recommended to use the available chicken manure where systemic fertilizers are expensive for cost effective and sustainable cabbage production.
4. It is recommended that farmers should use well decomposed manure to avoid root burn.

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APPENDICIES

Appendix 1: Analysis of variance

Variate: Height_cm_week2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	0.1319	0.0440	0.27	
Block.*Units* stratum					
Treatments	3	4.7769	1.5923	9.81	0.003
Residual	9	1.4606	0.1623		
Total	15	6.3694			

Analysis of variance

Variate: Height_cm_week_4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	0.61690	0.20563	2.39	
Block.*Units* stratum					
Treatments	3	127.21230	42.40410	492.63	<.001
Residual	9	0.77470	0.08608		
Total	15	128.60390			

Analysis of variance

Variate: Height_cm_week_6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	0.4165	0.1388	0.21	
Block.*Units* stratum					
Treatments	3	189.2615	63.0872	95.74	<.001
Residual	9	5.9306	0.6590		
Total	15	195.6086			

Analysis of variance

Variate: Height_cm_week_8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	8.877	2.959	1.04	
Block.*Units* stratum					
Treatments	3	201.802	67.267	23.55	<.001
Residual	9	25.711	2.857		
Total	15	236.389			

Appendix 2: Analysis of variance

Variate: No_of_loose_leaves_at_week_2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	0.20750	0.06917	1.11	
Block.*Units* stratum					
Treatments	3	4.22750	1.40917	22.55	<.001
Residual	9	0.56250	0.06250		
Total	15	4.99750			

Analysis of variance

Variate: No_of_loose_leaves_at_week_4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	0.1475	0.0492	0.12	
Block.*Units* stratum					
Treatments	3	13.7475	4.5825	10.73	0.002
Residual	9	3.8425	0.4269		
Total	15	17.7375			

Analysis of variance

Variate: No_of_loose_leaves_at_week_6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	0.1800	0.0600	0.30	
Block.*Units* stratum					

Treatments	3	40.6200	13.5400	67.70	<.001
Residual	9	1.8000	0.2000		
Total	15	42.6000			

Analysis of variance

Variate: No_of_loose_leaves_at_week_8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	4.5469	1.5156	2.91	
Block.*Units* stratum					
Treatments	3	74.9869	24.9956	47.96	<.001
Residual	9	4.6906	0.5212		
Total	15	84.2244			

Appendix 3: Analysis of variance

Variate: Head_Circumference_cm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	6.668	2.223	2.21	
Block.*Units* stratum					
Treatments	3	1488.134	496.045	494.11	<.001
Residual	9	9.035	1.004		
Total	15	1503.838			

Appendix 4: Analysis of variance

Variate: Head_weight_g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	43475.	14492.	2.95	
Block.*Units* stratum					
Treatments	3	22383275.	7461092.	1518.37	<.001
Residual	9	44225.	4914.		
Total	15	22470975.			