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Influence of *Tithonia diversifolia*-Derived Organic Fertilizer and Planting Density on Potato Productivity in Batu, East Java

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Abstract: A transition toward organic fertilizers has increasingly been adopted as a key strategy to support sustainable agriculture, particularly in highland farming systems. In Sumber Brantas Village, Batu City, East Java—one of Indonesia's major highland potato-producing regions—potato (*Solanum tuberosum*) cultivation plays a critical role due to its high market value, adaptability to altitude, and importance as a carbohydrate source. This study investigated the effects of *Tithonia diversifolia*-derived organic fertilizer and varying plant densities on potato growth and productivity. Four fertilizer application rates (0, 120, 175, and 230 kg N/ha) and three plant densities (35,000, 47,000, and 71,000 plants/ha) were evaluated using a randomized block design arranged in a split-plot layout. Results indicated that the application of *Tithonia diversifolia* organic fertilizer significantly enhanced plant height, tuber biomass, and nitrogen (N) uptake. The highest fertilizer dose (230 kg N/ha) was associated with a 25% increase in N absorption and a 28% improvement in tuber yield relative to the unfertilized control. However, plant density did not exert a statistically significant effect on measured agronomic parameters. These findings underscore the agronomic value of *Tithonia diversifolia* as an organic fertilizer capable of improving nutrient use efficiency and tuber productivity under highland cultivation conditions. The results support the integration of this bioresource into sustainable nutrient management strategies for potato production, particularly in regions where agroecological conditions favor organic inputs.

Keywords: Organic fertilizer; Potato yield; *Tithonia diversifolia*; Nutrient absorption

1. Introduction

Potatoes are a vital horticultural crop in Indonesia's highland regions, where environmental conditions support optimal growth. However, low productivity due to soil limitations necessitates innovative fertilization strategies. One promising organic amendment is *Tithonia diversifolia*, a plant rich in N, phosphorus (P), and potassium (K), commonly found in Batu City. Recent studies highlight its potential to enhance nutrient absorption and promote sustainable farming practices. The potato production in Indonesia, according to the Central Statistics Agency, reached 1.42 million tons, while the consumption level reached 874,250 tons. Besides being consumed by the public, potatoes are also one of the horticultural commodities with high protein (Hu et al., 2024) and export potential. Some countries with this export potential include Vietnam, the United States, Belgium, and India (Das et al., 2024). Population growth directly correlates with the increase in potato consumption, which not only comes from public consumption but also serves as a raw material for various food industries. This is why Indonesia still has to import potatoes from various countries, such as Australia, Canada, and Germany. One of the factors contributing to Indonesia's low potato production is the limited cultivars, quality, and quantity of potatoes that meet the growing environment's requirements.

Tithonia diversifolia, commonly known as the Mexican sunflower, is a plant native to the Americas that has rapidly spread to Asia. In the Batu area, this plant grows abundantly along roadsides and around community agricultural lands. Rozen et al. (2020) reported N concentrations ranging from 0.95% to 1.55%, P from 0.33% to 1.5%, and K from 0.35% to 0.88%. A separate study was conducted by Opala (2020) demonstrated higher N and

P levels, with N at 1.95%, P at 1.32%, and K at 0.29%. Another study also mentions that the *Tithonia diversifolia* plant can decompose well because it contains lignin and has a low carbon-to-nitrogen (C/N) organic matter ratio (Sunarti & Hasibuan, 2020). With those contents and characteristics, *Tithonia diversifolia* can be used as one of the alternative materials for organic fertilizer (Hasibuan et al., 2021). Its ability to enhance nutrient availability, especially N and P, and improve soil health through increased microbial activity and organic matter content makes it a valuable organic amendment for sustainable agriculture (Farni, 2024; Kong et al., 2024; Sinha et al., 2024). In the latest findings, it is also known that *Tithonia diversifolia* plays a role in maintaining the balance between productivity and emissions in the agricultural sector (Bizzuti et al., 2025).

Adding fertilizer is one way to increase crop productivity. Currently, organic fertilizers have been widely adopted to maintain agricultural sustainability and address land degradation caused by continuous farming and the massive use of chemical fertilizers in the past (Lu et al., 2024; Zhang et al., 2024). Numerous studies have explored the use of the *Tithonia diversifolia* plant as an organic fertilizer, focusing on soybean plants (Lestari, 2016), corn (Hutomo & Mahfudz, 2015), rice (Nkongolo et al., 2025), onion (Nasution et al., 2024), and kailan (Taofik et al., 2020). However, potato plants have not yielded any results. Consequently, this study aims to (a) evaluate the effects of *Tithonia diversifolia* organic fertilizer on potato growth and yield, (b) determine the optimal fertilizer dose and planting density, and (c) assess the implications for nutrient absorption and sustainable agriculture.

2. Methodology

2.1 Study Area

The research was conducted in Dusun Sumber Brantas, Tulung Rejo Village, Bumiaji District, Batu City. The altitude is approximately 1650 meters above sea level, with an air temperature of 20°C, and the soil type is Andisol. The research was initiated by planting the tubers on May 9, 2019, and harvesting them on September 8, 2019.

2.2 Research Material

The research utilized materials such as Granola variety purple flower potato seeds, which were acquired from farmer breeders in the Tosari Village. *Tithonia diversifolia*, a plant that grows abundantly in the area surrounding the research location, serves as organic fertilizer. Pest control was carried out using neem, *Tithonia diversifolia* soak, and tambon. The tools used for pest control include hoes, shovels, buckets, watering cans, ovens, machetes, scales, measuring tapes, cock borers, sprinklers, and stationery.

2.3 Experimental Design

A randomized block design with a split-plot arrangement was employed in this study to ensure statistical reliability. The experimental layout consisted of four replications, each including a main plot for plant density and a sub-plot for fertilization treatments. Blocks were arranged to minimize variability due to field conditions. Plant density consists of P1 (65 plants per plot or 35,000 tons ha^{-1}), P2 (78 plants per plot or 47,000 tons ha^{-1}), and P3 (130 plants per plot or 71,000 tons ha^{-1}). Fertilization doses (D) consist of D0 (control in the absence of fertilization), D1 (120 kg N/ha, or 5.882 t ha^{-1}), and D2 (175 kg N/ha). The list of treatment combinations for density and fertilizer can be seen in Table 1.

Table 1. List of treatment combinations (density × fertilization)

Density (plants/ha)	Fertilization Dose (kg N/ha)
35000	0 (control)
35000	120
35000	150
35000	230
47000	0 (control)
47000	120
47000	150
47000	230
71000	0 (control)
71000	120
71000	150
71000	230

2.3.1 Land preparation

Before planting the purple-flowering Granola potato seedlings, the soil was first prepared. Two weeks prior to planting, the soil was prepared by tilling and raking it until it became loose and level, reaching a depth of approximately 30 cm (Figure 1). Then, experimental plots were created with a size of 9.1 × 2 m², with a distance between rows of 70 cm and a distance between treatment plots of 50 cm. Each plot was spaced according to the treatment.

(a) (b)

Figure 1. (a) The size of the seed tuber potato variety, Granola purple flower, and (b) The process of making furrows

2.3.2 Fertilization process

The organic fertilizer, derived from *Tithonia diversifolia*, contained N (1.95%), P (1.32%), and K (0.29%), as determined by laboratory analysis. Preparation of organic fertilizer from fresh *Tithonia diversifolia* organic material was taken directly from the land around the research location. *Tithonia diversifolia* plants (Figure 2) were chopped into small pieces measuring approximately 2-3 cm. The organic material treatment was applied one week before planting by spreading the chopped *Tithonia diversifolia* into furrows with a width of 20 cm and a depth of 15 cm evenly, covered with a thin layer of soil, and adjusted according to the predetermined dosage for the treatment.

(a) (b)

Figure 2. (a) *Tithonia diversifolia* plant and (b) Process of *Tithonia diversifolia* plant chopping used in research

2.3.3 Planting and upkeeping process

Potato seeds were planted individually in the designated rows with the buds facing upwards, using the planting distance according to the treatment. Then, after the seedlings were planted, they were covered with soil from the left and right sides to a thickness of 5-10 cm.

Plant maintenance, from the initial planting stage to harvest, greatly influences the growth and development of potato plants. Maintenance includes irrigation, weeding, hilling, and plant protection. Irrigation was carried out using a sprinkler once a week, depending on the soil moisture condition. Weeding was done by carefully pulling out the grass by hand to avoid damaging the potato roots. Weeding started at around one month of age and was adjusted according to the growth conditions of the weeds in the surrounding area of the plants. Hilling was done 30 days after planting, with the next hilling stage at 50 days after planting to prevent plant lodging, maintain soil temperature, and protect against direct sunlight that can cause tubers to turn green. In terms of plant protection, pest control was carried out using a yellow trap, which is a 15 × 25 cm yellow plastic board coated with xyline and oil used as an insect trap. For fungicide prevention, a neem solution with a dosage of 1 ml/litre was applied once a week, and tambon with a dosage of 1 ml/litre was given to plants aged 55 days after planting. Meanwhile, a week-old *Tithonia diversifolia* soaking water was given biweekly from the beginning of growth until 60 days after planting. This Tithonia was given because this plant has the potential as a natural alternative to chemical pesticides (Wang et al., 2025). As shown in Figure 3, the process of controlling potato pest insects involves the use of yellow traps.

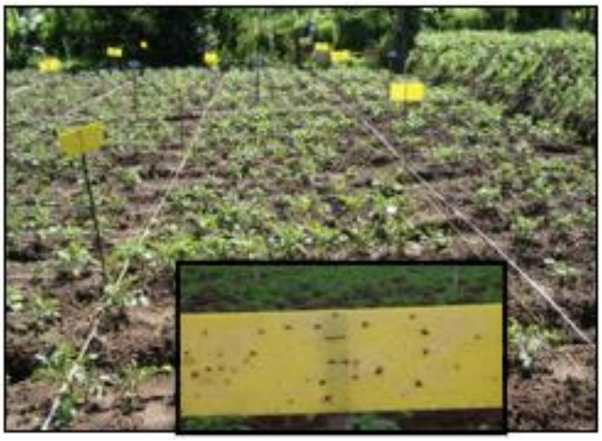

Figure 3. Process of controlling potato pest insects involving the use of yellow traps

2.3.4 Harvesting process

Harvesting was carried out when the plants were 120 days old, and the condition of the plants above the ground was dry. The harvest was done by digging up the soil ridges with a hoe, where the digging was done carefully from the side of the ridge. The criteria for harvest readiness can be observed when the skin of the tuber appears very tightly attached to the flesh of the tuber, and when rubbed or pressed with the thumb, the skin will not peel off. Potatoes like that are already quite old or have reached optimal harvest maturity. Figure 4 shows the harvesting activities at the research location.

Figure 4. Harvesting activities at the research location

2.3.5 Observed variables

Observations were conducted destructively on the 28th, 45th, 75th, and 90th days after planting, as well as at harvest. The observed variables were classified into growth variables and yield variables. Growth variables include plant height and fresh tuber weight. Soil analyses were conducted: (1) prior to planting (baseline), and (2) post-harvest. The organic matter content of *Tithonia diversifolia* biomass was analyzed before incorporation into soil. At 70 days after planting (DAP), potato leaf tissues were collected for nutrient uptake assessment. Samples were oven-dried at 65°C to constant weight, then ground for analysis. Nitrogen content was determined by the micro-Kjeldahl method (AOAC 978.02), phosphorus by molybdenum-blue spectrophotometry (ISO 15681), potassium by flame photometry (ISO 9964-1), and magnesium by atomic absorption spectrometry (AOAC 968.08).

2.4 Statistical Analysis

The obtained data were analysed using analysis of variance with a significance level of 5%. If there are significant differences, further testing was conducted using the Duncan test with a significance level of 5% or an orthogonal contrast comparison test (Gaspersz, 1991).

3. Results

3.1 Plant Height

The results of the analysis of variance indicate that there is no significant interaction between the density treatment and the dose on the variable of plant height at all observation ages. The height of plants grown at different densities did not differ significantly (Figure 5). However, the height of plants with different doses differed significantly at all observation ages, except on the 28th day after planting (Figure 6). The average plant height values for the density and fertilization dose treatments are presented in Table 2. The results of the orthogonal contrast comparison test show a significant difference in the height of potato plants between the treatment of fertilization and no fertilization, starting from the observation age of 45 days after planting. The application of the *Tithonia diversifolia* fertilizer can increase plant height by about 13–14% (Figure 6), compared to the plants with no fertilization.

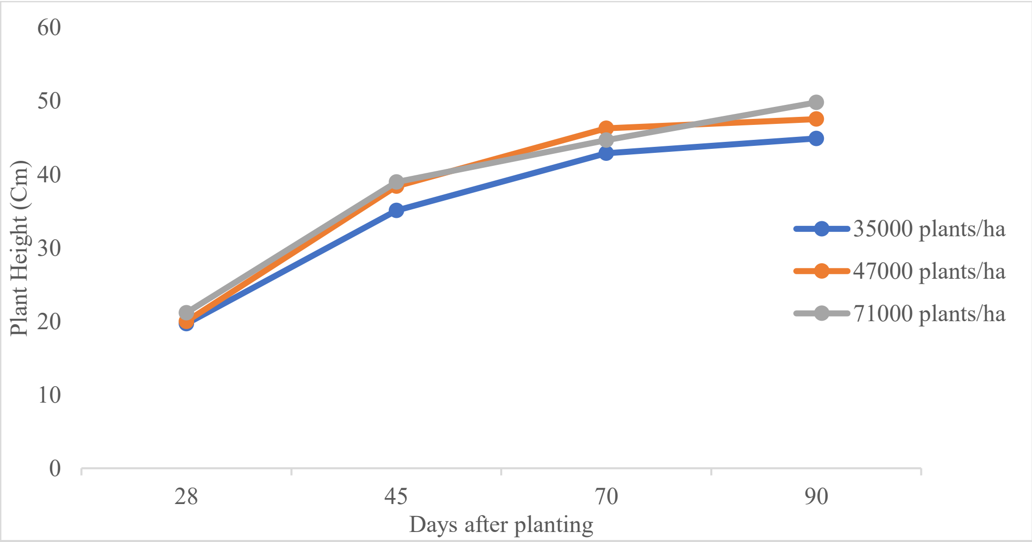

Figure 5. Effect of plant density on plant height in potato cultivars

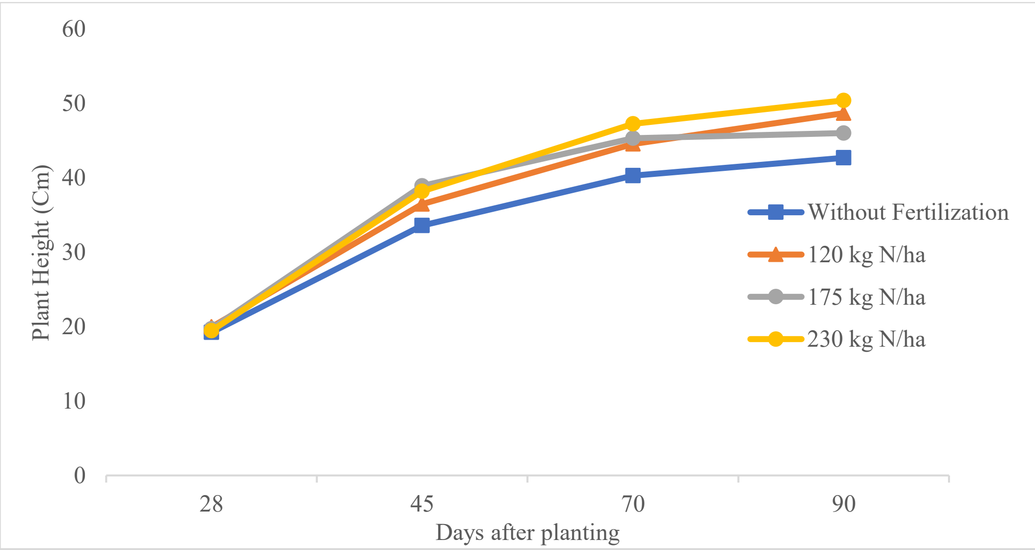

Figure 6. Effect of *Tithonia diversifolia* doses on plant height in potato cultivars

Table 2. The average height of potato plants resulting from various densities and doses

Treatment	Plant Height (cm) at the Time of Observation			
	28 DAP	45 DAP	70 DAP	90 DAP
Plant density (P)				
35000 plants/ha	19.67	35.07	42.90	44.90
47000 plants/ha	20.00	38.40	46.30	47.53
71000 plants/ha	21.17	38.97	44.68	49.80
Duncan 0.05	NS	NS	NS	NS
Tithonia diversifolia doses (D)				
Without fertilizer	19.22	33.56 b	40.28 b	42.67 b
120 kg N/ha	19.94	36.44 ab	44.53 ab	48.67 ab
175 kg N/ha	19.72	38.89 ab	45.31 ab	46.00 ab
230 kg N/ha	19.44	38.17 ab	47.22 a	50.39 a
Duncan 0.05	NS	S	S	S

Note: Means in the same column sharing a letter (a, b, ab) are not significantly different at $\alpha = 0.05$ (Duncan's multiple range test). "S" indicates a significant treatment effect by ANOVA; "NS" indicates non-significance.

3.2 Absorption of Nutrient Elements (N, P, K, and Mg)

The results of the analysis of variance indicate that there is no interaction between plant density treatments and fertilization doses in the absorption of N, P, K, and Mg nutrients on the 70th day after planting. The absorption of N, P, K, and Mg nutrients at different densities did not show significant differences (Figure 7), whereas the absorption of N nutrients at different doses on the 70th day after planting showed significant differences (Figure 8). Table 3 presents the average nutrient absorption values of N, P, K, and Mg under different density and fertilization dose treatments. The results of the orthogonal contrast comparison test indicate that between fertilization and no fertilization, the significant difference is only in the absorption of N nutrients, while the absorption of P, K, and Mg nutrients does not show significant differences. The 0.05% Duncan test results for density treatments show no significant differences between treatments for the absorption of N, P, K, and Mg. In the fertilization dose treatment, the N nutrient absorption shows significantly different values. The fertilization dose treatment of 230 kg N/ha demonstrates a significant difference. The application of organic fertilizer at a dose of 230 kg N/ha increases N nutrient absorption by 25% compared to no fertilization. The results above demonstrate that the *Tithonia diversifolia* plant's high N content, which is crucial for the plant's growth period, leads to the high absorption of N nutrients.

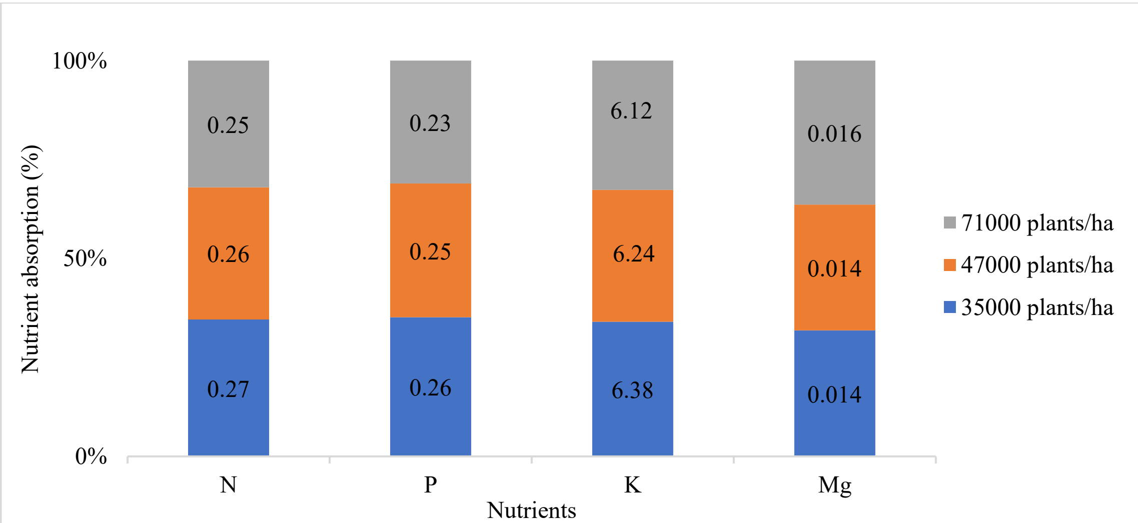

Figure 7. Effect of plant density on nutrient absorption in potato cultivars

3.3 Fresh Tuber Weight

The analysis of variance shows that there is no interaction between the treatment of plant density and the given fertilization dose and the fresh tuber weight of potato plants at any of the ages observed. The fresh tuber weight at different plant densities did not differ significantly (Figure 9). However, the fresh tuber weight at different fertilizer doses differed significantly at all observation ages, except for 45 days after planting (Figure 10). Table

4 presents the average fresh tuber weight for the density and fertilizer dose treatments. The results of the orthogonal contrast comparison test show that fertilizer application can increase the fresh tuber weight of potato plants by about 16.3% to 30.90%, even reaching 80% on the 45th day under 120, 175, and 230 kg N/ha after planting, compared to no fertilization. The 5% Duncan test shows that there is no significant difference in the average fresh tuber weight due to the treatment of inorganic and organic fertilizers starting from the observation age of 70 days after planting. The application of the *Tithonia diversifolia* fertilizer up to a dose of 175 kg N/ha resulted in an average fresh tuber weight that was not significantly different from the control (no fertilization) starting 45 days after planting. Meanwhile, the application of *Tithonia diversifolia* with a dose of 230 kg N/ha showed a significant difference from the control starting from 70 to 90 days after planting. The application of the *Tithonia diversifolia* fertilizer can increase the fresh tuber weight by 22.48–28.66% (Figure 10) compared to the plants with no fertilization.

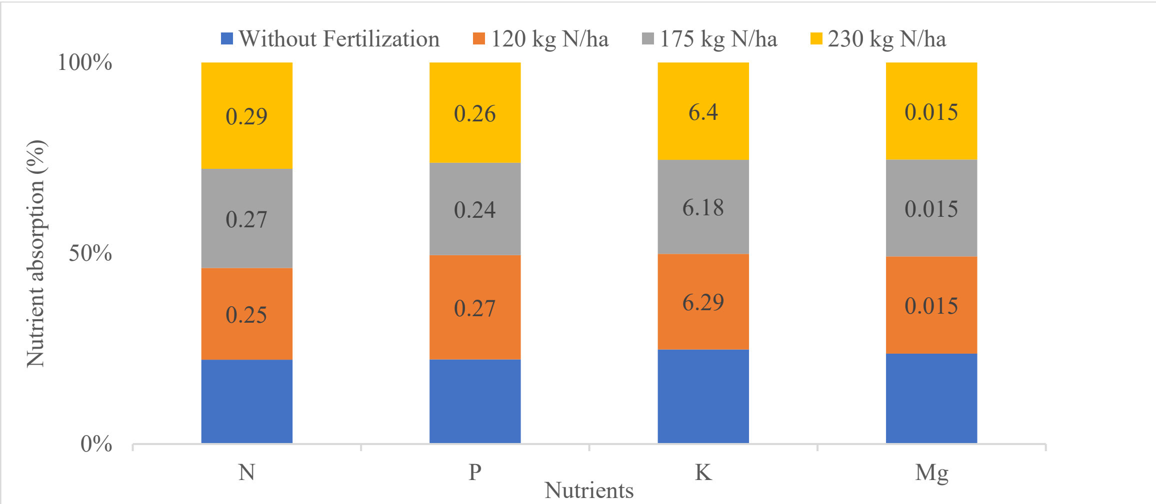

Figure 8. Effect of *Tithonia diversifolia* doses on nutrient absorption in potato cultivars

Table 3. Nutrient absorption of potato plants resulting from various densities and doses

Treatment	Nutrient Absorption (%) at 70 DAP			
	N	P	K	Mg
Plant density (P)				
35000 plants/ha	0.27	0.26	6.38	0.014
47000 plants/ha	0.26	0.25	6.24	0.014
71000 plants/ha	0.25	0.23	6.12	0.016
Duncan 0.05	NS	NS	NS	NS
Tithonia diversifolia doses (D)				
Without fertilization	0.23 b	0.22	6.22	0.014
120 kg N/ha	0.25 ab	0.27	6.29	0.015
175 kg N/ha	0.27 ab	0.24	6.18	0.015
230 kg N/ha	0.29 a	0.26	6.40	0.015
Duncan 0.05	S	NS	NS	NS

Table 4. Fresh weight of potato tubers resulting from various densities and doses

Treatment	Fresh Weight of Tubers (g)			
	45 DAP	70 DAP	90 DAP	120 DAP
Plant density (P)				
35000 plants/ha	41.50	422.90	533.77	439.00
47000 plants/ha	36.44	399.00	507.58	476.17
71000 plants/ha	32.35	355.62	468.24	502.40
Duncan 0.05	NS	NS	NS	NS
Tithonia diversifolia doses (D)				
Without fertilization	22.38	347.23 b	440.26 b	335.28 b
120 kg N/ha	28.21	370.77 ab	469.32 ab	425.28 ab
175 kg N/ha	38.03	384.45 ab	509.86 ab	491.44 ab
230 kg N/ha	41.5	425.29 a	566.54 a	630.61 a
Duncan 0.05	NS	S	S	S

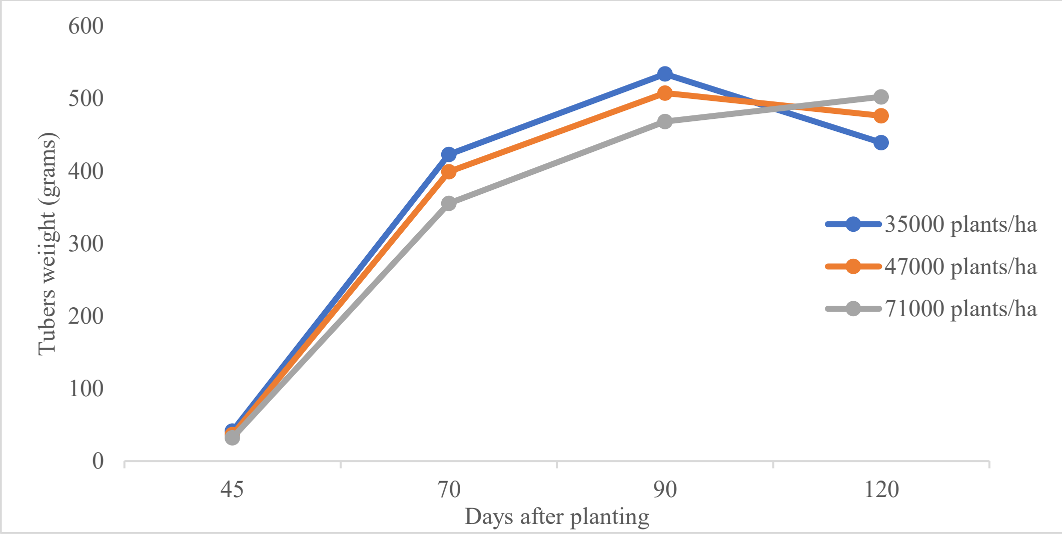

Figure 9. Effect of plant density on tuber weight in potato cultivars

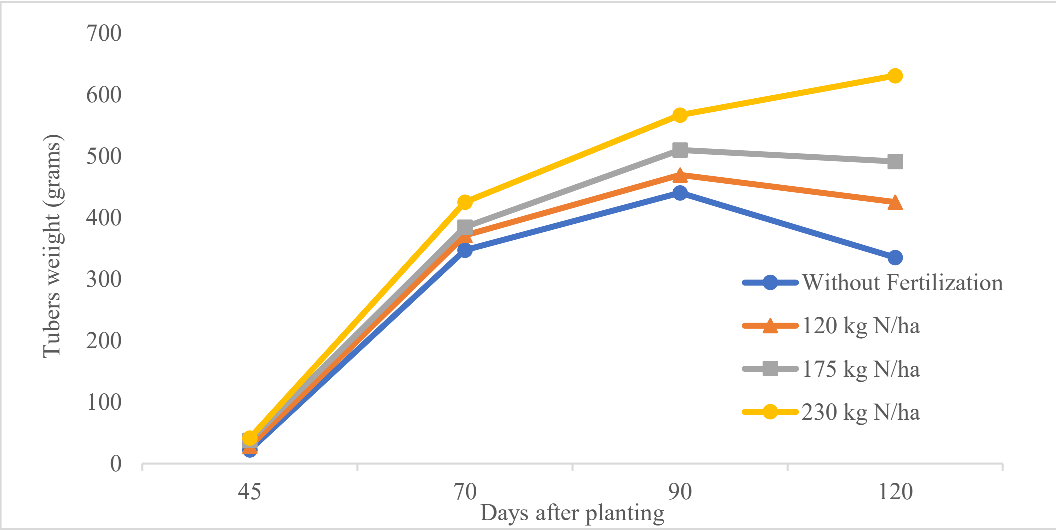

Figure 10. Effect of *Tithonia diversifolia* doses on tuber weight in potato cultivars

4. Discussion

The results of this study demonstrate the potential of *Tithonia diversifolia* as an effective organic fertilizer to enhance potato growth and productivity in highland agroecosystems. The application of *Tithonia diversifolia* significantly increased plant height, nutrient absorption, and fresh tuber weight, especially at higher dosage levels, while variations in plant density showed no significant effect on the observed parameters.

The findings indicate that increasing doses of the *Tithonia diversifolia* fertilizer positively influenced plant height starting from 45 days after planting. This response is likely due to the high N content in *Tithonia diversifolia*, which plays a key role in vegetative growth. The result aligns with prior studies (Ahmed et al., 2019; Gitahi et al., 2021), which reported improved plant growth and vigor under organic fertilizer applications rich in N. Nutrient absorption, particularly of N, was significantly improved with increasing *Tithonia diversifolia* doses, peaking at 230 kg N/ha. At this level, N absorption increased by approximately 25% compared to the control. This finding reinforces the nutrient-releasing capacity of *Tithonia diversifolia* during decomposition, supporting its use as a sustainable source of macroelements. The mechanism behind this improvement lies in the high N content of Tithonia, which promotes chlorophyll formation, boosts photosynthesis, and accelerates vegetative growth. While P and K are crucial for root development and stress tolerance, their absorption remained relatively unchanged, likely due to existing soil nutrient levels. Additionally, plant density did not significantly affect growth parameters, indicating that nutrient availability plays a more decisive role in highland conditions.

Fresh tuber weight also showed a marked increase with higher fertilizer doses, with significant differences starting from 70 days after planting. The highest yield was recorded at 230 kg N/ha, where tuber weight increased by up to 28.66% compared to unfertilized plots. This enhancement in yield is attributed to the improved nutrient availability and soil health supported by organic matter from *Tithonia diversifolia* (da Silva Júnior et al., 2025; Gusnidar et al., 2019), which boosts microbial activity and promotes better root development. Interestingly, plant density did not have a significant impact on plant height, nutrient uptake, or tuber yield. This suggests that in highland conditions, optimal fertilization may play a more critical role than spacing in determining potato productivity. It also indicates a potential flexibility in planting arrangements, which could benefit smallholder farmers with varying land sizes.

Comparisons with previous studies show both similarities and differences. Ahmed et al. (2019) demonstrated improved plant growth under N-rich organic amendments, aligning with this study's findings on increased tuber weight. However, Rozen et al. (2020) observed greater P availability in *Tithonia diversifolia*-based fertilizers, whereas this study did not find significant differences in P absorption. This discrepancy may stem from variations in soil composition and decomposition rates of organic matter. Furthermore, the influence of organic fertilizers on microbial activity and soil health warrants further investigation. Higher dosages of Tithonia likely stimulate microbial decomposition, increasing N availability, while long-term use could improve soil structure and water retention, reinforcing its viability for low-cost organic farming in plateau agriculture (Adebayo et al., 2025; Agbede, 2025; Robinson et al., 2024). Future research should explore long-term microbial interactions and their contributions to soil sustainability.

The application of *Tithonia diversifolia* not only improved agronomic performance but also supported the goal of sustainable agriculture. By reducing dependence on chemical fertilizers and utilizing locally abundant organic materials, this approach promotes ecological balance and cost-effective farming practices. These findings also align with global trends in sustainable agriculture, where organic inputs are increasingly favored for their environmental and soil health benefits (Bizzuti et al., 2025; Lu et al., 2024).

5. Conclusions

Based on the results of this study, it can be concluded that the *Tithonia diversifolia* organic fertilizer could increase plant height, tuber weight, and nutrient absorption. Specifically, fertilization dosages of 230 kg N/ha can increase N absorption by up to 25%. While plant densities do not show significant results, organic fertilization proved effective in improving overall crop growth.

Beyond immediate agronomic benefits, these findings support broader agricultural sustainability. Incorporating *Tithonia diversifolia* as an organic amendment may reduce dependence on synthetic fertilizers, mitigating environmental risks associated with chemical inputs. This approach aligns with global trends in low-cost organic farming, providing smallholder farmers with an affordable, locally sourced fertilization method. Further research could explore long-term soil health impacts, microbial activity dynamics, and scalability in different agro-climatic conditions to enhance its adoption in sustainable agriculture.

Author Contributions

Conceptualization, F.D.D. and M.; methodology, F.D.D.; software, D.P.H.; validation, M., F.D.D. and D.P.H.; formal analysis, F.D.D.; investigation, F.D.D.; resources, F.D.D.; data curation, F.D.D.; writing—original draft preparation, D.P.H.; writing—review and editing, M.; visualization, D.P.H.; supervision, M.; project administration, M.; funding acquisition, M. All authors have read and agreed to the published version of the manuscript.

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Data Availability

The data used to support the research findings are available from the corresponding author upon request.

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Conflicts of Interest

The authors declare no conflict of interest.

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