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Garden Egg (*Solanum melongena* L.) Performance under Different Sources of Animal Manure as a Sustainable Alternative Fertilizer for Farmers

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Abstract

To ensure food security, continuous intensive farming systems with limited fallowing periods and other farming systems like crop rotation have led to poor soil health with extremely low organic matter, especially in tropical regions with high organic matter mineralization. Small-scale farmers in developing countries cannot afford intensive agricultural systems with heavy chemical inputs, which have not improved soil health. Inorganic fertilizers are harmful to the environment, so farmers should use cheap, locally available organic fertilizers like animal manure, which supports organic agricultural systems and soil health. Animal manure is used as a soil amendment to improve soil health, fertility, and crop yields, but data on how different manures affect specific crops is scarce. Poultry, cattle, and goat manure were compared to no fertilizer and mineral fertilizer on garden egg phenology, vegetative growth, and yield. Poultry manure improved garden egg vegetative growth, phenology, yield, and yield components compared to the negative control and the other treatments. Poultry manure yielded the most fruit at 0.921 $kg \cdot ha^{-1}$, followed by cattle and goat manure at 0.709 $kg \cdot ha^{-1}$ and 0.698 $kg \cdot ha^{-1}$. In conclusion, poultry manure may be a better alternative to synthetic NPK with yield performance similar to garden eggs and long-term soil health benefits similar to other manure sources.

Keywords

Garden Eggs, Ghana, Organic Manure, Plant Phenology, Sustainability

1. Introduction

The current human population growth, urbanization, and the competition for farmland for other purposes have reduced farmland size [1]. Traditional and ancient systems such as crop rotation, fallow periods, and locally available organic soil amendments with enormous benefits [2] are replaced with more intensive cultivation systems that heavily depend on chemicals, which threaten both environmental and human health and have become unsustainably expensive for the growers to depend on. Excessive long-term application of chemical fertilizers leads to a negative effect on the ecosystem, such as nitrate leaching and phosphorus washing into water bodies causing adverse effects on aquatic ecosystems [3] [4]. The increasing cost of chemical fertilizers and negative attributes to soil has drawn attention to the use of alternatives fertilizers like organic fertilizer sources such as manure [5] [6] [7]. Organic resources, such as poultry manure, goat manure, cattle manure, and compost, with or without inorganic fertilizers, are one way to improve the nutrient status of soils [8].

Different types of organic manures such as poultry manure, cattle manure, goat manure, etc. have been used in agriculture for many years due to their mineral contents of nitrogen, phosphorus, and potassium (NPK) and could be good alternative fertilizer source for garden production in Ghana. Mpanga *et al.* [9] reported increase yield in garden eggs (*Solanum melongena* L.) fertilized with poultry manure compared to their control without fertilization and the effects was associated to mineral nutrition increases in the soil from poultry manure applications. Although the nutrients released from these organic sources are slow, they can create and sustain the ideal physical conditions for plant growth in the soil. Also, they are a less expensive and more effective source of plant nutrients and other micronutrients for long-term crop development. Organic fertilizers offer the advantage of improving soil organic matter, structure, chemical characteristics, microbial activity, and soil production [5] [7] [10] [11] [12]. Therefore, organic fertilizers, such as poultry manure, can be a viable alternative to inorganic fertilizers. Organic fertilizers are a less expensive way to improve soil fertility and are widely available. They are also vital for increasing soil microbial activities, enhancing the soil's moisture-holding capacity, and strengthening the soil structure [13].

Majority of farmers in Ghana engage in vegetable cultivation for their source of livelihood. Urban and peri-urban vegetable cultivation and marketing are critical to Ghana's socio-economic development because they supply raw materials to local food industries and fast-growing restaurants in the cities, resulting in employment growth, wealth creation, and poverty alleviation [14]. One of the major vegetable crops mostly grown is garden egg [15] [16] [17]. This crop is eaten almost daily by rural and urban households and constitute primary income source for a major rural family [16] [18]. The increasing cost of chemical fertilizers, the quest for a more environmentally sustainable alternative for long term benefits on soil health, and increasing demand for organically produced vegetable in Ghana calls for more investments into using manure sources for garden eggs and other vegetables productions. However, limited data exist on the how different garden eggs perform under different sources of manure in comparison to both negative (no fertilization and positive control (standard business as usual with chemical fertilizer application).

This study investigated the most appropriate type of animal manure source could be a close substitute or complement chemical fertilizers in the cultivating garden eggs. In addition, the study hypothesized no differences in animal manure application on garden eggs' vegetative growth, phenology, and yield.

2. Materials and Methods

2.1. Study Period and Location

Two field experiments were conducted on land near the Catholic University College of Ghana at Fiapre in the Sunyani West Municipality from August 2019 to May 2020. The municipality is located between latitudes 7˚19N and 7˚35N and longitudes 2˚08W and 2˚31W. It is bounded on the northeast by Wenchi Municipality, on the north by Tain District, on the west by Berekum Municipality, and on the south by Sunyani Municipality. The Sunyani West Municipality has a total land area of 1658.7 square kilometers [19]. It falls within the dry semi-deciduous forest zone and semi-equatorial climate zone, with an average monthly rainfall of 453 mm in October 2020 and an average temperature of 24˚C. It has Chromic Luvisol (forest Ochrosol) soils according to the FAO/UNESCO classification system. Therefore, it is ideal for cultivating cocoyam, maize, cassava, cocoa, plantain, yam, and vegetables.

2.2. Experimental Design and Treatments

The Treatments [poultry manure (PM), cattle manure (CM), goat manure (GM), positive control (NPK), and the no fertilizer (NF)] application were evaluated in a Randomized Complete Block Design with three replicates.

2.3. Land Preparation, Nutrient Composition, and Application Rates

The field was prepared by slashing the vegetation with a cutlass and then hoeing to loosen the soil. Each block was divided into plots of 4 m × 3 m (12 m^2) in size, with 1 m between plots and 2 m between blocks. The poultry manure, cattle manure, and goat manure were obtained locally from "Boadum" livestock farm in Sunyani. Dry ashing method, as described by Piper [20], was used to extract the percentages of Nitrogen from the various manure samples. They had N composition of 3.25%, 1.46%, and 2.16%, respectively. The N rate of 207 kg·N per ha was used to calculate the quantity of fresh manure required for each manure source. Manure was applied by hand and incorporated immediately using a hand-held rake. The application rate of fresh organic manure applied is shown in **Table 1** below:

Table 1. Application rate of fresh organic manure.

Rate per hectare			Rate per plot (12 m^2)		
Poultry Manure	Cattle manure	Goat manure	Poultry Manure	Cattle manure	Goat manure
6369.2 kg	14178.1 kg	9583.3 kg	7.64 kg	17.01 kg	11.50 kg

2.4. Nursery Establishment and Transplanting

A nursery bed of 2 m × 1.2 m was used to raise garden egg seedlings using a local variety called "Ntrowa Pa", which was obtained locally from a certified agricultural inputs dealer (Farmers Link Agrochemicals, Sunyani, Ghana). The seeds were thinly sown in rows 15 cm apart, mulched, and watered until they germinated. After germination, the mulches were removed and replaced with a shade of palm fronds over the nursery beds to protect the young seedlings from direct sunlight. Two weeks after germination, the seedlings were thinned to avoid overcrowding and to ensure healthy seedlings. The seedlings were watered as needed to supplement the rain until they reached the desired transplanting stage of four weeks. At four weeks, the seedlings were hardened off for two days by reducing the amount and frequency of watering. The shade was completely removed by week three to prepare them for the harsh field conditions. Before transplanting, the seedlings were thoroughly watered to soften the soil and allow for easy lifting of seedlings with a ball of earth around their roots. The seedlings were transplanted at 75 cm × 50 cm spacing with a total of forty (40) plants per plot size of 12 m^2 (24 plants in harvest area) and thoroughly watered afterwards.

2.5. Cultural Practices

The plots were weeded by hoeing, three times to prevent weeds from competing with the crops for nutrients, sunlight, and water. The plants were also watered on a regular basis. The plants were also sprayed with an insecticide [Lambda, 2.5%, Cyhalothrin, 20% Alkyl Benzene sulphonate, 57% Alkyl Benzene ethoxylate and 23% solvents (Methanol Isobutanol and Aromex 23%)] obtained from the Department of Agriculture, Berekum East Municipal Assembly at the rate of 100 ml per 15 L of water from day 21 after planting (DAP) at two weeks interval to prevent and control insect-pest attack. Throughout the study, no significant disease was observed in the field.

2.6. Data Collection

2.6.1. Analysis of Soil Samples

Before the experiment began, each plot had surface (0 - 20 cm) soil samples collected. The samples were bulked and air-dried, as Zublena *et al.* [21] described for further analysis. The Walkley-Black dichromate digestion method [22] was used to estimate organic matter, while the Kjeldahl method was used to determine total soil nitrogen [23]. The Bray-1 method was used to determine the amount of available P [24]. Ammonium acetate was used to extract exchangeable K^+, Ca^{2+}, and Mg^{2+}. The flame photometer was used to determine potassium, while EDTA titration was used to quantify Ca and Mg. Finally, a glass electrode was used to determine the pH of the soil in 0.01 M $CaCl_2$. The Physico-chemical soil properties of the study location are presented in **Table 2** below.

2.6.2. Analysis of Manures

Dry ashing method, as described by Piper [20], was used to extract the percentages of Nitrogen from the various manure samples. Samples of ground manure were air-dried, then sieved through a 2 mm sieve before being burned at 450˚C for 2 hours to remove the ash. Organic matter (O.M) was determined using the Walkley-Black dichromate digestion method [22], and total nitrogen was calculated using the Kjeldahl method [23]. The ammonium molydate/ammonium vanadate technique was used to determine the phosphorus content. Potassium was determined using a flame photometer, while Ca and Mg were quantified using EDTA titration. Finally, the pH of 0.01 M $CaCl_2$ was determined using a glass electrode. The composition of Nitrogen after analysis of the 3 manure samples is shown in **Table 3**.

2.6.3. Plant Data

All fieldwork for the two seasons used the same procedures, methods, and equipment to collect data for the same parameters. The percentage of each plot in which plants have established was calculated at 21 DAP by counting the number of plants in each plot. A meter rule was used to measure the height of four randomly chosen plants from the middle three rows of each plot. The height of each plot's plants was measured from the soil up to the highest leaf, and then averaged. The average number of leaves per plant was calculated by counting the leaves of the four plants selected for this study. After counting the number of branches on each of the four plants, an average was calculated. A vernier caliper was used to measure the stem diameter of four randomly selected

Table 2. Physico-chemical soil properties of the study location.

Experiment	Soil Texture	Soil pH	Organic Carbon (%)	Organic Matter (%)	Total N (g/kg)	Available P (mg/kg)	Available K (mg/kg)
2019 Minor season	Sandy loam	5.5	1.08	1.85	1.2	5.32	65.30
2020 Major season	Sandy loam	5.7	1.78	1.78	1.5	5.21	70.37

Source: Council for Scientific and Industrial Research-Soil Research Institute (CSIR-SRI), Kwadaso, Kumasi, Ghana.

Table 3. Percentage Nitrogen of the 3 organic manures.

Organic manure	Poultry manure	Cattle manure	Goat manure
Percentage Nitrogen	3.25	1.46	2.16

plants from each plot. Four plants were counted in each plot, and their average was taken. A meter rule was used to measure the canopy width of the four plants chosen, and an average was then calculated for each plot. Four new plants were taken from the middle two rows, wrapped in foil, and dried in a 75˚C oven for 48 hours. The dry weight was determined with the help of a digital scale.

2.6.4. Plant Establishment, Days to 50% Flowering, Days to 50% Fruiting, and Days to Fruiting

The percentage of plants on each plot 21 days after transplanting was used to calculate plant establishment. Days to 50% flowering were obtained by counting the days after transplanting till 50% of plants in the harvest area of the various plots had flowers. The days to 50% fruiting were obtained by counting the days after transplanting till 50% of plants in the harvest area of the various plots had fruits. Days to fruiting were obtained by counting the days after transplanting till 50% of plants in the harvest area of the various plots were first harvested.

2.6.5. Fruit Data

Each plot's total harvest was calculated by counting the number of fruits collected from that plot alone. We weighed, recorded, and converted the fruit yield from each plot's plants to kilograms per hectare. Vernier calipers were used to measure the length and width of five randomly selected fruit samples from each plot. After that, the averages were calculated and recorded.

2.6.6. Data Analysis

The statistical software SAS was used to run an analysis of variance (ANOVA) on the gathered data (SAS, University Edition, SAS Institute Inc., USA) using Tukey groupings for treatments least-square means at $P < 0.05$.

3. Results

3.1. Vegetative Growth

Manure amendments significantly ($P < 0.05$) affected garden egg plants height during both seasons of the trial, except on the first sampling day of the 2020 major season. In the minor season of 2019 and the major season of 2020, the NPK fertilizer (positive control) and poultry manure treatments had the highest plant heights at 44.0 cm and 43.4 cm, respectively. After goat manure, the control (no animal manure) had the shortest plants. The number of leaves per plant produced by garden eggs was significantly ($P < 0.05$) affected by soil amendments at all sampling periods in both seasons of the trial, except on the first sampling day of the 2020 major season. Table 4 shows that NPK fertilizer (positive control) produced the most leaves per plant (28.6), followed by poultry manure (27.5). Control plants had the fewest number of leaves. NPK fertilizer (positive control) produced the most branches per plant (Table 4). Poultry manure had more plant branches. Cattle and goat manure produced similar numbers of branches. The control plant had the fewest branches after sampling. NPK fertilizer

Table 4. Vegetative growth performance of garden eggs under three (3) different sources of organic manure application.

Treatments	Plant Height (cm)		No. of leaves per plant		No. of branches per plant		Stem diameter (cm)		Canopy width (cm)	
	21 DAP	51 DAP	21 DAP	51 DAP	21 DAP	51 DAP	21 DAP	51 DAP	21 DAP	51 DAP
2019 minor season										
Poultry manure (PM)	22.0^{a}	58.1^{ab}	7.8^{a}	50.2^{a}	2.4^{a}	18.4^{a}	1.02^{a}	2.42^{a}	26.8^{a}	59.3^{ab}
Cattle manure (CM)	19.2^{bcd}	52.1^{b}	6.3^{b}	43.9^{c}	2.2^{a}	15.2^{b}	0.80^{b}	2.11^{c}	22.3^{bc}	53.0^{b}
Goat manure (GM)	20.8^{abc}	53.9^{b}	6.5^{b}	46.8^{c}	1.8^{a}	15.3^{b}	0.76^{b}	2.02^{c}	22.1^{bc}	55.2^{ab}
Positive control (NPK)	18.7^{cd}	61.1^{a}	6.6^{b}	51.9^{a}	2.2^{a}	19.8^{a}	0.87^{ab}	2.53^{a}	26.0^{ab}	61.3^{a}
No fertilizer (NF)	17.0^{d}	36.8^{c}	5.7^{b}	27.9^{d}	2.1^{a}	10.9^{c}	0.58^{c}	1.49^{d}	20.9^{c}	39.9c
2020 major season										
Poultry manure (PM)	13.1^{a}	46.9^{a}	7.0^{a}	53.2^{ab}	2.10^{a}	16.83^{a}	1.02^{a}	2.42^{a}	30.5^{a}	61.8^{a}
Cattle manure (CM)	10.4^{a}	38.7^{d}	6.9^{a}	44.9^{c}	2.10^{a}	12.43^{b}	0.80^{b}	2.11^{c}	28.6^{a}	54.0^{b}
Goat manure (GM)	13.2^{a}	42.1^{bc}	6.5^{a}	42.1^{c}	2.03^{a}	10.53^{b}	0.76^{b}	2.02^{c}	27.8^{a}	53.9^{b}
Positive control (NPK)	12.3^{a}	48.1^{a}	7.0^{a}	53.7^{a}	1.80^{a}	17.63^{a}	0.46^{a}	1.57^{a}	27.9^{a}	62.6^{a}
No fertilizer (NF)	11.6^{a}	28.4^{e}	6.6^{a}	28.6^{d}	2.10^{a}	10.70^{b}	0.58^{c}	1.49^{d}	21.9^{b}	39.0^{c}

SAS, tukey test at $P < 0.05$, same letters means no significant differences among treatments in the same colum.

and poultry manure had the largest stem diameters of 1.9 cm and 1.8 cm, respectively, during sampling. No fertilizer (control) had the smallest stem diameter of 1.1 cm. Soil amendments significantly ($P < 0.05$) affected garden egg canopy on all sampling days in both trial seasons except the first sampling day of the 2020 major season. NPK fertilizer produced the largest canopy diameter of 44.1 cm. Poultry manure followed at 43.3 cm. The control had the smallest canopy diameter of 29.9 cm (Table 4).

3.2. Phenology

Results depicted that NPK fertilizer had the highest percentage of plant establishment at 90%. Poultry manure followed closely with 88%, while cattle manure and goat manure had the least percentage establishment. There was no statistically significant ($P > 0.05$) effect of soil amendments on the number of days to 50% flowering, fruiting, or maturity. However, days to 50% flowering results showed that garden egg plants treated with goat manure flowered earlier than those treated with the other soil amendments (Table 5).

3.3. Biomass and Yield Components

All sampling days in both seasons showed a significant ($P < 0.05$) effect of soil amendments on leaf and stem dry matter accumulation. Generally, all the manure-applied treatments increased dry matter accumulation in leaves and stem over the control treatment at all the sampling periods throughout the study. In addition, the results from Table 6 showed that dry matter accumulation in

Table 5. Mean percentage establishment and phenological development of garden eggs as influenced by soil amendments.

Treatment	Percentage plant establishment		Days to 50% flowering		Days to 50% fruiting		Days to maturity	
	2019 minor season	2020 major season	2019 minor season	2020 major season	2019 minor season	2020 major season	2019 minor season	2020 major season
Poultry manure (CM)	89[ab]	87[ab]	32[a]	32[a]	43[a]	44[a]	54[a]	56[a]
Cattle manure (CM)	79[a]	88[ab]	31[a]	31[a]	43[a]	44[a]	54[a]	56[a]
Goat manure (GM)	89[ab]	76[b]	33[a]	33[a]	43[a]	44[a]	54[a]	56[a]
Positive control (NPK)	89[ab]	91[a]	31[a]	33[a]	43[a]	44[a]	54[a]	56[a]
No Fertilizer (NF)	88[ab]	80[ab]	31[a]	31[a]	43[a]	44[a]	54[a]	56[a]

SAS, tukey test at $P < 0.05$, same letters means no significant differences among treatments in the same column.

Table 6. Mean dry matter accumulation of leaves and stem of garden eggs as influenced by soil amendments.

Treatments	Dry matter accumulation per plant (g)							
	2019 Minor season				2020 major season			
	21DAP	31DAP	41DAP	51DAP	21DAP	31DAP	41DAP	51DAP
Poultry2manure (PM)	9.3[a]	20.4[a]	29.1[ab]	38.1[ab]	5.4[a]	19.8[a]	31.4[ab]	42.6[a]
Cattle manure (CM)	5.5[bc]	11.9[b]	23.5[c]	31.0[ab]	5.1[a]	14.1[b]	24.9[abc]	33.2[b]
Goat2manure (GM)	6.0[bc]	14.1[ab]	22.2[c]	31.0[ab]	5.3[a]	12.3[b]	20.4[c]	33.9[b]
Positive Control (NPK)	9.5[a]	21.0[a]	30.8[a]	40.8[a]	5.5[a]	19.3[a]	31.7[a]	43.7[a]
No fertilizer (NF)	4.4[c]	10.4[b]	15.4[d]	21.6[b]	4.5[a]	11.5[b]	18.5[c]	23.8[c]

SAS, tukey test at $P < 0.05$, same letters means no significant differences among treatments in the same column.

leaves and stems in both seasons of the trial increased at an increasing rate from 21 DAP to 31 DAP but increased at a decreasing rate from 41 DAP to 51 DAP.

In both seasons, treatment application did not affect the number of plants in the harvest area, harvested plants, or rotten fruits ($P > 0.05$). From Table 7, treatment significantly ($P < 0.05$) affected plant fruit production. Mineral fertilizer produced the most fruits per plant in both seasons, outperforming all treatments except poultry manure. Cattle and goat manure had similar effects throughout the study. These differed greatly from the negative control (no fertilizer) treatment, which produced the fewest fruits per plant. Treatments significantly affected fruit length ($P < 0.05$). Mineral fertilizer produced the longest fruits in both seasons, outperforming all treatments except poultry manure. Cattle and goat manure had similar effects in the 2019 minor season. Negative control yielded the shortest fruits. Cattle and goat manure applied in 2020 had similar treatment effects. The negative control (no fertilizer) had the shortest fruit length. Manure did not affect fruit diameter in the 2019 minor season ($P > 0.05$).

Table 7. Yield components of garden eggs performance of garden eggs under three (3) different sources of organic manure application.

Treatments	No. of Plants in harvest area	No. of Plants harvested	No. of fruits per plant	No. of rotten fruits	Fruit Length (cm)	Fruit Diameter (cm)	Fruit yield (kg/ha)
2019 minor season							
Poultry manure (PM)	18.0[a]	8.6[a]	19.7[a]	5.6[a]	7.2[a]	4.9[a]	1.9[a]
Cattle manure (CM)	19.0[a]	7.1[a]	16.1[b]	6.1[a]	5.8[b]	4.1[b]	1.8[b]
Goat manure (GM)	19.7[a]	6.3[a]	16.4[b]	6.3[a]	5.9[b]	4.2[b]	1.8[b]
Positive Control (NPK)	19.3[a]	7.1[a]	19.9[a]	6.0[a]	7.3[a]	5.0[a]	1.9[a]
No fertilizer (NF)	21.0[a]	7.7[a]	12.7[c]	6.5[a]	4.4[c]	3.3[c]	1.5[a]
2020 major season							
Poultry manure (PM)	21.7[a]	11.6[a]	26.5[a]	10.3[a]	9.6[a]	5.7[a]	2.2[a]
Cattle manure (CM)	20.0[a]	11.4[a]	23.6[b]	8.9[a]	8.2[b]	4.	1.9[bc]
Goat manure (GM)	22.3[a]	11.5[a]	24.1[b]	10.3[a]	7.8[bc]	4.1[a]	1.8[bc]
Positive Control (NPK)	21.3[a]	12.4[a]	26.8[a]	9.5[a]	9.6[a]	5.8[a]	2.1[a]
No fertilizer (NF)	21.3[a]	11.1[a]	18.1[c]	8.9[a]	6. 9[c]	3.4[a]	1.7[a]

In the 2020 major season, mineral fertilizer produced the largest fruit diameter ($P < 0.05$), compared to all other treatments except poultry manure. Cattle and goat manure had similar effects. The negative control (no fertilizer) had the lowest fruit diameter. Treatments significantly affected fruit yield ($P < 0.05$) throughout the study. Mineral fertilizer yielded the most fruit in both seasons, outperforming all other treatments except poultry manure. Cattle and goat manure had similar treatment effects in the 2019 minor season. All treatments except cattle manure yielded more fruit than the negative control (no fertilizer). Cattle and goat manure applied in 2020 had similar treatment effects. These differed significantly from the lowest fruit yielding negative control (no fertilizer) treatment.

4. Discussion

4.1. Vegetative Growth of Garden Eggs

In both seasons, soil amendments significantly ($P < 0.05$) affected garden eggs plant height and branch count. Nutrient-applied treatments generally increased plant height and branch number. Poultry manure performed better in terms plant height, number of leaves and leaf area when compared to the other types of organic manures, according to a research by Mahamad *et al.* [25]. The positive control NPK 15-15-15 fertilizer and poultry manure performed best. The mineral fertilizer's high levels of nitrogen, phosphorus, and potassium may have helped garden egg plants grow taller and have more branches [26]. The nitrogen, phosphorus, calcium, and sulphur in organic manure may affect plant height and branching [27]. This study supports Dauda *et al.* [8], who suggested using organic materials like poultry, goat, cattle, or compost with or without inorganic fertilizers to improve soil nutrient status. Poultry manure rate with 15 t/ha recorded highest number of leaves and plant height of pepper [28]. Increased poultry manure application heightened garden eggplants, according to [29]. Poultry manure promotes healthy and vigorous plant growth, according to [30]. Soil amendments significantly ($P < 0.05$) affected garden eggs leaf production in both seasons. Tahir *et al.* [31] found that poultry manure application enhanced leaf and number of flowers in watermelon. This study again supports a research by [32] who found that, the application of poultry manure produced the tallest garden eggs plants. Poultry manure application enhanced leaf and number of flowers in garden eggs. The increase in the number of leaves of garden egg in plots treated with poultry manure indicates that the manure was able to release enough nutrients for the growth of garden egg. This is in agreement with a research by [33].

Poultry manure promotes healthy and vigorous plant growth, according to [30]. Garden egg stem diameter changed over sampling periods. NPK 15-15-15 and poultry manure had the largest stem diameter. Cattle manure with the same stem diameter followed. No fertilizer (control) had the smallest stem diameter. Dauda *et al.* [8] also found that poultry manure, animal remains, compost, and inorganic fertilizers can increase soil nutrient status. Poultry manure's essential nutrients boost plants' photosynthetic activities, resulting in high vegetative growth, according to [34]. Onyegbule *et al.* [33] also found increase in stem diameter poultry manure was applied to garden eggs plants. Garden egg canopy diameter was similarly observed over sampling periods. NPK 15-15-15 produced the largest canopy diameter in both seasons of the trial. Poultry manure followed. Poultry manure outperformed other organic fertilizers. This is also supported by Aliyu [30], who found that poultry manure greatly affects plant vegetative development and promotes healthy and vigorous plant growth.

4.2. Phenology of Garden Eggs

Plant establishment was unaffected by soil amendments during sampling. The NPK 15-15-15 fertilizer and poultry manure had 90% and 88%, respectively, while the other amendments had less significant differences. Nutrients and soil conditions may have led to photosynthesis and efficient dry matter partitioning for shoot growth. This supports a report by John *et al.* [34]. Treatment did not affect days to 50% flowering, fruiting, or maturity. Since environmental factors do not control measured parameters, the results may be genetic.

4.3. Biomass, Yield, and Yield Components of Garden Eggs

Fertilizer treatments over the sampling periods differed in leaf and stem dry matter accumulation ($P < 0.05$). Garden eggplants had the highest average dry matter accumulation of 42.2 g with NPK 15-15-15. Poultry manure followed with 40.4 g. The control's 25.9 g dry matter accumulation was the lowest. John *et al.* [34] found that poultry manure increases photosynthesis and dry matter partitioning for shoot growth by providing sufficient nutrients and improving soil conditions. In a similar research by Mahamad *et al.* [25], poultry manure outperformed all other organic manure in total plant fresh and dry weight in garden eggs. Kekong and Ojikpong [32] also found similar results and reported that poultry manure produced the highest dry matter and number of fruits per plant and fruit yield. Treatment significantly ($P < 0.05$) affected plant fruit production. Mineral fertilizer and poultry manure yielded the most fruit per plant in both seasons. The no-fertilizer treatment yielded the fewest fruits per plant. Santo *et al.* [26] found that poultry manure increased Bankyehemaa cassava root yield and yield components over NPK 15-15-15 fertilizer and the control (no fertilizer) treatments. They attributed the results to poultry manure's essential nutrients and organic matter for plant growth. According to Shafeek *et al.* [35], poultry manure increased nutritional elements in the cassava plant's rooting zone, which improved nutrient uptake and growth. Ayoola and Makinde [36] found that manure increased nutrient availability, especially N, P, K, Zn, Fe, and Mn, even in early crop growth. Organic manure improves soil water holding capacity, structure, aeration, cassava growth, yield, and root quality. These soil conditions may have improved assimilate partitioning for cassava root growth, resulting in high root yield.

Treatment application significantly affected fruit yield, number of fruits per plant, and fruit length ($P < 0.05$). In both seasons of the trial, the nutrient-applied treatments outperformed the negative control. Mineral fertilizer and poultry manure produced the highest yield, diameter, number of fruits per plant, and longest fruits. Mineral fertilizer and poultry manure increased yield parameters like fruit number per plant, length, and diameter, maximizing fruit yield. Poultry manure may increase fruit yield, number of fruits per plant, fruit length, and diameter due to nutrients, especially phosphorus and potassium, which are needed for fruit growth. Potassium boosts net photosynthetic ability, photoassimilate translocation to fruits, and soil nitrate uptake [37]. Garden egg crops perform better in terms of fruit number per plant, fruit length, and fruit diameter because inorganic fertilizer dissolves nutrients, especially phosphorus and potassium, which are essential for fruit growth. Fertilizer increased cassava root girth [36].

NPK 15-15-15 fertilizer and poultry manure had similar fruit yields, lengths, and diameters. Garden egg plants treated with poultry manure yielded more than any other type of organic manure Mahamad *et al.* [25] Poultry manure outperformed other organic manures and no fertilizer in fruit yield, number of fruits per plant, length, and diameter (**Table 5**). Onyegbule *et al.* [33] also reported that the number of fruits of garden eggs was highest in plots treated with poultry manure. Poultry manure's consistent nutrient release and soil physical improvements explain this. Poultry manure boosts growth Dauda *et al.* [8]. It supplies plant nutrients like N, P, K, and trace elements like Ca, Mg, S, Cu, Na, Fe, Mn, B, Mo, Zn, and others, which increases meristematic and physiological activities and produces adequate photosynthates for fruit production. Warren *et al.* [38] found that using an appropriate poultry manure rate improves soil physical and chemical qualities, reduces soil nutrient imbalance and promotes better crop growth and development. Aliyu [30], found that poultry manure's nitrogen boosts plant growth and crop yield.

Adediran *et al.* [39] compared poultry manure, house, market, and farm waste. The most nutrient-rich poultry manure at 20 t·ha^{-1} increased tomato yield and soil macro and micronutrient availability. Thus, poultry manure's nutrient content contributed to high vegetative growth, photosynthesis, and yield in the current study Mpanga *et al.* [9] (**Table 7**). John *et al.* [34] found that poultry manure increased watermelon growth and yield because it contained nutrients that boost photosynthetic activity and root and shoot growth. Again, Tahir *et al.* [31] found that, poultry manure application produced best watermelon fruit weight. Aliyu [40] [41] found a significant yield response to different manure rate applications.

5. Conclusion

Generally, the growth, phenology, yield, and yield components of garden eggs were improved due to the application of fertilizer. The application of poultry manure maximized the growth and yield of garden eggs over other organic fertilizers. However, further studies should be undertaken to understand manure nutrient availability in different soils, plant nutrient uptake in different plants, and effects on soil physical, chemical, and biological properties.

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Authors' Contributions

Conceptualization, E.A., K.G.S., A.O.A., D.A. and I.A.P.; methodology, E.A., K.G.S. and I.A.P.; formal analysis, E.A.; resources, E.A. and K.G.S.; data curation, E.A.; writing: original draft preparation, E.A.; writing: review and editing, E.A. K.G.S., A.O.A., DA and I.A.P.; visualization, E.A., K.G.S., A.O.A., D.A. and I.A.P.; supervision, K.G.S., and A.O.A.

Conflicts of Interest

All authors read, approved and have no conflict of interest regarding the publication of this manuscript.

Data Availability Statement

A formal written request to the corresponding author can access the study's data, which is stored locally.

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