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Original Article

Optimizing Organic Agriculture: Poultry manure dominates in enhancing germination and growth of common beans in Tanzania's semi-arid environment

Kelvin Ngongolo* and Doreen Mrimi

Department of Biology, University of Dodoma, Benjamin, Mkapa Road, 41218 Iyumbu, Dodoma

Abstract

The study aimed to investigate the impact of different organic manures on the germination and growth performance of common beans (Phaseolus vulgaris L.) in Tanzania's semi-arid region. Despite the widespread cultivation of common beans, limited research addresses the specific effects of diverse manure types on their germination and growth in this region. The primary objective is to assess and compare the influence of cow dung, poultry manure, rabbit manure, and a control (no manure) on common bean germination and growth. Understanding how different manure categories affect beans is crucial for optimizing agricultural practices in semi-arid environments. A randomized block design was employed with four treatments (cow dung, poultry manure, rabbit manure, and control), each replicated three times. Common bean seeds were planted, and growth parameters, including plant height, leaf width, and leaf length, were measured. Data were analyzed using the Kruskal-Wallis test and generalized linear models. Poultry manure consistently outperformed other categories, significantly enhancing bean germination and growth ($p < 0.05$). The association between manure types and total germinated seeds was positive, with poultry and cow manures showing the most significant impact ($P < 0.05$). Growth performance, especially plant height, demonstrated significant associations with manure type, plant parts' growth, time intervals, and distance from the bush. Poultry manure emerged as the most effective in promoting common bean germination and growth. The study highlights the need for tailored agricultural practices considering the diversity in manure effects. It suggests promoting organic farming practices, with an emphasis on poultry manure. Further research is encouraged to explore broader impacts on various crops. Educational initiatives are recommended to disseminate knowledge about organic manure benefits, and policy support is advocated to enhance soil fertility, crop yield, and environmental sustainability in Tanzanian agriculture.

Keywords: bean productivity, germination performance, poultry manure

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Introduction

The common bean (Phaseolus vulgaris L.), originating from ancient Mesoamerica and the Andes (Palilo et al., 2018), is extensively cultivated in Tanzania for its edible beans, leaves, and straw. Various common bean varieties, such as Masusu, Uyole-96, Kablanketi, Kasukanywele, Wanja, Wanja-small, Mwasipenjele, and Kabanima, are prevalent in Tanzania (Palilo et al., 2018). Efficient production and management of beans in cultivated areas are crucial to ensure maximum yields, benefiting both farmers and stakeholders in the production chain. A study conducted in Rombo and Moshi, Tanzania, revealed the significant impact of inoculation with (brady) rhizobial and fertilization with different nutrients like N and P supply on the production of common beans (Phaseolus vulgaris) and soybeans (Glycine max) (Ndakidemi et al., 2006). Despite these findings, there has been limited research in Tanzania to comprehend how the supply of different manure categories can influence the germination and growth performance of common beans (Phaseolus vulgaris L.) in semi-arid regions like Tanzania.

Organic manure from cow, poultry, and rabbit sources enhances soil fertility, improves structure, and sustains plant growth. Rich in essential nutrients, it fosters microbial activity, promotes water retention, and reduces environmental impact. Its slow nutrient release, carbon sequestration, and cost-effectiveness contribute to sustainable agriculture, fostering biodiversity and mitigating climate change. Additional investigations have demonstrated compelling evidence supporting the positive effects of manure on soil quality and crop growth (Rayne & Aula, 2020). Nevertheless, the extent of these impacts is contingent upon the inherent physical and chemical properties of the manure, as well as diverse factors such as application rate and timing, soil composition, and climatic conditions (Rayne & Aula, 2020).

In 2018, compared to the previous year, various treatments, including Control, rabbit manure, cow dung, poultry manure, green manure, pig manure, and NPK fertilizer, increased okra pod yield by different percentages. Poultry manure stood out among organic options, showing superior results in plant growth, yield, and the mineral and proximate composition of okra. This superiority was linked to its favorable soil chemical properties, including the lowest C: N ratio, lignin, and lignin: N ratio (Adekiya et al., 2020).

In Tanzania, more studies need to be conducted to understand the beneficial effects organic manure has on the production of common beans (Phaseolus vulgaris L.) in terms of germination and growth performance.

Several factors influence the germination and growth performance of beans, including soil quality, moisture levels, temperature, and light. Bean varieties, seed quality, and planting depth also play crucial roles. Additionally, the presence of pests, diseases, and nutrient availability significantly impacts the overall germination

*Corresponding Author:
Kelvin Ngongolo
Department of Biology, University of Dodoma, Benjamin Mkapa Road, 41218 Iyumbu, Dodoma
E-mail: kelvinkngongolo@yahoo.com or kelvin.ngongolo@udom.ac.tz

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and growth success of beans. Among the nutrients that affect the growth and germination performance of beans are those found in organic manures such as poultry, cow dung, and rabbit manure. This study emphasizes assessing the effects of different manure types on the germination and growth performance of common beans (Phaseolus vulgaris L.) in the Dodoma semi-arid region. As the world transitions to organic farming, understanding the performance of different manures is essential to ensure sustainable agriculture.

Methods

Study area

The investigation was conducted in March 2021 at the College of Natural and Mathematical Sciences, University of Dodoma, situated in the semi-arid Dodoma region. Characterized by a dry season rendering the bush leafless and dry, the area transforms into a vibrant green landscape during the rainy season. Woodlands dominate the region, particularly in hilly areas, featuring dry savanna shrub-thicket regions with scattered trees and grassland patches interspersed with trees and shrubs (Kayombo et al., 2020; Ngongolo & Mmbaga, 2022). Indigenous plant species include Bussea massaiensis, Commiphora coerulea, C. ugogensis, C. africana, Acacia tortilis, A. senegal, Maerua decumbens, Combretum apiculatum, Grewia forbesii, Brachystegia spiciformis, Sclerocarrya birrea, Julbernardia globiflora, Delonix elata, Markhamia acuminate, Euphorbia candelabrum, and Terminalia sericea, complemented by exotics like Peltophorum pterocarpum and Tamarindus indica (Kayombo et al., 2020). The research site is positioned at a latitude range of 6° 57′ to 3° 82′ and a longitude range of 36° 26′ to 35° 26′, with an elevation estimated at 1120 meters above sea level. This location represents a semi-arid region characterized by sandy loam soil classified as Oxisol. The average annual rainfall in the area is recorded at 447 mm (Ngongolo & Kilonzo, 2022). Temperatures fluctuate seasonally, with average minimum and maximum temperatures of 180C to 320C respectively (Ngongolo & Kilonzo, 2022).

Research design & experimental set-up

The experimental design employed in this study was a completely randomized block design (CRBD) with four treatments (cow dung (CD), poultry manure (PM), rabbit manure (RM), and no manure (NM or Control)), each replicated three times. Common bean (Phaseolus vulgaris L.) seeds were planted in a meticulously prepared seedbed for germination. The planting was organized into three blocks (Block I, II, and III), positioned at distances of 2.5, 2, and 1 m away from the bush, respectively. Each block comprised four equally sized plots, each measuring 2 × 2 m.

Plants were strategically spaced at 20 cm intervals, each hole receiving a single seed placed at a depth of 3–5 cm. This aligns with the recommended spacing of 20–30 cm apart, allowing for optimal growth. Additionally, the option of placing up to three seeds per hole at the same depth was considered(Salcedo, 2008). In each seed bed, two rows, each containing five holes spaced at intervals of 20 cm, were prepared. To prevent the influence of one block on its neighbors (similarly for the plots within each block), a 1-meter gap was maintained between them, following the suggestion by Clewer & Scarisbrick (2001). Consequently, 10 seeds were planted per plot, resulting in a total of 40 seeds across the four treatments.

Subsequent to seed planting, daily watering ensured adequate moisture for seedling development and plant growth, with each session delivering 6 mm of water. In the same conditions, 0.5 kg (500g) of each used bio-fertilizer (organic manure) was measured using a triple beam balance, mixed with the soil to expedite the process before seed sowing. Manure undergoes a 3-month maturation process before application as fertilizer. This intentional duration facilitates the breakdown of organic matter, ensuring that nutrients are transformed into a readily usable form for plants and crops. The reported C:N ratio for poultry manure (PM) is 7:1, rabbit manure (RM) is 6:1, and cow dung is 15:1 (Janssen, 1996). Germination and growth were closely monitored, with the number of germinated seeds recorded from day one of planting. The growth performance observation commenced immediately after the first observed day of germination and continued for seven consecutive days.

In terms of germination, monitoring spanned 12 days for the 40 planted seeds, treating each observation per seed as a sample (n=480). Simultaneously, growth performance monitoring commenced on the day of the first germination and continued for seven consecutive days. The authors hypothesized that the carbon-to-nitrogen (C:N) ratio in Cow dung (CD), Rabbit manure (RM), and Poultry manure (PM) could be a significant factor influencing the germination of Phaseolus vulgaris L beyond the commonly recognized essentials like water, air, temperature, and light. The reported C:N ratios for these manures (7:1 for PM, 6:1 for RM, and 15:1 for CD) suggest that the balance of carbon and nitrogen content in the soil amendment might play a crucial role in affecting the germination process.

Data collection for germination performance

In each plot, the number of seed germinated were counted and recorded. In addition, the manure applied in the plots were recorded. Observation was done from the day they were planted until day 12 after planting. The time interval was classified into three which are, Early germination (1-4days), Mid germination (5-8 days), and late germination (9-12 days).

Data collection growth performance

The growth performance of the common bean (Phaseolus vulgaris L.) was determined by measuring the following variables; Plant height (cm), Leaf width(cm), Leaf length (cm), and number of leaves. The categories of manure to which the plants are growing was taken and recorded.

Data analysis

The data collected on the growth performance of Phaseolus vulgaris L, including leaf width, leaf length,

plant height, and the number of leaves under various manure types, underwent statistical analysis. The non-parametric Kruskal-Walli's test (H) was employed for this purpose. Additionally, generalized linear models (GLM) utilizing the 'lme4' package (version 1.1-28) in in R software (R Development Core Team 2023) with maximum likelihood estimation were employed to assess the impact of factors such as time interval and treatment (various manure types) on the growth performance of Phaseolus vulgaris L. Significance differences were considered at $P \leq 0.05$, and all analyses were conducted using R Studio Version 1.1.456.

Results

Germination of bean seed in the study plots

In the initial time interval, from day 1 to day 4, no seeds exhibited signs of germination. Germination initiated on the 5th day following seed sowing. On the fifth day, the plot utilizing rabbit manure had the maximum number of germinated seeds, with 2 (20%), while others had 1 (10%) germinated seed each, resulting in a total of 13 (8.13%) germinated seeds across four plots. The highest number of germinations occurred in the later time interval, between day 9 to 12, where the plot treated with cow manure had the most significant number, with 8 (80%) seeds germinating. Overall, poultry manure outperformed other manure categories, especially in the later time interval (see Figure 1). The variation in germination performance among the treatments during the mid-time interval (day 5 to day 8) was not statistically significant (Kruskal-Wallis test = 3.88, P = 0.25), while a significant variation was observed during the later time interval (Kruskal-Wallis test = 14.86, P = 0.002).

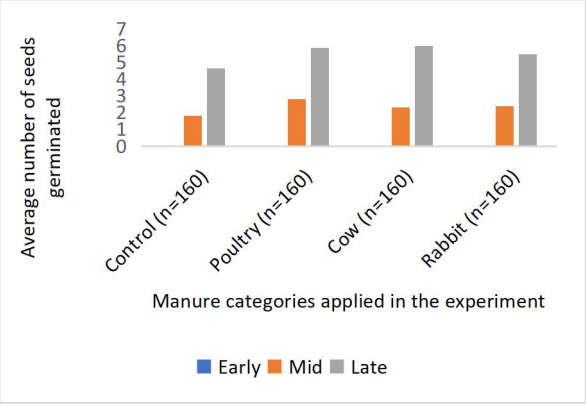

Figure 1. The germination performance of bean seeds across the treatments of different manure categories from 1st day to 12th day of monitoring

The association of the total germinated seed with different categories of manure

Significant association was observed to poultry and cow manure to influence the total number of germinated seed in study plots. The association was observed to be positive ($p<0.005$) (Table 1).

Growth performance under different categories of manure applied in the study area

Overall, growth performance, including plant height, leaf width, and leaf length, varied across different manure treatments and the control. Poultry manure exhibited the highest growth performance in bean plants. For instance, on day 7, the average growth included 69±11.16 in plant height, 12±0.71 cm in leaf width, 14.25±0.95 cm in leaf length, and 14.75±2.59 in the number of leaves, surpassing other manure treatments (Table 2).

Associations Between Plant Height and Other Variables, Such as Leaf Length, Width, and Manure Categories

Significant associations were observed between manure application and plant height. Poultry manure demonstrated a higher likelihood of height increase compared to other categories. The number of leaves and time interval also showed significant associations with plant height (Table 3).

Discussion

The application of organic manure is vital for soil health, crop production, and agro-ecological functioning. This study confirms that the use of organic manure is essential for the germination and growth performance of beans in semi-arid areas. Research conducted at Tezpur University in the north bank plain zone of Assam, India, investigated the impact of organic manure on the germination and growth of Okra. The findings indicated that plant height, root length, and leaf area were notably higher in vermicompost and biochar treatments than in farmyard manure.

The study highlighted that, in comparison to biochar, both vermicompost and farmyard manure significantly improved the germination and growth of Okra seedlings, with vermicompost demonstrating the most effective stimulation in the amended plots. Another study on the effects of composted swine manure on weed and corn demonstrated varying impacts on growth and nutrient uptake. Compost consistently improved corn height and leaf K concentration, but its influence on weed biomass and seed production differed among species, necessitating customized weed management strategies in corn production systems (Liebman et al., 2004).

Table 1. The association of the total germinated seed with different categories of manure

s/n	Variables	Coeff. Estimate	S.E	Z-Value	P-value
1	Intercept	-21.36	-3201.30	-0.007	0.99
2	Control	0.05	0.04	1.23	0.22
3	Poultry	0.21	0.05	4.60	4.15e-06 ***
4	Cow	0.09	0.04	2.41	0.0162 *
5	Rabbit	0.03	0.05	0.49	0.62

Table 2. Growth performance under different control treatment and time interval

S/n	Time interval	Treatments	Plant height (cm)	Leaf width(cm)	Leaf length (cm)	Number of leaves
1	Early (Day1-3), n=120	Control	6.98±0.45	5.29±0.51	6.25±0.54	3.17±0.42
2	Mid (Day 4-6), n=120	Control	10.17±0.66	5.92±0.36	7±0.33	5.42+0.42
3	Late (day 7), n=40	Control	31.63±7.83	6±0	6.5±0.19	8.38±0.96
4	Early (Day1-3), n=120	Cow	6.34±0.45	5.06±0.40	6.25±0.41	3±0.24
5	Mid (Day 4-6), n=120	Cow	8.83±0.45	5.83±0.40	7.25±0.41	5.08±0.27
6	Late (day 7), n=40	Cow	26.5±8.89	6.75±0.48	7.75±0.79	8±0.82
7	Early (Day1-3), n=120	Poultry	8.15±0.52	6.48±0.29	9.08±0.45	3.92±0.36
8	Mid (Day 4-6), n=120	Poultry	15.5±2.14	8.1±0.38	10.7±0.33	7.8±0.57
9	Late (day 7), n=40	Poultry	69±11.16	12±0.71	14.25±0.95	14.75±2.59
10	Early (Day1-3), n=120	Rabbit	5.36±0.34	5.02±0.37	6.27±0.38	3.09±0.25
11	Mid (Day 4-6), n=120	Rabbit	7.75±0.64	5.5±0.26	6.92±0.38	5.42±0.25
12	Late (day 7), n=40	Rabbit	19.75±9.16	6±0	6.75±0.25	9±0.71
13		Kruskal Wallis	17.57	31.04	91.63	116.1
14		P-Value	0.0005	3.775E-07	1.346E-17	4.057E-20

Germination of bean seed in the study plots

The germination of bean seeds was observed to perform best under poultry and cow manure when compared with other organic manures. This observation aligns with a study on the impact of organic manure and potting media on Eucalyptus torelliana F. Muell's germination and early growth, which found that poultry droppings, especially in large-sized polythene pots, significantly outperformed other treatments. This emphasizes their recommendation for optimal Eucalyptus torelliana F. Muell cultivation (Odunayo James et al., 2020). Another study explored the impact of cattle dung from farms with diverse feeding strategies on cress germination and initial root growth. Results showed varied effects linked to dung characteristics. While inhibitory effects were observed at specific concentrations, organic farming (ORGE) dung exhibited superior performance, suggesting potential agronomic distinctions in cow dung based on farming practices (Hoekstra et al., 2002).

The effectiveness of poultry manure lies in its rich nutrient content, featuring nitrogen, phosphorus, potassium, and organic matter. These components create an optimal environment for plant growth, with nitrogen stimulating leaf and stem growth, phosphorus supporting root development, and potassium facilitating crucial physiological processes. The organic matter enhances soil structure, water retention, and nutrient availability, fostering ideal conditions for germination and early growth (Oosterhuis et al., 2014). Similarly, cow dung, a natural organic fertilizer, is valued for promoting the germination of bean seeds. It supplies essential nutrients, enhances soil fertility, improves structure, and sustains gradual nutrient release, making it a preferred choice for supporting the initial stages of bean seed growth (Zörb et al., 2014).

Growth performance under different categories of manure

The poultry manure consistently outperformed other manure categories across varying time intervals. The superior growth performance of beans with poultry manure, compared to alternatives such as cow dung and rabbit manure, can be attributed to several factors. Poultry manure is rich in essential nutrients, including nitrogen, phosphorus, and potassium, along with organic matter (Zörb et al., 2014). These nutrients play a vital role in plant development, with nitrogen promoting robust leaf and stem growth, phosphorus supporting root development, and potassium contributing to overall physiological processes (Nicholson et al., 1996).

The balanced nutrient profile in poultry manure creates an optimal environment for bean growth, resulting in increased plant height, leaf length, and leaf width. Additionally, the organic matter in poultry manure enhances soil structure, water retention, and nutrient availability, providing sustained benefits to the beans throughout their growth stages. The specific composition and nutrient balance in poultry manure make it a more effective and favorable choice for promoting the growth of beans compared to other manure categories across varying time intervals (Mažeika et al., 2021).

Conclusion

The study elucidates the critical role of organic manure in the germination and growth performance of common beans (Phaseolus vulgaris L.) in the semi-arid region of Tanzania. Poultry manure demonstrated superior efficacy, fostering optimal growth in terms of plant height, leaf width, and leaf length. The positive impact of poultry manure can be attributed to its rich nutrient composition, including nitrogen, phosphorus, and potassium, along with organic matter, creating an ideal environment for plant development. The study underscores the need for further research in Tanzania to comprehensively understand the benefits of organic manure, considering its potential to contribute to sustainable agriculture

To promote organic farming, emphasize poultry manure for superior crop growth. Tailor practices based on diverse manure effects and crop needs. Advocate for additional research on different manure types' impacts, contributing to a comprehensive understanding of Tanzanian organic farming. Implement educational programs to disseminate knowledge and raise awareness about the benefits of organic manure, fostering sustainable agricultural practices. Encourage policy formulation supporting organic manure for its positive impact on soil fertility, crop yield, and environmental sustainability. This multifaceted approach aims to enhance agricultural practices, emphasizing adaptability, knowledge dissemination, and policy alignment for sustainable organic farming in Tanzania.

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Data availability

The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request at the Department of Biology in the University of Dodoma.

Disclosure of interest

The authors report no conflict of interest).

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