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Physiological responses of *Hiyung* chili to different animal manures under acid sulfate soil conditions

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Abstract. *Abdillah MH, Lukmana M, Rahmawati L, Iswahyudi H, Indayaty A, Indriani. 2026. Physiological responses of* Hiyung *chili to different animal manures under acid sulfate soil conditions. Asian J Agric 10 (1): g100109. https://doi.org/10.13057/asianjagric/g100109.* Acid sulfate soils are marginal lands characterized by low pH, high saturation with Fe and Al, and poor nutrient availability. This study evaluated the effects of four types of animal manure-chicken, swiftlet, goat, and cattle-at five dosage levels (100-500 g) on *Hiyung* chili growth and yield, conducted from January to July 2024 at Politeknik Hasnur, South Kalimantan, Indonesia, using a Randomized Complete Block Design (RCBD) with 80 experimental units. Manures were composted aerobically, and dolomite was applied to plants. The data collected included plant height, leaf number, flower number, mature fruit count, fruit weight, and dry biomass, which were analyzed using ANOVA and DMRT at a 5% significance level. Chicken manure exhibited the most consistent and significant dose-response effects on the growth and yield of *Hiyung* chili pepper, with the 300 g dose increasing plant height, leaf number, flower number, fruit number, and fruit weight by approximately 30-60% compared to the lowest dose and showing significant differences from other manure types (DMRT 5%). In contrast, higher doses of cattle and swiftlet manure tended to reduce yield components by about 40-65%, indicating threshold effects and declining nutrient-use efficiency, with overall treatment effectiveness ranked as chicken manure > goat manure > swiftlet manure ≈ cattle manure. Chicken manure is recommended to improve *Hiyung* chili productivity on acid sulfate soils. This study highlights the role of local organic resources as sustainable inputs to improve soil fertility and crop productivity on acid sulfate soils, supporting long-term soil health and sustainable farming on marginal lands.

Keywords: Acid sulfate soil, amelioration, *Hiyung* chili, manure, yield

INTRODUCTION

Hiyung chili (*Capsicum annuum* L. var. Hiyung) is a strategic horticultural commodity originating from South Kalimantan and is widely recognized for its extreme pungency and long shelf life (Mahmudah and Badruzsaufari 2020; Hidayah et al. 2023). These distinctive attributes have driven a consistently high market demand. However, the cultivation of *Hiyung* chili remains geographically constrained, being largely limited to rainfed alluvial lands with relatively favorable soil conditions (Hayati and Hardarani 2019). In response to increasing domestic demand and the need to strengthen regional horticultural production systems (Kementerian Perindustrian RI 2023), expanding *Hiyung* chili cultivation into marginal lands has become a strategic necessity.

Among marginal land types, acid sulfate soils represent one of the most challenging agroecosystems for crop production. These soils are characterized by extremely low pH values, often below 4, high concentrations of soluble aluminum and iron that are toxic to plants, and low availability of essential nutrients (Pusparani 2018). Such conditions severely restrict root development, nutrient uptake, and overall plant growth. As a result, successful crop cultivation on acid sulfate soils requires integrated soil management strategies that address not only nutrient limitations but also chemical toxicity and poor soil physical conditions. Organic amendments have been widely recognized as a promising approach to overcome these constraints by improving soil quality and buffering adverse chemical conditions (Abdillah and Widiyastuti 2022). Despite their limitations, acid sulfate soils hold substantial potential to support horticultural and food crop self-sufficiency programs if managed appropriately.

The application of animal manures represents a sustainable and cost-effective soil amendment strategy, particularly in resource-limited agricultural systems (Indriani et al. 2023; Pajura 2024). Animal manures contribute to soil improvement through multiple pathways: enhancing soil aggregation and porosity, increasing water-holding capacity, and supplying both macro and micronutrients essential for plant growth (Semenov et al. 2021). Furthermore, organic matter derived from manure can reduce soil acidity and mitigate aluminum toxicity through complexation reactions, thereby improving the root-zone environment for crop development (Goldan et al. 2023). Numerous studies have demonstrated the general benefits of organic amendments on acid sulfate soils and water (Dang et al. 2015; Kölbl et al. 2017, 2018; Domene et al. 2025), confirming their role in improving soil fertility and crop performance (Shamshuddin et al. 2004; Cardelli et al. 2008; Santri et al. 2019; Abdillah et al. 2022; Abdillah et al. 2024; Maharani et al. 2025).

However, acid sulfate soils pose complex constraints that cannot be addressed solely by nutrient addition. Aluminum toxicity, for instance, directly inhibits root elongation and damages root apices, leading to reduced nutrient and water uptake. In horticultural crops such as chili, these effects translate into poor vegetative growth, delayed flowering, reduced fruit set, and ultimately lower yields. Organic amendments play a critical role in alleviating these stresses by modifying the chemical, physical, and biological properties of the soil simultaneously. By increasing cation exchange capacity and supplying organic ligands, manure-derived organic matter can immobilize toxic aluminum and iron ions, while also fostering beneficial microbial activity in the rhizosphere.

Importantly, the effectiveness of animal manures is not uniform and varies substantially depending on their origin and composition. Different manure types such as chicken, swiftlet, goat, and cattle manure differ in nutrient content, carbon-to-nitrogen ratio, decomposition rate, and the presence of bioactive compounds (Michael et al. 2015; Basuki and Sitompul 2019; Lubis et al. 2021; Soleha et al. 2023). Manures with higher nitrogen and phosphorus contents, such as poultry and swiftlet manure, tend to release nutrients more rapidly, supporting early vegetative growth. In contrast, cattle and goat manures generally contain higher proportions of stable organic matter, contributing to longer-term improvements in soil structure and fertility. Additionally, several studies suggest that organic amendments may indirectly influence plant growth through stimulation of soil microorganisms capable of producing phytohormones, such as auxins and cytokinins, which enhance root development and shoot growth under stress conditions (Jindo et al. 2020; Abobatta and Al-Taey 2023; Zaghloul et al. 2024).

Under abiotic stress environments like acid sulfate soils, these indirect effects on the soil-plant-microbe continuum may be as critical as direct nutrient supply. Improved root system architecture and enhanced microbial interactions can increase plant tolerance to acidity and metal toxicity, ultimately leading to better growth and yield stability. Despite the recognized importance of organic amendments, comparative evaluations of different animal manure types on *Hiyung* chili cultivation under acid sulfate soil conditions remain scarce. Most existing studies focus on general crop responses or single manure types, leaving a significant knowledge gap regarding manure-specific effects on this unique and economically valuable chili variety.

Therefore, this study aims to scientifically examine the morphological response of *Hiyung* chili plants, which is reviewed through a phytohormonal approach, due to the application of various types of manure to acid sulfate soil. By addressing this gap, the study seeks to provide a scientifically grounded, locally adapted agronomic strategy to optimize the production of *Hiyung* chili on marginal lands.

Beyond its local relevance, this research contributes to global efforts to enhance food production amid climate change and growing food security challenges. The sustainable utilization of marginal lands such as acid sulfate soils offers a pathway to increase crop output without further land clearing. Moreover, the use of locally available animal manures aligns with circular economy principles by transforming agricultural waste into valuable inputs that enhance soil resilience, improve nutrient cycling, and mitigate land degradation. By offering a validated and replicable model for crop optimization under adverse soil conditions, this study contributes to the development of more sustainable and adaptable food systems worldwide.

MATERIALS AND METHODS

Location of the experimental field

The study was conducted from January to July 2024 at the experimental field of the Plantation Crop Cultivation Study Program, the Politeknik Hasnur, South Kalimantan, Indonesia. The initial soil properties are presented in Table 1. During the experimental period, the site experienced the rainy season, with an average monthly rainfall of 203 mm and temperate 31°C until June 2024 (Badan Meteorologi, Klimatologi, dan Geofisika 2024).

A factorial experiment was arranged in a Randomized Complete Block Design (RCBD) with two factors and four replications, resulting in 80 experimental units. The first factor was the type of animal manure, consisting of chicken (A), swiftlet (W), goat (K), and cattle (S) manure. The second factor was the manure dosage, applied directly into each planting hole at five levels: 100 g (2.8 t ha^{-1}), 200 g (5.7 t ha^{-1}), 300 g (8.5 t ha^{-1}), 400 g (11.4 t ha^{-1}), and 500 g (14.2 t ha^{-1}).

Procedures

Tools and materials

The tools used in this study included large and small hoes, a mechanical spring scale, measuring tape, and wooden battens. The materials consisted of *Hiyung* chili seeds, composted manures (chicken, swiftlet, goat, and cattle), NPK fertilizer 16-16-16, and dolomite. The content of composted manures is presented in Table 2.

Seed germination and seedling management

Hiyung chili seeds were first subjected to a uniform pre-germination process to ensure homogeneous seedling emergence. The seeds were surface-sterilized by soaking in 1% sodium hypochlorite solution for 2 minutes, followed by thorough rinsing with sterile distilled water, and then air-dried at room temperature. Subsequently, the seeds were sown in plastic seed trays filled with a sterilized mixture of topsoil and burned rice husk at a ratio of 2:1 (v/v). The seed trays were maintained under nursery conditions with regular watering twice daily to keep the substrate moist but not waterlogged. Germination occurred within 5-7 days after sowing, and seedlings were allowed to grow until they developed 4-5 true leaves, which corresponded to approximately 25-30 days after sowing.

During the nursery phase, seedlings were protected from excessive rainfall and direct sunlight using a transparent plastic cover and shade net, respectively, to minimize environmental stress and promote uniform growth. No additional fertilizers were applied at the seedling stage to avoid confounding nutritional effects prior to treatment application. Seedlings at 25-30 days old, with uniform height and vigor, were selected and transplanted into the prepared planting holes in the experimental beds. Transplanting was conducted in the late afternoon to reduce transplant shock. Immediately after transplanting, plants were watered to ensure good root-soil contact and facilitate establishment. Throughout the growing period (110 days after transplanting), all plants received uniform irrigation, pest control, and weed management to ensure that observed differences in growth and yield were attributable solely to the manure treatments.

Table 1. The initial acid sulfate soil properties

Soil properties	Content
Fe-soluble (mg kg^{-1})	236.2[*]
Al (mg kg^{-1})	363.7[*]
pH	3.93[*]
FeS_2 (%)	0.26[**]
C-organic (%)	6,84[**]
Bulk density (g cm^{-3})	1.32[**]

Note: [*]: Abdillah and Widiyastuti (2022), [**]: Abdillah (2022)

Preparation and implementation

The preparation and implementation can be seen at Figure 1. The experiment began with the aerobic composting of chicken, swiftlet, goat, and cattle manures for 30 days until their moisture content reached approximately <15%. No additional materials were added during the composting process, but the compost piles were turned weekly to facilitate uniform decomposition.

While composting and seedling growth were underway, *Hiyung* chili seeds were sown in seed trays filled with a mixture of topsoil and burned rice husk. Concurrently, the experimental plots were prepared by creating raised beds from acid sulfate soil, classified as type B tidal land. Each bed measured 20×400 cm and contained 20 planting holes designated for the experimental units. Treatment plots were assigned randomly using a random number table to avoid positional bias. A total of 80 experimental units were arranged using a randomized complete block design. The use of four replications (80 experimental units total) was employed to ensure statistical reliability and is considered standard practice for field experiments with the randomized complete block design.

The standardize basal soil conditions across all experimental units and mitigate pH related variability, dolomite was uniformly applied to each planting hole at a rate of 25 g, seven days before transplanting. One week later, composted manures were applied according to the assigned treatment doses and thoroughly incorporated into the soil. Ten days thereafter, seedlings with four to five true leaves were transplanted into the planting holes and maintained for 110 days.

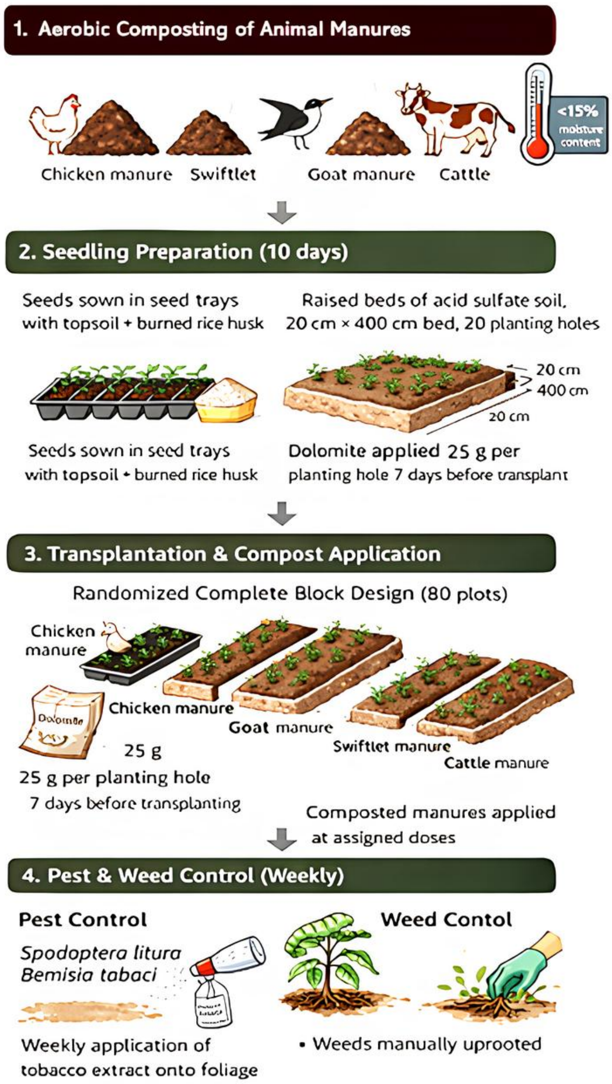

Figure 1. Stages of activities carried out in research

Table 2. Content of composted manures

Kind of manure/manure content	N (%)	P (%)	K (%)	C-organic (%)	pH	Water content (%)
Swiftlet manure	3.3	5.2	1.2	26	7.6	3.7
Chicken manure	4.2	3.9	1.8	31	6.8	8.3
Goat manure	3.7	0.7	1.3	44	7.4	6.8
Cattle manure	5.9	0.3	1.4	64	5.2	14.3

Source: Lab analysis in 2024

Ensure uniformity and eliminate potential biases from pest and weed pressure, control measures were implemented across all experimental treatments. Common pests attacking *Hiyung* chili leaves included *Spodoptera litura* and *Bemisia tabaci*. Pest control was performed uniformly weekly by spraying tobacco extract onto the foliage (Harismah et al. 2022; Siregar 2022). Additionally, weed control was carried out manually by uprooting.

Data analysis

The observed variables included plant height, number of leaves, number of flowers, number of mature fruits, fresh fruit weight, and plant dry weight. Plant height was measured using a measuring tape extended from the soil surface to the apex of the tallest branch, closely aligning the tape along the stem. Leaf count was performed manually by counting each leaf from the lowest to the highest branches (Taiz et al. 2015).

Measurements for plant height and leaf number were taken only from plants at the end of the vegetative stage, characterized by the appearance of the first flower bud. Flower count was conducted by recording the number of fully bloomed flowers on all branches, starting ten days after the emergence of flower buds at leaf axils (Kaur 2014). This count was repeated over three flowering cycles (30 days), and the total number of flowers per plant was calculated by summing the results of each cycle.

Fruit count was carried out after flowering, focusing on physiologically mature fruits with more than 70% red coloration. These fruits were harvested and weighed using a digital scale. Harvesting and weighing were conducted over three harvest cycles, each spaced three weeks apart, corresponding to fruit maturation from green to red (Beadle 1985).

At the end of the growth period, plant dry weight was measured. Whole plants were uprooted, rinsed with water, drained under sunlight for 15 minutes, and then oven-dried at 70°C for 72 hours (Sampson 1939).

All data were recorded in a research notebook and subsequently analyzed. Observations and harvest data were collected on six randomly selected plants per plot. In each plot, each plant was labeled 1 through 20. This was done using a random number table to avoid sampling bias. These selected plants were used for yield measurements, including fruit number and fresh weight, during three harvests. Normality was tested using the Shapiro-Wilk test, and homogeneity of variance was assessed using Levene's test. Once assumptions were met, Analysis of Variance (ANOVA) was performed to determine treatment effects. Significant differences among treatments were further analyzed using Duncan's Multiple Range Test (DMRT) at a 5% significance level. Statistical analyses were conducted using SPSS version 25, with Microsoft Excel utilized for data tabulation and formatting.

RESULTS AND DISCUSSION

Plant height

Plant height measurements at the end of the vegetative phase (Table 3) showed that the application of different types and doses of animal manure had a significant effect on the growth of *Hiyung* chili plants. The highest plant height, 107 cm, was recorded with the application of 500 g of chicken manure, which was significantly different from all other treatments based on DMRT at the 5% level. In contrast, the lowest plant height (62 cm) was observed with the application of 400 g of swiftlet manure, which did not differ significantly from swiftlet manure at 100 g and 200 g, or from goat manure at 200 g. A consistent upward trend in plant height was observed with increasing doses of chicken manure, indicating a dose-dependent response. Conversely, treatments with swiftlet manure showed irregular fluctuations, with a noticeable decline at the 400 g dose. Goat manure treatments produced relatively stable plant heights ranging from 64 to 84 cm. Cattle manure showed an increase at 200 g, followed by a decline at higher doses. These findings suggest that the effectiveness of organic manure varies according to its chemical composition, nutrient availability, and compatibility with plant nutrient requirements.

The number of leaves

Observations on leaf number (Table 4) revealed that the application of 500 g of chicken manure resulted in the highest number of leaves, averaging 217, which was significantly greater than all other treatments based on DMRT at the 5% level. A linear increase in leaf number was observed with increasing doses of chicken manure, aligning with the findings of Diri and Kedoneojo (2024), who reported a similar trend in maize grown with chicken manure amendments. In contrast, swiftlet manure exhibited a slower and relatively flat response, with leaf numbers ranging from 129 to 151. DMRT analysis indicated no significant differences among the 100 g, 200 g, and 400 g doses, while the 300 g and 500 g treatments showed significantly different results, producing 151 and 132 leaves per plant, respectively. Goat manure treatments produced moderate outcomes, with stable increases in leaf number, particularly between the 300 g and 500 g doses. Cattle manure treatments showed inconsistent trends. For example, the 200 g dose resulted in a relatively high leaf count (178 leaves), but this declined at the 300 g and 500 g doses. These results indicate that the effectiveness of each manure type is closely related to its nutrient composition and its interaction with the applied dosage.

The number of flowers

According to DMRT analysis at the 5% significance level (Table 5), the application of chicken manure at 300 g and 400 g resulted in the highest number of flowers, averaging 115 blooms per plant, and differed significantly from all other treatments. A linear increase in flower production was observed from 100 g to 300 g, followed by a plateau at 400 g and a slight decline at 500 g (109 blooms). In contrast, swiftlet and goat manure treatments exhibited more fluctuating patterns. Both achieved their highest flower counts at 500 g, with 102 and 101 flowers per plant, respectively. Meanwhile, cattle manure produced inconsistent results, with the highest number of flowers (103) recorded at the 200 g dose. This was followed by a sharp decline, reaching only 63 flowers at 500 g. These results suggest that both manure type and dosage significantly influence plant physiological processes, particularly flower formation, which serves as an early indicator of yield potential.

The number of mature fruits

As presented in Table 6, the application of 300 g of chicken manure resulted in the highest number of mature fruits, averaging 102 fruits per plant, which was significantly different from most other treatments. Chicken manure consistently supported high and stable fruit development across the 200-400 g range, although a slight decrease was observed at 500 g. Goat manure showed a steady and significant increase in fruit number from 63 fruits at 200 g to 96 fruits at 500 g, making it a strong alternative to chicken manure. In contrast, cattle manure treatments exhibited a sharp decline in fruit production at higher doses, producing only 51 and 34 fruits at the 400 g and 500 g levels, respectively. This suggests a potential adverse effect of excessive cattle manure on the plant's reproductive development. Swiftlet manure demonstrated moderate performance, with a gradual increase from 51 to 87 fruits across applied doses, although it remained less effective compared to the optimal doses of chicken and goat manure.

Weight of mature fruits

Based on the results presented in Table 7, chicken manure consistently produced the highest mature fruit weights across all doses, with the maximum value of 108.5 g recorded at the 500 g application rate. DMRT analysis at the 5% significance level indicated no significant difference between the 400 g and 500 g chicken manure treatments. Swiftlet manure showed a significant increase in fruit weight at 500 g (77.43 g), although this remained lower than the values observed with chicken manure. Goat manure demonstrated a consistent positive response at higher doses, reaching 94.08 g at the 500 g level, suggesting a beneficial effect likely due to its high potassium content. In contrast, cattle manure treatments displayed a decreasing trend in fruit weight with increasing doses, peaking at only 89.6 g at 200 g and sharply declining to 28.22 g at 500 g. Overall, goat manure produced relatively stable and moderately high fruit weights, while swiftlet manure also showed potential, particularly at the highest dose (87.45 g). Although these results were not as high as those achieved with chicken manure, they indicate a positive trend in fruit weight improvement under specific conditions.

Discussion

Based on the comparative percentage effectiveness of various types of manure on the growth and yield of *Hiyung* chili, chicken manure demonstrated the most balanced and consistent performance in enhancing all observed parameters. It increased plant height by 42.7%, leaf number by 47.6%, flower number by 36.9%, mature fruit number by 29.1%, and fruit weight by 41.1%. Goat manure demonstrated favorable effects, particularly on generative components, increasing fruit number and fruit weight by 39.1% and 54.9%, respectively, although its influence on vegetative traits was relatively lower than that of chicken manure. Swiftlet manure also markedly enhanced generative performance, with fruit weight and fruit number increasing by 102.4% and 70.6%, respectively; however, its contribution to vegetative growth was minimal, as indicated by only a 2.3% increase in leaf number. By contrast, the application of cattle manure at higher doses resulted in significantly negative effects across all measured variables, including reductions of 68.5% in fruit weight and 57.5% in fruit number, along with decreases in plant height, leaf number, and flower number by 21.3%, 23.6%, and 38.8%, respectively.

Table 3. The average plant height of *Hiyung* chili grown in media treated with various types and doses of animal manure

Treatment/Doses	100 g	200 g	300 g	400 g	500 g
Swiftlet manure	64a±8.7	67a±12.2	84c±12.7	62a±12.5	75b±6.7
Chicken manure	75b±11.1	78b±7.7	88c±12.9	92d±14.2	107e±11.1
Goat manure	70a±8.5	64a±10.1	78b±13.2	78b±13.3	84c±9.7
Cattle manure	75b±9.9	89d±12.7	72b±10.1	75b±15.7	70a±8.3

Note: The results indicate that different types and levels of manure significantly affected plant height, as shown by the distinct superscript letters based on the DMRT test at a 5% significance level

Table 4. The average number of leaves *Hiyung* chili grown in media treated with various types and doses of animal manure

Treatment/Doses	100 g	200 g	300 g	400 g	500 g
Swiftlet manure	129a±12.1	129a±7.5	151c±11.6	136a±14.2	132b±10.2
Chicken manure	147b±13.7	155c±14.1	176d±12.2	184d±11.8	217e±11.1
Goat manure	136a±11.2	123a±12.2	154c±10.6	154c±9.1	164c±13.7
Cattle manure	147b±8.2	178d±8.2	144b±11.7	150b±12.2	136a±12.2

Note: The results indicate that different types and levels of manure significantly affected plant height, as shown by the distinct superscript letters based on the DMRT test at a 5% significance level

Organic manure application plays a critical role in alleviating iron (Fe) and aluminum (Al) toxicity under acidic and acid sulfate soil conditions through multiple physicochemical and biological mechanisms. The incorporation of organic matter promotes the formation of stable organo-metal complexes, in which Fe^{2+} and Al^{3+} ions are chelated by humic and fulvic substances, thereby reducing their solubility and toxic activity in the rhizosphere (Abdillah and Widiyastuti 2022). In addition, organic amendments improve soil buffering capacity and cation exchange capacity, which collectively decrease exchangeable Fe and Al while enhancing the availability of essential nutrients such as nitrogen, phosphorus, potassium, calcium, and magnesium. These improvements create a more favorable root environment, support nutrient uptake efficiency, and enhance overall plant vigor.

Improved nutrient availability resulting from organic manure application directly influences key leaf physiological processes, particularly chlorophyll synthesis and stomatal regulation (Sonntag et al. 2023). Nitrogen and magnesium released during organic matter mineralization are fundamental structural components of chlorophyll molecules, leading to increased chlorophyll content and enhanced photosynthetic capacity. Potassium plays a pivotal role in stomatal opening and closing, thereby improving stomatal conductance, CO_2 assimilation, and transpiration efficiency (Taiz et al. 2015). The observed increases in leaf number, leaf greenness, and biomass accumulation in this study are therefore closely associated with enhanced photosynthetic performance driven by balanced nutrient supply.

Plant height serves as a key indicator of physiological responses to nutrient availability in soil. Organic amendments derived from various animal manures, such as chicken, swiftlet, goat, and cow, demonstrate diverse effects on plant elongation and vegetative development. Among these, chicken manure significantly enhanced plant height, reaching 107 cm at the 500 g dosage, which may be attributed to its balanced nitrogen and phosphorus content that supports protein, enzyme, and growth hormone synthesis (Ye et al. 2021).

Auxins and gibberellins are primary regulators of stem elongation and cell division. Chicken manure, through its nitrogen availability, enhances the production of tryptophan, an auxin precursor, and facilitates ATP synthesis critical for hormonal biosynthesis (Depuydt and Hardtke 2011; Chaiwanon et al. 2016). These interactions clarify the superior vertical growth observed under chicken manure treatments.

In contrast, swiftlet and cow manure treatments yielded inconsistent outcomes. Swiftlet manure, originating from waste of edible-nest swiftlet farms, is known to be rich in micronutrients but may experience slower mineralization due to its complex organic matter. High C/N ratios and the presence of lignocellulosic materials in cow manure may also retard decomposition, limiting nitrogen release and reducing enzymatic activities necessary for optimal growth (Yang et al. 2021; Chen et al. 2025; Tang et al. 2025).

Table 5. The average number of flowers *Hiyung* chili grown in media treated with various types and doses of animal manure

Treatment/Doses	100 g	200 g	300 g	400 g	500 g
Swiftlet manure	64a±12.8	87c±12.2	77b±14.2	87c±7.7	102d±9.2
Chicken manure	84c±9.7	105d±8.7	115e±10.5	115e±8.2	109e±10.4
Goat manure	77b±11.5	68a±13.8	89c±8.2	99d±10.5	101d±12.7
Cattle manure	78b±12.3	103d±11.6	80b±8.1	75a±6.8	63a±7.4

Note: The results indicate that different types and levels of manure significantly affected plant height, as shown by the distinct superscript letters based on the DMRT test at a 5% significance level

Table 6. The average number of mature fruits *Hiyung* chili grown in media treated with various types and doses of animal manure

Treatment/Doses	100 g	200 g	300 g	400 g	500 g
Swiftlet manure	51b±3.4	79d±6.6	63c±4.2	82d±6.1	87d±2.2
Chicken manure	79d±6.7	100e±10.3	102e±9.8	100e±10.2	90d±5.9
Goat manure	69c±7.2	63c±2.2	82d±7.2	88d±4.7	96e±6.5
Cattle manure	71c±7.9	80d±8.1	51b±8.8	51b±3.2	34a±4.3

Note: The results indicate that different types and levels of manure significantly affected plant height, as shown by the distinct superscript letters based on the DMRT test at a 5% significance level

Table 7. The average weight of mature fruits *Hiyung* chili grown in media treated with various types and doses of animal manure

Treatment/Doses	100 g	200 g	300 g	400 g	500 g
Swiftlet manure	38.25a±4.2	64.78b±4.9	61.74b±4.4	60.68b±3.2	77.43c±5.1
Chicken manure	76.867c±7.1	95.2d±7.4	93.96d±8.1	105e±9.8	108.5e±6.2
Goat manure	60.72b±2.6	61.11b±2.2	91.84d±2.9	91.52d±5.1	94.08d±7.7
Cattle manure	63.19b±6.5	89.6d±6.3	59.67b±4.7	37.74a±2.9	28.22a±1.6

Note: The results indicate that different types and levels of manure significantly affected plant height, as shown by the distinct superscript letters based on the DMRT test at a 5% significance level

Goat manure showed promising effects at moderate levels (200 g), but lacked consistency at higher doses. The variation likely stems from slower nutrient release and the microbial enzymatic activity required to decompose organic substrates in the soil, which affects the synchronization between nutrient availability and vegetative demand (Islam et al. 2021).

The number of leaves is another crucial indicator of vegetative vigor, reflecting the plant’s photosynthetic potential. Chicken manure treatment consistently increased leaf production across doses. The improvement was supported by the synergistic action of auxins, cytokinins, and gibberellins, which were stimulated by amino acid precursors such as tryptophan and adenine (Barik 2020; Nurita and Yuliani 2023; Xu et al. 2023).

Goat manure, characterized by its higher potassium content, also promoted leaf formation at higher doses by supporting osmotic balance and tissue development (Trivana and Pradhana 2017). In contrast, swiftlet and cow manures showed erratic trends, which may result from delayed decomposition and the inhibition of enzymatic processes like nitrate reductase and Rubisco (Lee et al. 2019).

The number of flowers serves as an early predictor of reproductive potential. Organic input from chicken origin significantly promoted flower formation up to 115 blossoms at the 400 g dosage. This enhancement aligns with the increased biosynthesis of key floral hormones such as gibberellin, auxin, and florigen (Gray 2004; Zhang et al. 2021). Phosphorus and potassium supplied by chicken manure also activate ATPase and kinase enzymes that are crucial for floral induction (Ye et al. 2019). Goat manure followed a similar trend at higher doses, suggesting potassium’s role in carbohydrate utilization and floral organ development (Biswas et al. 2025). Meanwhile, cow manure’s low mineralization rate may have restricted hormone synthesis and hindered floral differentiation (Jun et al. 2023).

Fruit count reflected similar treatment effects. Organic input from chicken manure at 300 g yielded the highest fruit number (102 fruits), likely due to its facilitation of ethylene and abscisic acid biosynthesis and activation of fruit-ripening enzymes such as pectinase, cellulase, and ACC oxidase (Carbonell-Bejerano et al. 2014; Sonntag et al. 2023; Carlew et al. 2025). Cow manure resulted in significantly reduced fruit numbers at higher dosages. This may be caused by high lignin and phenolic compound content, which slows microbial activity and nutrient release (Alzagameem et al. 2019; Silva et al. 2021). Although swiftlet manure displayed a moderate increase in fruit count, its long mineralization time suggests a need for further investigation.

Fruit weight patterns closely followed those of fruit number. Chicken manure produced the highest fruit weight, reaching up to 108.5 g per plant at a dosage of 500 g. Enhanced phytohormone production and increased activities of metabolic enzymes, such as invertase and ACC oxidase, contributed to efficient cell expansion and improved sugar transport (Iqbal et al. 2017; Tipu and Sherif 2024; Liu et al. 2025). In addition, other enzymes, including NADH dehydrogenase and nitrogenase, were likely stimulated by the nitrogen-rich composition of chicken manure, thereby supporting amino acid synthesis and biomass accumulation (Miller et al. 2008; Cánovas et al. 2018; Moosavi et al. 2019). By contrast, cow and swiftlet manure treatments showed less consistent improvements in fruit biomass. From a physiological perspective, fruit mass development depends on synchronized hormonal signaling and adequate nutrient supply. Chicken manure offered optimal support for both processes by providing fast-mineralizing nutrients in line with plant demand. Swiftlet manure, despite its rich micronutrient profile (Azizon et al. 2013; Yeo et al. 2021), exhibited reduced efficacy at high dosages due to potential ionic antagonism or nutrient imbalance (Rietra et al. 2017). Cow manure’s high fiber and lignin content slowed decomposition, impeding nutrient availability and suppressing enzymatic activity. This led to significantly lower fresh weights at higher dosages. Although cow manure is still valuable for long-term soil improvement, its performance as a short-term nutrient source is limited (Michael 2020).

In conclusion, these findings highlight the importance of synchronizing nutrient release dynamics with crop physiological demand when selecting organic amendments for acid sulfate soils. Chicken manure, characterized by its low C/N ratio and rapid mineralization rate, enables timely nutrient release that aligns with crop demand. This synchronized nutrient supply supports the biosynthesis of growth-regulating hormones such as auxins, cytokinins, and gibberellins, which are essential for cell division, stem elongation, and reproductive development. In contrast, swiftlet and cow manures contain more complex organic structures and decompose more slowly, potentially delaying nutrient release and temporarily limiting nitrogen availability, thereby restricting chlorophyll formation and stomatal activity. Consequently, chicken manure provides the most effective balance between nutrient availability, physiological regulation, and yield formation in *Hiyung* chili.

While this study provides valuable insights into the comparative efficacy of various manures on *Hiyung* chili, it is not without limitations. This research was conducted under specific field conditions in South Kalimantan and did not include a detailed analysis of the soil's microbial community, which plays a crucial role in nutrient mineralization and plant-microbe interactions. Therefore, future research should focus on a more comprehensive analysis of the soil's microbial diversity and activity in response to different manure applications. These findings directly address the study objective by demonstrating how differences in nutrient composition and mineralization dynamics among organic manures shape the physiological responses and yield formation of *Hiyung* chili under acid soil stress conditions. Further studies could also explore the long-term cumulative effects of these organic amendments on soil fertility and plant performance, as well as investigate the potential for combining different manure types to create a more balanced and efficient fertilizer.

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The authors declare that artificial intelligence tools (ChatGPT and SciSpace) were used in a limited capacity during the manuscript preparation process. Specifically, these tools assisted in summarizing relevant literature, organizing the structure of the manuscript, improving language quality and readability, and verifying the alignment between the research objectives and the discussion developed by the authors. The use of artificial intelligence was strictly supportive in nature and accounted for approximately 10% of the overall manuscript preparation process. All scientific content, data interpretation, critical analysis, and final conclusions remain the sole responsibility of the authors.

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