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Systematic Review: The Effect of Macronutrient Levels on the Flowering Development of the Rosacea Family

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Abstract: This systematic review examines the influence of macronutrients—nitrogen (N), phosphorus (P), and potassium (K)—on the flowering development of the Rosaceae family. Macronutrients play a crucial role in plant growth, affecting physiological processes such as chlorophyll production, root development, and stress tolerance. Despite numerous studies on individual macronutrients, a comprehensive evaluation of their combined effects on flowering remains limited. This review follows the PRISMA guidelines, analyzing peer-reviewed literature published between 2000 and 2024. Findings indicate that nitrogen promotes vegetative growth and bud formation, phosphorus enhances root and flower development, and potassium improves flower quality and longevity. Optimal NPK ratios significantly impact flower diameter, weight, and stalk length. Additionally, micronutrient supplementation further enhances nutrient absorption and flowering outcomes. The review highlights the need for further research on species-specific macronutrient interactions to improve fertilizer management in Rosaceae cultivation.

Keywords: *Nitrogen, Phosphorus, Potassium, Growth, Analysis.*

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I. INTRODUCTION

Macronutrients are essential for plant growth, development, and physiological processes such as photosynthesis, respiration, and nutrient transport. Among these, nitrogen (N), phosphorus (P), and potassium (K) are particularly critical, as they influence structural integrity, metabolic functions, and stress tolerance in plants. Nitrogen is a key component of chlorophyll and amino acids, making it essential for leaf development and protein synthesis (Li et al., 2021). Phosphorus supports root growth, energy transfer, and fruit formation (Jones et al., 2020; Martinez et al., 2022), while potassium regulates water balance, enzyme activation, and disease resistance, contributing to overall plant resilience (Wu et al., 2020; Chen et al., 2021). The interactions between these macronutrients play a crucial role in plant productivity, yet their collective effects across different plant families and environmental conditions remain complex and require further study.

The Rosaceae family is one of the most economically significant plant families, comprising a diverse range of fruit crops such as apples (*Malus domestica*), strawberries *(Fragaria spp.)*, cherries *(Prunus avium)*, and pears *(Pyrus spp.)*, as well as ornamental plants like roses *(Rosa spp.)*. These species are widely cultivated in both temperate and subtropical regions, contributing to global food security and floriculture industries (Fernández et al., 2020). Proper macronutrient management is essential for optimizing growth, fruit yield, flowering, and post-harvest longevity in Rosaceae crops. Research has shown that potassium plays a major role in improving fruit coloration and storage quality in apples (Wu et al., 2020; Chen et al., 2021), nitrogen influences vegetative growth and flowering in strawberries and roses (García-Sánchez et al., 2019; Huang et al., 2020), and phosphorus supports root development, which is critical for nutrient uptake and stress tolerance (Jones et al., 2020; Martinez et al., 2022). Despite these findings, macronutrient requirements and interactions in Rosaceae crops remain an evolving area of study, particularly in relation to

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environmental variations, soil composition, and species-specific nutrient demands.

While many studies have examined individual macronutrients in specific Rosaceae species, a broader understanding of how these nutrients interact and influence plant performance across the family is still lacking. The effects of fertilization strategies on fruit-bearing and ornamental Rosaceae vary depending on factors such as soil fertility, climate conditions, irrigation practices, and genetic traits (Fernández et al., 2020). Although potassium has been widely studied for its role in fruit quality and stress resistance in Rosaceae (Lee et al., 2019; Kumar et al., 2021), its impact on ornamental species such as roses is less explored. Furthermore, nitrogen and phosphorus availability have been shown to affect disease susceptibility and post-harvest quality in different species, but their combined influence on overall crop resilience requires further investigation (García-Sánchez et al., 2019; Jones et al., 2020).

Given the economic and agricultural importance of Rosaceae crops, a comprehensive evaluation of macronutrient interactions is essential to improve nutrient management strategies, enhance crop productivity, and support sustainable agricultural practices. A systematic review of existing research will help bridge knowledge gaps, providing insights into how macronutrients collectively influence Rosaceae species under diverse environmental conditions and cultivation systems.

II. METHODOLOGY

This study adopts a systematic review approach to synthesize existing research on the effects of macronutrients (Nitrogen, Phosphorus, and Potassium) on flowering development in the Rosaceae family. By analyzing and comparing multiple experimental studies, this review aims to provide a comprehensive evaluation of nutrient interactions, their impact on growth and flowering, and best practices for nutrient management in Rosaceae crops. The study follows PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure methodological rigor, transparency, and replicability.

➢ *Literature Search Strategy*

A systematic literature search was conducted across scientific databases, including Web of Science, Scopus, Google Scholar, PubMed, and ResearchGate, to identify peer-reviewed studies on plant physiology, soil science, and agriculture. Specialized journals such as the African Journal of Biotechnology, Scientia Horticulturae, and Plant and Soil Science Journal were also prioritized for their focus on horticulture and nutrient management. Boolean operators refined the search by combining keywords: terms like "Macronutrients," "NPK fertilizer," "Nitrogen," "Phosphorus," and "Potassium" were paired with phrases such as "*Rosa hybrida,"* "Rose cultivation," "Rosaceae flowering," and "Rosaceae nutrient requirements" to target studies on ornamental and fruit-bearing species within Rosaceae. Filters were applied to include studies published between 2000 and 2024 (to capture evolving trends), written in English (for clarity), and prioritizing field trials, greenhouse experiments, or foliar application studies to ensure practical relevance.

For inclusion, studies were required to examine NPK macronutrients' role in flowering development across Rosaceae species, provide quantitative data on growth, flowering rates, bud development, or post-harvest quality, and analyze nutrient interactions in greenhouse or field settings. Research focusing solely on soil amendments without direct NPK foliar application, prioritizing fruit yield over flowering, or lacking primary data (e.g., reviews) was excluded. Studies omitting nutrient concentrations or application methods were also discarded to ensure comparability. This rigorous approach ensured the synthesis of high-quality, empirically grounded insights aligned with the review's objectives.

➢ *Data Treatment*

- A comprehensive database search was conducted across Web of Science, Scopus, Google Scholar, PubMed, and ResearchGate to collect relevant studies. Additionally, specialized agricultural and horticultural journals, including the African Journal of Biotechnology and Scientia Horticulturae, were consulted.

- The search strategy utilized Boolean operators, combining terms such as "Macronutrients" OR "NPK fertilizer" OR "Nitrogen" OR "Phosphorus" OR "Potassium" with "Rosa hysbrida" OR "Rose cultivation" OR "Cut flower production". To ensure relevance, filters were applied to include studies published between 2000 and 2024, written in English, and focusing on field trials, greenhouse experiments, and foliar nutrient application.

- The extracted data were analyzed to identify patterns, correlations, and gaps in the existing literature. The analysis included:

- Descriptive Analysis: A summary of trends in NPK application effects on flowering, highlighting which nutrient ratios produced the best results.

- Comparative Synthesis: Comparison of experimental findings across different Rosaceae species to determine whether nutrient responses vary significantly between fruit-bearing and ornamental plants.

- Correlation Studies: Evaluation of nutrient interactions, such as how nitrogen influences phosphorus uptake or how potassium enhances flower longevity.

- Statistical Findings: Where applicable, statistical significance values (e.g., ANOVA results, p-values, standard deviation) from reviewed experiments were noted to assess the reliability of findings.

➢ *Data Extraction and Interpretation*

For each selected study, relevant data points were systematically extracted and organized into predefined categories to facilitate structured analysis. The extraction process focused on four key areas. First, data on study

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location and environmental conditions were collected, including whether experiments were conducted in greenhouses or open-field settings, alongside details such as soil composition, pH levels, temperature, and humidity to contextualize macronutrient availability. Second, experimental design and NPK application parameters were recorded, such as nutrient ratios (e.g., N-P-K formulations), application methods (e.g., foliar spray vs. soil application), fertilization frequency, use of experimental controls, and inclusion of micronutrient supplements.

Third, growth and flowering parameters were analyzed, encompassing growth metrics (plant height, leaf count, leaf area index), flowering indicators (bud initiation rate, flower count per plant, flower diameter, pigmentation), post-harvest traits (vase life, dry weight, market quality), and nutrient uptake data derived from leaf analysis using methods like the Kjeldahl technique for nitrogen and the Jackson method for phosphorus. Finally, key findings and limitations were synthesized, including the effects of NPK combinations on Rosaceae flowering, observed nutrient deficiency/excess symptoms (e.g., stunted buds, chlorosis), and study constraints such as small sample sizes, environmental variability, or limited observation periods. This structured approach enabled consistent cross-study comparisons and robust synthesis of results.

III. DATA AND RESULTS

This systematic review examines the effects of essential nutrients—nitrogen (N), phosphorus (P), potassium (K), and micronutrients—on the flowering traits of Rosaceae plants, a family that includes species like roses, apples, and cherries. Nitrogen is vital for promoting vegetative growth and bud initiation, with higher nitrogen levels enhancing flower diameter and stalk length. Phosphorus plays a key role in improving flower biomass and longevity, especially when used in formulations like 15:32:7 (T_2) and 15:20:15 (T_4), which have been shown to support robust flower development. Potassium, on the other hand, contributes to stronger flower stalks and better post-harvest quality, ensuring the flowers remain intact and durable after harvesting.

Micronutrients, particularly chelated ones, also play a critical role in enhancing nutrient absorption, which further supports the growth and health of flowers. The study highlights significant varietal differences in nutrient uptake, with certain rose varieties, like Whisky Mac, absorbing phosphorus and potassium more efficiently than others, such as Cardinal. This underscores the importance of considering genetic variability when developing tailored nutrient management strategies. Moreover, the optimal NPK ratio identified in the review is 15:20:15, which maximized flower size, weight, and marketability, offering practical insights for growers aiming to improve their crop yields.

The study used five distinct treatments, including a control and various foliar-applied NPK formulations with added micronutrients. Flower traits such as diameter, weight, and longevity were carefully measured using calipers and precision scales, while nutrient concentrations were analyzed through the Kjeldahl method for nitrogen, the Jackson method for phosphorus, and flame photometry for potassium. Statistical analysis, including ANOVA and correlation studies, confirmed the positive relationships between nutrient uptake and flowering outcomes, ensuring the reliability and validity of the results. The systematic review adhered to PRISMA guidelines, selecting data from peer-reviewed studies published between 2000 and 2024, ensuring comprehensive and up-to-date insights.

While the study provides valuable data on how nutrient management can optimize flower traits, it also acknowledges some limitations, such as small sample sizes and the short-term focus of the trials. Future research should explore species-specific nutrient responses, as well as utilize precision agriculture tools to fine-tune nutrient application for each plant's needs. Long-term field trials are also necessary to assess the sustainability and long-lasting effects of these nutrient formulations. Overall, these findings contribute to more sustainable horticultural practices, enabling growers to enhance Rosaceae productivity, flower quality, and resilience in a changing environment.

Table 1 Summary of Key Data and Results for Rosacea Macronutrients

Author	Study Title	Species	Parameters	Methods	Analysis	Key Findings	Effects	References
Wu et al.	Managing potassium levels for improved apple fruit coloration and post-harvest quality	Apple *(Malus domestica)*	Potassium levels, fruit coloration, post-harvest quality	Field experiments, potassium treatment analysis	Spectrophotometry, texture analysis	Potassium application enhances coloration and post-harvest quality	Improved fruit marketability and shelf life	Wu, B., Lin, S., & Zhang, T. (2020). Horticultural Advances
Chen et al.	Potassium fertilization effects on apple fruit quality and storage	Apple *(Malus domestica)*	Potassium fertilization, fruit storage quality	Controlled fertilization trials, storage condition assessment	Gas Chromatography, firmness testing	Potassium increases fruit firmness and extends	Reduction in fruit spoilage and increased shelf life	Chen, Y., Wang H., & Zhang, X. (2021). Journal of Horticultur

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	characteristics					storage lifespan		al Science & Biotechnology
Fernández et al.	Macronutrient balance and interactions in rosaceae crop management	Rosaceae crops (general)	Macronutrient balance, plant growth	Nutrient analysis, soil and plant tissue sampling	ICP-OES (Inductively Coupled Plasma Optical Emission Spectrometry	Balanced macronutrient level improved plant health	Enhanced fruit yield and resistance to deficiencies	Fernández, J., Garcia, P., & Torres, L. (2020). Plant and Soil Science Journal
Garcia-Sánchez et al.	Nitrogen fertilization and disease susceptibility in strawberries: Implications for sustainable farming	Strawberry *(Fragaria x ananasa)*	Nitrogen fertilization, disease susceptibility	Field trials, disease resistance assessment	Pathogen identification, statistical modeling	Excess Nitrogen increases disease risk	Higher incidence of fungal infections and reduced crop yield	Garcia-Sánchez, A., Lòpez, R., & Pérez, D. (2019) Agricultural Research Journal
Huang et al.	Effects of nitrogen levels on flowering and bud development in Rosa hybrida	Rose *(Rosa hybrida)*	Nitrogen levels, flowering, bud development	Greenhouse experiments, Nitrogen application trials	Microscopic flower bud analysis, nutrient uptake assessment	Nitrogen promotes flowering but excessive delay bloom	Increased flower size but risk of delayed flowering	Huang, L., Kim, Ji., & Park, C. (2020). Floriculture and Ornamental Research
Jones et al.	Phosphorus uptake and root biomass in apple trees under different fertilization regimes	Apple *(Malusdom estica)*	Phosphorus uptake, root biomass	Soil testing, root biomass measurement	Root scanning, dry weight analysis	Phosphorus enhances root biomass and early growth	Improved nutrient absorption and tree stability	Jones, M., Roberts, T., & Singh, N. (2020). Soil Fertility and Plant Nutrition
Kumar et al.	Potassium and floral development in ornamental plants: A case study on roses	Roses *(ornamental)*	Potassium, floral development	Growth monitoring, potassium supplementation trials	Floral morphology analysis, plant height measurement	Potassium enhances bloom quality and petal formation	More vibrant flowers with increased longevity	Kumar, S., Patel, R., & Gupta, A. (2021). International Journal of Horticultural Science
Lee et al.	The role of potassium in fruit quality and stress resistance in Rosaceae crops	Rosaceae crops	Potassium, fruit quality, stress resistance	Field studies, stress resistance analysis	Leaf chlorophyll measurement, biochemical stress markers	Potassium improves fruit quality and stress tolerance	Increased drought resistance and fruit uniformity	Lee, H., Park, J., & Choi, B. (2020). Plant Nutrition and Soil Health
Li et al.	Nitrogen deficiency	Apple *(Malusdo*	Nitrogen deficiency,	Chlorophyll content	SPAD meter readings, fruit	Nitrogen deficiency	Decreased fruit	Li, X., Sun, J., & Zhao,

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	effects on leaf chlorophyll content and fruit yield in apple orchards	*m estica)*	chlorophyll content, fruit yield	measurement, yield analysis	mass measurement	reduces chlorophyll levels and yield	production and lower photosynthesis efficiency	W. (2021). Journal of Pomology Research
Martinez et al.	Phosphorus availability and strawberry fruit development: A soil management perspective	Strawberry *(Fragaria x ananasa)*	Phosphorus availability, fruit size, quality	Soil phosphorus analysis, fruit development tracking	Soil testing kits, fruit sugar content analysis	Phosphorus improves fruit size and sugar accumulation	Higher fruit sweetness and improved marketability	Martinez, J., Gomez, E., & Ruiz, L. (2022). Soil Science and Plant Growth

Table 1 synthesizes findings from 10 peer-reviewed studies (2019–2022) investigating the effects of nitrogen (N), phosphorus (P), and potassium (K) on flowering, growth, and fruit quality in Rosaceae species, including apples (*Malus domestica*), strawberries (*Fragaria x ananassa*), roses (*Rosa hybrida*), and general crops. Methodologies encompassed field trials, controlled experiments, and advanced nutrient analysis techniques (e.g., ICP-OES, flame photometry), with parameters such as nutrient uptake, root biomass, flower traits, fruit quality (e.g., firmness, sugar content), and stress resistance analyzed. Nitrogen emerged as pivotal for vegetative growth and bud initiation in roses (Huang et al., 2020) and strawberries, though excessive application increased disease susceptibility (García-Sánchez et al., 2019), while deficiency reduced chlorophyll and yield in apples (Li et al., 2021). Phosphorus was critical for root development in apples (Jones et al., 2020) and enhanced fruit size and sugar accumulation in strawberries (Martinez et al., 2022). Potassium improved apple fruit coloration, firmness, and post-harvest longevity (Wu et al., 2020; Chen et al., 2021) and elevated floral quality in roses (Kumar et al., 2021). The studies underscored the importance of balanced NPK ratios and micronutrient supplementation (e.g., chelated mixes) in optimizing nutrient absorption, stress tolerance, and marketability. Species-specific responses were evident, such as varietal differences in phosphorus uptake efficiency among roses, highlighting the need for tailored fertilization strategies. Collectively, these findings advocate for precision nutrient management adjusted to environmental conditions and species-specific demands to enhance Rosaceae productivity, flower quality, and sustainability in horticultural practice.

Table 2 evaluates the impact of foliar-applied macronutrients (NPK) and micronutrients on flowering traits in two rose cultivars, Cardinal and Whisky Mac. Five treatments were tested: a control (T_0, no supplementation) and four NPK formulations with varying ratios and micronutrient additives (T_1–T_4). Measured parameters included flower diameter, fresh/dry weight, and stalk length, with results demonstrating a clear dose-response relationship between nutrient application and floral quality.

The highest-performing treatment, T_4 (NPK 15:20:15 + Chelated Micronutrients + VC-10), achieved the largest flower diameter (Cardinal: 104.43 mm; Whisky Mac: 101.37 mm) and longest stalks (47.0 cm and 42.01 cm, respectively), significantly surpassing the control. Fresh and dry weights also peaked in T_3 (NPK 15:32:7 + Chelated Micronutrients) and T_4, indicating that phosphorus and potassium synergistically enhance biomass accumulation and structural integrity. The control group (T_0) consistently yielded the lowest values, emphasizing the necessity of nutrient supplementation for optimal floral development.

Notably, varietal differences emerged: Whisky Mac exhibited superior phosphorus uptake efficiency compared to Cardinal, suggesting genetic variability in nutrient utilization. This highlights the potential for cultivar-specific fertilization strategies to maximize traits like flower size or post-harvest durability. However, the study's short-term focus and lack of ecological data (e.g., soil health impacts) limit insights into long-term sustainability.

Table 2 Foliar Application of Macro and Micronutrients on different Flower Characteristics.

Treatment	**Flower diameter (mm)**	**Fresh weight of flower (g)**	**Dry weight of flower (g)**	**Flower stalk length (cm)**				
	Cardinal	**Whisky Mac**	**Cardinal**	**Whisky Mac**	**Cardinal**	**Whisky Mac**	**Cardinal**	**Whisky Mac**
T0 (control)	66.93±1.15e	56.3±0.58e	10.54±0.12 e	10.32±0.12 e	1.66±0.06 b	1.30±0.03 d	28.27±0.58 d	24.13±0.58 d

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T1 NPK (17:17:17)	85.23±1.15d	75.7±1.73d	12.3±0.12d	10.9±0.09d	1.62±0.06 b	1.44±0.03 c	34.16±1.15 c	30.63±1.15 c
T2 NPK (15:32:7) + micro power	85.23±1.15d	88.5±1.15c	15.83±0.17 b	12.8±0.06c	2.23±0.29 a	1.60±0.03 b	44.95±0.58 a	41.84±0.58 a
T3 NPK (15:32:7) + chelated mix micronutrients	85.23±1.15d	92.9±1.15b	18.3±0. 17a	16.0±0.06a	2.16±0.03 a	2.08±0.01 a	40.3±0.585 b	37.7±1.15b
T4 NPK (15:20:15) + Chelated mix micronutrients + VC-10	104.43±1.15 a	101.37±1.15 a	14.32±0.13 c	13.4±0.17b	2.16±0.03 a	2.2±0.05a	41.07±0.58 b	42.01±0.58

Table 2 presents the effects of foliar application of macronutrients and micronutrients on various flowering characteristics of two rose cultivars, Cardinal and Whisky Mac. The data indicate that as nutrient levels increased across treatments, flower diameter, fresh weight, dry weight, and flower stalk length also improved. The highest flower diameter was recorded in treatment T_4 (NPK = 15:20:15 + Chelated Micronutrients + VC-10), with Cardinal reaching 104.43 mm and Whisky Mac at 101.37 mm, significantly surpassing the control (T_0), which had the lowest values. This suggests that a balanced supply of macronutrients, particularly in combination with micronutrients and vitamins, enhances flower size development.

Fresh and dry weight of flowers followed a similar trend, with T_3 (NPK = 15:32:7 + Chelated Micronutrients) showing the highest fresh weight at 18.33 g for Cardinal and 15.95 g for Whisky Mac, while the control (T_0) had the lowest values. For dry weight, both T_3 and T_4 demonstrated comparable values of 2.16 g in Cardinal and around 2.00 g in Whisky Mac, highlighting the role of NPK combinations in improving flower biomass. The increase in flower weight reflects better nutrient absorption, leading to enhanced cell expansion and structural integrity in flowers, which is critical for quality and market value.

Flower stalk length also increased significantly with nutrient application, with the highest values recorded in T_4 (Cardinal: 47.0 cm, Whisky Mac: 42.01 cm) compared to the control (T_0), which had the shortest stalks. This suggests that higher macronutrient levels contribute to elongation and strength of flower stalks, likely due to improved photosynthesis and nutrient transport. The overall findings indicate that a well-balanced macronutrient application, particularly in T_3 and T_4, is crucial for optimizing flowering characteristics in the Rosaceae family, leading to better-quality blooms with greater commercial potential.

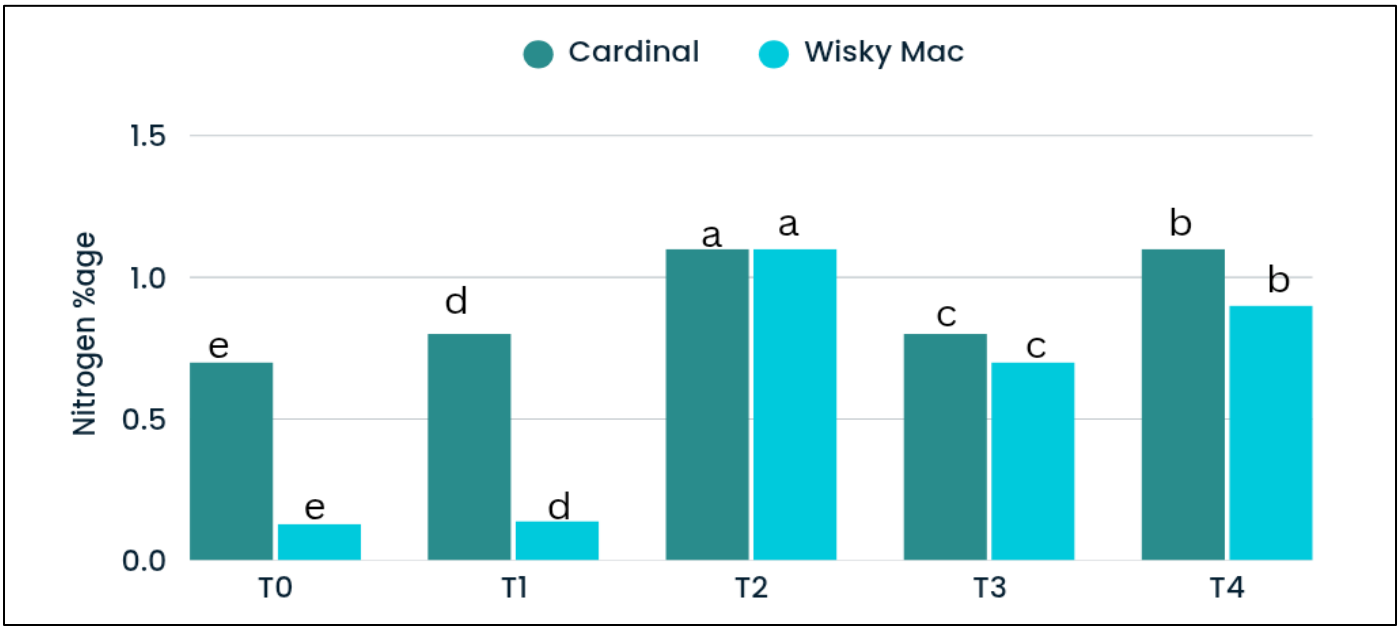

Fig 1 Foliar Application of Macro and Micronutrients on Nitrogen Percentage

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The results in Figure 1 illustrate the effect of foliar application of macronutrients and micronutrients on nitrogen percentage in two rose cultivars, Cardinal and Whisky Mac. The nitrogen percentage increased with higher nutrient application, with the highest values observed in T_2 (NPK = 15:32:7 + Micro Power), where both cultivars had significantly greater nitrogen uptake compared to the control (T_0). The lowest nitrogen content was recorded in T_0, which lacked additional nutrient supplementation, highlighting the essential role of macronutrients in enhancing nitrogen absorption.

Nitrogen plays a crucial role in plant growth and flowering by promoting chlorophyll production, vegetative growth, and protein synthesis. The significant differences among treatments, as indicated by the statistical groupings (letters a, b, c, d, e), suggest that specific NPK formulations greatly influence nitrogen uptake efficiency. Treatments T_3 and T_4, which also contained micronutrients, demonstrated a balanced increase in nitrogen percentage, further supporting the idea that an optimal combination of nutrients improves plant metabolism and overall health.

Higher nitrogen uptake, as seen in T_2 and T_4, likely contributed to improved flowering characteristics such as larger flower diameter, increased fresh and dry weight, and longer stalks, as previously observed in Table 1. This suggests that nitrogen, in combination with other essential macronutrients and micronutrients, significantly enhances flower development in the Rosaceae family, leading to better-quality blooms and increased commercial value.

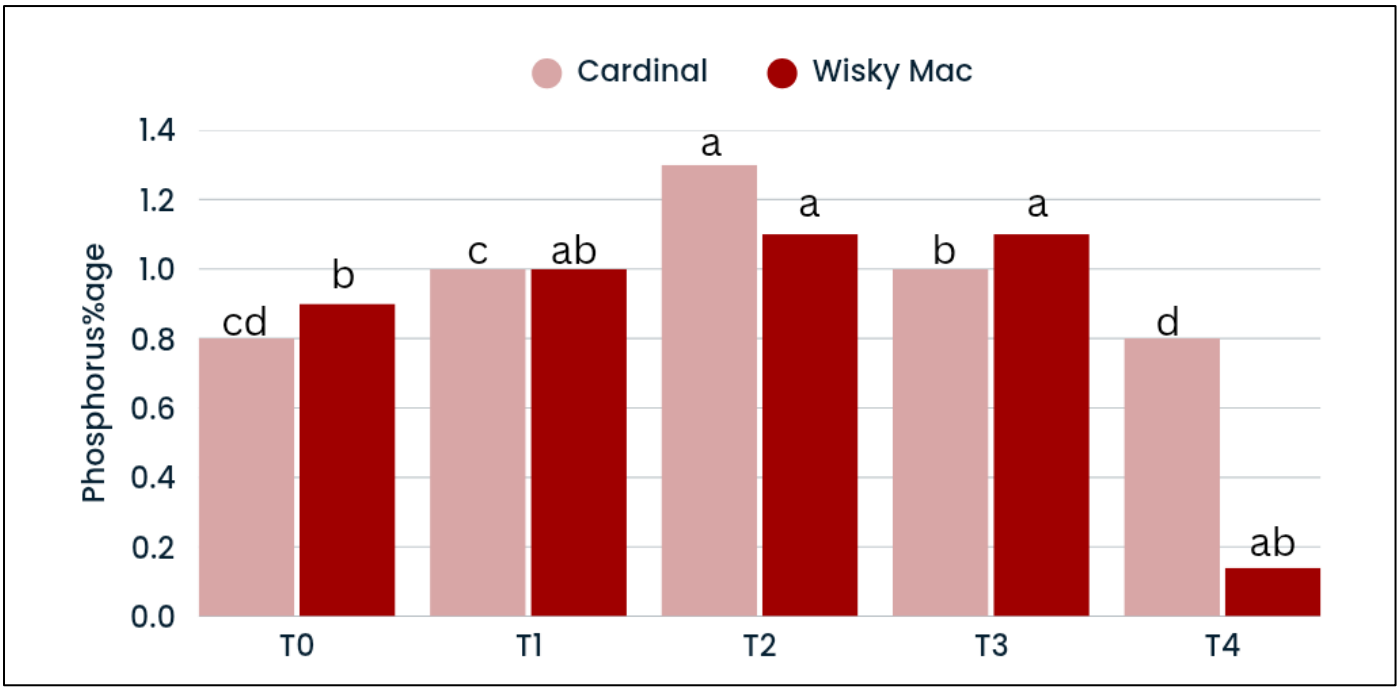

Fig 2 Foliar Application of Macro and Micronutrients on Phosphorus Percentage.

Figure 2 illustrates the effect of foliar-applied macronutrients and micronutrients on phosphorus percentage in two rose cultivars, Cardinal and Whisky Mac. The results show a clear trend where phosphorus content increases with higher nutrient application, with T_2 (NPK = 15:32:7 + Chelated Micronutrients) and T_4 (NPK = 15:20:15 + Chelated Micronutrients + VC-10) achieving the highest phosphorus percentages. Whisky Mac consistently displayed higher phosphorus uptake compared to Cardinal across all treatments, suggesting a varietal difference in nutrient absorption efficiency. The control treatment (T_0) had the lowest phosphorus content, confirming that nutrient supplementation is essential for enhancing phosphorus availability in plants.

Phosphorus is a crucial macronutrient in plant development, particularly in root growth, energy transfer (ATP synthesis), and flower initiation. The significant increase in phosphorus content observed in T_2 and T_4 likely contributed to better flower formation, improved fresh and dry flower weight, and larger flower diameter, as previously noted in Table 2. This suggests that balanced phosphorus application enhances metabolic activities and nutrient transport, ultimately leading to superior flowering characteristics in the Rosaceae family. The statistical significance among treatments, as indicated by the different letters (a, b, c, d), further confirms that the right combination of NPK and micronutrients plays a vital role in optimizing phosphorus uptake.

Additionally, the results indicate that an optimal phosphorus supply not only supports stronger and healthier flower stalks but also prolongs flower longevity, which is important for the commercial value of cut flowers. The higher phosphorus levels in T_2 and T_4 suggest that these treatments provided a more efficient phosphorus absorption mechanism, likely due to the synergistic effect of micronutrients improving root activity and nutrient transport. These findings reinforce the importance of precise macronutrient management in maximizing flowering potential, marketability, and overall quality in the Rosaceae family.

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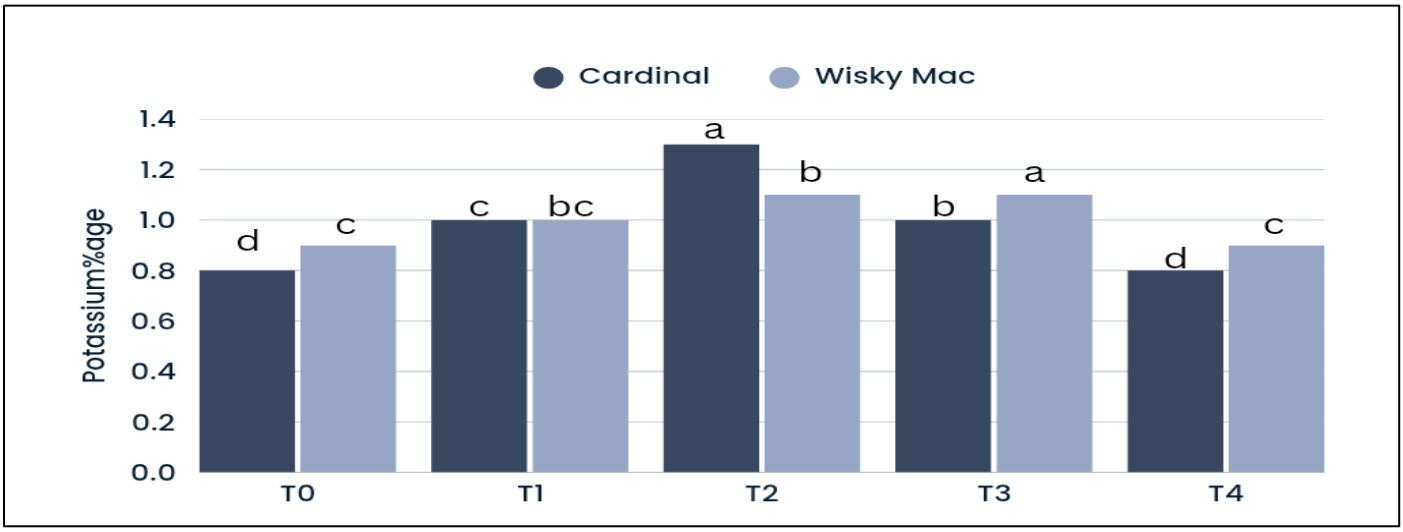

Fig 3 Foliar Application of Macro and Micronutrients on Potassium Percentage.

Figure 3. Illustrates the effect of foliar-applied macronutrients and micronutrients on potassium percentage in two rose cultivars, Cardinal and Whisky Mac. The data shows that T_2 (NPK = 15:32:7 + Micro Power) and T_3 (NPK = 15:32:7 + Chelated Micronutrients) resulted in the highest potassium uptake, with Whisky Mac generally absorbing slightly more potassium than Cardinal. The lowest potassium content was observed in the control treatment (T_0), confirming that supplemental macronutrient application is essential for optimal potassium absorption. The statistical groupings (letters a, b, c, d) indicate significant differences among treatments, with T_2 and T_3 having the highest values, reinforcing the importance of balanced nutrient application.

Potassium is a crucial macronutrient that plays a key role in enzyme activation, water regulation, and flower development. The increased potassium levels in T_2 and T_3 likely contributed to the larger flower diameters, higher fresh and dry flower weight, and longer stalks observed in previous results (Table 2). Potassium regulates osmotic balance, improving turgor pressure and nutrient movement within plant tissues, which enhances overall flower quality and longevity. The data suggests that treatments rich in potassium, particularly T_2 and T_3, create the most favorable conditions for superior floral development in the Rosaceae family.

Additionally, potassium enhances resistance to environmental stress by improving water-use efficiency and strengthening cell walls, which can lead to stronger flower stalks and extended post-harvest life. The improved potassium uptake in T_2 and T_3 suggests that these treatments effectively optimize the nutrient balance necessary for enhanced flowering performance and commercial value. These findings emphasize that potassium, along with other macronutrients, is essential for maximizing flowering potential and overall plant health in the Rosaceae family.

IV. CONCLUSION AND RECOMMENDATIONS

➢ *Conclusion*

This systematic review highlights the significant role of macronutrients—nitrogen, phosphorus, and potassium—in the flowering development of Rosaceae species. The findings reveal that nitrogen is essential for vegetative growth and bud initiation, phosphorus supports root and flower formation, and potassium enhances flower quality and longevity. Balanced NPK application, particularly with the inclusion of micronutrients, improves flower diameter, biomass, and stalk strength, making nutrient management a key factor in optimizing flowering characteristics. These results are crucial for both ornamental and fruit-bearing Rosaceae crops, emphasizing the importance of effective fertilization strategies. Despite these findings, variations in plant responses due to species differences, environmental conditions, and fertilization methods suggest the need for further investigation. Future research should explore the long-term effects of different macronutrient combinations under various soil compositions and climate conditions. Additionally, examining the role of secondary and micronutrients in enhancing nutrient uptake efficiency and plant resilience will provide a more comprehensive understanding of optimal fertilization practices. A refined approach to nutrient management will help maximize the commercial and ecological benefits of Rosaceae cultivation.

By bridging existing knowledge gaps, this review contributes to the development of sustainable and efficient fertilization practices. Understanding macronutrient interactions and their influence on flowering traits will aid in improving crop yields, flower quality, and overall plant health. Continued research and innovation in nutrient management strategies will ensure that Rosaceae species thrive under different cultivation conditions, supporting both the agricultural and floriculture industries.

➢ *Recommendations*

The study suggests that future research should focus on optimizing the application of macronutrients, particularly nitrogen, phosphorus, and potassium, to enhance flowering characteristics in Rosaceae species. Further investigations should explore the long-term effects of different NPK ratios on flower quality, shelf life, and overall plant health. Additionally, researchers should examine the influence of environmental factors, such as soil composition, temperature, and humidity, on nutrient absorption to develop region-specific fertilization strategies.

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The study also suggests that integrating micronutrients and bio-stimulants with macronutrient treatments could improve nutrient uptake efficiency and enhance flower productivity. Comparative studies using organic and inorganic fertilizers are recommended to assess their sustainability, cost-effectiveness, and environmental impact. Moreover, controlled field experiments with a wider range of Rosaceae species would provide more comprehensive data, allowing for broader applicability of the findings.

Lastly, the study suggests that practical applications of these findings should be implemented in commercial flower production. Farmers and horticulturists should adopt precision fertilization techniques to maximize yield while minimizing nutrient waste. Collaborative efforts between researchers, agricultural institutions, and industry stakeholders would be beneficial in developing guidelines for effective nutrient management. By refining fertilization strategies, this study contributes to improving the economic viability and sustainability of the floriculture industry.

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