

Growth Response of Tomato Plants (*Lycopersicum esculentum* Mill) to Liming and Fertilizer Types on Acid Soils

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Abstract

Acid soils with low pH are a major constraint for tomato cultivation in Indonesia, including in Kwandang District, North Gorontalo Regency, which has a soil pH of 5.23. This study aimed to determine the growth response of tomato plants (*Lycopersicum esculentum* Mill.) to liming and fertilizer types on acid soils. The research was conducted in Molingkapoto Village, Kwandang District, North Gorontalo Regency, for four months (November 2025–February 2026). A Factorial Randomized Block Design was employed with two factors: agricultural lime dosage (K0 = no lime; K1 = 1,000 g/plot; K2 = 1,300 g/plot) and fertilizer type and dosage (P0 = no fertilizer; P1 = organic fertilizer 7,000 g/plot; P2 = NPK fertilizer 8 g/plant), replicated three times for 27 experimental units. Parameters observed included plant height, leaf number, leaf color score, and leaf area index at 14, 30, and 44 days after planting (DAP). Results showed that liming at 1,300 g/plot (K2) and NPK fertilizer at 8 g/plant (P2), both independently and in combination (K2P2), produced the best growth across all parameters at 44 DAP: plant height, leaf number, leaf color score, and leaf area index. Liming improved soil pH and increased macro and micronutrient availability, while NPK fertilizer provided essential nutrients rapidly available to the plant.

Keywords: *acid soil, liming, NPK fertilizer, organic fertilizer, tomato*

INTRODUCTION

Tomato (*Lycopersicum esculentum* Mill.) is one of the most important horticultural commodities widely consumed by the Indonesian population. Tomatoes have high economic

value and beneficial nutritional content, including vitamin C, vitamin A, minerals, and lycopene as an antioxidant (Pitojo, 2005). National tomato production continues to fluctuate, influenced by various factors including poor land quality (Badan Pusat Statistik, 2022). In North Gorontalo Regency, this situation is exacerbated by the dominance of acid soils that have not been managed optimally.

One of the main constraints in tomato cultivation in North Gorontalo Regency is acid soil conditions. Acid soils are characterized by pH below 6.0, which causes low availability of macronutrients such as nitrogen (N), phosphorus (P), and potassium (K), as well as high solubility of aluminum (Al) and manganese (Mn) that are toxic to plants (Hakim et al., 2012). Approximately 50% of the world's agricultural land is classified as acid, and this condition is a major limiting factor for crop production in various tropical regions (Wenyika et al., 2025). The research site in Kwandang District, North Gorontalo Regency, has a soil pH of 5.23, placing it in the acid soil category that requires special management (Hardjowigeno, 2012). At such low pH, Al^{3+} becomes highly soluble and enters root tissues, inhibiting cell division and slowing overall plant growth (Hardjowigeno, 2012).

Liming is one of the soil amelioration measures for acid soils, aimed at raising soil pH, improving physical and chemical soil properties, and increasing nutrient availability for plants. Agricultural lime ($CaCO_3$) applied to soil reacts with H^+ ions, thereby increasing soil pH and suppressing Al toxicity (Hakim et al., 2012). A meta-analysis conducted by Holland et al. (2023) of 142 studies showed that liming on average increased crop yield by 29% and improved soil pH by 15%, especially when combined with fertilization. In addition to liming, the type of fertilizer applied also determines the success of cultivation on acid soils.

Organic fertilizer plays a role in improving soil structure, increasing cation exchange capacity (CEC), and providing nutrients gradually (Wihardjaka, 2021). Hartatik et al. (2015) affirmed that organic fertilizer also improves soil biological properties by enhancing the activity of microorganisms involved in the nutrient cycle. Meanwhile, NPK fertilizer can supply essential nutrients (N, P, and K) directly and rapidly to plants, thereby supporting optimal vegetative growth (Purnomo, 2020). Daroini et al. (2023) demonstrated that the combination of NPK fertilizer at 32 g/plant with liquid organic fertilizer significantly increased leaf number and accelerated tomato plant growth. Sendy et al. (2024) also reported that the application of chicken manure and NPK on acid sulfate soils had a positive effect on tomato growth, with NPK at 450 kg/ha as the optimal dose.

Research on crop response to liming and fertilization on acid soils remains limited, particularly in the North Gorontalo region. Therefore, this study aimed to determine the effect



of agricultural lime dosage and fertilizer type, as well as their interactions, on the growth of tomato plants in acid soils of Kwandang District, North Gorontalo Regency.

MATERIALS AND METHODS

Time and Location

This research was conducted for approximately four months, from November 2025 to February 2026, at Molingkapoto Village, Kwandang District, North Gorontalo Regency. The research site has a soil pH of 5.23, classified as acid soil.

Tools and Materials

Tools used in this study included a machete, digital scale, hoe, rake, watering can, hand sprayer, measuring tape, and seedling tray. Materials used included tomato seeds (Servo variety), organic fertilizer, NPK fertilizer, agricultural lime (CaCO_3), and bamboo stakes.

Research Design

This study used a Factorial Randomized Block Design (RBD) with two treatment factors. The first factor was agricultural lime dosage (K), consisting of three levels: K0 = no lime, K1 = 1,000 g/plot, and K2 = 1,300 g/plot. The second factor was fertilizer type and dosage (P), consisting of three levels: P0 = no fertilizer, P1 = organic fertilizer 7,000 g/plot, and P2 = NPK fertilizer 8 g/plant.

There were 9 treatment combinations replicated 3 times, yielding 27 experimental units. Each treatment consisted of 4 sample plants, giving a total of 432 plants with 108 sample plants. Treatment combinations tested were: K0P0, K0P1, K0P2, K1P0, K1P1, K1P2, K2P0, K2P1, and K2P2. Data were analyzed using analysis of variance (ANOVA) at the 5% significance level, and where significant differences were found, analysis was continued using Duncan's Multiple Range Test (DMRT) at 5%.

Research Implementation

Research implementation included land preparation, seed germination, construction of experimental plots, lime application according to treatment, seedling transplanting, fertilization, and maintenance activities including irrigation, replanting, hilling, staking, and pest and disease control. Growth parameters observed included plant height (cm), number of leaves, leaf color score (based on Leaf Color Chart), and leaf area index (cm^2) at 14, 30, and 44 days after planting (DAP).



RESULTS AND DISCUSSION

Plant Height (cm)

Observations and analysis of variance showed that liming and fertilizer type treatments significantly affected tomato plant height at 14 DAP and 30 DAP. Average plant height under various treatments is presented in Table 1.

Table 1. Average Plant Height of Tomato (cm) under Various Treatments

Treatment	14 DAP	30 DAP	44 DAP
K0P0	20,2bc	41,3b	68,2
K0P1	23,3d	55,8d	89,0
K0P2	25,8f	59,4i	93,6
K1P0	19,0a	35,3a	64,8
K1P1	24,8e	55,7g	91,6
K1P2	26,5g	57,6h	100,1
K2P0	19,9b	41,5c	71,4
K2P1	23,1d	51,0e	92,3
K2P2	24,3e	54,6f	96,1

Note: Numbers followed by the same letter in the same column are not significantly different based on Duncan's Multiple Range Test (DMRT) at 5% level.

Table 1 shows that the K1P2 treatment combination (lime 1,000 g/plot + NPK fertilizer 8 g/plant) produced the tallest plants at 14 and 30 DAP, reaching 26.5 cm and 57.6 cm, respectively. At 44 DAP, K1P2 still produced the highest value of 100.1 cm, followed by K2P2 at 96.1 cm. The K1P0 treatment produced the shortest plants at almost all observation times. This indicates that NPK fertilizer plays a major role in increasing plant height because the nitrogen (N) it contains is essential for chlorophyll formation and stimulation of vegetative growth (Purnomo, 2020). This is consistent with the findings of Khoiruddin et al. (2018), who reported that rice husk ash and NPK fertilizer application on Servo variety tomatoes significantly affected plant height. Liming combined with NPK fertilization optimized nutrient availability in acid soils, enabling more efficient nutrient uptake by plants (Hakim et al., 2012).

Number of Leaves

Leaf number is one indicator of vegetative growth closely related to the plant's photosynthetic capacity. Average leaf numbers under various treatments are presented in Table 2.

Table 2. Average Number of Tomato Leaves under Various Treatments

Treatment	14 DAP	30 DAP	44 DAP
K0P0	6,3a	9,8	13,9
K0P1	7,0a	10,5	19,5
K0P2	7,4b	11,5	20,9
K1P0	5,8a	8,6	13,5
K1P1	7,4b	11,6	21,9
K1P2	7,9c	12,4	22,0
K2P0	6,0a	9,5	15,2
K2P1	7,5bc	11,3	21,1
K2P2	7,2a	12,2	23,1

Note: Numbers followed by the same letter in the same column are not significantly different based on Duncan's Multiple Range Test (DMRT) at 5% level.

Analysis results in Table 2 show that at 14 DAP, the K1P2 treatment produced the highest leaf number (7.9 leaves) and was significantly different from the other treatments. At 44 DAP, the K2P2 treatment produced the highest leaf number of 23.1 leaves, followed by K1P2 at 22.0 leaves. The no-lime, no-fertilizer treatment (K0P0) and K1P0 produced the lowest leaf counts. The increased availability of N and P from liming and NPK fertilizer application stimulated the formation of new cells in the leaf meristem, accelerating leaf production (Hakim et al., 2012). Organic fertilizer also contributed to increasing leaf number, although its response was slower due to the longer decomposition process (Wihardjaka, 2021). This is consistent with the findings of Kayupa et al. (2022), who reported that organic fertilizer type significantly affected the number of tomato leaves. Rosmarkam & Yuwono (2002) added that adequate N availability is the primary factor determining the rate of new leaf formation in plants.

Leaf Color

Leaf color was assessed using a Leaf Color Chart with scores ranging from 2 to 5, where

higher scores indicate darker green leaves and higher chlorophyll content. Average leaf color scores under various treatments are presented in Table 3.

Table 3. Average Leaf Color Score of Tomato Plants under Various Treatments

Treatment	14 DAP	30 DAP	44 DAP
K0P0	3,0a	3,1	3,1
K0P1	2,8a	3,0	3,7
K0P2	3,8a	3,8	3,9
K1P0	3,0a	3,0	3,1
K1P1	3,1a	3,0	4,0
K1P2	3,6a	3,9	4,1
K2P0	2,8a	3,0	3,0
K2P1	2,9a	3,4	3,2
K2P2	3,8a	3,9	4,5

Note: Numbers followed by the same letter in the same column are not significantly different based on Duncan's Multiple Range Test (DMRT) at 5% level.

At 14 DAP, treatments did not significantly affect leaf color scores. However, at 44 DAP, the K2P2 treatment produced the highest score (4.5), indicating higher chlorophyll content. Darker green leaf color reflects adequate nitrogen and magnesium availability required for chlorophyll synthesis (Purnomo, 2020). Liming at 1,300 g/plot raised soil pH, thereby increasing macro and micronutrient availability, supporting more optimal chlorophyll synthesis (Hakim et al., 2012). According to Salisbury & Ross (1995), chlorophyll synthesis is highly dependent on the availability of Mg^{2+} and Fe^{2+} ions, whose availability increases with rising soil pH. Improved leaf color from NPK fertilizer application was also reported by Hardiyanti et al. (2022), who stated that N in NPK fertilizer directly participates in chlorophyll molecule synthesis.

Leaf Area Index (cm²)

The Leaf Area Index (LAI) reflects the plant's capacity to capture sunlight for photosynthesis. The higher the LAI value, the greater the plant's photosynthetic capacity. Average LAI values under various treatments are presented in Table 4.

Table 4. Average Leaf Area Index (cm²) of Tomato Plants under Various Treatments

Treatment	14 DAP	30 DAP	44 DAP
K0P0	31,3	55,4	88,3
K0P1	52,4	127,7	140,5
K0P2	79,5	205,5	179,8
K1P0	27,2	51,7	77,4
K1P1	90,9	250,0	191,8
K1P2	74,8	285,2	203,3
K2P0	28,7	69,7	55,7
K2P1	58,6	139,6	166,7
K2P2	95,5	253,0	222,6

Note: Numbers followed by the same letter in the same column are not significantly different based on Duncan's Multiple Range Test (DMRT) at 5% level.

Table 4 shows that at 14 DAP, the K2P2 treatment produced the highest LAI (95.5 cm²). At 30 DAP, K1P2 produced the highest LAI (285.2 cm²), followed by K2P2 (253.0 cm²). At 44 DAP, the K2P2 treatment produced the highest LAI (222.6 cm²), followed by K1P2 (203.3 cm²) and K1P1 (191.8 cm²). Overall, combined lime and fertilizer treatments produced higher LAI compared to treatments without inputs. NPK fertilizer containing P and K promotes leaf cell formation and expansion (Wihardjaka, 2021). Liming also supports this process by improving soil conditions that enable roots to absorb nutrients more effectively (Hakim et al., 2012). These results are consistent with Daroini et al. (2024), who reported that optimal nutrient availability positively correlated with increased leaf area in tomato plants. Wirayuda (2023) added that adequate K availability plays a role in leaf cell osmoregulation, enabling more optimal leaf expansion.

CONCLUSION

Based on the research results, it can be concluded that:

Liming at various dosages significantly affected the growth of tomato plants on acid soils. The lime dosage of 1,300 g/plot (K2) consistently produced better growth compared to lower dosages, through the mechanism of increasing soil pH, which subsequently improved macro and micronutrient availability and suppressed aluminum and manganese toxicity.

Fertilizer type and dosage significantly affected all growth parameters of tomato plants.

Application of NPK fertilizer at 8 g/plant (P2) gave the best growth response due to its ability to supply N, P, and K in rapidly available form, while organic fertilizer at 7,000 g/plot (P1) provided slower but more sustainable improvements to soil physical and chemical properties.

The interaction between liming and fertilizer type significantly affected tomato plant growth. The combination of 1,300 g/plot lime with 8 g/plant NPK fertilizer (K2P2) produced the best growth in plant height (96.1 cm), leaf number (23.1 leaves), leaf color score (4.5), and leaf area index (222.6 cm²) at 44 DAP, and is therefore recommended as the optimal treatment for tomato cultivation on acid soils in Kwandang District, North Gorontalo Regency.

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