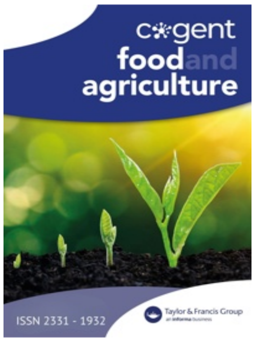

Cogent Food & Agriculture

Taylor & Francis
Taylor & Francis Group

ISSN: 2331-1932 (Online) Journal homepage: www.tandfonline.com/journals/oafa20

Growth and yield response of cabbage (*brassica oleracea var. capitata* '*star 3011*') to different liquid organic manure types and their combinations

Mandhlenkosi Zhou, Zivanayi Musabayana, Lenon Tembo, Ndabanye Mathema & Pesanai Zanamwe

To cite this article: Mandhlenkosi Zhou, Zivanayi Musabayana, Lenon Tembo, Ndabanye Mathema & Pesanai Zanamwe (2026) Growth and yield response of cabbage (*brassica oleracea var. capitata* '*star 3011*') to different liquid organic manure types and their combinations, Cogent Food & Agriculture, 12:1, 2666927, DOI: 10.1080/23311932.2026.2666927

To link to this article: https://doi.org/10.1080/23311932.2026.2666927

Published online: 04 May 2026.

COGENT FOOD & AGRICULTURE
2026, VOL. 12, NO. 1, 2666927
https://doi.org/10.1080/23311932.2026.2666927

SOIL & CROP SCIENCES | RESEARCH ARTICLE

OPEN ACCESS   Check for updates

Growth and yield response of cabbage (*brassica oleracea var. capitata* '*star 3011*') to different liquid organic manure types and their combinations

Mandhlenkosi Zhou, Zivanayi Musabayana, Lenon Tembo, Ndabanye Mathema and Pesanai Zanamwe

Department of Horticulture and Crop Production, Gwanda State University, Filabusi, Zimbabwe

ABSTRACT

The application of organic liquid manures is deemed a viable alternative to the application of inorganic fertilisers in vegetable production. This study was carried out to evaluate the effect of different types of liquid manure and their combinations on the growth and yield of cabbage, cultivar Star 3301. The study was conducted during the 2020–2021 and 2021–2022 seasons at the Tshaka Maoko Organic Nutrition Garden in Chiredzi, Zimbabwe. The experiment was arranged in a randomised complete block design with nine liquid manure treatments, namely, cattle, poultry, green groundnut, combinations of cattle-poultry, cattle-green groundnut, poultry-green groundnut, cattle-poultry-green groundnut, a negative control and a positive control. Liquid manure types and their combinations significantly affected cabbage growth and yield attributes, including days to heading, days to horticultural maturity, head diameter and head weight. The negative control showed the lowest values in all the attributes measured. The combination of cattle-poultry-green groundnut liquid manure showed the best performance and was comparable to the positive control and the poultry-green groundnut liquid manure. Crops treated with these treatments took a short time to form heads and to reach maturity and had heavy and large heads. The single liquid manure treatments showed intermediate performance. Among the single liquid manures, cattle liquid manure was the least effective. It was concluded that combining organic liquid manure, such as a combination of extracts from cattle, poultry and green groundnut, could be used as an alternative to inorganic fertilisers in cabbage production.

ARTICLE HISTORY
Received 5 February 2026
Revised 17 April 2026
Accepted 26 April 2026

KEYWORDS
Cabbage production; liquid manure; organic vegetable production; sustainable agriculture; botanical extracts

SUBJECTS
Agriculture & Environmental Sciences; Soil Sciences; Agronomy

1. Introduction

Crop productivity is significantly influenced by biotic and abiotic factors such as weeds, pests, diseases, and soil fertility. Soil fertility management is essential aspect since poor management of soil nutrients can negatively impact crop growth and productivity (Al-Kaisi et al., 2023; Parker & West, 2022). Soil fertility can be maintained through organic and inorganic fertilisers, which provide crops with necessary nutrients for optimal growth (Al-Kaisi et al., 2023; Debele, 2021). Soil nutrients are essential for vegetable crops such as cabbage, which require adequate nutrients such as nitrogen, phosphorus, potassium, and boron for optimal growth and development (Maboko & Du Plooy, 2021; Parker & West, 2022; Singh et al., 2023).

Organic farming involves the use of crop rotation, organic manure, green manure and crop residues to maintain soil fertility for optimal crop growth and productivity while minimising or completely avoiding the use of inorganic fertilisers. Organic manure is used in modern days in nutrition gardening as an alternative to agrochemicals due to its role in improving soil structure and nutrient availability for optimal plant growth (Carter & Lee, 2021; Davis & Kaisi, 2023). Organic manure is however, less effective for use in semi-arid regions due to limited moisture availability which limit microbial activity, slowing down nutrient mineralisation and release (Lal, 2020; Ravi et al., 2021).

CONTACT Mandhlenkosi Zhou zhoumandhlenkosi@gmail.com Department of Horticulture and Crop Production, Gwanda State University, Epoch Mine Campus, P. O. Box 30 Filabusi, Zimbabwe.

Liquid organic manures have been identified as an alternative option, especially under conditions of low rainfall. These conserve water, reduce crop burn, and provide nutrients in forms that are readily available for rapid uptake by the crop (Hao et al., 2023; Kumar et al., 2022; Ravi et al., 2021). Moreover, they improve the soil's physical and chemical properties (Davis & Kaisi, 2023).

Despite the rising interest in organic manures, there is still limited information on how different types of liquid organic manures and their combinations affect cabbage production (Maboko & Du Plooy, 2021; Ravi et al., 2021). This issue is particularly important in semi-arid areas, where soil fertility problems and lack of moisture continue to restrict productivity (Maboko & Du Plooy, 2021; Moyo et al., 2020). Additionally, the nutrient content and effectiveness of liquid organic manures can vary greatly based on their source and application, and the effect of this variation is not yet fully understood (Kumar et al., 2022; Parker & West, 2022). As a result, this study examined the effects of individual and combined cattle, poultry and green groundnut liquid manures on growth and yield of cabbage. The main aim was to find cost-effective and sustainable alternatives to inorganic fertilizers.

2. Materials and methods

2.1. Study area and site description

The experiment was carried out in the Tshaka Maoko Organic Nutrition Garden within the Chiredzi Urban Industrial Site in the Southeastern Lowveld of Zimbabwe. The research was conducted during the 2020–2021 and 2021–2022 seasons under the auspices of Family Aids Caring Trust-Chiredzi (FACT-Chiredzi). The site is situated at an altitude of about 534 m above sea level. Its geographical location is 21°20′ S and 30°27′ E. The site has a gentle slope of about 2%. The soils are mainly of the sandy loam type (Moyo et al., 2020). The site is characterised by a semi-arid climate with an annual rainfall of less than 450 mm. The rainfall occurs mainly during summer months from November to March (Food and Agriculture Organization of the United Nations, 2021). The mean air temperatures range from 26 °C in summer to 16 °C in winter.

2.1.2. Soil analysis

Soil samples were collected before the establishment of the experiment and analysed at ICRISAT laboratories to determine baseline soil fertility status. The soil had a pH of 6.2 (slightly acidic) and moderate levels of nitrogen, phosphorus, and potassium (Table 1).

2.2. Experimental design and treatments

The experiment was laid out in a randomised complete block design (RCBD) with nine treatments replicated three times. The slope of the field was used as the blocking factor to minimise variability. The experimental treatments are shown in Table 2.

2.3. Experimental materials

2.3.1. Liquid manure Preparation materials

Materials used for the preparation of the liquid manures included three 210-litre plastic drums, three 90 kg empty sacks, and organic materials such as cattle manure, poultry manure, and fresh green groundnut plants.

Table 1. Soil test results.

Soil attributes	pH	Nitrogen	Potassium	Phosphorus	Calcium	Magnesium	Organic matter	CEC
Value	6.2	0.71%	2.05%	1.22 mg/g	71.06%	26.44%	1.81%	23.03 meq/100g

Table 2. Experimental treatments.

Treatment code	Liquid manure type or combination
C	Cattle liquid manure
P	Poultry liquid manure
G	Green groundnut liquid manure
cp	Cattle + poultry liquid manure
cg	Cattle + green groundnut liquid manure
pg	Poultry + green groundnut liquid manure
cpg	Cattle + poultry + green groundnut liquid manure
N	No liquid manure (negative control)
Z	Compound C and ammonium nitrate (positive control)

2.3.2. Planting material

The variety of cabbage used for this experiment was Star 3311 (*Brassica oleracea var capitata* 'Star 3311'). This variety is an early-maturing hybrid type with oval and compact head and is tolerant to heat. It is best planted during the low-rainfall season in low-latitude regions. It is commonly planted during the winter and spring seasons and is most preferred for its use during these two seasons.

2.3.3. Preparation of liquid organic manures

Preparation of liquid organic manures used in this experiment was done through by extraction of manure tea. Three-quarters of 90 kg sacks were filled with the different types of manure (cattle, poultry and green groundnut materials) and tightly closed. The tightly closed manure containing bags were hung on a pole made of wood and placed across the opened 210 L drum containing 200 L of clean water such that the sack is completely immersed and positioned about 30 cm above the base of the drum (different manure type were extracted in different drums). The suspension pole was shaken every three days for a period of 15 days, to enhance nutrient extraction. The maturity of the liquid manure was determined on the basis of the change of colour to dark brown and the reduction of the original strong ammonia smell. The sacks was removed after 15 days and the liquid extract was diluted with water at a ratio of 1:2 and used for the experiment.

2.4. Experimental management

2.4.1. Land Preparation and plot layout

The land was dug using hoes and the soil clods were crushed to a fine tilth. Beds/plots measuring 2.20 m x 2.4 m were prepared and each plot had four rows with four planting stations in each row. This gave a total of 16 plants per plot. Plant spacing was maintained at 60 cm between rows and 45 cm within rows. Basins of 15 cm radius and 10 cm depth were made at each planting station for water conservation.

2.4.2. Transplanting and thinning

The seedlings were raised in 45 cm x 20 cm triangular trays and transplanted after five weeks from sowing. Healthy seedlings, about 16 cm tall, were selected for transplanting. Two seedlings were transplanted per planting station in the late afternoon at around 16:00 h after irrigating the plots to field capacity. Thinning was done two weeks after transplanting leaving one vigorous seedling per planting station.

2.4.3. Application of treatments

Liquid manures were applied at transplanting and then at two-week intervals until a month before harvesting. For combined liquid manures, equal parts of different manure extracts were mixed together before application. Liquid manure was applied at a rate of 1 L per planting basin per application. Based on the planting spacing used (0.60 m × 0.45 m), this corresponds to approximately 37,000 L ha^{-1} per application. The study standardized application based on volume instead of nutrient equivalence because the liquid manures had not been chemically characterized. Moreover, Muktamar et al. (2020) proposed the use of volume arguing that the nutrient composition of liquid organic fertilizers vary according to source materials and preparation methods, complicating standardization based on nutrient content. Therefore, the differences in crop performance would be deemed to reflect variation in nutrient content of different types of manure. The negative control used only water for application, while the positive control used Compound C (6:15:12; NPK+ 6S + 0.1B), and ammonium nitrate (34.5% N), applied as a top dressing at a rate of approximately 200 kg ha^{-1} at three and six weeks after transplanting; in line with standard agronomic recommendations for cabbage production.

2.4.4. Mulching, irrigation, and weed management

Grass straw was used to thinly mulch the basins to reduce evaporation and increase water conservation. Plants were irrigated using watering cans to fill the basins halfway during transplanting and then at two weeks interval. Weed management was carried out by hand-pulling.

2.4.5. Pest and disease management

Pests and diseases were naturally controlled. Chilli (*Capsicum frutescens)* fruits were used for preparing botanical sprays for pest and disease management. Chilli fruit extracts were used as a foliar spray for pest management. Again Milkweed (*Asclepias syriaca)* plants were used as decoy plants for aphid management.

2.4.6. Harvesting

Cabbages were ready for harvesting 98 days after transplanting when the heads were compact and firm. The cabbages were harvested per plot on the same day and three wrapper leaves were left intact.

2.5. Data collection

Days to heading, days to horticultural maturity, head diameter and head weight measurements were recorded. Days to heading was determined as the **n**umber of days from transplanting to when 50% of plants in a plot showed head formation. Days to horticultural maturity was determined as the number of days from transplanting to when 50% of plants had compact and firm heads. Head diameter was determined using a veneer calliper. To measure cabbage head weight, randomly selected three plants per plot were harvested at 7, 11 and 14 weeks after transplanting and weighed on a digital electronic scale.

2.6. Data analysis

The data was subjected to analysis of variance (ANOVA) using GenStat version 14. Significantly different treatment means were separated using Fisher's Least Significant Difference (LSD) at 5% level of significant.

3. Results

3.1. Days to heading

The results revealed a significant effect of liquid manure types and their combinations on the number of days to heading ($p < 0.05$) as shown in Figure 1. The negative control (n) and cattle liquid manure (c) took the longest time to heading. The mean values were 60 and 59 days, respectively. The negative control (n) and cattle liquid manure (c) did not differ significantly in the number of days to heading ($p > 0.05$), but they differed significantly from the other treatments.

The cattle-poultry-green groundnut (cpg), poultry-green groundnut (pg), and positive control (z) took a significantly shorter time to heading. The mean values were 49, 49, and 48 days, respectively. The cpg, pg, and z did not differ significantly in the number of days to heading ($p > 0.05$), indicating that they were comparable in accelerating the crop to heading. The lower number of days to heading in the cpg, pg, and z compared to the control and cattle liquid manure treatments could be attributed to the improved nutrient supply to the crop.

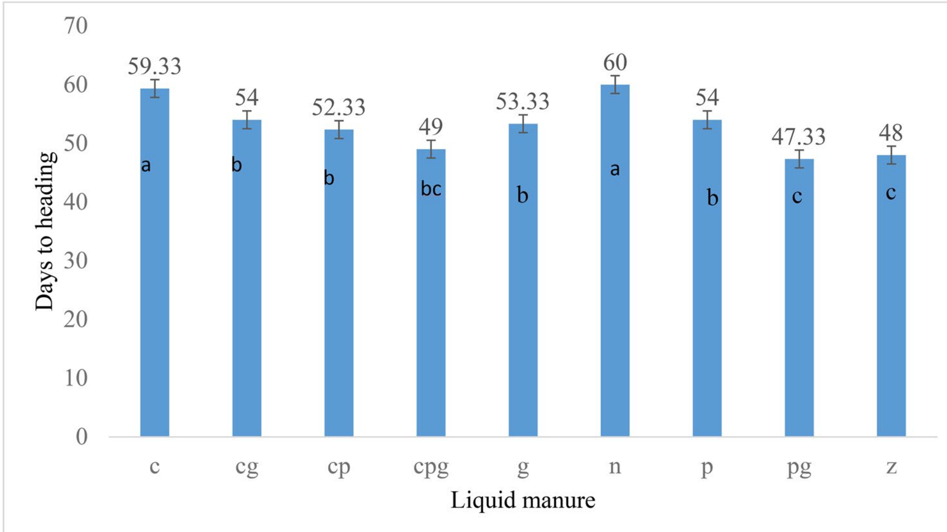

Figure 1. Effect of different liquid organic manure types and their combinations on days to 50% heading of cabbage. Where, c = cattle; cg = cattle + green groundnut, cp = cattle + poultry cpg = cattle + poultry + green groundnut; g = green groundnut; n = negative control; p = poultry; pg = poultry + green groundnut; z = positive control. Means followed by different letters are significantly different at 5% level of significance.

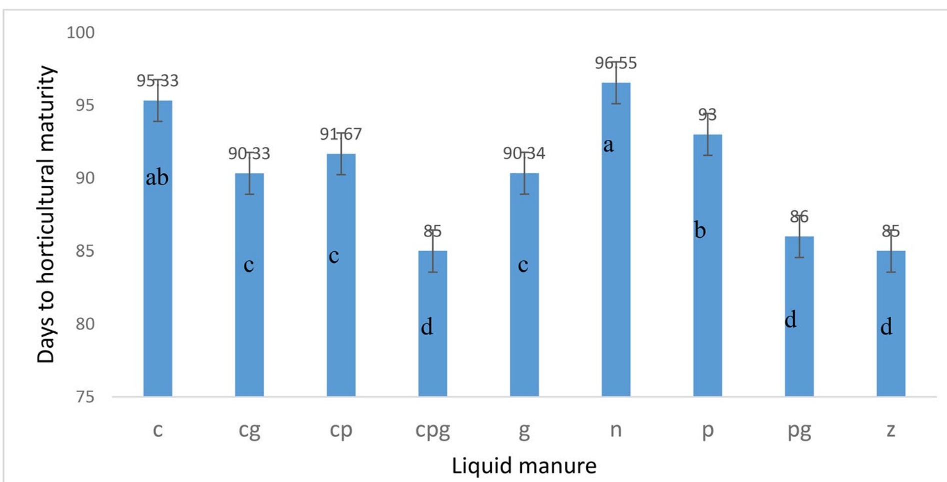

Figure 2. Effect of liquid organic manure types and their combinations on days to 50% horticultural maturity of cabbage. Where, c = cattle; cg = cattle + green groundnut, cp = cattle + poultry cpg = cattle + poultry + green groundnut; g = green groundnut; n = negative control; p = poultry; pg = poultry + green groundnut; z = positive control. Means followed by different letters are significantly different at 5% level of significance.

3.2. Days to horticultural maturity

Significant differences existed between the treatments in the number of days to horticultural maturity ($p < 0.05$), as shown in Figure 2. The negative control (n) took the longest time to horticultural maturity (96 days). This shows that the crop developed slowly in the absence of the application of liquid manure. There were no significant days to horticultural maturity differences between the untreated control crop and the crop treated with cattle liquid manure. The crop treated with cattle-poultry-green groundnut (cpg) liquid manure and the positive control (z) took the shortest time to horticultural maturity, 85 days, respectively. The time taken by cpg, z and pg (86 days) were not significantly different. The time to horticultural maturity taken by crops treated by cattle + green groundnut (cg) cattle-poultry (cp), green groundnut (g) and poultry (p) liquid manure was not significantly different but longer compared to cpg, z and pg treated crops.

3.3. Cabbage head weight

The mean weight of the cabbage was significantly affected by liquid manure types and their combination at 7, 11 and 14 weeks after transplanting growth stages ($p < 0.01$) as depicted in Figure 3. The highest mean head weights were obtained from the crops treated with cattle-poultry-green groundnut (cpg) liquid manure and the positive control at week seven after transplanting, implying that these treatments supported the best biomass production at the early stage of cabbage growth. There were no significant mean head weight differences between cpg treated and the positive control crops. However, the mean cabbage head weight of these crops was significantly different from that of double combination treatments, i.e. cattle-green groundnut (cg), cattle-poultry (cp) and poultry-green groundnut (pg) liquid manure, and single liquid manure treatments (cattle, poultry and green groundnut liquid manure). The lower head weights were obtained from the negative control crops and crops treated with single liquid manures, i.e. cattle (c), poultry (p), and green groundnut (g) liquid manures. There were no significant head weight differences between c, p, g and the untreated control treatments. The absence of significant head weight differences among the crops treated with single liquid manure and the negative control treatments suggest that these treatments failed to promote early cabbage growth.

The cattle-poultry-green groundnut (cpg) and poultry-green groundnut (pg) combination treatments and the positive control had the highest mean cabbage head weight at week 11 after transplanting. The mean head weight of the cpg and pg treated and the positive control crops was not significantly different, but significantly larger compared to c, cg, cp, g, p treated and the negative control crops.

The negative control and cattle liquid manure treatments had the lowest mean cabbage head weight, implying that these combinations promoted least biomass production. Again, there were no significant mean head weight difference between cattle manure and the negative control treatment crops. The mean cabbage head weight of crops treated with cg, cp, g and p liquid manure were not significantly different but, significantly lower compared to cpg, pg and the positive control plants, and significantly higher compared to negative control and cattle liquid manure treated crops.

The cattle-poultry-green groundnut (cpg) and positive control (pg) treatments had the highest mean cabbage head weight after 14 weeks from planting. There was no significant mean cabbage head weight difference between these treatments. The negative control (1.59 kg) and cattle liquid manure (2.1 kg) had the least mean cabbage head weight and the mean cabbage head weight of these treatments was not

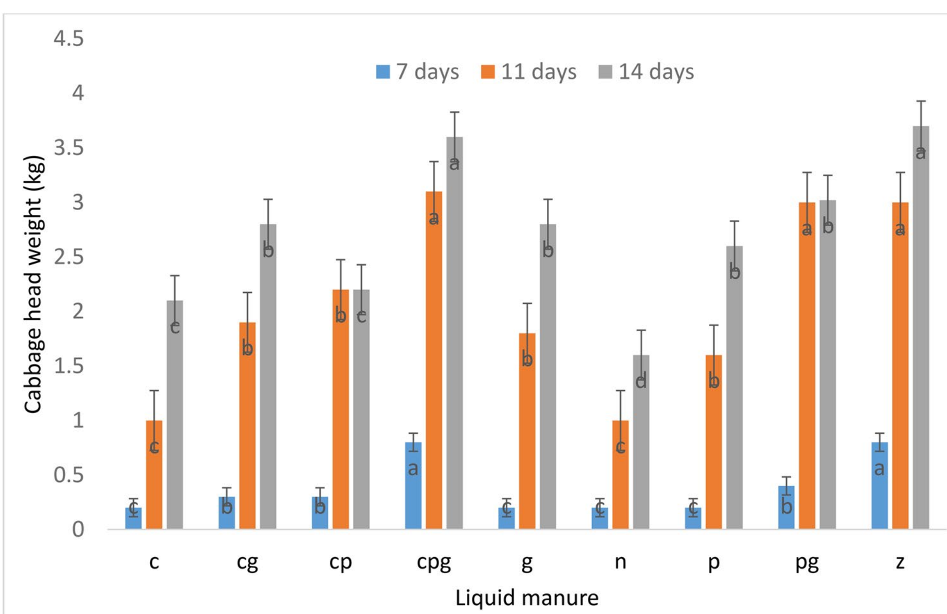

Figure 3. Effect of liquid organic manure types and their combinations on cabbage head weight at 7, 11, and 14 weeks after transplanting. Where, c = cattle; cg = cattle + green groundnut, cp = cattle + poultry cpg = cattle + poultry + green groundnut; g = green groundnut; n = negative control; p = poultry; pg = poultry + green groundnut; z = positive control. Means followed by different letters are significantly different at 5% level of significance.

significantly different. The mean cabbage head weight of crops treated with cg,cp, g and p were nit significantly different but significantly lower compared tp the positive control and cpg treated crops and significantly high compared to negative control and cattle liquid manure treated crops.

3.4. Head diameter

Different liquid manure and their combinations treatments significantly affected the cabbage head diameter ($p < 0.05$. The cattle-poultry- green groundnut liquid manure (cpg, 26 cm), poultry- green groundnut (pg, 24 cm) and the positive control (25 cm) treatments resulted in the large cabbage head diameter and the cabbage head diameter of these treatments were not significantly different (Figure 4). The negative control (10 mm) and cattle liquid manure (c, 12.33 mm) treatments had significantly smaller cabbage head diameter compared to cpg, positive control, pg, cattle-green groundnut (cg), cattle-poultry (cp), green-groundnut (g) and poultry (p) liquid manure. The cabbage head diameter for crops treated with cp, g and p liquid manure were not significantly different, but significantly lower compared to cg, cpg, pg and the positive control treatment crops and higher compared to negative control and c treatment crops.

4. Discussion

The results of this study clearly indicate that application of cattle, poultry liquid manure, and green groundnut teas and their combinations significantly improved cabbage growth, development and yield. The negative control treatment, which did not receive any fertiliser input, showed delayed heading, delayed horticultural maturity, reduced head diameter and the minimum head weight. This is an indication of nutrient limitation, particularly nitrogen, which is essential for vegetative growth and biomass development of cabbage (Singh et al., 2023). The lack of fertiliser input might have limited nutrient availability, photosynthetic activity, and overall crop growth, as observed in unfertilised crops where inadequate nutrient supply reduces vegetative development and biomass accumulation (Davis et al., 2019).

On the other hand, the positive control treatment, which received Compound C and ammonium nitrate fertiliser at recommended rates, showed comparable results with the best-performing liquid manure combinations with respect to early heading (Figure 1) and days to maturity (Figure 2) of cabbage. This is an indication of the effectiveness of mineral fertilisers in providing nutrients, particularly

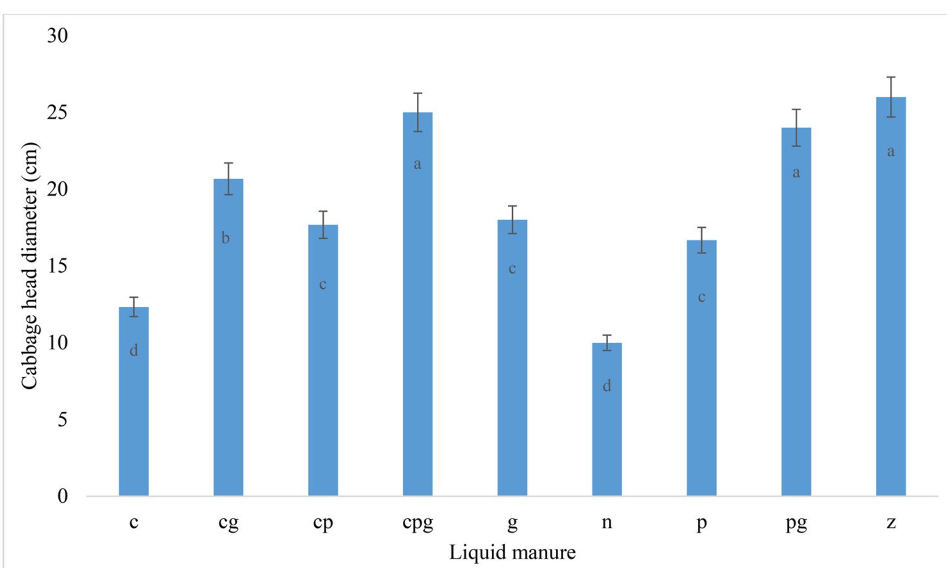

Figure 4. Effect of different liquid organic manure types and their combinations on cabbage head diameter at physiological maturity. Where, c = cattle; cg = cattle + green groundnut, cp = cattle + poultry cpg = cattle + poultry + green groundnut; g = green groundnut; n = negative control; p = poultry; pg = poultry + green groundnut; z = positive control. Means followed by different letters are significantly different at 5% level of significance.

nitrogen, phosphorus, and potassium, which are essential for vegetative growth of cabbage (Zhang et al., 2025). The comparable results of the positive control treatment with liquid manure combinations, such as a combination of poultry and green groundnut and cattle, poultry and green groundnut manure, suggest that organic liquid manure combinations are as effective as mineral fertilisers in promoting cabbage productivity.

A combination of cattle, poultry and green groundnut liquid manure treatment consistently gave the best results for all parameters, including days to heading, days to horticultural maturity, head diameter and cabbage head weight. This can be attributed to the combination of nutrient composition of each of the liquid manure components. Poultry manure, for example, is a rich source of readily nitrogen and phosphorus, while cattle manure contributes organic matter, thereby improving the physical properties of the soil. Green groundnut liquid manure contribute to improved crop performance primarily through mineralisation of organic nitrogen compounds extracted during the fermentation process (Wu et al., 2025).

The poultry-green groundnut liquid manure treatment also gave outstanding results, comparable to those obtained with the cattle-poultry-green groundnut liquid manure treatment for parameters such as days to heading and cabbage head weight. This indicates that cattle manure, although useful in improving the physical properties of the soil, may not be necessary for optimal crop yield, as seen with the other treatment options. Similar results have also been reported in other studies, where a combination of poultry manure and legume residues significantly improved cabbage growth and yield due to improved nitrogen availability and improved nutrient synchronisation (Singh et al., 2023; Nguyen & Gupta, 2020).

The single-source liquid manures, such as cattle, poultry, and green groundnut liquid manure, exhibited intermediate performance. Poultry liquid manure always performed better than cattle liquid manure, which recorded some of the lowest values among fertilised treatments. This result is in line with previous studies, which reported that cattle manure tends to contain fewer immediately available nutrients due to nutrient losses during storage and slower mineralisation rates (Shivran et al., 2025). Green groundnut liquid manure exhibited strong early growth responses but failed to maintain similar performance during later stages, which implies that while legume based liquid manures contain nitrogen, they probably lack enough phosphorus to support late stage biomass growth and head formation (Lee et al., 2025).

The observed differences in days to heading and physiological maturity further reinforce the significance of nutrient balance. The treatments involving integrated nutrient sources attained heading and maturity earlier than the negative control and cattle manure treatments. This shows that the treatments involving integrated nutrient sources promoted higher metabolic activity and hence, faster canopy development. This is particularly advantageous in cabbage growth, as early maturity reduces the crop's time of exposure to pests and environmental stress, allowing for earlier harvesting (Davis et al., 2019).

The results of this study reveal that integrated liquid manure systems, such as those involving a combination of poultry and green groundnut, with or without cattle manure, have the potential to function effectively as alternatives to inorganic fertilisers. Not only did these treatments improve yield and growth parameters, but they also performed equally well when compared to recommended mineral fertilisers. This finding is in line with the results of other studies showing that organic liquid fertilisers have the potential to play a role in the development of sustainable vegetable growth, improving nutrient availability and potentially enhancing soil health (Lee et al., 2025; Singh et al., 2023).

5. Conclusion

The conclusion drawn from the study is that liquid manure type and combination significantly impact cabbage growth and yield, The negative control, which did not receive any fertiliser input, recorded the poorest performance in all parameters. The positive control, which received Compound C and ammonium nitrate at recommended application rates, recorded good performance but similar to that of the best performing liquid manure combinations. The cattle-poultry-green groundnut liquid manure recorded the best performance in terms of cabbage head weight, head diameter and time to heading and horticultural maturity. The second best, which recorded no statistically significant difference from cattle-poultry-green groundnut treatment was poultry-green groundnut liquid manure. The result shows that organic liquid manure can effectively replace inorganic fertiliser in cabbage production.

6. Recommendations

Based on the findings from this study, it is recommended that farmers use cattle-poultry-green groundnut liquid manure in cabbage production to improve cabbage yield while hastening maturity. In cases where cattle manure is not readily available or is in short supply, poultry-green groundnut liquid manure can be recommended as an alternative.

The use of liquid manure combinations is particularly relevant to smallholder resource-constrained farmers, especially where access to inorganic fertilisers is limited or expensive. The use of integrated liquid manure systems would be beneficial to improving soil fertility while maintaining high cabbage yield levels. Again, the use of liquid manure promote sustainable farming practices such as organic farming which discourage the use of synthetic inputs.

7. Future areas of study

Future studies should include detailed chemical characterization to better quantify nutrient contributions of each manure type. Again, further research should assess the effects of repeated application of liquid manure on soil properties. Furthermore, further research may seek to assess the economic viability of liquid manure, especially where conventional inorganic fertilisers are used.

Acknowledgments

Mandhlenkosi Zhou conducted the research and did the writing of the original draft. Zivanayi Musabayana, Ndabanye Mathema, Lenon Tembo and Pesanai Zanamwe supervised, analysed data, interpreted results and edited the draft.

Author contributions

CRediT: **Mandhlenkosi Zhou**: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing; **Zivanayi Musabayana**: Supervision, Writing – review & editing; **Ndabanye Mathema**: Supervision, Writing – review & editing; **Lenon Tembo**: Supervision, Writing – review & editing; **Pesanai Zanamwe**: Supervision, Writing – review & editing.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

No funding was received for the study.

ORCID

Mandhlenkosi Zhou http://orcid.org/0009-0004-7155-6601
Zivanayi Musabayana http://orcid.org/0009-0003-3701-2101
Lenon Tembo http://orcid.org/0009-0008-4363-4894
Ndabanye Mathema http://orcid.org/0000-0002-5722-2160
Pesanai Zanamwe http://orcid.org/0000-0001-6011-2416

Data availability statement

Data will be made available upon request

References

Al-Kaisi, M. M., Lal, R., & Singh, B. R. (2023). Soil fertility and nutrient management for sustainable crop production. *Soil Science Society of America Journal*, *87*(2), 345–360. https://doi.org/10.1002/saj2.20451

Carter, M. R., & Lee, H. (2021). Organic farming systems and soil fertility management. *Renewable Agriculture and Food Systems*, *36*(3), 225–234. https://doi.org/10.1017/S1742170520000354

Davis, J. G., Nelson, P. V., & Sanders, D. C. (2019). Nutrient requirements of cabbage and other Brassica vegetables. *Horticultural Science*, *54*(5), 789–796. https://doi.org/10.21273/HORTSCI13975-19

Davis, J. G., & Kaisi, M. (2023). Effects of organic nutrient sources on soil health and crop resistance to pests and diseases. *Journal of Sustainable Agriculture*, *45*(1), 88–101. https://doi.org/10.1080/10440046.2022.2135679

Debele, T. (2021). Integrated soil fertility management and crop productivity: A review. *International Journal of Agronomy*, *2021*, 6696784. https://doi.org/10.1155/2021/6696784

Food and Agriculture Organization of the United Nations. (2021). *Agroecological practices for sustainable agriculture in sub-Saharan Africa*. FAO.

Hao, X., Li, Y., Zhang, Q., Chen, W., & Wu, J. (2023). Combined application of organic and inorganic amendments improves yield and biomass production. *Agronomy*, *13*(4), 896. https://doi.org/10.3390/agronomy13040896

Kumar, R., Singh, A., & Patel, D. (2022). Liquid organic fertilizers: Composition, application and effects on crop productivity. *Journal of Plant Nutrition*, *45*(9), 1345–1358. https://doi.org/10.1080/01904167.2021.2012385

Lal, R. (2020). Managing soils for sustainable agriculture and climate resilience. *Soil and Tillage Research*, *204*, 104731. https://doi.org/10.1016/j.still.2020.104731

Lee, J., Jo, N.-Y., Shim, S.-Y., Le, T. Y. L., Jeong, W. Y., Kwak, K. W., Choi, H. S., Lee, B.-O., Kim, S.-R., Lee, M.-G., & Hwang, S.-G. (2025). Impact of organic liquid fertilizer on plant growth of Chinese cabbage and soil bacterial communities. *Scientific Reports*, *15*(1)Article, 10439. https://doi.org/10.1038/s41598-025-95327-w

Maboko, M. M., & Du Plooy, C. P. (2021). Growth and nutrient uptake of cabbage under different fertility regimes. *South African Journal of Plant and Soil*, *38*(4), 289–296. https://doi.org/10.1080/02571862.2021.1889024

Moyo, S., Nyamapfene, K., & Mapfumo, P. (2020). Soil fertility challenges in smallholder vegetable production systems in Zimbabwe. *African Journal of Agricultural Research*, *15*(8), 1124–1133. https://doi.org/10.5897/AJAR2020.14892

Muktamar, Z., Lifia, L., & Adiprasetyo, T. (2020). Phosphorus availability as affected by the application of organic amendments in Ultisols. *SAINS TANAH - Journal of Soil Science and Agroclimatology*, *17*(1), 16. https://doi.org/10.20961/stjssa.v17i1.41284

Nguyen, T. T., & Gupta, R. K. (2020). Organic manures and their role in improving soil healthand crop productivity. *Soil Use and Management*, *36*(2), 237–248. https://doi.org/10.1111/sum.12562

Parker, D., & West, H. (2022). Macronutrient and micronutrient dynamics in organic and inorganic fertilization systems. *Nutrient Cycling in Agroecosystems*, *123*(3), 391–405. https://doi.org/10.1007/s10705-022-10226-9

Ravi, S., Reddy, M. S., & Kumar, P. (2021). Liquid organic manures for sustainable crop production in arid and semi-arid regions. *Agricultural Water Management*, *250*, 106842. https://doi.org/10.1016/j.agwat.2021.106842

Shivran, U., Lakhawat, S. S., & Kumari, M. (2025). Effect of Organic Manure on Nutrient Content of Cabbage Head (Brassica oleracea var. capitata). *International Journal of Plant & Soil Science*, *37*(5), 10–13. https://doi.org/10.9734/ijpss/2025/v37i55423

Singh, H., Kumar, R., & Patel, S. (2023). Effect of organic manure and biofertilizer on growth, yield and quality in cabbage. *International Journal of Environment and Climate Change*, *13*(5), 112–123. https://doi.org/10.9734/IJECC/2023/v13i51716

Wu, L., Hu, J., Shaaban, M., Wang, J., Liu, K., Xu, M., & Zhang, W. (2025). Long-term manure amendment enhances nitrogen mineralization and nutrient availability in soils. *Journal of Integrative Agriculture*, *25*(1), 262–272.

Zhang, C., Zhang, Y., Wang, X. X., Zhang, J., Li, H., Zhang, R., & Zhang, J. (2025). Optimizing water and organic fertilizer use to enhance seedling growth and soil health in Chinese cabbage (*Brassica rapa* spp. *pekinensis)* cultivation. *BMC Plant Biology*, *25*(1), 1757. https://doi.org/10.1186/s12870-025-07620-5