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Effects of fermented plant juice (FPJ) concentration and application frequency on the growth and flowering of *Ruellia simplex* C. Wright 'Katie Pink'

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ABSTRACT

The increasing popularity of organic farming and home gardening in the Philippines has heightened interest in sustainable alternatives to synthetic fertilizers. Fermented plant juice (FPJ), a liquid organic supplement from plant materials and molasses, shows potential for promoting plant growth and development but remains understudied in ornamental species. This study evaluated the effects of different FPJ concentrations and application frequencies on the growth and flowering responses of *Ruellia simplex* C. Wright 'Katie Pink', a widely cultivated ornamental plant. The experiment followed a completely randomized design with eight treatments, including different FPJ concentrations (1.5%, 3%, 6%) and application frequencies (once, twice, four times, and eight times per month), along with ammonium sulfate (21-0-0) and a control (T1 - no fertilizer application). Results showed that application of ammonium sulfate (21-0-0) (T8) significantly enhanced all growth parameters and flowering traits, including plant height, leaf number, chlorophyll content, and flower production. Among the FPJ treatments, 6% FPJ applied eight times per month (T7) demonstrated the best performance in both vegetative and reproductive development, characterized by early bud emergence, the highest bud count, and high root volume. However, its flower conversion rate (52.4%) was lower than that of T8 (86.6%), although the difference was not statistically significant. Treatments with lower FPJ concentrations or reduced application frequency resulted in delayed or absent flowering but still performed better than the control (T1). These findings highlight the importance of optimizing both FPJ concentrations and application frequency. High-concentration and high-frequency FPJ applications can enhance plant growth and reproductive performance, making FPJ a viable and sustainable alternative to chemical fertilizers when properly managed.

Keywords: ammonium sulfate, concentration, frequency, organic fertilizer, ornamental plant

INTRODUCTION

In the Philippines, home gardening became an internet sensation during the COVID-19 pandemic, with the terms "plantito" and "plantita" emerging on social media to refer to individuals who developed an interest in growing plants, particularly ornamental plants at home (Sunga and Advincula 2021).

Following the popularity of home gardening, people began using fertilizers indiscriminately, driven by the belief that higher dosages promote better plant growth. In principle, fertilizer application is intended to optimize growth and yield for maximum profit and to increase production to meet the demands of a growing population. The introduction of synthetic fertilizers during the Green Revolution has led to an exponential increase in the yield of most crops (Paull 2009; Maaz 2025; Sharafi et al. 2025). However, the continuous overapplication of fertilizers has led to various environmental issues, including soil degradation, water pollution, and ecosystem imbalance (Li et al. 2018; Gaytancıoğlu and Yılmaz 2024). In response to these issues, there has been growing advocacy for sustainable agriculture.

Sustainable agriculture is a holistic farming system that focuses on increasing agricultural productivity while considering the short- and long-term effects of farm practices on the environment and human health (Velten et al. 2015; Hiywotu 2025; Singh et al. 2025). One of the key sustainable agricultural practices is organic farming, which prohibits or limits the use of synthetic fertilizers and pesticides. Instead, organic agriculture relies on natural alternatives such as organic concoctions or plant-based supplements (Reganold and Wachter 2016; Seufert and Ramankutty 2017; Caipang and Avillanosa 2019; Chojnacka et al. 2020). These inputs are derived from locally available natural materials and include common types such as indigenous microorganisms (IMO), fermented fruit juice (FFJ), fermented plant juice (FPJ), fish amino acid (FAA), lactic acid bacteria serum (LABS), and natural indigenous activator (NIA) (BAFS 2014; Keliikuli et al. 2019).

According to the Bureau of Agriculture and Fisheries Standards (BAFS, 2014), these organic plant supplements are compounds of organic origin in liquid or solid form that, in low concentration, promote or modify physiological processes in plants. Recent studies have shown that organic and biologically derived inputs applied at low rates can influence plant physiological functions by enhancing nutrient use efficiency, stress tolerance, and overall growth performance, even without serving as direct nutrient sources (du Jardin 2015; Rouphael and Colla 2020; Mannino et al. 2025). Moreover, these supplements should contain a total nitrogen, phosphorus, and potassium (NPK) content of not less than 0.5% and not more than 2.5%. They may also include beneficial microorganisms, micronutrients, and naturally occurring plant growth regulators, which contribute to improved plant physiological responses under sustainable and organic farming systems (Silva et al. 2025; Win et al. 2025).

Fermented plant juice is an organic plant supplement made up of plant extracts and molasses. The current recommendation of the Agricultural Training Institute for preparing FPJ is a 1:1:1 ratio of chopped plant materials, molasses or crude sugar, and clean water. It has been applied to a wide range of crops, including organic rice, corn, fruit trees, and vegetables (ATI-DA 2022). The use of FPJ and related organic concoctions has been found to have positive effects on plant growth, yield, and soil biological and chemical properties when applied as foliar or soil amendments (Sakimin et al. 2017; Sulok et al. 2021; Taer 2025). Another important benefit of using organic fertilizers such as FPJ is their potential to recycle food waste by utilizing large volumes of discarded fruits and vegetables resulting from poor marketability, quality rejection, and overproduction of perishable crops.

Several studies have shown that the application of FPJ significantly enhances various aspects of crop production. For instance, Anuada et al. (2021) reported that FPJ induced early flowering and significantly increased the number of flowers and fruits per plant in cherry tomato. Sakimin et al. (2017) observed that the application of FPJ increased plant height, induced early flowering and fruiting, and enhanced photosynthetic rates in tomato plants. Other studies have also noted improvements in reproductive and yield parameters, such as reduced days to fruit setting in pepper, increased fruit number and weight in eggplant, and higher yield per hectare in cowpea and eggplant (Pagluanan and Anical 2010). Denona et al. (2020) observed increased productivity in leaf mustard, while Lorio and De Asis (2021) reported improved fruit production in hot pepper (*Capsicum frutescens* L.). Similarly, Alam (2021) and Tagotong and Corpuz (2015) found that FPJ enhanced both the growth and yield of lettuce (*Lactuca sativa* L.) and pechay (*Brassica pekinensis* L.), respectively.

Although FPJ and other organic fertilizers are often considered environmentally friendly, excessive application can still have negative effects beyond economic considerations. High application rates of organic fertilizers can compromise soil physical and chemical properties, including salinization, clay dispersion, and reduced soil function, ultimately affecting plant growth and soil ecosystem services (Silva et al. 2024). In addition, increased use of organic fertilizers, such as manure and compost, can lead to higher nitrogen and phosphorus loads in surface waters, raising concerns about nutrient runoff and water quality degradation (Lisenbee et al. 2024). Fertilizer inputs also interact with broader environmental systems and can contribute to contamination of soil, air, and water if not properly managed (Tagkas et al. 2024). These considerations underscore that appropriate fertilizer rates and sustainable management are crucial not only for economic efficiency but also for mitigating potential environmental impacts.

While several studies have explored the use of FPJ on fruit and vegetable crops, there is limited research on its effects on ornamental plants. Unlike food crops, ornamental plants are primarily cultivated for aesthetic traits, such as flowering intensity, plant form, and visual quality, rather than for yield or biomass. The nutritional requirements of ornamental species are often less well established than those of major food crops, and imbalanced fertilization can lead to poor ornamental quality or increased production costs (Khoddamzadeh et al. 2025; Furtini Neto et al. 2015). In ornamentals, proper nutrient balance, particularly of macronutrients such as nitrogen and potassium, can enhance quality traits, including plant height, flower formation, and postharvest performance (Bashaboina et al. 2025; Joiner et al. 1983). Studies on biostimulants, including organic inputs, have shown significant effects on growth, nutrient uptake, and quality traits in ornamental plants (Tütüncü et al. 2024). Because ornamental plants differ from food crops in production goals and physiological priorities, responses to organic inputs such as FPJ may not be directly comparable across plant types, underscoring the need for focused research on ornamental species and caution in extrapolating results to other crops.

In this study, *Ruellia simplex* C. Wright 'Katie Pink', a perennial herbaceous flowering plant, was used. It belongs to the family Acanthaceae, a large family of angiosperms that is widely distributed across tropical, subtropical, temperate, and subtemperate regions. This species is widely cultivated as an ornamental ground cover or border in various landscapes due to its adaptability to diverse environmental conditions, minimal cultural requirements, and attractive, brightly colored flowers. It is easily propagated through cuttings or seeds and is tolerant of drought, soil acidity, and salinity, although it grows best in well-drained soils. The plant can thrive under full sun or partial shade and flowers throughout the year, particularly during the summer season (Wilson et al. 2020; Gilman 1999). Because of its rapid growth, consistent flowering response, and widespread use in ornamental landscaping, *R. simplex* was selected as a model ornamental species to evaluate the effects of FPJ on vegetative growth and flowering. While responses to FPJ may vary among ornamental species, this study provides baseline information that may guide future research on other ornamentals with similar growth habits.

This study focused on the growth and flowering responses of *R. simplex* to different concentrations and application frequencies of FPJ, compared with a synthetic fertilizer applied at the recommended rate. Specifically, this study aimed to: (1) identify the optimal frequency of FPJ application at a fixed concentration, (2) determine the most effective FPJ concentration when applied at a consistent frequency, and (3) assess the overall effectiveness of FPJ in comparison with ammonium sulfate application.

METHODS

Plant Material and Experiment Treatments

The experiment was conducted from March to June 2023 at the Fruit Crops Nursery, University of the Philippines Los Baños (UPLB), under full sunlight conditions. Uniform juvenile-stage *R. simplex* plants were obtained from a local nursery in Bay, Laguna, and transplanted into 4-inch plastic pots filled with a mixture of garden soil, coir dust, compost, and carbonized rice hull in a 3:1:1:1 ratio. After a week of acclimatization (root establishment period), fertilizer treatments were applied. Soil pH was monitored weekly using a soil pH tester (AgraTronix^{TM}, USA).

The experiment was laid out in a completely randomized design (CRD) with eight treatments and three replicates per treatment. The treatments were as follows: (T1) control (no fertilizer); (T2) 3% FPJ applied once a month; (T3) 3% FPJ applied twice monthly (every other week); (T4) 3% FPJ applied four times a month (once a week); (T5) 3% FPJ, (T6) 1.5% FPJ, and (T7) 6% FPJ – all applied eight times per month (twice a week); and (T8) 0.4% ammonium sulfate (21-0-0) (w/v) applied twice monthly. All treatments were summarized in Table 1.

The FPJ treatments were based on either increasing or decreasing the general recommendation of the Department of Agriculture – Agricultural Training Institute (ATI-DA 2022), which prescribes two tablespoons (approximately 15 mL) of concentrated FPJ per liter of water. In contrast, the rate of ammonium sulfate (T8) followed common nursery practice at the source of the planting material. Each plant received 300 mL of treatment solution per application for six weeks. Commercially available FPJ and ammonium sulfate were used to prepare the fertilizer treatments.

The commercial FPJ used in the study was sourced from a local manufacturer (Natural Organic Fertilizer) and was formulated from a 1:1 mixture of molasses and fresh malunggay (*Moringa oleifera* Lam.) and oregano (*Origanum vulgare* L.) leaves, fermented for two weeks as specified on the product label. Chemical analysis of the FPJ was conducted at the Division of Soil Science Laboratory, Agricultural Systems Institute, College of Agriculture and Food Science, University of the Philippines Los Baños, to verify its nutrient composition.

Table 1. Summary of fertilizer treatments with corresponding classification, concentration, and application frequency. *Based on the type of fertilizer input.

Treatment			Fermented Plant Juice (FPJ) Concentration (%)	Frequency of Application (per month)
Code	Description	Classification*		
T1	Control	None	0.0	0.0
T2	FPJ (2 tbsp/L)	Organic	3.0	1.0
T3	FPJ (2 tbsp/L)	Organic	3.0	2.0
T4	FPJ (2 tbsp/L)	Organic	3.0	4.0
T5	FPJ (2 tbsp/L)	Organic	3.0	8.0
T6	FPJ (1 tbsp/L)	Organic	1.5	8.0
T7	FPJ (4 tbsp/L)	Organic	6.0	8.0
T8	Ammonium sulfate (21-0-0) (0.25 tbsp/L)	Inorganic	0.0	2.0

Plant Growth and Reproductive Parameters

Growth parameters were measured at designated intervals throughout the experiment. At the onset, plant height (cm) was measured from the base of the stem to the highest leaf. Leaf area (cm^2) was estimated non-destructively using linear leaf dimensions, where maximum leaf length (L) and width (W) were measured with a ruler, and leaf area was calculated as:

Leaf area = L × W × 0.75

The correction factor (0.75) accounts for the non-rectangular shape of most leaves and is commonly used in simplified leaf-area models based on length and width measurements (Stickler et al. 1961). Recent work also supports the use of shape-based correction factors for estimating leaf area from length and width (Schrader et al. 2021). The total number of leaves and chlorophyll content (SPAD value) were recorded weekly, with SPAD readings taken in the morning from three leaves per plant using a SPAD meter (Minolta SPAD-502Plus, Singapore).

At termination, plant height and leaf area were re-measured. Stem diameter (mm) was measured at mid-height using a digital vernier caliper (HilkaTools, China), and root volume (mL) was determined using the water displacement method. The samples were then harvested and air-dried for one week, after which dry weight (g) was measured using a digital weighing scale.

Flowering response was assessed by recording four key parameters: (1) days to first floral bud emergence, defined as the number of days from transplanting to the emergence of the first visible floral bud; (2) days to first anthesis, measured as the number of days from transplanting to the full opening of the first flower; (3) total floral bud count per plant, including both open and unopened buds; and (4) total number of flowers that reached anthesis per plant. Data were collected on individual plants and averaged per treatment. Plants that did not exhibit flowering were recorded as non-flowering and excluded from analyses involving flowering time and flower counts.

Statistical Analysis

Analysis of variance (ANOVA) and Tukey's HSD (Honestly Significant Difference) test were performed using Jamovi *version 2.3.28.0* (Jamovi 2024).

RESULTS

Optimal Frequency of FPJ Application

The application of 3% FPJ at varying frequencies (T2-T5) showed no statistically significant differences compared with the control (T1), although some increase in vegetative growth parameters was observed. Application at four times per month (T4) resulted in the tallest plants (16.37 cm), followed by T5 (14.97 cm), but neither differed significantly from T1 (13.47 cm) (Table 2). Chlorophyll content also tended to increase with frequency, with T5 (40 SPAD units) recording higher values than T2-T4 and the control (35.30 SPAD). Similarly, leaf area peaked in T5 (13.47 cm^2), with all FPJ treatments exceeding T1 (11.01 cm^2). Root volume and dry biomass were also enhanced, especially in T4 and T5 (7 mL and 6.67–4 g, respectively), compared with T1 (3.33 mL and 2 g), but the differences were not significant.

Table 2. Effects of fermented plant juice (FPJ) and ammonium sulfate (21-0-0) applications on the growth of *Ruellia simplex* C. Wright 'Katie Pink'. Values (Mean ± SE; n = 3) within each column followed by the same letter are not significantly different using Tukey's HSD test at $P \leq 0.05$.

Treatment		Plant Height (cm)	Stem Diameter (mm)	Chlorophyll Content (SPAD value)	No. of Leaves	Leaf Area (cm²)	Root Volume (ml)	Dry Weight (g)
T1	Control	13.47 ± 0.44[b]	16.90 ± 0.83[a]	35.30 ± 1.25[b]	17.00 ± 3.06[b]	11.01 ± 2.00[ab]	3.33 ± 0.33[b]	2.00 ± 0.00[b]
T2	3.0% FPJ (1x/month)	13.60 ± 2.02[b]	15.20 ± 0.68[a]	36.97 ± 4.43[b]	38.00 ± 12.5[ab]	9.27 ± 0.65[b]	5.67 ± 1.76[ab]	2.30 ± 0.33[b]
T3	3.0% FPJ (2x/month)	14.27 ± 0.72[ab]	16.47 ± 0.81[a]	36.20 ± 4.48[b]	34.00 ± 8.08[ab]	11.09 ± 0.31[ab]	4.67 ± 0.67[b]	7.00 ± 1.15[ab]
T4	3.0% FPJ (4x/month)	16.37 ± 1.35[ab]	16.80 ± 0.70[a]	37.20 ± 3.65[b]	53.00 ± 9.29[ab]	11.16 ± 0.44[ab]	7.00 ± 0.58[ab]	6.67 ± 1.76[ab]
T5	3.0% FPJ (8x/month)	14.97 ± 1.49[ab]	14.13 ± 0.46[a]	40.00 ± 2.10[b]	36.67 ± 1.67[ab]	13.47 ± 1.95[ab]	7.00 ± 1.15[ab]	4.00 ± 1.00[b]
T6	1.5% FPJ (8x/month)	13.50 ± 0.76[b]	12.13 ± 0.57[a]	36.90 ± 1.56[b]	26.67 ± 1.76[ab]	8.94 ± 0.17[b]	3.33 ± 0.88[b]	2.67 ± 1.20[b]
T7	6.0% FPJ (8x/month)	17.07 ± 1.45[ab]	15.83 ± 0.72[a]	45.70 ± 3.20[ab]	39.33 ± 9.4[ab]	11.46 ± 0.28[ab]	11.00 ± 2.65[a]	3.67 ± 0.88[b]
T8	0.4% Ammonium sulfate (2x/month)	19.97 ± 1.16[a]	12.97 ± 0.86[a]	55.93 ± 2.36[a]	57.33 ± 12.6[a]	15.23 ± 1.11[a]	7.00 ± 0.58[ab]	10.67 ± 0.67[a]

Leaf production trends over time (Figure 1) showed a rapid increase in T4 and T5 starting at week 2, with T4 maintaining a consistent lead from weeks 4 to 6, outperforming T1 throughout. As shown in Figure 2, T4 increased plant height by approximately 21.5%, leaf number by 211.8%, and dry weight by 233.5% relative to T1, while T5 increased leaf area by 22.3%, SPAD value by 13.3%, and root volume by 110.1% compared with the control. These results indicated that more frequent applications promoted more robust growth, particularly in leaf development and root expansion.

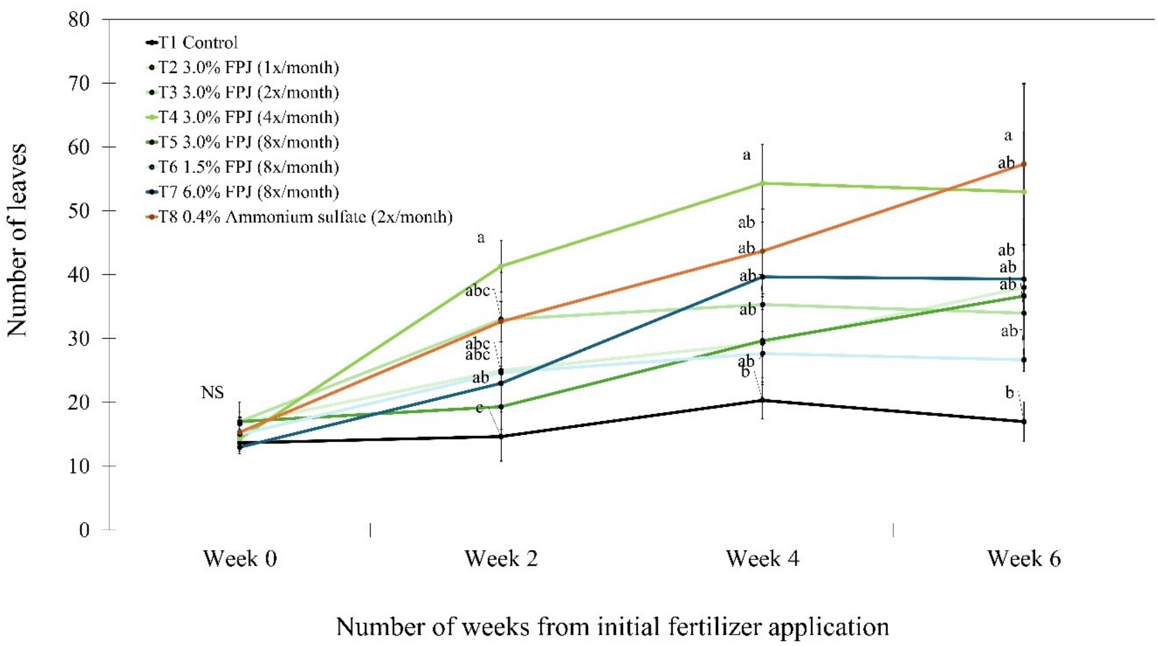

Figure 1. Leaf production in *Ruellia simplex* C. Wright 'Katie Pink' over six weeks as affected by different concentrations and application frequencies of fermented plant juice (FPJ) and ammonium sulfate (21-0-0). Means within each week with the same letter are not significantly different using Tukey's HSD test at $P \leq 0.05$. Error bars indicate ± SE; n = 3.

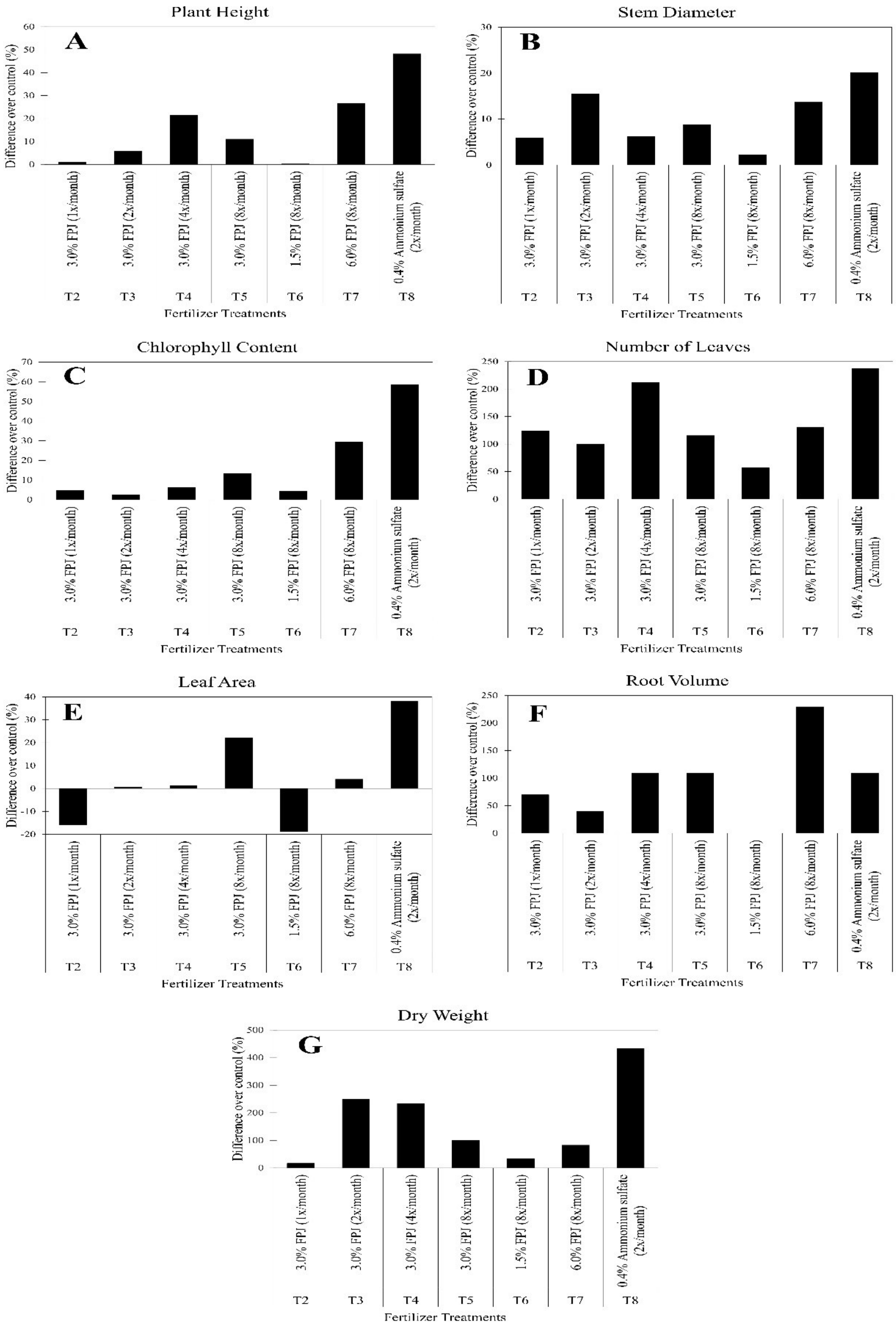

Figure 2. Percent difference from control in various growth parameters of Rohelia (*Ruellia simplex* C. Wright 'Katie Pink') in response to concentrations and application frequencies of fermented plant juice (FPJ) and ammonium sulfate (21-0-0). Parameters measured include (A) plant height, (B) stem diameter, (C) chlorophyll content (SPAD), (D) number of leaves, (E) leaf area, (F) root volume, and (G) dry weight. All values are expressed as percentage differences relative to the untreated control (T1).

In terms of reproductive development, all FPJ frequency treatments (T2–T5) induced bud formation, while T1 remained non-flowering. Treatments T4 and T5 showed earlier bud emergence (26–28 days) than T2 (42.33 days) and produced 1.33–2 floral buds per plant (Figure 3). However, all frequency treatments produced only one flower per plant, with moderate conversion rates (50–75%) (Figure 4). Among the frequency treatments, four applications per month (T4) were identified as the optimal frequency, although the results also suggested that frequency alone was insufficient to significantly enhance floral yield.

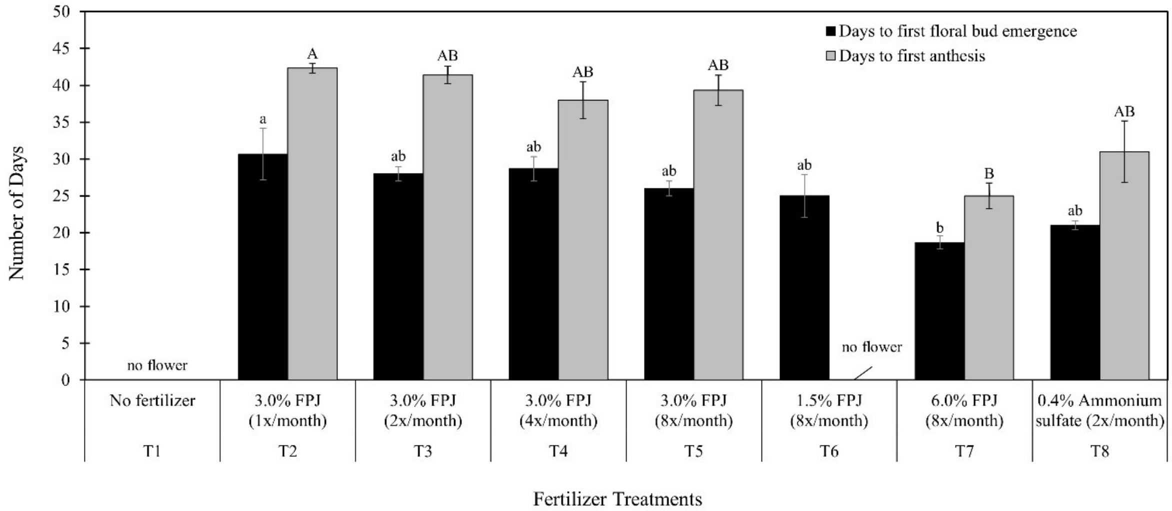

Figure 3. Effect of different concentrations and application frequencies of fermented plant juice (FPJ) and ammonium sulfate (21-0-0) on days to first floral bud emergence (black bars) and days to first anthesis (gray bars) in *Ruellia simplex* C. Wright 'Katie Pink'. Bars with the same letter are not significantly different based on Tukey's HSD test at $P \leq 0.05$. Error bars indicate ± SE; n = 3. Lowercase letters denote significant differences in bud emergence; uppercase letters denote significant differences in anthesis. No flowering was observed in T1 and T6.

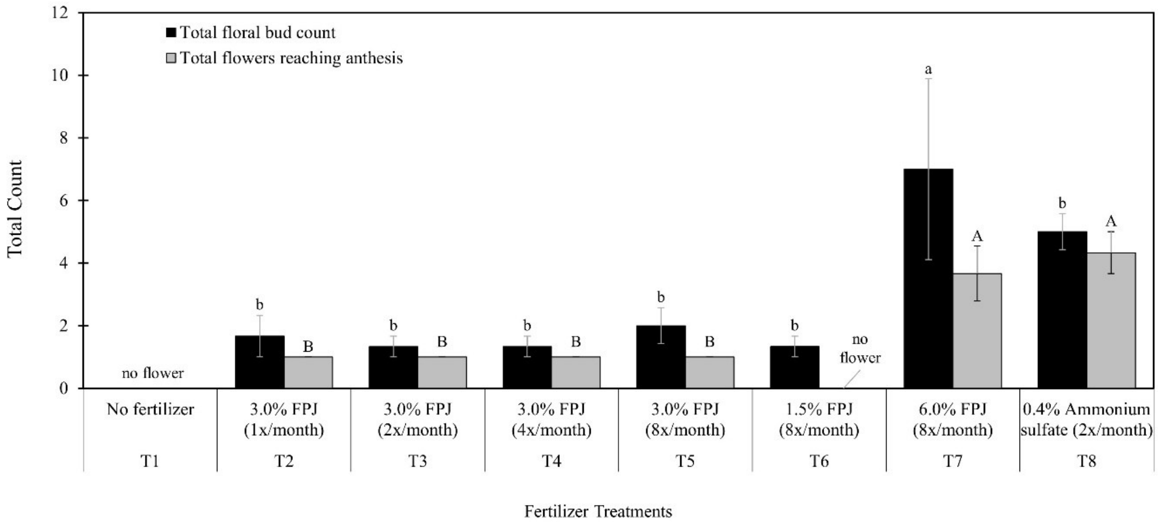

Figure 4. Effect of different concentrations and application frequencies of fermented plant juice (FPJ) and ammonium sulfate (21-0-0) on total floral bud count (black bars) and total flowers reaching anthesis (gray bars) in *Ruellia simplex* C. Wright 'Katie Pink'. Bars with the same letter are not significantly different based on Tukey's HSD test at $P \leq 0.05$. Error bars indicate ± SE; n = 3. Lowercase letters denote significant differences in bud count; uppercase letters denote significant differences in flower count. No flowering was observed in T1 and T6.

Most Effective FPJ Concentration

With frequency fixed at eight applications per month, increasing FPJ concentration resulted in an apparent dose-dependent improvement in both vegetative and reproductive performance. The application of 6% FPJ (T7) produced the tallest plants (17.07 cm), outperforming both 3% (T5; 14.97 cm) and 1.5% (T6; 13.50 cm), the latter being statistically similar to the control (T1; 13.47 cm) (Table 2). Chlorophyll content peaked in T7 (45.70 SPAD), significantly exceeding values recorded in other FPJ treatments and the control (35.30 SPAD). Root volume was also greatest in T7 (11.00 mL), compared with 7.00 mL in T5 and only 3.33 mL in both T6 and T1. Leaf area was highest in T5 (13.47 cm²), followed by T7 (11.46 cm²), with both treatments surpassing T1 (11.01 cm²). Dry weight in T7 (3.67 g) was slightly lower than T5 (4 g) but remained markedly higher than T6 and T1.

Leaf production was notably higher in T7 (39.33) and T5 (36.67) than in T1 (17.00), as shown in Figure 1. The percent difference analysis revealed that T7 increased plant height by 26.7%, SPAD value by 29.5%, and root volume by 230.0% relative to T1 (Figure 2A, 2C, 2F). Leaf number increased by 131.4%, while dry weight increased by 83.5% (Figure 2G). In contrast, T6 showed minimal improvements over the control, with only a 0.2% gain in height and no change in root volume, indicating that 1.5% FPJ was ineffective even at high frequency. Treatment T5 provided moderate gains, including a 21.9% increase in SPAD and a 100.3% increase in leaf area, supporting the interpretation that concentration had a more substantial impact than frequency when held constant.

Reproductive performance was most prominent in T7, which produced 7 floral buds and 3.67 open flowers per plant, with a flower conversion rate of 52.4% (Figures 3 and 4). In comparison, T5 produced only one flower from fewer buds (1–2), while T6 and T1 remained non-flowering throughout the experiment. These findings indicated that a higher FPJ concentration was essential to support floral development when frequency is controlled.

Among the concentration treatments, 6% FPJ (T7) was identified as the optimal concentration at a fixed frequency of eight applications per month, producing the most consistent improvements in both vegetative and flowering stages.

Overall Effectiveness of FPJ and Comparison with Ammonium Sulfate

Across all FPJ treatments (T2–T7), application resulted in consistent improvements in vegetative growth parameters compared to the control (T1). The FPJ treatments demonstrated significant percent gains: plant height increased by up to 26.7% (T7), SPAD value by 29.5% (T7), number of leaves by 211.8% (T4), and dry weight by 233.5% (T4) (Figure 2A-G). Reproductive success also improved, with T5 and T7 producing up to 2 and 7 floral buds, respectively, whereas T1 produced none (Figures 3 and 4). The highest number of flowers among FPJ treatments was observed in T7 (3.67), corresponding to a conversion rate of 52.4% (Figure 4).

When compared with ammonium sulfate (T8), however, FPJ treatments remained inferior in most parameters. T8 produced the tallest plants (19.97 cm), the highest SPAD reading (55.93), the greatest number of leaves (57.33), and the largest leaf area (15.23 cm²), all of which exceeded the top-performing FPJ treatments (Table 2; Figure 2). Treatment T8 also yielded the highest dry weight (10.67 g), representing a 433.5% increase over T1 and substantially exceeding all FPJ treatment. Root volume in T8 reached 7 mL, which, although higher than the control (+110.1%), was still lower than T7 (11 mL), indicating that FPJ may provide a specific advantage in root enhancement (Figure 2F).

In terms of flowering, ammonium sulfate outperformed all FPJ treatments. Treatment T8 initiated bud emergence earliest (21 days), produced 5 buds and 4 flowers per plant, and achieved the highest conversion rate (86.6%) (Figures 3 and 4). Although T7 produced more buds (7), it yielded fewer flowers (3.67) due to its lower conversion efficiency, reflecting a gap in bud-to-flower transition under organic treatment (Figure 4).

Among the FPJ treatments, T7 (6% concentration applied eight times per month) emerged as the most effective, achieving the highest gains in height, SPAD value, root volume, and flowering capacity. Despite not outperforming ammonium sulfate, T7 demonstrated substantial improvements over the control.

DISCUSSION

Optimal Frequency of FPJ Application

The application frequency of FPJ significantly influenced the vegetative and reproductive development of *R. simplex*. Moderate treatments (T2–T5) resulted in enhanced plant height, leaf number, and chlorophyll content, with the most notable improvements observed under four (T4) and eight (T5) applications per month. These findings suggest that more frequent applications support sustained nutrient availability and possibly stimulate rhizosphere microbial activity, thereby promoting vegetative growth.

All frequency-based FPJ treatments induced flowering, though floral output was modest and generally limited to one flower per plant. This limitation may be associated with insufficient phosphorus levels. The FPJ used in this study was analyzed and found to contain 0.14% nitrogen (N), 0.04% phosphorus (P_2O_5), and 0.52% potassium (K_2O)—a relatively low macronutrient profile. This composition may explain the limited reproductive response observed, despite the enhancements in vegetative traits. The absence of flowering in the control (T1) and the restricted performance under moderate FPJ frequencies (T2–T5) are consistent with reports that phosphorus deficiency delays floral initiation and reduces flower production, as phosphorus plays a key role in energy transfer and reproductive development (Malhotra et al. 2018; Heriansyah et al. 2025). Recent studies indicate that macronutrient availability regulates flowering time through integrated physiological and molecular signaling pathways, and inadequate nutrient supply can constrain floral development (Baek et al. 2026). Similarly, potassium has been shown to enhance flower development and reproductive performance by facilitating carbohydrate transport and cellular regulation, suggesting that limited potassium availability may further restrict floral output (Ye et al. 2019; Biswas et al. 2025).

These results indicate that while frequent application enhances growth and induces bud initiation, it alone is insufficient for maximizing flower production. Frequent application increases the cumulative supply of nutrients and organic compounds, enhances nutrient availability in the rhizosphere, and may stimulate microbial activity that supports vegetative growth and early reproductive signaling. However, increased application frequency cannot compensate for deficiencies in essential macronutrients required for sustained flower development. Adequate phosphorus and potassium are critical for floral initiation, energy transfer, carbohydrate transport, and flower formation, while nitrogen primarily supports vegetative growth (Baek et al. 2026; Malhotra et al. 2018). Thus, frequency amplifies nutrient delivery and microbial effects but does not offset limitations imposed by low concentrations of key macronutrients.

Most Effective FPJ Concentration

At a fixed frequency of eight applications per month, increasing FPJ concentration produced a clear dose response trend. The 6% treatment (T7) resulted in the most pronounced gains in plant height, SPAD value, and root volume. The relatively low nutrient content of the FPJ used in this study suggests that its effectiveness may be attributed to microbial and organic constituents rather than direct nutrient supply. Sulok et al. (2021) described fermented inputs as rich in beneficial microorganisms capable of solubilizing phosphorus and potassium, which can enhance nutrient availability and soil health. This microbial action, likely compounded by frequent application, may account for the improved leaf development, chlorophyll content, and floral bud formation observed in this treatment.

In terms of reproductive response, the 6% FPJ concentration also produced the highest number of floral buds and flowers among FPJ treatments. However, the flower conversion rate remained lower than that achieved with ammonium sulfate. This may be explained by the limited availability of nitrogen and phosphorus, as emphasized by Ruamrungsri et al. (2021), who noted that nutrient-deficient ornamental plants tend to exhibit delayed flowering and reduced floral quality.

Overall Effectiveness of FPJ and Comparison with Ammonium Sulfate

Among all FPJ treatments, the 6% concentration applied eight times monthly (T7) produced the most consistent improvements in both vegetative and reproductive parameters. These outcomes—increased plant height, SPAD value, leaf number, root volume, and floral bud production—can be attributed to the cumulative effects of bioactive stimulation and potential microbial synergy resulting from sustained application. Despite its low nitrogen and phosphorus content, the FPJ used in this study demonstrated the capacity to support moderate growth and floral initiation when applied intensively.

However, ammonium sulfate (T8) delivered superior results across nearly all parameters. As a synthetic fertilizer with readily available nitrogen (21-0-0), it promoted vigorous vegetative growth, enhanced chlorophyll biosynthesis, and supported higher dry biomass accumulation. These findings align with previous reports on nitrogen-driven increases in chlorophyll content and biomass. Recent studies have documented that increased nitrogen availability enhances chlorophyll concentration and photosynthetic capacity, leading to greater vegetative growth and dry matter accumulation (Zhang et al. 2021; Oner et al. 2024). Ammonium-based fertilizers have also been shown to alter leaf nutrient composition and promote growth when applied at appropriate rates (Al-Dosary et al. 2022). That said, the type and rate of nitrogen source can influence outcomes; excessive or imbalanced nitrogen application may reduce growth or cause physiological stress in some cases (Gülüt and Şentürk 2024).

In reproductive development, T8 achieved the highest number of flowers per plant (4.33), along with the earliest bud emergence and most efficient flower conversion rate (86.6%). While the 6% FPJ treatment initiated more floral buds (7), fewer were successfully converted to flowers, underscoring a limitation in nutrient sufficiency for completing the reproductive cycle. These results are consistent with the findings of Malhotra et al. (2018) and Ruamrungsri et al. (2021), who highlighted phosphorus and nitrogen limitations as constraints on flowering potential.

Despite this, all FPJ treatments—particularly the high-concentration, high-frequency group—outperformed the control and demonstrated strong potential as organic alternatives. Moderate treatments (T2–T5) also led to measurable vegetative improvements and occasional flowering, validating the utility of FPJ in low-input systems. Prior studies support the effectiveness of FPJ in enhancing plant growth across various crops, although responses vary depending on species and application strategies. For instance, FPJ increased the number of leaves and the mean weight per hill in lettuce (Alam 2021). Different FPJ concentrations also influenced mustard growth, where 2 tbsp/L produced lower fresh weight than 1.5 and 2.5 tbsp/L (Denona et al. 2020). Weekly FPJ application increased plant height in hot pepper but had limited effects on overall yield (Lorio and De Asis 2021). Similarly, a one-time FPJ application at 2 tbsp/L significantly increased plant height, leaf number, and yield in pechay (Tagotong and Corpuz 2015).

Overall, the 6% FPJ applied eight times monthly (T7) showed strong potential in promoting plant vigor, root development, chlorophyll content, and floral initiation in *R. simplex*. Despite its low nutrient content, this optimized treatment outperformed the control and lower FPJ rates, highlighting its value as a sustainable input. While ammonium sulfate application remained superior in overall growth and flowering, FPJ presents a viable organic alternative for reducing reliance on synthetic fertilizers in ornamental crop production, particularly when applied at optimized concentrations and frequencies.

Based on the findings of this study, the application of FPJ at a 6% concentration with a high application frequency (8 times per month) may be considered the most effective FPJ-based input for improving vegetative growth and initiating flowering in *R. simplex.* This treatment can be recommended for growers practicing organic or low-input ornamental production systems where synthetic fertilizers are limited or undesirable. However, given the relatively low macronutrient content of FPJ, particularly phosphorus and nitrogen, supplementation with other organic nutrient sources may be necessary to achieve optimal flowering performance and improve flower conversion rates.

Future studies may explore integrating FPJ with other organic nutrient inputs or biofertilizers to enhance nutrient balance and reproductive development in ornamental crops. Further investigation into nutrient dynamics, rhizosphere microbial activity, and the long-term effects of repeated FPJ application under different environmental conditions would provide deeper insights into optimizing its use in sustainable ornamental plant production.

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A generative AI tool, specifically Grammarly (Grammarly, Inc., web-based version, accessed in 2026), was used solely for language improvement and editing purposes. The authors take full responsibility for the content of the manuscript.

ETHICAL CONSIDERATIONS

This study did not involve human participants or animals; therefore, ethical approval was not required.

DECLARATION OF COMPETING INTEREST

The authors declare that there are no competing interests among the authors.

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