

Effect of NPK fertilizer dose to improve brazilian spinach (*Alternanthera sissoo*) growth in the Jakabaring Kitchen Garden, South Sumatera

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ABSTRACT

Nitrogen, phosphorus, and potassium (NPK) fertilization in Brazilian spinach cultivation in kitchen gardens is generally still carried out without clear Dose references, which has the potential to reduce plant growth efficiency. This study aimed to evaluate the growth response of Brazilian spinach to several doses of NPK fertilizer to determine the most suitable dose for the urban kitchen garden system. The research was conducted in Jakabaring District, South Sumatera, using a Randomised Block Design with four NPK fertiliser treatments (0, 3, 5, and 7 g per plant) and twenty replications. The data were analyzed using analysis of variance (ANOVA) at a 5% significance level. The results indicated that NPK fertilizer doses did not significantly affect ($p>0.05$) the number of leaves, canopy length, canopy width, and canopy area of Brazilian spinach. Descriptively, several growth parameters tended to show higher average values at the medium dose compared to the low or high doses. NPK fertilizer application showed no significant effect on plant fresh weight ($p>0.05$); however, the 3 g per plant treatment tended to produce higher average biomass compared to other treatments. This condition indicates that Brazilian spinach has good adaptability and was capable of growing optimally in relatively limited nutrient availability in kitchen gardens. It could be concluded that the use of low to moderate doses of NPK fertilizer was sufficient to support the growth of Brazilian spinach efficiently and sustainably in kitchen garden systems.

Keywords: fertilization efficiency, leafy vegetables, sustainable cultivation, urban agriculture, vegetative growth

INTRODUCTION

The escalating land scarcity has increased demand for food. Addressing food requirements in regions with constrained land, such as urban environments, requires sustainable strategies (Mohapatra et al., 2024). Kitchen gardens represent an initial approach to optimizing limited land by employing domestic food trash (Liu et al., 2023b). Leafy vegetables suitable for cultivation in these conditions include Brazilian spinach (*Alternanthera sissoo*), a species well-suited to tropical environments and with

considerable nutritional value (Muda et al., 2023). Nonetheless, the use of kitchen gardens for cultivating Brazilian spinach remains limited by inadequate nutrient inputs through fertilisation. At the community or home scale, people are already familiar with fertilising without adhering to the plant's nutritional requirements; thus, a practical approach, such as growing plants and fish, is essential (Setyawan et al., 2023). Nitrogen, phosphorus, and potassium (NPK) fertiliser is commonly utilised; however, its application is often not optimised to meet plant nutrient requirements, which may reduce

growth efficiency (Tan et al., 2022). Insufficient fertilizer limits growth, while excessive application reduces efficiency, increases costs, and harms plants and the environment (Gaytancıoğlu & Yılmaz 2024; Islam et al., 2022). These issues highlight inadequate fertilization management in Brazilian spinach cultivation in kitchen gardens, particularly due to the lack of scientifically based guidelines for appropriate NPK doses under local environmental conditions (Koniko, 2025). Consequently, it is imperative to optimize the NPK fertilizer Dose to establish an optimal and sustainable production procedure for Brazilian spinach (Muda et al., 2024).

NPK nutrients play an essential role in plant growth, particularly in vegetative development, root formation, and physiological processes such as enzyme activity (Abobatta & Abd Alla 2023; Valenzuela, 2024). Numerous studies demonstrate that the appropriate quantity of NPK fertiliser can enhance plant height, leaf area, and fresh weight in diverse leafy vegetable crops (Muda et al., 2022). Prior studies on Brazilian spinach concentrated on certain production methods, such as hydroponic systems, rather than optimal nutrient studies for the plants (Puspita et al., 2025). Scientific research on Brazilian spinach remains limited, particularly regarding field-based evaluation of optimal NPK fertilizer doses under kitchen garden conditions, as most studies focus on other leafy vegetables or controlled environments.

(Ahmed et al., 2024). Moreover, fertilisation studies have exclusively been performed on agricultural land or potting substrates in controlled settings; therefore, the outcomes do not accurately reflect the characteristics of kitchen garden plots, which exhibit distinct management practices, intensity, and maintenance levels (Yang et al., 2025). Previous studies have focused on nutrient processes in controlled conditions (Rui, Mao & Li, 2022). Consequently, while NPK fertilizers have been theoretically established as significant for plant growth, additional research is required on Brazilian spinach species that are appropriate for field settings in kitchen gardens (Neofytou et al., 2024).

This material reveals a disparity in research between current knowledge and the requirements at the home or community level (Bernzen et al., 2023). Nevertheless, few studies have specifically investigated the optimum NPK fertiliser doses for growing Brazilian spinach, particularly under local soil conditions in Jakabaring District, South Sumatera. Local environmental factors significantly influence nutrient availability (Umasugi et al., 2023). The lack of tailored fertilizer Dose recommendations that account for local site specifics results in inefficiency and inconsistent growth outcomes (Hasan et al., 2022). This study provides field-based evidence on the growth response of Brazilian spinach to varying NPK fertiliser doses under real kitchen garden conditions, characterised by low-input management and heterogeneous soils. Unlike previous studies conducted under controlled environments, the objective of the research was to evaluate fertilisation practices in an urban tropical setting, thereby offering context-specific insights for nutrient management in Jakabaring, South Sumatra.

MATERIALS AND METHODS

Time and Place

This study was conducted in a kitchen garden located in Jakabaring District, Palembang City, South Sumatra, Indonesia. The site was situated at coordinates -3.018271, 104.787559, representing an urban lowland tropical environment characterized by relatively high temperatures, moderate to high light intensity, and stable humidity conditions. The experiment was carried out over a two-month period, from August to September 2024, covering all stages from soil preparation to harvesting.

Experimental Design

The study employed a Randomized Block Design (RBD) consisting of four NPK fertilizer treatments: 0, 3, 5, and 7 g per plant. Each treatment was replicated twenty times, resulting in 80 experimental units. NPK fertiliser (16-16-16) was applied once at 4 days after transplanting using the broadcasting method, based on a

recommended dose of 5 g per plant (Muda et al., 2022).

Brazilian Spinach Cultivation

The preparation of the planting medium begins with clearing the land of weeds and remnants of previous plants, followed by loosening the soil to improve its structure and aeration (Getahun et al., 2022). Furrows were made with sizes adjusted to the predetermined planting distance to provide the plants with optimal growing space. Well-decomposed cow manure was evenly applied as a base fertilizer, then mixed with the soil to increase organic matter content and improve the physical and chemical properties of the soil. The planting material in the form of Brazilian spinach stem cuttings was obtained from healthy parent plants free from signs of pest or disease attacks. Cuttings were taken from the middle part of the stem, two nodes long, and all the leaves on the cuttings were trimmed to reduce water loss through transpiration and increase the success of root formation. The prepared cuttings are then used as planting material in the prepared media.

The planting of Brazilian spinach was done by inserting the stem cuttings into the soil vertically, with one node of the stem in the soil and the other node above the soil surface to obtain uniform planting materials (Muda et al., 2023). The planting distance used is 15×20 cm between plants to provide sufficient growing space and reduce competition among plants in obtaining light, water, and nutrients. The plants are maintained with uniform agronomic treatments throughout the growth period. Watering was done manually with a frequency adjusted to the soil moisture conditions, that was, it was done when the soil appears dry and stopped when the soil was still moist. Weed control was carried out mechanically by uprooting the weeds that grow around the plants to prevent competition in water and nutrient absorption.

Observation of plant growth was conducted starting one week after planting and continued periodically every week until the plants reach harvest age. The data collection method was conducted thru sampling on plants that represented each treatment. The growth

parameters observed include the number of leaves, canopy length, canopy width, and canopy area of Brazilian spinach plants. The counting of the number of leaves was done by counting the leaves that had fully opened, while the measurement of the length and width of the canopy was done by measuring the spread of the plant's crown in both the longitudinal and transverse directions. The canopy area was calculated from the canopy length and width using Easy Leaf Area software as an indicator of the plant's ability to capture sunlight and support photosynthesis.

Harvesting was done at five weeks after planting. Harvesting was done by carefully uprooting the plants along with their roots to avoid damaging the plant tissues (Liu et al., 2023a). The harvested plants were then cleaned of any adhering soil and weighed to obtain data on the fresh weight per plant. The fresh weight measured using an analytical balance could be used as an indicator of the productivity of Brazilian spinach plants as well as the plants' response to the NPK fertilizer treatment given during the research period. All observational data were recorded systematically and used as the basis for evaluating plant growth and yield in this study.

Data Analysis

The observational data were analysed using analysis of variance (ANOVA) at a 5% significance level, utilising RStudio software. This analysis was to observe the significant effect of NPK fertilizer doses on the growth of Brazilian spinach in kitchen gardens in Jakabaring, South Sumatera.

RESULTS

Number of Leaves

Based on the ANOVA results, there was no significant difference among NPK fertiliser doses. The highest average number of leaves was observed in the third week with a 7 g fertiliser dose, yielding 41.65 leaves, followed by a 3 g Dose with 33.85 leaves, no fertiliser with 31.75 leaves, and a 5 g Dose with 26.65 leaves (Figure 1).

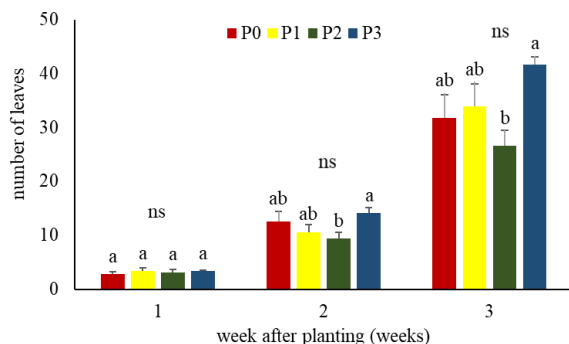


Figure 1. Average number of leaves from the first week to the third week. Error bars represent standard error (SE). Means followed by the same letter were not significantly different (ns) at $p \leq 0.05$ based on ANOVA. P0 = 0 g NPK per plant; P1 = 3 g NPK per plant; P2 = 5 g NPK per plant; P3 = 7 g NPK per plant.

Length of the Canopy

The results of the variance analysis show that applying multiple Doses of NPK fertiliser in Brazilian spinach agriculture had no significant effect on the canopy length. The canopy length value was highest in the third week of measurement, specifically in plants receiving a 3 g fertiliser dose at 20.80 cm, while the lowest value was recorded in plants receiving a 7 g fertiliser treatment at 19.5 cm (Figure 2).

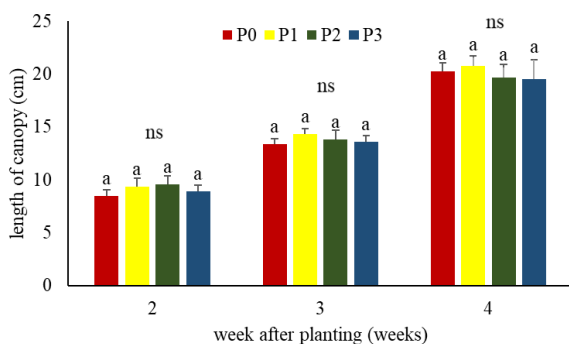


Figure 2. Canopy length (cm) of the plants after two weeks of planting until the fourth week. Error bars represent standard error (SE). Means followed by the same letter were not significantly different at $p \leq 0.05$ based on ANOVA. P0 = 0 g NPK per plant; P1 = 3 g NPK per plant; P2 = 5 g NPK per plant; P3 = 7 g NPK per plant.

Width of Canopy

Applying various doses of NPK fertiliser did not significantly affect canopy width. This graph shows that the highest canopy width in the third week was in plants with a 3 g dose (16.98 cm), and the lowest was in plants with a 7 g dose (14.86 cm) (Figure 3).

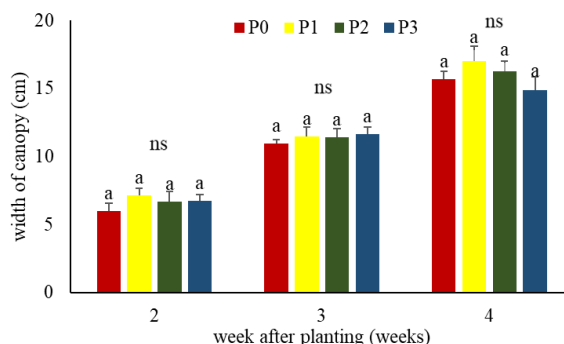


Figure 3. Canopy width (cm) of the plants after two weeks of planting until the fourth week. Error bars represent standard error (SE). Means followed by the same letter were not significantly different (ns) at $p \leq 0.05$ based on ANOVA. P0 = 0 g NPK per plant; P1 = 3 g NPK per plant; P2 = 5 g NPK per plant; P3 = 7 g NPK per plant.

Canopy Area

Based on the ANOVA test, the canopy area values in each observation did not show a significant effect. The highest average canopy area was observed in the third week, specifically in plants with a 5 g Dose, measuring 472.574 cm^2 , while the lowest average was found in plants with a 7 g fertilizer Dose, measuring 396.112 cm^2 (Figure 4).

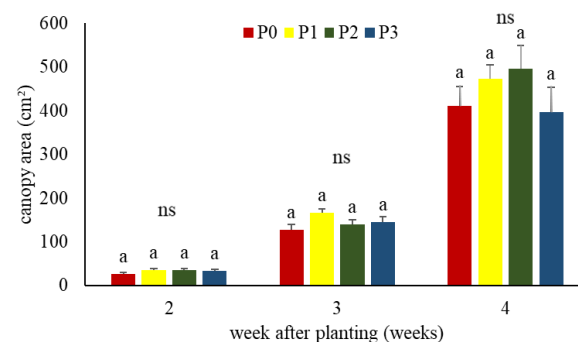


Figure 4. Canopy area (cm^2) of the plants after two weeks of planting until the fourth week. Error bars represent standard error (SE). Means followed by the same letter were not significantly different (ns) at $p \leq 0.05$ based on ANOVA. P0 = 0 g NPK per plant; P1 = 3 g NPK per plant; P2 = 5 g NPK per plant; P3 = 7 g NPK per plant.

Fresh Weight of Plants

Based on the fresh weight data, the highest average values were observed in the 3 g treatment, with 102.6 g for leaves, 5.8 g for stems, 17 g for branches, and 2.554 g for roots. However, these values were not significantly different from other treatments (Table 1). Fresh weight was used as an indicator of plant biomass in this study (Table 1).

Table 1. Fresh weight of plants

Treatment	fresh weight (g)			
	Leaves	Stems	Branches	Roots
P0	89	5	16.4	2.544
P1	102.6	5.8	17	2.554
P2	90.4	5.4	14.2	2.06
P3	88.6	5.6	16	1.516
	ns	ns	ns	ns

Note: P0=0 g NPK per plant, P1=3 g NPK per plant, P2=5 g NPK per plant, P3=7 g NPK per plant, ns= No significant effect

DISCUSSION

The overall absence of significant responses to NPK fertilizer application indicates that Brazilian spinach exhibits strong adaptability to low-input conditions, particularly in kitchen garden systems (Zhang et al., 2023). This suggests that Brazilian spinach adapts well to kitchen garden settings. Several studies on leafy vegetables show that the plant's reaction to NPK fertiliser is minimal if the plant's basic nutritional requirements are satisfied by the growth medium or environment (Yang et al., 2025). In limited areas, such as kitchen gardens, factors inhibiting plant growth are influenced not only by macronutrient availability but also by soil physical and chemical properties, such as the soil's low ability to retain nutrients, unstable soil structure, and limited nutrient absorption by the root system (Gustiar et al., 2025). This condition causes an increase in inorganic fertiliser; it does not always be followed by a significant increase in plant growth (Xu et al., 2025b). The number of leaves on Brazilian spinach (*Alternanthera sissoo*) reflects the dynamics of the plant's vegetative growth, with an increase in leaf count indicating the plant's ability to optimally construct photosynthetic organs throughout the growth phase. The absence of significant differences in leaf number indicates that nutrient availability in the growth medium may have already met the minimum requirements for vegetative development, thereby limiting the plant response to additional fertilisation. These findings are similar to previous studies on lettuce and spinach, which found that raising NPK concentrations above the plants' optimal demands did not usually significantly improve leaf development (Hijrah & Khaliq, 2025). Nitrogen is essential for the production of leaves and vegetative tissues; nevertheless, excess nitrogen can limit nutrient

consumption efficiency and produce nutritional imbalances within the plant (Yang et al., 2025).

Several studies have found that increasing nitrogen fertilizer doses does not necessarily result in significant gains in yield or nutrient usage efficiency. For example, high nitrogen application in maize does not increase seed production or nitrogen efficiency over time, despite the fact that several morphological parameters improve (Ren et al., 2025). In very small kitchen garden plots, the nutritional imbalance in the crops is compounded by the soil's restricted ability to store and give nutrients over time, resulting in a limited response of the plants to fertilization.

The lack of significant differences in canopy dimensions suggests that plant growth was not primarily limited by nutrient availability, but rather by environmental factors and inherent growth characteristics under kitchen garden conditions. The length and width of the canopy show the growth of the plant's crown, which is directly tied to its photosynthetic ability (Zhang et al., 2023). Several studies have found that the development of fresh weight in leafy vegetable plants is more impacted by nutritional balance and developing ambient conditions than an increase in a single fertilizer dose (Esposito et al., 2025). Moderate fertilizer levels may have provided sufficient nutrients to support canopy development, while higher doses did not further enhance growth, possibly due to reduced nutrient use efficiency or physiological limitations (Piao et al., 2022). This behavior has also been observed in lettuce and spinach plants, where excessive fertilizer doses do not significantly improve canopy formation and may even lower nutrient use efficiency (Fitriatin et al., 2023).

The canopy area is an integrative metric that describes the accumulation of vegetative growth in plants (Zhang et al., 2023). The absence of significant differences in canopy area indicates that additional nutrient input did not substantially influence vegetative biomass accumulation under the given environmental conditions. In addition, Brazilian spinach can thrive in shaded locations (Linda et al., 2023). Several investigations on vegetable plants have also found that the use of NPK fertiliser has a direct impact on the nutrients available in the soil (Sara et al., 2024). In kitchen

garden circumstances, the restricted soil carrying capacity causes plants to achieve an optimum development point, thus fertilizer addition no longer significantly increases canopy area (Xu et al., 2025a). The plant's fresh weight indicates the accumulation of biomass that occurs throughout the photosynthetic process (Abideen et al., 2022). The absence of a significant response in fresh weight suggests that biomass accumulation was not strongly influenced by increasing fertilizer doses. This indicates that nutrient availability may have already reached a sufficient level, and further additions did not translate into increased growth, likely due to environmental constraints and limitations in nutrient uptake efficiency. (Zhang et al., 2023). These findings are consistent with previous study on lettuce and spinach, which found that increasing NPK fertilizer doses did not always lead to an increase in plant fresh weight (Hijrah & Khaliq, 2025). Nutrient balance, water availability, and the plant's physiological condition all significantly affect fresh weight. In kitchen gardens, environmental considerations frequently become the primary constraint on biomass accumulation, rather than the amount of fertilizer supplied (Al-hashemi, 2025). The insignificance of the effect of varying NPK fertilizer doses on the growth of Brazilian spinach has important implications for the management of kitchen gardens on suboptimal land (Iqbal et al., 2023).

This result indicates that the use of low to moderate doses of NPK fertiliser is already capable of supporting optimal plant growth. This approach is considered more efficient, economical, and environmentally friendly, especially for household-scale cultivation systems (Korpelainen, 2023). Several studies emphasise that fertilisation strategies on suboptimal land should focus on nutrient use efficiency and nutrient balance, rather than solely increasing inorganic fertiliser doses (Fitriatin et al., 2023). However, this study did not include dry weight measurements, which are generally considered a more stable indicator of plant biomass. The absence of dry weight data may limit the interpretation of biomass accumulation, as fresh weight can be influenced by plant water content. Therefore, future studies are recommended to include dry weight analysis to

provide a more comprehensive evaluation of plant responses to fertilisation.

CONCLUSION

The results indicate that Brazilian spinach shows good adaptability to kitchen garden conditions with limited nutrient availability, as different NPK fertiliser doses did not result in significant differences in growth performance. This suggests that moderate fertilizer input may be adequate to support plant development without excessive application. Therefore, the use of low to moderate NPK fertilizer doses may be a more efficient, economical, and environmentally sustainable option for Brazilian spinach cultivation in kitchen garden systems.

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