Scientific Research Publishing

Agricultural Sciences, 2026, 17(9), 959-975
https://www.scirp.org/journal/as
ISSN Online: 2156-8561
ISSN Print: 2156-8553

From Farmyard to Field: Comparing Three Manure Blends and NPK Fertilizer for Garden Egg (*Solanum melongena* L.) Production under Ghanaian Conditions

Adjei Eric[1,2], Kwadwo Gyasi Santo[2], Adu Poku Isaac[3], Danson Anokye-Alexander[1,2], Kennedy Kontor[2], Grace Nartey[2,4], Ayensu Patrick[1,2], Sylvia Kyeremaah Hinneh[1]

[1]Department of Agriculture, Berekum East Municipal Assembly, Berekum, Ghana
[2]Department of Horticulture and Crop Production, University of Energy and Natural Resources, Sunyani, Ghana
[3]Department of Science, Robert B. Glenn High School, Kernersville, USA
[4]Kwabeng Anglican Senior High Technical School, Kwabeng, Ghana
Email: przyeric@yahoo.com

How to cite this paper: Adjei, E., Santo, K.G., Isaac, A.P., Anokye-Alexander, D., Kontor, K., Nartey, G., Patrick, A. and Hinneh, S.K. (2026) From Farmyard to Field: Comparing Three Manure Blends and NPK Fertilizer for Garden Egg (*Solanum melongena* L.) Production under Ghanaian Conditions. *Agricultural Sciences*, **17**, 959-975.
https://doi.org/10.4236/as.2026.179054

Received: August 27, 2026
Accepted: September 21, 2026
Published: September 24, 2026

Abstract

Continuous cultivation with limited organic inputs has accelerated soil fertility depletion across Ghana's vegetable-producing regions, while increasing dependence on inorganic fertilizers has raised production costs and environmental concerns for smallholder farmers. Garden egg (*Solanum melongena* L.) is an economically and nutritionally important vegetable crop, yet the agronomic performance of locally available blended animal manures remains inadequately understood under Ghanaian conditions. Existing studies have primarily evaluated individual organic manure sources or compared organic and inorganic fertilizers, with limited attention to synergistic blends of poultry, cattle, and goat manures that differ in nutrient composition, nitrogen availability, and mineralization dynamics. This study compared three blended animal-manure combinations for garden egg production to determine which performed best and how its performance compared with conventional inorganic fertilization and no fertilization, over two consecutive cropping seasons in the humid semi-equatorial zone of Ghana. A field experiment was conducted during the 2019 minor and 2020 major cropping seasons using a randomized complete block design with five treatments replicated three times. Treatments comprised three organic combinations (1/2 chicken + 1/2 cattle manure, 1/2 chicken + 1/2 goat manure, 1/2 goat + 1/2 cattle manure) evaluated against NPK (15-15-15) as a positive control and an unfertilized treatment as a negative control. All organic treatments were applied at an equivalent nitrogen rate of 207 kg N ha^{-1}. NPK consistently produced the highest fruit yield (0.789 and 1.103 $t \cdot ha^{-1}$ in 2019 and 2020, respectively). All three organic manure combinations significantly improved vegetative growth, biomass accumulation, and fruit yield relative to the unfertilized control, and were statistically comparable to one another in both seasons. In 2020, 1/2 goat + 1/2 cattle manure recorded the highest numerical fruit yield among the organic treatments (0.822 $t \cdot ha^{-1}$), but this difference was not statistically significant; no organic combination was consistently superior to the others across both seasons. These findings indicate that blended animal manures can meaningfully narrow, without closing, the productivity gap with inorganic fertilization, offering smallholder farmers a lower-cost nutrient management option whose relative performance depends on which manures are blended and on seasonal conditions.

Keywords

Garden Egg, Solanum Melongena, Organic Manure, Integrated Nutrient Management, NPK Fertilizer, Smallholder Farmers, Ghana

1. Introduction

Vegetable production underpins food and income security for smallholder farming households across sub-Saharan Africa, yet intensification without adequate nutrient replenishment is progressively degrading soil fertility in many production zones, including Ghana's Bono and Ahafo regions. Continuous cultivation without fallow or organic amendment depletes soil organic matter and available nitrogen, while the rising cost and environmental footprint of inorganic fertilizers such as nutrient runoff, water pollution, and soil acidification are prompting renewed interest in organic and integrated nutrient management strategies [1] [2].

Garden egg (*Solanum melongena* L.) is among the most widely consumed vegetables in Ghanaian households and an important income source for smallholder farmers, valued for both its dietary and economic role in rural livelihoods. Its productivity is strongly nitrogen and phosphorus-dependent; nitrogen supports chlorophyll synthesis and vegetative expansion, while phosphorus governs root establishment, flowering, and fruit development. Recent work confirms that both inorganic and organic fertilization measurably affect growth, nutrient uptake, chlorophyll fluorescence, and fruit quality in *Solanum melongena*, underscoring that nutrient source, not only nutrient quantity shapes crop performance [3] [4].

Organic manures from different livestock species differ substantially in nutrient composition and release dynamics. Poultry manure typically has the highest total nitrogen content of common livestock manures owing to its low-fiber, high-protein feed origin, while cattle and goat manures release nutrients more slowly due to higher lignocellulose content, but contribute more durably to soil organic matter and structure [5]. Combining manure sources is therefore agronomically rational; it can balance the rapid mineralization of poultry manure against the longer-term soil-conditioning contribution of ruminant manures, while diversifying the micronutrient and microbial inputs to the rhizosphere [6].

Field evidence from tropical sandy-loam soils supports this rationale, showing that poultry manure application measurably improves both garden egg yield and underlying soil fertility indicators in semi-arid and tropical settings [7] [8], while comparative work on garden egg under different animal manure sources has demonstrated that manure type and combination significantly affect yield outcomes relative to inorganic fertilizer [9].

Beyond direct nutrient supply, organic manure inputs are reported in the literature to influence soil microbial biomass and activity, which govern the rate and pattern of nutrient mineralization and, over successive seasons, may contribute to soil organic carbon accumulation [10], a longer-term soil-health dimension that this two-season field trial was not designed to measure. Integrated nutrient management, which combines the immediate nutrient availability of inorganic fertilizer with the slow-release properties of organic manure, has been proposed as a pathway to reconcile short-term productivity needs with longer-term soil-building goals [11], though such benefits require dedicated soil monitoring beyond the scope of the present agronomic comparison.

Despite this rationale, empirical comparisons of blended manure combinations, rather than single manure sources tested against NPK alone, remain limited for garden egg under West African humid semi-equatorial conditions [5], and multi-season data that capture how treatment performance varies between minor and major cropping seasons are particularly scarce.

There is limited multi-season field evidence comparing blended combinations of poultry, cattle, and goat manure against NPK fertilizer for garden egg production under Ghanaian climatic conditions, and existing studies rarely report how organic-manure performance shifts between minor and major growing seasons [12] [13]. This study is among the first to evaluate three distinct half-and-half manure combinations (poultry-cattle, poultry-goat, goat-cattle) alongside NPK and an unfertilized control across two consecutive cropping seasons in the Sunyani West Municipality, providing season-resolved evidence on organic manure blending as an integrated nutrient management strategy for garden egg.

The study hypothesized that (i) blended organic manure combinations would significantly improve garden egg vegetative growth, phenology, and yield relative to an unfertilized control; and (ii) the three blended manure combinations would differ in agronomic performance, reflecting differences in the nutrient composition and mineralization dynamics of their poultry, cattle, and goat manure components, without presupposing which specific blend would perform best. No directional assumption was made regarding the ranking of the organic treatments relative to NPK.

Objectives of the study were to: (i) to compare the effects of three blended organic manure combinations, NPK fertilizer (positive control), and an unfertilized treatment (negative control) on vegetative growth, phenology, dry matter accumulation, and yield components of garden egg; (ii) to evaluate treatment performance consistency across the 2019 minor and 2020 major cropping seasons; and (iii) to identify the best-performing manure combination for garden egg production and determine its relative performance compared with NPK fertilizer. The study is expected to generate season-resolved, quantitative evidence to guide extension recommendations on organic manure blending for garden egg production, supporting integrated nutrient management adoption among smallholder farmers in tropical West Africa.

2. Materials and Methods

2.1. Study Area

The experiment was conducted at Fiapre, Sunyani West Municipality, Bono Region, Ghana (approximately 7˚20′N, 2˚22′W; elevation ~300 m above sea level), from August 2019 to May 2020, spanning the minor (2019) and major (2020) cropping seasons. The site falls within the wet semi-equatorial climate zone, characterized by a bimodal rainfall pattern: a primary rainy season from April to July and a secondary rainy season from September to early November, with mean annual rainfall of 1,700 mm and mean annual temperature of 26˚C [14].

2.2. Experimental Design and Treatments

The trial followed a Randomized Complete Block Design (RCBD) with five treatments replicated three times across three blocks, giving 15 experimental plots. Treatments were:

1) 1/2 chicken manure + 1/2 cattle manure,
2) 1/2 chicken manure + 1/2 goat manure,
3) 1/2 goat manure + 1/2 cattle manure,
4) NPK 15-15-15 (positive control), and
5) no fertilizer (negative control).

Each experimental plot measured 4 m × 3 m (12 m^2) and consisted of five rows, each 4 m long. Seedlings were transplanted at a spacing of 75 cm between rows (inter-row spacing) and 50 cm within rows (intra-row spacing), resulting in 40 plants per plot, of which 24 plants within a 6 m^2 net harvest area were used for data collection.

2.3. Crop Establishment and Management Practices

The garden egg cultivar used in the experiment was "Ntrowa Pa", a locally adapted improved variety. Certified seeds were obtained from Farmers Link Agro Input, Sunyani, Ghana. Seedlings were raised in two nursery beds measuring 2.0 m × 1.2 m each. Seeds were sown thinly in rows at a depth of approximately 2.5 cm, and the nursery beds were watered and mulched immediately after sowing. Following seed germination, the mulch was removed and temporary shade was provided to protect the young seedlings from excessive solar radiation. Seedlings were thinned to prevent overcrowding and watered daily until transplanting. Transplanting was carried out at 4 weeks after sowing following a hardening-off period.

Irrigation water was sourced from a borehole located adjacent to the experimental field. Watering cans were used during the seedling establishment phase immediately after transplanting, after which irrigation was applied using a pump-and-hose system. Irrigation was conducted twice daily (morning and evening) during the first two weeks after transplanting. Thereafter, the frequency was progressively reduced to once every two days, then once every three days, and finally once every four days, depending on crop growth stage and soil moisture conditions.

Weeds were controlled by manual hoe weeding, which was carried out three times during the cropping season to minimise competition for nutrients, water, and sunlight. The principal insect pest observed was stem borer, while no major disease incidence was recorded throughout the experiment. Pest management was achieved through the application of Lambda-cyhalothrin 2.5% EC at a rate of 40 mL per 15 L of water, beginning at 21 days after transplanting (DAP) and repeated at two-week intervals until the end of the cropping period.

Harvesting commenced when fruits reached marketable maturity, based on fruit size, colour, and firmness. Fruits were harvested at five-day intervals for five consecutive pickings. At each harvest, fruits from the net plot were counted and weighed separately, and the mean yield across the five harvests was used for statistical analysis.

2.4. Manure Application

Poultry, cattle, and goat manures were sourced locally, air-dried, and analyzed for nitrogen content (3.25%, 1.46%, and 2.16% N, respectively) prior to application. Application rates were calculated on a nitrogen-equivalent basis at 207 kg N ha^{-1}, a rate consistent with recommended nitrogen supply for solanaceous vegetables under tropical conditions. Manure was incorporated manually into the top 0 - 15 cm of soil one week before transplanting to allow initial mineralization.

2.5. Soil Sampling and Analysis

Composite surface soil samples (0 - 20 cm depth) were collected from each plot before treatment application, air-dried, and analyzed for pH (0.01 M $CaCl_2$, glass electrode), organic carbon and organic matter (Walkley-Black dichromate digestion) [15], total nitrogen (Kjeldahl method) [16], available phosphorus (Bray-1 method) [17], and exchangeable Ca, Mg, and K (ammonium acetate extraction, EDTA titration, and flame photometry, respectively). Organic matter (%) was calculated from organic carbon (%) using the conventional Van Bemmelen factor (OM = OC × 1.724) associated with the Walkley-Black method [15]; the organic matter values reported in the originally submitted table (0.12% and 0.15%) were transcription/calculation errors and have been corrected here. Original laboratory bench sheets were checked to confirm the organic carbon values themselves were correctly transcribed (Table 1).

Table 1. Physico-chemical soil properties of the study location.

Experiment	Soil Texture	Soil pH	Organic Carbon (%)	Organic Matter (%)	Total N (mg/100g)	Available P (mg/kg)	Available K (mg/kg)
2019 Minor season	Sandy loam	5.98	1.85	3.19	5.32	65.30	55.0
2020 Major season	Sandy loam	6.09	1.78	3.07	5.21	70.37	57.0

2.6. Manure Nutrient Analysis

Manure nutrient content was determined by dry ashing [18]: samples were air-dried, sieved (2 mm), and ashed at 450˚C for 2 hours. Organic matter was estimated by Walkley-Black dichromate digestion, total nitrogen by the Kjeldahl method, phosphorus by the ammonium molybdate/vanadate technique, potassium by flame photometry, and Ca/Mg by EDTA titration.

2.7. Plant and Yield Data Collection

Data were collected at 21, 31, 41, and 51 days after planting (DAP) for plant height, leaf number, branch number, stem diameter, and canopy width, each averaged from four randomly tagged plants per plot. Phenological milestones (days to 50% flowering, 50% fruiting, and maturity) and plant establishment percentage were recorded per plot. At harvest, fruit number, rotten fruit count, fruit length and diameter (five randomly sampled fruits per plot), and total fruit yield (converted to kg/ha) were recorded.

2.8. Statistical Analysis

Data were subjected to two-way analysis of variance (ANOVA), with treatment and block as factors, for each season separately. Measurements taken at 21, 31, 41, and 51 days after planting (DAP) were analyzed separately, with each DAP treated as an independent analysis rather than as repeated observations in a repeated-measures or mixed-effects model. Treatment means were separated using Tukey's honestly significant difference (HSD) test at $P < 0.05$ using SAS University Edition (SAS Institute Inc., USA). Means within the same year and DAP followed by the same letter were considered not significantly different according to Tukey's HSD test at $P < 0.05$.

3. Results

3.1. Vegetative Growth

3.1.1. Plant Height

Among the three organic manure combinations, plant height was statistically comparable at every measurement period in 2019, including at 51 DAP, where 1/2 chicken + 1/2 cattle (53.9 cm), 1/2 chicken + 1/2 goat (53.4 cm), and 1/2 goat + 1/2 cattle (53.5 cm) shared the same Tukey grouping despite small numerical differences. This indicates that the three manure combinations produced broadly similar vegetative height responses under the 2019 conditions. In 2020, the pattern was largely similar through 41 DAP, but by 51 DAP 1/2 chicken + 1/2 goat (43.1 cm) was statistically taller than 1/2 chicken + 1/2 cattle (39.9 cm), with 1/2 goat + 1/2 cattle (41.6 cm) intermediate and not significantly different from either. No single combination was therefore consistently superior across both seasons; 1/2 chicken + 1/2 goat showed a modest but statistically supported advantage only late in the 2020 season. The NPK (positive control) recorded the highest plant height overall in both seasons, while the unfertilized (negative control) recorded the lowest (Table 2).

Table 2. Mean plant height (cm) of garden eggs as influenced by soil amendments in the minor (2019) and major (2020) seasons.

Treatment	2019 minor season				2020 major season			
	21DAP	31DAP	41DAP	51DAP	21DAP	31DAP	41DAP	51DAP
1/2 Chicken + 1/2 Cattle	19.4bc	38.3abc	47.3b	53.9b	10.7a	22.9c	32.8bc	39.9cd
1/2 Chicken + 1/2 Goat	21.3ab	36.5c	47.2b	53.4b	11.8a	23.9bc	32.4bc	43.1b
1/2 Goat + 1/2 Cattle	19.2bcd	36.7bc	46.2b	53.5b	11.7a	23.2c	34.8abc	41.6bc
NPK (+ control)	18.7cd	42.2a	53.9a	61.1a	12.3a	29.2a	39.7a	48.1a
Control (−control)	17.0d	26.3d	30.4c	36.8c	11.6a	18.0d	24.0b	28.4e
CV (%)	**4.16**	**4.37**	**2.91**	**3.92**	**11.56**	**5.99**	**7.08**	**2.39**

3.1.2. Number of Leaves and Branches

Leaf number did not differ significantly among the three organic manure combinations at any measurement period in either season. At 51 DAP, 1/2 chicken + 1/2 cattle, 1/2 chicken + 1/2 goat, and 1/2 goat + 1/2 cattle carried statistically comparable numbers of leaves in 2019 (46.0, 47.5, and 44.6, respectively) and in 2020 (45.1, 45.9, and 46.5), despite modest numerical spread. Branch number likewise showed no statistically significant differences among the three combinations at 51 DAP in either season (2019: 15.0, 14.7, 14.3; 2020: 13.03, 12.60, 12.53), although 1/2 chicken + 1/2 goat recorded a numerically higher branch count at several mid-season readings e.g., at 31 DAP in 2020. A possible explanation is that the timing of nitrogen release differs subtly among the manure sources, but this was not directly measured here and the branching differences observed did not reach statistical significance, so this should be treated as a numerical trend rather than an established effect. The NPK positive control produced the highest leaf and branch counts in both seasons, while the unfertilized negative control produced the lowest (Tables 3-4).

Table 3. Mean number of leaves per plant of garden eggs as influenced by soil amendments (2019 and 2020).

Treatment	2019 minor season				2020 major season			
	21DAP	31DAP	41DAP	51DAP	21DAP	31DAP	41DAP	51DAP
1/2 Chicken + 1/2 Cattle	6.6b	18.4c	28.8c	46.0c	6.7a	21.0b	30.3c	45.1c

Continued

1/2 Chicken + 1/2 Goat	6.7b	18.6c	28.7c	47.5c	6.2a	21.6b	30.5c	45.9c
1/2 Goat + 1/2 Cattle	5.8b	17.9c	26.6c	44.6c	6.8a	22.0b	30.3c	46.5bc
NPK (+ control)	6.6b	22.3a	33.7a	51.9a	7.0a	26.6a	37.3a	53.7a
Control (– control)	5.7b	14.6d	21.5d	27.9d	6.6a	14.6c	23.8d	28.6d
CV (%)	**5.77**	**4.44**	**3.52**	**2.98**	**9.68**	**5.62**	**5.61**	**5.18**

Note: Tukey test at P<0.05; identical letters within a column indicate no significant difference.

Table 4. Mean number of branches per plant of garden eggs as influenced by soil amendments (2019 and 2020).

Treatment	2019 minor season				2020 major season			
	21DAP	31DAP	41DAP	51DAP	21DAP	31DAP	41DAP	51DAP
1/2 Chicken + 1/2 Cattle	1.9a	5.7bc	11.7b	15.0b	1.77a	6.37a	8.63b	13.03b
1/2 Chicken + 1/2 Goat	2.2a	5.7c	11.4b	14.7b	2.27a	7.33a	10.10ab	12.60b
1/2 Goat + 1/2 Cattle	2.0a	5.9bc	11.7b	14.3b	2.13a	5.60a	9.83ab	12.53b
NPK (+ control)	2.2a	7.8a	13.5a	19.8a	1.80a	8.03a	12.17a	17.63a
Control (– control)	2.1a	4.3d	7.7c	10.9c	2.10a	5.60a	8.00b	10.70b
CV (%)	**11.34**	**11.05**	**5.39**	**3.83**	**23.96**	**14.84**	**11.05**	**6.74**

3.1.3. Stem Diameter and Canopy Width

Table 5. Mean stem diameter (cm) of garden eggs as influenced by soil amendments (2019 and 2020).

Treatment	2019 minor season				2020 major season			
	21DAP	31DAP	41DAP	51DAP	21DAP	31DAP	41DAP	51DAP
1/2 Chicken + 1/2 Cattle	0.74b	1.58b	1.74c	2.03c	0.39a	0.62bc	0.87b	1.08b
1/2 Chicken + 1/2 Goat	0.84b	1.56b	1.75c	2.21c	0.39a	0.55c	0.81b	1.20b
1/2 Goat + 1/2 Cattle	0.82b	1.60b	1.72c	1.97c	0.38a	0.66abc	0.86b	1.06bc
NPK (+ control)	0.87ab	1.89a	2.15a	2.53a	0.46a	0.85a	1.24a	1.57a
Control (– control)	0.58c	1.05c	1.29d	1.49d	0.37a	0.54c	0.67b	0.89c
CV (%)	**6.59**	**3.4**	**4.52**	**5.12**	**18.58**	**12.13**	**9.40**	**5.34**

Note: Tukey test at P < 0.05; identical letters within a column indicate no significant difference.

Stem diameter did not differ significantly among the three organic manure combinations at any measurement period in either season; at 51 DAP, 1/2 chicken + 1/2 cattle, 1/2 chicken + 1/2 goat, and 1/2 goat + 1/2 cattle were statistically comparable in both 2019 (2.03, 2.21, 1.97 cm) and 2020 (1.08, 1.20, 1.06 cm), despite modest numerical spread favoring 1/2 chicken + 1/2 goat. Canopy width followed a similar pattern; the three organic combinations were statistically comparable at 51 DAP in both seasons (2019; 55.1, 54.5, 53.7 cm; 2020: 54.1, 54.1, 55.2 cm), with no combination showing a consistent statistical advantage across seasons. Taken together, none of the three organic combinations produced a distinguishable vegetative architecture advantage over the others for stem diameter or canopy width. NPK produced the largest stem diameter and widest canopy overall, while the unfertilized control produced the smallest of both (Tables 5-6).

Table 6. Mean canopy width (cm) of garden eggs as influenced by soil amendments (2019 and 2020).

Treatment	2019 minor season				2020 major season			
	21DAP	31DAP	41DAP	51DAP	21DAP	31DAP	41DAP	51DAP
1/2 Chicken + 1/2 Cattle	22.8abc	34.0bc	46.9bc	55.1ab	26.5ab	37.6c	50.7a	54.1b
1/2 Chicken + 1/2 Goat	24.2abc	33.7bc	47.9abc	54.5ab	27.4ab	37.3c	47.4a	54.1b
1/2 Goat + 1/2 Cattle	22.3bc	33.4c	45.3c	53.7b	28.3a	38.1c	50.0a	55.2b
NPK (+ control)	26.0ab	37.8a	51.4a	61.3a	27.9a	44.4a	53.9a	62.6a
Control (– control)	20.9c	26.6d	32.3d	39.9c	21.9b	27.4d	33.3b	39.0c
CV (%)	**6.07**	**2.79**	**2.96**	**4.23**	**7.28**	**4.48**	**6.03**	**3.28**

Note: Tukey test at P < 0.05; identical letters within a column indicate no significant difference.

3.2. Phenology

Table 7. Mean percentage plant establishment and phenological development of garden eggs (2019 and 2020).

Treatment	2019 minor season				2020 major season			
	PPEst	D50fl	D50fr	DM	PPEst	D50fl	D50fr	DM
1/2 Chicken + 1/2 Cattle	88ab	31a	43a	54a	81ab	31a	44a	56a
1/2 Chicken + 1/2 Goat	89ab	32a	43a	54a	80ab	33a	44a	56a
1/2 Goat + 1/2 Cattle	86ab	33a	43a	54a	82ab	33a	44a	56a
NPK (+ control)	89ab	31a	43a	54a	91a	33a	44a	56a
Control (– control)	88ab	31a	43a	54a	80ab	31a	44a	56a
CV (%)	**9.54**	**31.8**	**NS**	**NS**	**5.16**	**4.02**	**NS**	**NS**

Note: PPEst = percentage plant establishment; D50fl = days to 50% flowering; D50fr = days to 50% fruiting; DM = days to maturity. Tukey test at P < 0.05.

The three organic manure combinations produced broadly similar phenological responses; percentage plant establishment, days to 50% flowering (31 - 33 days), days to 50% fruiting (43 - 44 days), and days to maturity (54 - 56 days) showed no statistically meaningful separation among 1/2 chicken + 1/2 cattle, 1/2 chicken + 1/2 goat, and 1/2 goat + 1/2 cattle (Table 7), with the phenology-related Co-efficient of Variations (CVs) for fruiting and maturity reported as non-significant (NS). This suggests that differences among the manure sources had a greater influence on vegetative growth than on developmental timing. The NPK (positive control) and the unfertilized (negative control) followed a similar phenological pattern to the organic treatments, indicating that developmental timing in this trial was largely unaffected by fertilizer source.

3.3. Biomass and Yield Components

3.3.1. Dry Matter Accumulation

At 51 DAP, the three organic manure combinations accumulated statistically comparable dry matter in both seasons: 29.3, 30.5, and 30.7 g/plant in 2019 for 1/2 chicken + 1/2 cattle, 1/2 chicken + 1/2 goat, and 1/2 goat + 1/2 cattle, respectively, and 32.5, 31.6, and 32.3 g/plant in 2020. No organic combination maintained a statistically superior position across both seasons; 1/2 chicken + 1/2 cattle showed a modest numerical edge at some mid-season 2020 readings e.g., 41 DAP, but this did not translate into a significant difference by 51 DAP. NPK produced the highest dry matter accumulation overall in both seasons, and the unfertilized control the lowest (Table 8).

Table 8. Mean dry matter accumulation of leaves and stem (g/plant) of garden eggs as influenced by soil amendments (2019 and 2020).

Treatment	2019 minor season				2020 major season			
	21DAP	31DAP	41DAP	51DAP	21DAP	31DAP	41DAP	51DAP
1/2 Chicken + 1/2 Cattle	6.3b	13.9ab	25.0bc	29.3b	5.3a	13.8b	24.7abc	32.5b
1/2 Chicken + 1/2 Goat	6.6b	13.7ab	23.3c	30.5ab	3.8a	13.5b	21.6c	31.6b
1/2 Goat + 1/2 Cattle	5.9bc	13.9ab	24.1c	30.7ab	5.3a	13.3b	24.1c	32.3b
NPK (+ control)	9.5a	21.0a	30.8a	40.8a	5.5a	19.3a	31.7a	43.7a
Control (− control)	4.4c	10.4b	15.4d	21.6b	4.5a	11.5b	18.5c	23.8c
CV (%)	**9.5**	**17.31**	**6.13**	**19.08**	**28.07**	**14.84**	**11.05**	**6.74**

Note: Tukey test at $P<0.05$; identical letters within a column indicate no significant difference.

3.3.2. Fruit Yield and Yield Components

In 2019, the three organic manure combinations produced statistically comparable fruit yields (1/2 chicken + 1/2 cattle: 0.669 $t \cdot ha^{-1}$; 1/2 chicken + 1/2 goat: 0.666 $t \cdot ha^{-1}$; 1/2 goat + 1/2 cattle: 0.663 $t \cdot ha^{-1}$), sharing the same Tukey grouping despite their close numerical values; number of fruits, fruit length, and fruit diameter likewise did not differ significantly among the three combinations that season. In 2020, 1/2 goat + 1/2 cattle recorded the highest numerical fruit yield (0.822 $t \cdot ha^{-1}$) compared with 1/2 chicken + 1/2 cattle (0.754 $t \cdot ha^{-1}$) and 1/2 chicken + 1/2 goat (0.744 $t \cdot ha^{-1}$); however, the Tukey groupings for these values overlap (b for 1/2 goat + 1/2 cattle; bc for the two poultry-containing combinations), indicating that this difference does not meet the threshold for statistical significance. The 2020 numerical advantage of 1/2 goat + 1/2 cattle should therefore be read as a performance trend rather than a confirmed statistical superiority. None of the fruit-count, length, or diameter comparisons among the three organic combinations reached significance in 2020 either. Taken together, the three organic combinations performed similarly across both seasons on yield and yield components, with 1/2 goat + 1/2 cattle showing the most favorable, though not statistically distinct, numerical trend in 2020. For context, the NPK positive control recorded the highest fruit yield numerically in both seasons (0.789 and 1.103 $t \cdot ha^{-1}$), and the unfertilized negative control the lowest (0.430 and 0.575 t·ha^{-1}). In 2019, NPK's fruit yield shared the same Tukey grouping as the three organic combinations, indicating no statistically significant difference between NPK and the organic treatments that season, although NPK did produce a significantly higher number of fruits and greater fruit length and diameter (Table 9).

Table 9. Yield and yield components of garden eggs as influenced by soil amendments (2019 and 2020).

Treatment	Plants Harvest area	Plants harvested	No. fruits	Rotten fruits	Fruit length (cm)	Fruit diam. (cm)	Fruit yield (t·ha^{-1})
2019							
1/2 Chicken + 1/2 Cattle	18.3a	7.20a	16.07b	5.60a	6.16b	4.19b	0.669b
1/2 Chicken + 1/2 Goat	19.0a	7.33a	16.40b	5.53a	5.78b	4.04b	0.666b
1/2 Goat + 1/2 Cattle	20.0a	8.40a	15.80b	6.73a	6.09b	4.22b	0.663b
NPK (+ control)	19.3a	7.07a	19.93a	6.00a	7.25a	5.02a	0.789b
Control (− control)	21.0a	7.67a	12.73c	6.47a	4.41c	3.29c	0.430a
CV (%)	6.76	10.89	3.62	17.01	2.98	1.96	4.07
2020							
1/2 Chicken + 1/2 Cattle	23.3a	12.3a	22.5b	10.60a	8.20b	4.23b	0.754bc
1/2 Chicken + 1/2 Goat	21.7a	11.5a	23.9b	10.13a	8.02b	4.13b	0.744bc
1/2 Goat + 1/2 Cattle	21.0a	11.8a	23.9b	8.67a	7.92bc	4.14b	0.822b
NPK (+ control)	21.3a	12.4a	26.8a	9.47a	9.60a	5.76a	1.103a
Control (−control)	21.3a	11.1a	18.1c	8.93a	6.89c	3.35c	0.575c
CV (%)	**7.26**	**7.23**	**3.61**	**11.82**	**4.41**	**5.70**	**8.34**

Note: Tukey test at $P < 0.05$; identical letters within a column (within a given year) indicate no significant difference.

4. Discussion

4.1. Vegetative Growth of Garden Eggs

1/2 Chicken (Poultry) + 1/2 Cattle Manure combination produced vegetative growth that was statistically comparable to the other two organic combinations across most measurement periods and both seasons, including plant height, leaf number, branch number, stem diameter, and canopy width at 51 DAP, consistent with reports that combined poultry manure and NPK application produces comparable growth-parameter responses in eggplant [19]. Its dry matter accumulation showed a modest numerical edge over the other two combinations at some mid-season 2020 readings, though this did not translate into a significant advantage by 51 DAP. A possible explanation is that the comparatively fast mineralization of poultry manure [7], paired with the more gradual nutrient release and structural organic matter contribution of cattle manure [20], may have supported an early period of active growth; however, this proposed mechanism was not directly tested through soil nutrient sampling and should be regarded as plausible rather than confirmed. Overall, 1/2 chicken + 1/2 cattle did not distinguish itself as clearly superior to the other combinations for vegetative growth in either season, consistent with broader regional evidence that manure-type effects on vegetative performance are often inconsistent across studies [5] [9].

1/2 Chicken (Poultry) + 1/2 Goat Manure combination recorded the only statistically significant vegetative advantage observed among the three organic combinations in this study, a pattern broadly consistent with other reports of blended organic treatments producing standout vegetative gains relative to single-source or unblended alternatives [21] [22]; at 51 DAP in 2020, its plant height (43.1 cm) was significantly greater than that of 1/2 chicken + 1/2 cattle (39.9 cm), with 1/2 goat + 1/2 cattle intermediate. It also showed a numerically higher branch count at several mid-season readings, though this difference was not statistically significant. For leaf number, stem diameter, canopy width, and dry matter accumulation, 1/2 chicken + 1/2 goat was statistically comparable to the other two combinations in both seasons. A possible explanation for its height advantage late in the 2020 season is that blending two relatively fast-mineralizing manure sources may have sustained nitrogen availability slightly longer into the vegetative period than the other combinations [6] [20], but this was not directly measured and should be treated as a tentative interpretation pending further verification.

The 1/2 Goat + 1/2 Cattle Manure combination did not differ statistically from the other two organic combinations for plant height, leaf number, branch number, stem diameter, or canopy width in either season, despite recording the highest numerical fruit yield in 2020, a vegetative-yield decoupling that has also been noted where integrated or blended nutrient treatments raised yield without a matching gain in vegetative growth traits [23]. Its vegetative performance was therefore broadly comparable to, rather than clearly superior to, the poultry-containing combinations. It should not be assumed that the slower, more gradual mineralization typically associated with cattle and goat manure automatically confers an advantage for this combination [20]; on the vegetative traits measured here, no such advantage was statistically evident, and any interpretation linking its later-season yield performance to nutrient-release timing should be treated as a plausible hypothesis rather than an established finding, since soil nitrate/ammonium dynamics were not monitored; a limitation that direct soil-monitoring approaches in other systems have been specifically designed to address [24].

4.2. Phenology of Garden Eggs

The three organic manure combinations produced statistically similar flowering, fruiting, and maturity timing, indicating that differences among the manure sources influenced the magnitude of vegetative and yield responses more than the timing of developmental transitions. This pattern is broadly consistent with previous work at the same site [9], where soil amendments similarly had no significant effect on phenological timing despite producing significant differences in vegetative growth. A related decoupling has also been reported elsewhere in vegetable systems, where different organic fertilizer combinations altered vegetative and quality outcomes without producing corresponding differences in an overall developmental endpoint such as yield [25], and broader regional evidence likewise indicates that manure-type effects on plant performance are often inconsistent rather than uniformly directional across traits [5]. The NPK positive control and unfertilized negative control followed a comparable phenological pattern, suggesting that under the conditions of this trial, flowering and fruiting timing are not a useful indicator for distinguishing among fertilizer treatments, including among the organic combinations themselves.

4.3. Biomass and Yield Components of Garden Eggs

4.3.1. Dry Matter Accumulation

Dry matter accumulation at 51 DAP did not differ significantly among the three organic combinations in either season, a pattern broadly consistent with reports that combined organic fertilizer treatments frequently converge on statistically similar biomass or yield outcomes despite differing manure or amendment compositions [5] [25]. 1/2 chicken + 1/2 cattle showed a modest numerical advantage at some 2020 mid-season readings, but by 51 DAP the three combinations converged to statistically comparable values in both years. This suggests that, despite differing manure compositions, the three blends supported broadly similar cumulative vegetative biomass production over the growing period. NPK produced the highest dry matter accumulation overall, and the unfertilized control the lowest, providing context for the magnitude of the organic treatments' performance relative to the positive and negative controls, consistent with the general pattern that organic manure combinations narrow, but do not eliminate, the productivity gap with inorganic fertilization [6] [23].

4.3.2. Fruit Yield and Yield Components

Fruit yield and yield components are the most direct basis for identifying the most suitable organic manure combination in this study. In 2019, the three organic combinations produced statistically comparable fruit yields, fruit numbers, fruit lengths, and fruit diameters, indicating no clear agronomic separation among 1/2 chicken + 1/2 cattle, 1/2 chicken + 1/2 goat, and 1/2 goat + 1/2 cattle that season, a lack of separation among manure sources that has also been reported for other fruiting vegetables receiving blended or single organic amendments [9] [22]. In 2020, 1/2 goat + 1/2 cattle recorded the highest numerical fruit yield, but its Tukey grouping overlapped with the two poultry-containing combinations, meaning the difference did not reach statistical significance. This numerical trend is nonetheless noteworthy: a possible explanation is that the higher lignocellulose content of cattle and goat manure may sustain nutrient release later into the reproductive period than poultry-containing blends, potentially better matching the sustained nitrogen demand of fruit filling, a mechanism broadly consistent with evidence that ruminant manures mineralize more slowly and over a longer period than poultry manure [7] [20]. However, this remains a plausible hypothesis rather than a confirmed mechanism, since soil nitrate/ammonium levels and rainfall distribution were not directly monitored across the season, a limitation that direct soil-monitoring approaches in other systems have been specifically designed to address [24]. For context, the NPK positive control recorded the highest numerical fruit yield in both seasons, though in 2019 its yield shared the same statistical grouping as the three organic combinations; the unfertilized negative control recorded the lowest yield in both seasons, a pattern in line with wider evidence that integrated or blended organic strategies can approach, without consistently exceeding, inorganic fertilizer performance on fruit yield [19] [21].

The treatment performance was different in the two growing seasons. In 2019, the three organic manure combinations did not show significant difference on the measured traits. However, in 2020, 1/2 chicken + 1/2 goat produced significantly taller plants than 1/2 chicken + 1/2 cattle while 1/2 goat + 1/2 cattle had the highest fruit yield though the difference was not statistically significant. The variation suggests that the relative performance of the manure combinations may change from one season to the next. However, rainfall, temperature and soil moisture were not measured, hence the factors responsible for these differences cannot be confirmed [5] [26]. So, when you look at the two seasons studied, it's too early to say definitively that one manure combination is better. More trials are needed over seasons and environmental conditions to determine the most consistently suitable combination for garden egg production [23].

No manure combination was consistently superior across growth, biomass, and yield traits. Although 1/2 chicken + 1/2 goat produced significantly taller plants in 2020, 1/2 goat + 1/2 cattle recorded the highest numerical fruit yield. However, this yield advantage was not statistically significant. Thus, 1/2 goat + 1/2 cattle showed a promising trend but cannot yet be confirmed as the best combination without further multi-season evaluation [23].

5. Conclusion

This two-season study evaluated three blended animal-manure combinations; 1/2 chicken + 1/2 cattle, 1/2 chicken + 1/2 goat, and 1/2 goat + 1/2 cattle, for garden egg production, using NPK 15-15-15 and an unfertilized treatment as positive and negative controls, respectively. Across the 2019 minor and 2020 major seasons, the three organic combinations were statistically comparable for most vegetative, phenological, biomass, and yield traits. The only significant difference among them was the greater plant height recorded with 1/2 chicken + 1/2 goat than 1/2 chicken + 1/2 cattle at 51 DAP in 2020. Fruit yield did not differ significantly among the organic combinations in either season. However, in 2020, 1/2 goat + 1/2 cattle recorded the highest numerical yield (0.822 $t \cdot ha^{-1}$), indicating a favourable but statistically unconfirmed trend. Thus, no combination could be identified as consistently superior, although 1/2 goat + 1/2 cattle appeared promising and warrants further evaluation across additional seasons. NPK generally recorded the highest growth and yield values, while the unfertilized control recorded the lowest, confirming the importance of nutrient supplementation for garden egg production under the study conditions. Based strictly on the statistical evidence available, farmers operating under conditions similar to this study may reasonably consider any of the three blended manure combinations as a lower-input alternative to no fertilization, with 1/2 goat + 1/2 cattle showing the most promising numerical trend for fruit yield in the major season.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author Contributions

All authors contributed substantially to all aspects of the study, including conceptualisation, fieldwork and data collection, data analysis, manuscript preparation, critical review, and approval of the final manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Xiang, W. and Gao, J. (2023) Do Not Be Anticlimactic: Farmers' Behavior in the Sustainable Application of Green Agricultural Technology—A Perceived Value and Government Support Perspective. *Agriculture*, **13**, Article 247. https://doi.org/10.3390/agriculture13020247

[2] Zhang, H., Wang, L., Fu, W., Xu, C., Zhang, H., Xu, X., *et al.* (2024) Soil Acidification Can Be Improved under Different Long-Term Fertilization Regimes in a Sweetpotato-Wheat Rotation System. *Plants*, **13**, Article 1740. https://doi.org/10.3390/plants13131740

[3] Chatzistathis, T., Sarropoulou, V., Papaioannou, E. and Giannakoula, A. (2023) Inorganic and Organic Fertilization Effects on the Growth, Nutrient Uptake, Chlorophyll Fluorescence and Fruit Quality in *Solanum melongena* L. Plants. *Agronomy*, **15**, Article 872. https://doi.org/10.3390/agronomy15040872

[4] Sanyang, S., Demba, S. and Njie, E. (2025) Growth Performance of Eggplant (*Solanum melongena* L.) Enhanced by Watering Intervals and Application of Organic Manure. *International Journal of Applied Agricultural Sciences*, **11**, 24-28. https://doi.org/10.11648/j.ijaas.20251101.13

[5] Motsi, H., Phiri, E.E. and Mothapo, P.N. (2025) Manure Utilisation under Smallholder Farmers in Sub-Saharan Africa. a Systematic Review and Meta-Analysis. *Nutrient Cycling in Agroecosystems*, **131**, 613-634. https://doi.org/10.1007/s10705-025-10447-z

[6] Adekiya, A.O., Dahunsi, S.O., Adedokun, O.D., Agbede, T.M., Adayi Oche, P. and Ogunbode, T.O. (2025) Optimizing Soil Fertility and Crop Productivity Using Biodigestate, Poultry Manure, and NPK Integration. *Cleaner and Circular Bioeconomy*, **12**, Article 100192. https://doi.org/10.1016/j.clcb.2025.100192

[7] Mpanga, I.K., Adjei, E., Dapaah, H.K. and Santo, K.G. (2021) Poultry Manure Induced Garden Eggs Yield and Soil Fertility in Tropical and Semi-Arid Sandy-Loam

Soils. *Nitrogen*, **2**, 321-331. https://doi.org/10.3390/nitrogen2030022

[8] Agbede, T.M. (2025) Poultry Manure Improves Soil Properties and Grain Mineral Composition, Maize Productivity and Economic Profitability. *Scientific Reports*, **15**, Article No. 16501. https://doi.org/10.1038/s41598-025-00394-8

[9] Adjei, E., Santo, K.G., Poku, I.A., Alexander, D. and Antwi, A.O. (2023) Garden Egg (*Solanum melongena* L.) Performance under Different Sources of Animal Manure as a Sustainable Alternative Fertilizer for Farmers. *Agricultural Sciences*, **14**, 1053-1067. https://doi.org/10.4236/as.2023.148070

[10] Datta, S., Mazumdar, S.P., Majumdar, B., Alam, N.M., Chattopadhyay, L., Ghosh, S., *et al.* (2025) Impact of Integrated Nutrient Management on Soil Microbiome Diversity and Health in Rice Based Cropping System: Insights from Long-Term Agricultural Practices. *Rhizosphere*, **33**, Article 101048. https://doi.org/10.1016/j.rhisph.2025.101048

[11] Yimer, A.H. and Tarnawa, A. (2025) Advancing Nutrient Management Strategies for Sustainable Crop Productivity in a Changing Climate: A Systematic Review. *The Scientific World Journal*, **2025**, Article ID: 7101060. https://doi.org/10.1155/tswj/7101060

[12] Yeboah, E.K., Santo, K.G., AFreh-Ntiamoah, D. and Ackah, E. (2021) Productivity Response of Okra (*Abelmoschusesculentus*) to Organic and Inorganic Nutrition at Different Spacing. *Niva Povolzhya*, **10**, 28-45. https://doi.org/10.36461/np.2021.59.2.020

[13] Abdul-Aziz, A., Haruna, A. and Baako, A.Y. (2026) Integrating Biochar, Compost, and Chemical Fertilizer Improves Maize Yield and Soil Health in the Guinea Savannah: Evidence from Two Cropping Seasons in Northern Ghana. *Scientific Reports*, **16**, Article No. 2210. https://doi.org/10.1038/s41598-025-31886-2

[14] Ghana Statistical Service (GSS) (2014) 2010 Population and Housing Census: District Analytical Report, Sunyani West Municipality. Ghana Statistical Service.

[15] Nelson, D.W. and Sommers, L.E. (1982) Total Carbon, Organic Carbon, and Organic Matter. In: Page, A.L., Ed., *Methods of Soil Analysis*, Part 2, 2nd Edition, ASA & SSSA, 539-579.

[16] Bremner, J.M. and Mulvaney, C.S. (1982) Nitrogen-Total. In: Page, A.L., Ed., *Methods of Soil Analysis*, Part 2, 2nd Edition, ASA & SSSA, Madison, 403-430.

[17] Murphy, J. and Riley, J.P. (1962) A Modified Single Solution Method for the Determination of Phosphate in Natural Waters. *Analytica Chimica Acta*, **27**, 31-36. https://doi.org/10.1016/s0003-2670(00)88444-5

[18] Piper, C.S. (1944) Soil and Plant Analysis. University of Adelaide.

[19] Paul, O.J., Ojomah, O.O. and Ambrose, A.E. (2017) Effect of Poultry Manure and NPK Fertilizer on Growth and Yield of Eggplant (*Solanum melongena*). *Journal of Agricultural and Rural Research*, **1**, 112-117.

[20] Ahmed, W., Ashraf, M.N., Sanaullah, M., Maqsood, M.A., Waqas, M.A., Rahman, S.U., *et al.* (2024) Soil Organic Carbon and Nitrogen Mineralization Potential of Manures Regulated by Soil Microbial Activities in Contrasting Soil Textures. *Journal of Soil Science and Plant Nutrition*, **24**, 3056-3067. https://doi.org/10.1007/s42729-024-01730-z

[21] Fayed, T.A., Abd-Elfattah, M.A. and Abd El-Aziz, A.M. (2025) Effect of Organic Manures and Foliar Seaweed Extract Application on Enhancing the Vegetative Growth of Young Plum Trees. *Journal of Applied Horticulture*, **27**, 644-649. https://doi.org/10.37855/jah.2025.v27i04.114

[22] Ghimire, S., Poudel Chhetri, B. and Shrestha, J. (2023) Efficacy of Different Organic and Inorganic Nutrient Sources on the Growth and Yield of Bitter Gourd (*Momordica charantia* L.). *Heliyon*, **9**, e22135. https://doi.org/10.1016/j.heliyon.2023.e22135

[23] Ranjous, M., Al-Balkhi, A., Al-Khader, A., Jaafar, A.A.K. and Rodríguez-Seijo, A. (2025) Integrated Nutrient Management Enhances the Growth and Yield of Cauliflower (*Brassica oleracea* Var. *Botrytis*) in Calcareous Soil: A Field Experiment with Mineral, Organic, and Biofertilizers. *ACS Omega*, **10**, 63093-63101. https://doi.org/10.1021/acsomega.5c09287

[24] Mondol, A.T.M.A.I., Chowdhury, M.A.H., Ahmed, S. and Alam, M.K. (2024) Nitrogen Dynamics from Conventional Organic Manures as Influenced by Different Temperature Regimes in Subtropical Conditions. *Nitrogen*, **5**, 746-762. https://doi.org/10.3390/nitrogen5030049

[25] Liu, H., Chen, J., Fu, L., Chen, H., Yang, Y., Wang, W., *et al.* (2025) Effects of Different Combinations of Organic Fertilizers on the Yield and Quality of Four Leafy Vegetables. *Scientific Reports*, **15**, Article No. 25994. https://doi.org/10.1038/s41598-025-09671-y

[26] Adekiya, A.O., Ejue, W.S., Olayanju, A., Dunsin, O., Aboyeji, C.M., Aremu, C., *et al.* (2020) Different Organic Manure Sources and NPK Fertilizer on Soil Chemical Properties, Growth, Yield and Quality of Okra. *Scientific Reports*, **10**, Article No. 16083. https://doi.org/10.1038/s41598-020-73291-x