



Interactive Effects of Soil Type and Chicken Manure Application Rate on the Growth and Soil Nutrient Status of Curly Lettuce (*Lactuca sativa* L.)

Eggye Andrew Sebayang¹, Amir Noviyanto^{1*}, Retni Mardu Hartati¹

¹Department of Agrotechnology, Faculty of Agriculture, Stiper Agricultural University, Special Region of Yogyakarta 55283, Indonesia

Corresponding Author : amir@instiperjogja.ac.id

ABSTRACT

*Andosols and Latosols are widely distributed tropical soils with inherent limitations for horticultural production. Andosols, despite their high porosity and water retention, often exhibit phosphorus fixation and structural instability, while Latosols are characterized by low nutrient reserves and poor cation exchange capacity due to intense weathering. However, limited empirical data exist on how different organic input rates interact with these soil types to influence crop performance and soil properties. This study investigates the interactive effects of chicken manure dosage and soil type on the growth of curly lettuce (*Lactuca sativa* L. var. *crispa*), aiming to improve crop productivity and soil fertility through organic input management. A factorial experiment was conducted from February to March 2025 at INSTIPER Yogyakarta (118 m asl), using a Completely Randomized Design (CRD) with two factors: soil type (Andosols and Latosols) and chicken manure dosage (0 g, 250 g, 500 g, and 750 g per polybag). Each of the 8 treatment combinations was replicated three times, totaling 48 experimental units. Growth variables measured included plant height, leaf number, biomass, and leaf area index, while post-harvest soil analyses evaluated pH, moisture, organic carbon, total nitrogen, and selected physical properties (bulk density and aggregate stability). All variables were assessed using standard laboratory procedures, and data were analyzed with ANOVA and Duncan's test ($p \leq 0.05$). Results revealed a significant interaction between soil type and manure dosage on leaf number and fresh shoot weight. At 500 g dosage in Andosols, fresh shoot weight increased by 35% compared to the control. Chicken manure also improved soil fertility, particularly organic carbon and nitrogen content. These findings provide practical guidance for optimizing organic fertilization strategies tailored to soil type, supporting sustainable and productive horticultural systems in tropical regions.*

Keywords: *Andosols, chicken manure fertilizer, curly lettuce, Latosols*

INTRODUCTION

The demand for vegetables in Indonesia continues to rise, reflecting a broader public commitment to healthier lifestyles and increased fruit and vegetable consumption. Vegetables such as lettuce (*Lactuca sativa* L.) are valued not only for their nutritional composition—including calcium, phosphorus, iron, and vitamins A, B, and C—but also for their increasing consumer demand driven by population growth ((Schreinemachers *et al.*, 2018). Curly lettuce grows optimally at 15–20 °C, with annual rainfall of 1000–1500 mm, and at elevations of 600–1200 m above sea level (Febriani *et al.*, 2025).

According to Statistics Indonesia (2023), national lettuce production reached 727,467 tons in 2021, increased to 760,467 tons in 2022, but

declined to 686,867 tons in 2023. Meanwhile, exports totaled 603,859 tons during 2021–2023. The recent decline in domestic production has been attributed in part to declining soil fertility, particularly a deficiency in soil organic matter. Low organic matter reduces soil quality, limiting its capacity to support crop growth. Applying organic amendments is therefore critical, as these improve soil physical and chemical properties, enhance water retention, and increase nutrient availability. Chicken manure is one of the most effective organic fertilizers, supplying essential nutrients while improving soil structure and fertility (Semenov *et al.*, 2023).

Andosols and Latosols are two important tropical soils for vegetable cultivation. Andosols, typically found on volcanic slopes such as Mount Merapi in Central Java, are characterized by sandy textures, low bulk density, and high porosity, which favor

typically found on volcanic slopes such as Mount Merapi in Central Java, are characterized by sandy textures, low bulk density, and high porosity, which favor root growth. However, high amorphous materials cause strong phosphorus fixation, with less than 1% of total soil P (1600–5000 mg kg⁻¹) available to plants. Organic inputs such as chicken manure can improve P availability in Andosols (Wu & Wan, 2023).

Latosols, in contrast, are clay-rich, red to yellow soils formed under intense weathering. They are generally acidic (pH 4.5–6.0), with low organic matter, low cation exchange capacity, and deficiencies in phosphorus, potassium, magnesium, and calcium. These conditions contribute to poor fertility and low productivity. Organic amendments, including chicken manure, have been shown to increase nutrient availability (Noviyanto *et al.*, 2025), improve soil structure (Nusantara *et al.*, 2025), and enhance the agricultural potential of Latosols (Yafizham & Sumarsono, 2020).

Despite these advances, limited empirical studies have directly compared how different chicken manure dosages interact with Andosols and Latosols to influence both crop performance and soil properties, leaving a critical gap in developing soil-specific organic fertilization strategies. Therefore, this study aims to evaluate the interactive effects of chicken manure dosage and soil type on the growth performance of curly lettuce and the improvement of soil fertility, to provide practical recommendations for sustainable horticultural management in tropical regions.

MATERIALS AND METHODS

Description of the experimental plot and sources of soil and manure

The study was conducted from February to March 2025 at the Experimental Garden KP-2, INSTIPER Yogyakarta, located at 118 m above sea level. The site has a tropical monsoon climate with average temperatures of 25–28 °C and relative humidity of 75–85%. Daily air temperature and humidity were monitored using a digital thermohygrometer to ensure uniform environmental conditions.

Two soil types, Andosols and Latosols, were collected from the upper 0–20 cm layer of agricultural fields in Sleman (volcanic Andosols) and Kulon Progo (weathered Latosols), Yogyakarta. Before the experiment, soils were air-dried, sieved (2 mm), and analyzed for initial properties, including pH,

organic C, total N, available P, and bulk density, to establish baseline fertility status.

Chicken manure was obtained from a local poultry farm, air-dried, and homogenized. Its nutrient composition (total N, P, K, C-organic, moisture content) was determined before application. Dosage levels of 0 g (control), 250 g, 500 g, and 750 g per polybag were chosen based on previous studies showing positive growth responses of leafy vegetables to organic inputs within this range.

Experimental design and setup

The experiment followed a factorial arrangement in a Completely Randomized Design (CRD) with two factors: soil type (Andosols, Latosols) and manure dosage (0, 250, 500, 750 g polybag⁻¹). Treatments were applied in 40 cm diameter polybags, each filled with 15 kg of soil. Chicken manure was thoroughly mixed with the soil one week before transplanting. Each treatment combination was replicated three times with two plants per replicate, totaling 48 experimental units. Lettuce (*Lactuca sativa* L. var. *crispa*) seedlings were germinated in a nursery and transplanted at the 2–3 leaf stage. The crop was grown for 40 days after transplanting. Standard practices, including regular irrigation, manual weeding, and biological pest control, were applied uniformly.

Plant and soil measurements

Growth parameters included plant height, number of leaves, leaf area index (LAI, calculated as leaf area per plant ground area using a portable leaf area meter), fresh and dry shoot biomass, root length, and fresh and dry root biomass. Total yield was expressed as fresh shoot weight per plant at harvest. Post-harvest soil analyses included moisture content (gravimetric method), porosity (calculated from bulk and particle density), pH (1:2.5 soil-to-water suspension), organic carbon (Walkley–Black method), and total nitrogen (Kjeldahl method).

Statistical analysis

Data were analyzed using analysis of variance (ANOVA) at a 5% significance level. Prior to analysis, assumptions of normality and homogeneity of variance were tested using Shapiro–Wilk and Levene's tests, respectively. When significant differences were detected, treatment means were compared using Duncan's Multiple Range Test (DMRT) at $p \leq 0.05$. Statistical analyses were performed using SPSS version 25 (IBM Corp., Armonk, NY, USA).

RESULTS AND DISCUSSION

Effect of chicken manure on soil physical properties

The results of soil physical analysis are presented in Table 1, which shows the moisture content of air-dried soil samples tested using two particle size fractions: 2 mm and natural soil aggregates. The data indicate that Latosols soil exhibited a higher moisture content compared to Andosols. Among the treatments, the highest moisture content (27.67%) was recorded in Latosols soil treated with 500 g of chicken manure, whereas the lowest moisture content (13.34%) was observed in the control treatment of Andosols soil.

These findings align with the report by (Nusantara *et al.*, 2025), who stated that the availability of organic matter in soil directly affects soil porosity. Increased organic matter enhances the soil's capacity to retain moisture due to improved porosity. Organic materials like chicken manure contribute to the formation of soil aggregates, which enhance water-holding capacity and overall soil structure.

Table 1. Analysis results of the effect of chicken manure on soil physical properties

Soil Type	Fertilizer Dose (g)	Moisture Content	Porosity (%)
Andosols	0	13.34	52.36
	250	27.27	59.44
	500	25.26	57.17
	750	43.16	60.93
Latosols	0	18.38	50.23
	250	23.57	59.04
	500	27.67	59.09
	750	24.36	60.63

Soil porosity refers to the proportion of pore spaces within the soil matrix, which plays a critical role in the movement and retention of air and water. There are two main types of pores: macropores, which facilitate air exchange and drainage, and micropores, which retain capillary water essential for plant uptake. Both types of pores are essential for optimal soil and plant health (Sekucia *et al.*, 2020).

An increase in soil porosity was observed across treatments following the application of chicken manure fertilizer, with a notable improvement recorded up to 35 days after planting. As presented in Table 1, the application of 750 g chicken manure fertilizer

resulted in the highest increase in porosity. This effect is attributed to the role of organic fertilizer in stimulating microbial activity and increasing organic matter and humus content, which collectively improve soil aggregation and physical structure.

According to Oued Lhaj *et al.*, (2025), composted organic fertilizers such as chicken manure serve dual functions: as a source of plant nutrients and as soil conditioners. These fertilizers loosen the soil, increase pore spaces, and enhance both drainage and aeration. Well-decomposed compost also acts as a food source for beneficial soil microorganisms, contributing to a crumbly and friable soil texture that promotes better porosity.

Furthermore, emphasized that higher soil porosity translates to a greater volume of pore spaces in the soil, thereby enhancing the soil's capacity to retain both water and air (Nusantara *et al.*, 2025). This condition is favorable for root development and microbial processes, ultimately supporting plant growth.

Effect of chicken manure fertilizer on soil chemical properties

Table 2 presents the results of the analysis of soil chemical properties, including soil organic carbon (C-organic), total nitrogen (N), carbon-to-nitrogen (C/N) ratio, and soil pH at 15 and 35 days after treatment (DAT) with varying doses of chicken manure fertilizer in two different soil types is Andosols and Latosols.

Table 2. Analysis results of the effect of chicken manure fertilizer on soil chemical properties

Soil type	Fertilizer dose (g)	Soil organic carbon	Total nitrogen	C/N ratio	Soil pH	
					15 DAT	35 DAT
Andosols	0	3.2	0.31	10.29	6.17	6.40
	250	6.8	0.51	13.28	6.17	6.75
	500	8.5	0.57	14.83	6.08	6.75
	750	7.6	0.45	16.81	6.30	6.58
Latosols	0	4.1	0.43	9.47	6.08	6.55
	250	4.6	0.31	14.65	6.08	6.83
	500	6.7	0.38	17.4	6.25	6.83
	750	6.6	0.41	16.02	6.00	6.75

The highest organic carbon content (8.5%) and total nitrogen content (0.57%) were recorded in Andosols soil treated with 500 g of chicken manure fertilizer. This indicates that Andosols soil responds more positively to organic input compared to Latosols, likely due to its inherent mineralogical and physicochemical characteristics that support higher microbial activity and organic matter stabilization. The data also show that the application of chicken manure significantly enhanced nitrogen content

across treatments, consistent with findings from (Guo *et al.*, 2023), who reported that chicken manure decomposes more rapidly and releases nutrients more efficiently than other types of animal waste, especially during the early growth phase of plants.

Interestingly, the highest C/N ratio was observed in Latosols soil with the 500 g treatment, reaching a value of 17.40. A higher C/N ratio reflects increased carbon input relative to nitrogen, which may suggest a slower decomposition rate in Latosols due to its denser texture and lower microbial activity. The elevated C/N ratios following fertilizer application are consistent with the report by (Cui *et al.*, 2022), which stated that organic manure contributes to an increase in soil organic matter and modulates the nitrogen mineralization process, thus temporarily elevating the C/N ratio. This enhancement in organic matter content can play a crucial role in improving long-term soil fertility and nutrient cycling.

In addition to carbon and nitrogen content, the application of chicken manure also influenced soil pH. Both Andosols and Latosols soils exhibited an increase in pH levels after the application of organic fertilizer, as shown in the 15 DAT and 35 DAT observations. The highest increase in soil pH was observed in Latosols treated with 250 g and 500 g of chicken manure, where pH values rose to 6.83. This change is attributed to the decomposition of organic matter in the chicken manure, which releases base-forming cations such as calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+), and sodium (Na^+) into the soil solution. These cations neutralize soil acidity and increase the pH, making the soil more favourable for plant growth. Organic fertilizers can enhance nutrient availability through mineralization, wherein complex organic compounds are broken down into simpler molecules such as CO_2 and H_2O , further supporting pH enhancement (Li *et al.*, 2022).

Overall, the application of chicken manure not only improved key soil chemical properties such as C-organic, nitrogen, and pH but also modulated the C/N ratio, reflecting enhanced nutrient cycling. The magnitude of these improvements varied with soil type and fertilizer dosage, highlighting the importance of optimizing organic amendment strategies based on site-specific soil conditions.

Effect of chicken manure fertilizer dosage and soil type on leaf number and fresh plant weight

The results presented in Table 3 demonstrate the effects of different dosages of chicken manure fertilizer and growing media (soil type) on two important vegetative variables: number of leaves and fresh plant weight. The data reveal that the appli-

cation of 500 g chicken manure fertilizer to Andosols soil yielded the highest number of leaves (23 leaves), significantly outperforming other treatments within the same soil category. This result suggests that the 500 g dosage effectively met the nutritional needs of the plant, particularly in improving the physical and chemical properties of Andosols soil, which typically has high phosphorus retention but benefits from organic matter inputs.

Table 3. Effect of chicken manure fertilizer dosage and growing media on leaf number and fresh plant weight

Soil type	Fertilizer dose (g)	Number of leaves	Fresh weight (g)
Andosols	0	7.33 e	7.66 e
	250	16 d	18.66 c
	500	23 a	21.33 b
	750	18.1 c	20.33 b
Latosols	0	26.22 g	16.59 f
	250	60.97 e	70.86 d
	500	101.64 a	102.48 a
	750	82.48 c	88.51 b

Note: Numbers followed by the same letter in the same column or row indicate no significant difference according to the Duncan's Multiple Range Test (DMRT) at the 5% significance level.

Leaf development is strongly associated with nitrogen availability in the soil, as nitrogen plays a crucial role in promoting vegetative growth, particularly in stems and foliage. According to (Liang *et al.*, 2020), adequate nitrogen levels are essential for maximizing leaf number, supporting photosynthesis, and ensuring robust plant growth. (Liu *et al.*, 2023) further emphasized nitrogen's pivotal role in enhancing shoot elongation and leaf expansion during the early growth stages.

In terms of fresh plant weight, the highest values were recorded in both Andosols and Latosols soils treated with 500 g of chicken manure, yielding 21.33 g and 102.48 g respectively. These results suggest that 500 g of chicken manure is the optimal dosage for enhancing plant biomass across different soil types. The significant increase in fresh weight is likely due to improved nutrient supply from the decomposed organic material, which releases essential macro and micronutrients gradually, thus supporting sustained plant growth.

The application of chicken manure not only enriches the soil with organic matter but also enhances humus content, improves soil structure, and creates favourable pH conditions. For crops such as lettuce, optimal growth occurs within a neutral to slightly

acidic pH range of 6.5 to 7.0. As (Barrow & Hartemink, 2023) noted, soil pH below 6 can limit nutrient availability, while pH values above 7 may induce chlorosis due to micronutrient deficiencies. The pH-buffering effect of organic matter, therefore, supports nutrient availability and optimal physiological function in plants.

The analysis of variance revealed a significant interaction between chicken manure dosage and soil type on fresh plant weight. The best outcomes were observed with the application of 500 g manure on both Andosols and Latosols soils, with no statistically significant difference between them. In contrast, the lowest fresh weights were found in the control treatments for both soil types, indicating the critical role of organic inputs in promoting early plant growth.

These findings highlight the effectiveness of moderate chicken manure dosages (particularly 500 g polybag⁻¹) in improving plant vegetative performance and demonstrate that the response is consistent across soil types with differing physical and chemical characteristics.

Effect of chicken manure fertilizer dosage on growth and yield of lettuce

The results in Table 4 show that varying chicken manure fertilizer dosages significantly influenced the growth and yield variables of lettuce, including plant height, leaf area index, dry plant weight, root length, root biomass, and total yield. Applying 500 g of chicken manure fertilizer consistently produced the best results across most variables.

Specifically, the tallest plants (23.37 cm) and

Table 4. Effect of chicken manure fertilizer dosage on the growth and yield of lettuce

Variables	Chicken manure fertilizer dosage (g)			
	0	250	500	750
Plant height (cm)	9.38 c	21.43 b	23.37 a	22.02 b
Leaf Area Index (cm)	62.87 c	168.06 b	229.83 a	166.31 b
Dry plant weight	0.20 d	1.10 c	6.07 a	3.78 b
Root length (cm)	13.24 b	14.63 ab	15.31 a	15.76 a
Fresh root weight	2.48 b	4.57 a	5.40 a	4.76 a
Dry root weight	3.02 c	3.02 b	3.18 a	3.61 a
Yield (g)	47.45 d	47.45 c	85.51 a	63.76 b

Note: Numbers followed by the same letter in the same row indicate no significant difference according to the Duncan's Multiple Range Test (DMRT) at the 5% significance level.

the highest leaf area index (229.83 cm²) were observed in the 500 g treatment, indicating optimal vegetative growth under this dosage. These results

suggest that the 500 g application provided an adequate balance of nutrients, especially nitrogen, which is critical for promoting cell division, elongation, and expansion of leaves. The lowest plant height (9.38 cm) and leaf area index (62.87 cm²) were recorded in the control treatment (0 g), indicating limited vegetative development in the absence of organic fertilization.

Dry plant weight also showed significant differences among treatments, with the highest biomass (6.07 g) recorded in the 500 g treatment, followed by 3.78 g in the 750 g dosage. The control treatment yielded the lowest dry weight (0.20 g), indicating poor biomass accumulation due to inadequate nutrient availability. The increase in dry biomass with manure application aligns with improved photosynthetic capacity, driven by better canopy development and leaf expansion (Jin *et al.*, 2023).

In terms of root development, the longest root length (15.76 cm), fresh root weight (5.40 g), and dry root weight (3.61 g) were also achieved at the 500 g and 750 g dosages, with no significant difference between these two treatments for these variables. This suggests that increasing the manure dosage beyond 500 g may not substantially improve below ground growth. The control treatment again produced the lowest values, emphasizing the importance of organic matter in supporting root expansion.

The overall yield of lettuce, expressed in fresh weight, followed a similar trend. The 500 g treatment produced the highest yield at 85.51 g, significantly outperforming the other dosages. The yield under 750 g dosage was slightly lower at 63.76 g, while both 250 g and control treatments resulted in the lowest yields at 47.45 g. The enhanced yield under 500 g manure application is likely due to improved soil physical conditions—such as increased porosity and better water-holding capacity—which promote healthy root development and efficient nutrient uptake.

According to Solly *et al.*, 2020, well-decomposed organic matter contributes to a loose and crumbly soil structure, increasing cation and anion exchange capacity, which in turn improves nutrient availability. Under such conditions, root penetration is facilitated, enhancing plant access to water and nutrients. Thus, the 500 g dosage appears to be the most effective in optimizing the balance between nutrient supply and soil structure, resulting in improved growth and yield performance in lettuce.

Effect of soil type on the growth and yield of lettuce

The results presented in Table 5 show that soil type had no significant effect on all observed growth and yield variables of lettuce, including plant height,

leaf area index, dry plant weight, root length, root biomass, and total yield. The values recorded for both Andosols and Latosols soils were statistically similar, as indicated by the identical letters in the Duncan's Multiple Range Test (DMRT), signifying non-significant differences at the 5% level.

Table 5. Effect of soil type on the growth and yield of lettuce

Variables	Soil type	
	Andosols	Latosols
Plant height (cm)	19.09 a	19.01 a
Leaf Area Index (cm)	158.02 a	155.51 a
Dry plant weight (g)	3.04 a	2.54 a
Root length (cm)	15.11 a	14.36 a
Fresh root weight (g)	4.58 a	4.03 a
Dry root weight (g)	2.37 a	2.70 a
Yield (g)	51.88 a	51.89 a

Note: Numbers followed by the same letter in the same row indicate no significant difference according to the Duncan's Multiple Range Test (DMRT) at the 5% significance level.

Although slight variations were observed, such as higher dry plant weight and fresh root weight in Andosols, and marginally greater dry root weight and total yield in Latosols, these differences were not statistically meaningful. This uniformity across variables suggests that both soil types were equally capable of supporting lettuce growth under the conditions of this study.

One possible explanation for this result is the positive influence of chicken manure fertilizer, which was applied across all treatments. The organic amendment likely enhanced the physical and chemical properties of both Andosols and Latosols soils, improving nutrient availability and moisture retention. As noted by (Azam *et al.*, 2024) soil fertility enhanced by organic inputs is a key determinant of root system development, which in turn governs the efficiency of water and nutrient absorption. Well-developed root systems support optimal plant growth and lead to improved yield, regardless of soil type.

These findings underscore the potential for chicken manure fertilizer to mitigate limitations associated with varying soil textures or compositions by enhancing soil fertility to a level where differences in inherent soil characteristics become negligible in terms of their effect on crop performance. Thus, both Andosols and Latosols soils can be considered suitable media for lettuce cultivation when adequately supplemented with organic fertilizers.

CONCLUSION

This study aimed to evaluate the interactive effects of soil type and chicken manure dosage on the growth performance of curly lettuce (*Lactuca sativa*) and soil fertility improvement. The results demonstrated a significant interaction, particularly in leaf number and fresh shoot weight, with the 500 g dosage consistently producing the best growth responses across variables such as plant height, leaf area index, biomass, and root development. In Andosols, the 500 g dosage resulted in the highest leaf number and fresh shoot weight, while in Latosols, it produced the greatest biomass accumulation. Application of chicken manure also enhanced soil fertility, with Andosols recording maximum organic carbon (8.5%) and total nitrogen (0.573%) at 500 g, while Latosols reached maximum organic carbon (6.7%) at 500 g and total nitrogen (0.412%) at 750 g.

These findings confirm that the research objective was achieved, providing evidence that optimized organic manure application can mitigate soil constraints and improve lettuce production in tropical soils. Practically, the 500 g dosage of chicken manure per polybag offers a useful guideline for farmers and horticultural practitioners to enhance both crop yield and soil health, contributing to more sustainable and productive vegetable cultivation systems in tropical regions.

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