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Optimization of *Ruscus hypophyllum* L. Growth Using Manure and Nitrogen Applications in Subtropical Conditions of Punjab

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Authors' contributions

This work was carried out in collaboration among all authors. Authors RS and PS conceptualized, designed and conducted the experiment. Author PK analyzed the data and assisted in the interpretation of results. Author DSM drafted the manuscript with contributions from all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: This study aimed to evaluate the impact of farmyard manure (FYM) and nitrogen (N) on the growth and development of *Ruscus hypophyllum* L., a valuable cut foliage crop.
Study Design: The research was conducted as a two-year field experiment using a randomized complete block design (R.C.B.D.).
Place and Duration of Study: The experiment was conducted at the Department of Floriculture & Landscaping, Punjab Agricultural University, Ludhiana, Punjab, during 2020-2021.

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Methodology: The study utilized four treatments: control, 50 g N + 10 kg FYM, 100 g N + 20 kg FYM, and 150 g N + 30 kg FYM. Key growth parameters measured included plant height, spread, stem diameter, leaf dimensions, and number of harvestable stems. Data were collected and analyzed using standard agronomic methods to determine the effectiveness of each treatment.

Results: The 100 g N + 20 kg FYM treatment consistently produced optimal results. Plants under this treatment reached a maximum height of 73.34 cm and had a stem diameter of 1.55 cm. Leaf breadth and length were significantly improved, with values reaching 4.03 cm and 8.05 cm, respectively. The number of harvestable stems increased from 16.66 in the control to 20.5. Higher nutrient levels (150 g N + 30 kg FYM) often reduced performance, indicating potential over-fertilization effects.

Conclusion: The findings underscore the importance of balanced nutrient management in *R. hypophyllum* cultivation. The 100 g N + 20 kg FYM treatment is recommended for optimal growth and yield. These results provide evidence-based recommendations for commercial production, highlighting the need to avoid over-fertilization to prevent reduced plant performance.

Keywords: Farm yard manure; nitrogen; Ruscus hypophyllum; cut foliage; subtropical agriculture.

1. INTRODUCTION

The floriculture industry has witnessed significant diversification and growth in recent decades, with cut foliage emerging as a crucial segment alongside traditional cut flowers. This foliage, characterized by their deep green coloration and extended post-harvest longevity, serve as essential components in floral arrangements and bouquets, enhancing aesthetic appeal and structural integrity [1,2]. The global market for cut foliage has exhibited robust growth, driven by increasing consumer demand for diverse and long-lasting floral products. India, in particular, has emerged as a significant supplier to European markets, capitalizing on its favorable climatic conditions and lower production costs [3,4]. Recent market analyses underscore the economic significance of the cut foliage sector, projecting a compound annual growth rate of 6.3% from 2021 to 2026 [4]. This growth trajectory is attributed to evolving consumer preferences, the expansion of the event planning industry, and the increasing popularity of green spaces in urban environments. As the market expands, there is a growing need for high-quality, sustainably produced cut foliage to meet global demand.

Within this burgeoning market, *Ruscus hypophyllum* L. has garnered attention as a high-value cut foliage crop. Its popularity stems from its aesthetic appeal, characterized by glossy, deep green cladodes that resemble leaves, and its exceptional vase life, which can extend up to several weeks post-harvest [2]. These attributes make *R. hypophyllum* particularly desirable for use in both fresh and dried floral arrangements, contributing to its increasing economic importance in the floriculture sector.

While few of researchers has explored various aspects of *R. hypophyllum* cultivation, including propagation techniques and postharvest treatments, there remains a scarcity of data regarding optimal nutrient management strategies, particularly in subtropical environments. This knowledge gap is significant, as proper nutrient management is crucial for maximizing crop yield and quality while minimizing environmental impacts associated with excessive fertilization [5].

The present study aims to elucidate the impact of farmyard manure (FYM) and nitrogen (N) applications on the growth and developmental parameters of *R. hypophyllum* L. By investigating the plant's response to various nutrient regimes, this research seeks to establish evidence-based protocols for commercial cultivation. The study focuses on key growth parameters, providing a comprehensive assessment of the crop's performance under different nutrient conditions. Furthermore, this research addresses the broader context of sustainable agriculture practices in ornamental plant production. As the floriculture industry faces increasing pressure to adopt environmentally friendly cultivation methods, optimizing nutrient management becomes paramount. By determining the most effective balance of organic and inorganic nutrients for *R. hypophyllum* production, this study contributes to the development of sustainable cultivation practices that can enhance crop productivity while minimizing environmental impact.

2. MATERIALS AND METHODS

The experiment was conducted at the research farm of the Department of Floriculture and Landscaping, Punjab Agricultural University, Ludhiana, India. (30.9°N, 75.8°E) from April 2019 to March 2020. Plants were grown under 75% shade using green agro-shade nets, following recommended practices for shade-loving ornamentals. A 75% shade environment was created using arched GI pipes and green agro-shade nets. Two-meter square beds were prepared, and pre-sprouted rhizomes were planted at a density of 18 plants per square meter. Four treatments were applied: T1 (Control: 0 FYM + 0 N), T2 (50 g N + 10 kg FYM), T3 (100 g N + 20 kg FYM), and T4 (150 g N + 30 kg FYM). Plants were spaced at 30 x 30 cm (18 plants/m^2). The experiment used a randomized complete block design with three replications. Soil amendments were applied one week prior to planting. Data on plant height, spread, stem diameter, leaf number, leaf size, and harvestable stems were collected and analyzed using ANOVA ($p \leq 0.05$).

Morphological and growth parameters were quantified at monthly intervals, commencing 90 days post-planting and continuing until the experiment's conclusion. Plant height was ascertained using a calibrated measuring tape, with measurements taken from the substrate surface to the apical meristem of the tallest leaf. Canopy spread was determined by measuring the maximum horizontal extension of the plant in two perpendicular axes and calculating the arithmetic mean. Stem diameter was measured at a standardized height of 5 cm above the substrate surface using precision digital Vernier caliper, ensuring consistent placement for each measurement. Leaf quantification involved a manual enumeration of fully expanded leaves, defined as those with fully unfolded laminae. Leaf area was assessed using a LI-COR LI-3100 leaf area meter, with measurements taken on a subsample of five randomly selected, fully expanded leaves per experimental unit to ensure representativeness. The criterion for harvestable stems was established at a commercially viable length of 45 cm, with counts recorded at each assessment interval. These methodologies were employed to ensure standardized, reproducible measurements across all treatments and replicates throughout the experimental period.

3. RESULTS AND DISCUSSION

3.1 Plant Height

In 2020, plant height ranged from 66.87 cm (T1) to 73.34 cm (T3), decreasing slightly to 70.18 cm in T4. In 2021, the range was more pronounced, from 27.21 cm (T1) to 72.67 cm (T3), dropping to 49.33 cm in T4. The maximum height was 73.34 cm with T3 in 2020. This response aligns with findings by Siddiqui et al*.* [6], who reported enhanced growth in ornamental plants with balanced fertilization. The decline in T4, particularly in 2021, suggests a potential nutrient excess effect, consistent with observations by Kumar et al*.* [7] in other ornamental species.

3.2 Plant Spread

Plant spread showed modest variations across treatments and years. In 2020, it ranged from 41.25 cm (T1) to 45.12 cm (T3). In 2021, the range was from 40.58 cm (T1) to 44.77 cm (T3). The maximum spread was 45.12 cm in 2020 with T3. The relatively small variation in plant spread suggests this parameter may be less responsive to nutrient inputs. This aligns with research by Zhang et al*.* [8], indicating some morphological traits in ornamental plants are more genetically controlled than environmentally influenced.

3.3 Number of Leaves

Leaf number showed significant increases with nutrient application, especially in 2021. In 2020, it ranged from 109.66 (T1) to 120.46 (T3). In 2021, there was a dramatic response, ranging from 10.6 (T1) to 119.9 (T3). The maximum was 120.46 leaves with T3 in 2020. This substantial increase highlights the critical role of fertilization in enhancing the marketable yield of *R. hypophyllum.* The findings support research by Taiz et al*.* [9], emphasizing the importance of nitrogen and organic matter in promoting vegetative growth in ornamental plants.

3.4 Stems Harvested

In 2020, the number of stems harvested ranged from 16.66 (T1) to 20.5 (T3). In 2021, the range was from 15.3 (T1) to 20.1 (T3). The maximum was 20.5 stems with T3 in 2020. This positive correlation between nutrient application and stem yield is consistent with findings by Wang et al*.* [10] on cut flower production. The increased stem count in T2 and T3 indicates enhanced overall plant vigor and potential economic value for cut foliage producers.

Overall, T3 (100 g N + 20 kg FYM) consistently showed the best results across parameters and years, suggesting this level of fertilization provides an optimal balance for *R. hypophyllum* growth and yield. The decline in some parameters at T4 indicates that excessive fertilization may be counterproductive, emphasizing the importance of precise nutrient management in cut foliage production [5].

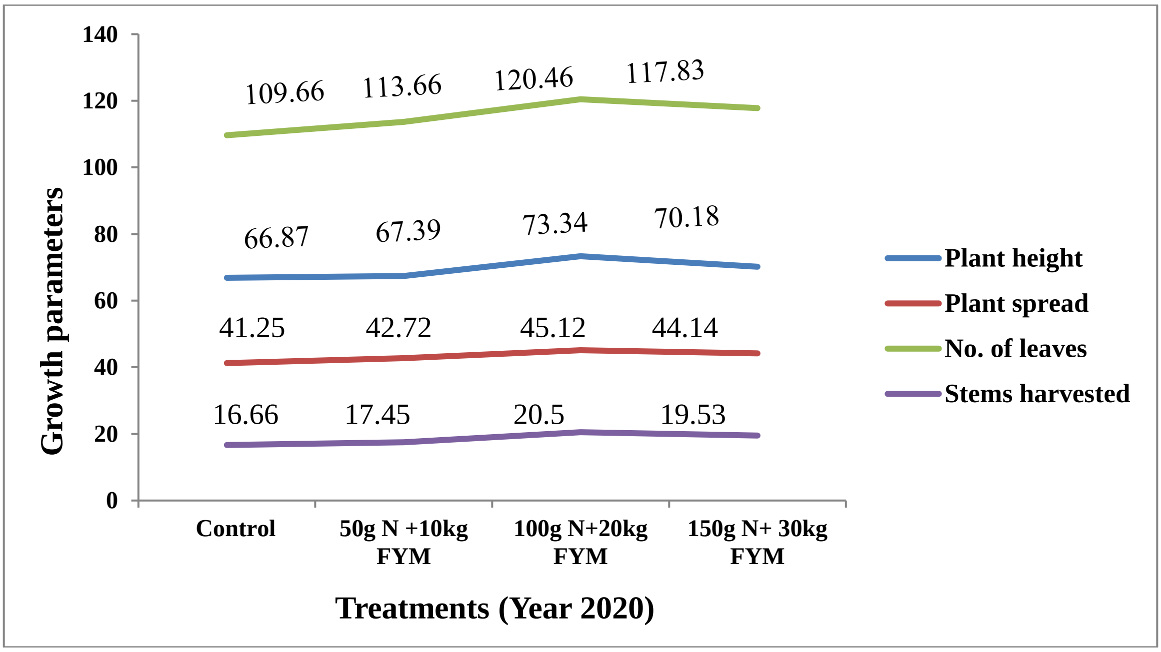

Fig. 1. Effect of FYM and N application on growth parameters of *R. hypophyllum* in the year 2020

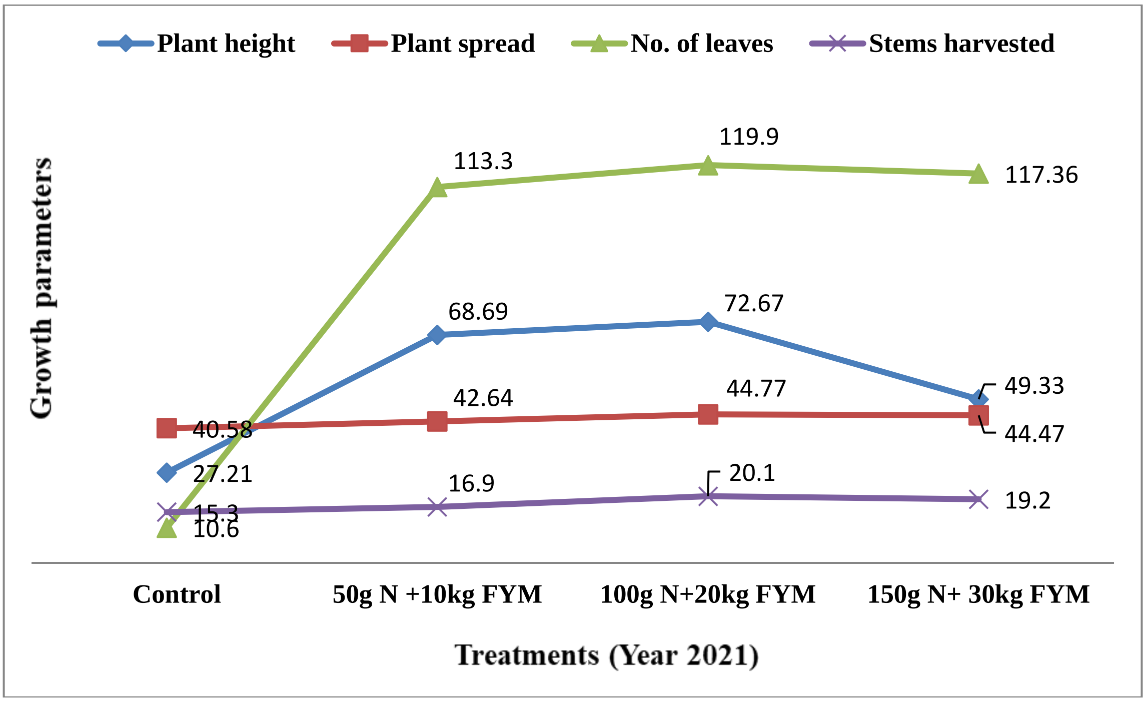

Fig. 2. Effect of FYM and N application on growth parameters of *R. hypophyllum* in the year 2021

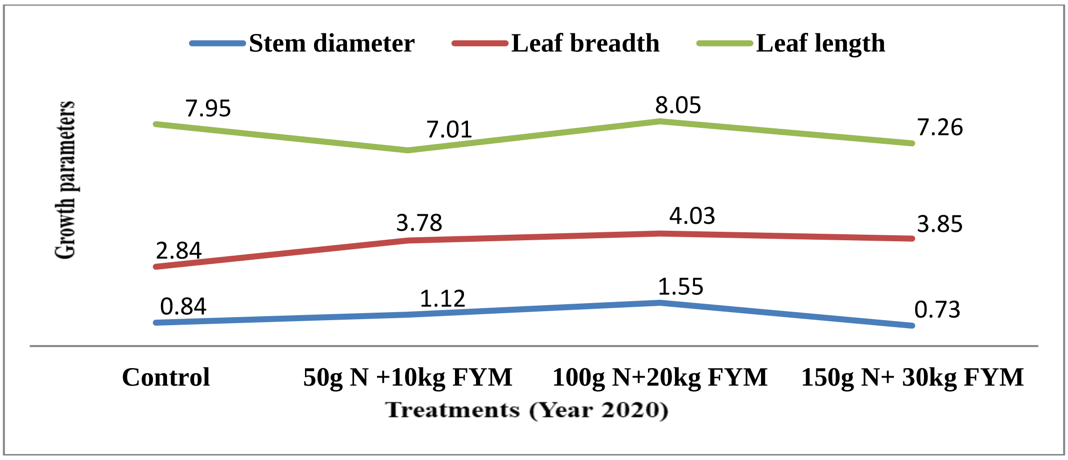

Fig. 3. Effect of FYM and N application on Stem diameter, Leaf breadth and Leaf length of *R. hypophyllum* in the year 2020

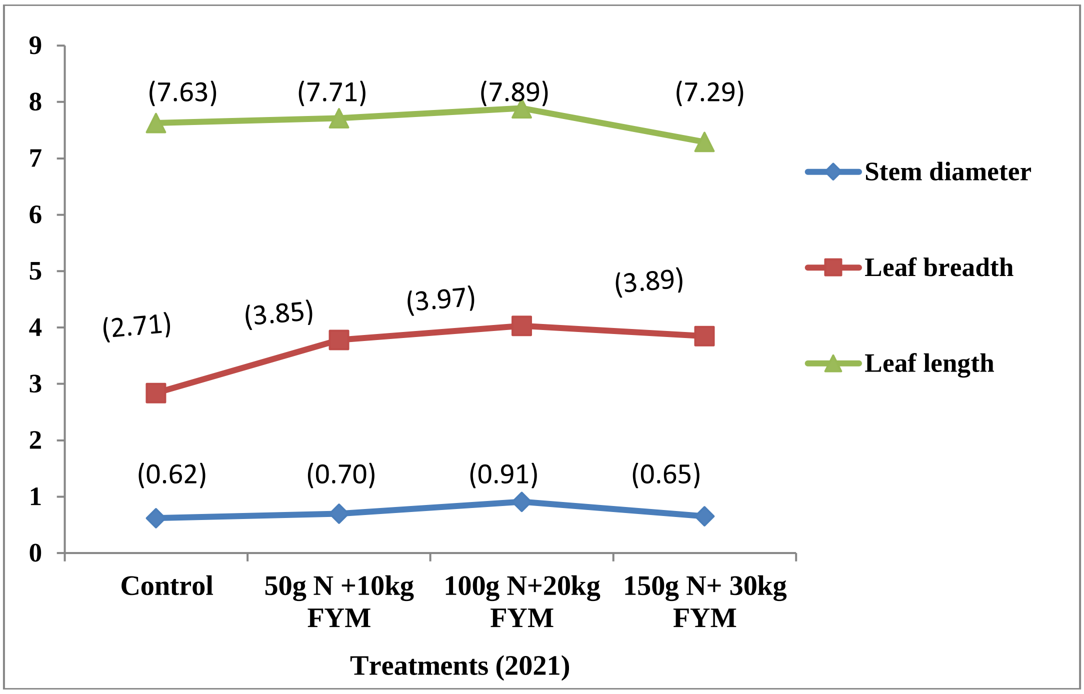

Fig. 4. Effect of FYM and N application on Stem diameter, Leaf breadth and Leaf length of *R. hypophyllum* in the year 2021

3.5 Stem Diameter

Stem diameter showed a similar trend in both 2020 and 2021, increasing from the control to peak at the T3-100 g N+20 kg FYM treatment (1.55 cm in 2020, 0.91 cm in 2021), then decreasing at the highest treatment level. This pattern suggests improved plant growth and resource allocation with balanced nutrient application, aligning with findings by Zhang et al. [8] on enhanced stem growth under optimal fertilization. The decrease at the highest treatment level may indicate nutrient toxicity or imbalance, as noted by Li et al. [11] in their study on excessive fertilization effects.

3.6 Leaf Breadth

Leaf breadth demonstrated a consistent increase from the control to the T3-100 g N+20 kg FYM treatment in both years (peaking at 4.03 cm in 2020 and 3.97 cm in 2021), with a slight decrease at the highest treatment level. This trend indicates improved leaf expansion and potentially enhanced photosynthetic capacity with increasing nutrient levels, supporting research by Wang et al. [10] on the positive effects of balanced N and organic fertilizer application on leaf development. The slight decrease at the highest treatment level suggests a threshold effect, where additional nutrients no longer contribute to leaf expansion.

3.7 Leaf Length

Leaf length exhibited more variability, particularly in 2020, where it fluctuated from 7.95 cm in the control, dropping to 7.01 cm, then peaking at 8.05 cm with T3-100 g N+20 kg FYM. In 2021, the trend was more consistent, peaking at 7.89 cm with the same treatment. This complex response to nutrient application aligns with findings by Chen et al. [12], who observed non-linear responses in leaf morphology to nutrient gradients. The more consistent trend in 2021 might reflect plant adaptation to nutrient regimes over time. The variability in leaf length response highlights the intricate interplay between nutrient availability and leaf development, suggesting that factors beyond simple nutrient concentration, such as nutrient ratios and environmental conditions, play significant roles in determining leaf morphology [13,12].

4. CONCLUSION

This study provides compelling evidence for the efficacy of balanced nutrient management in cultivating *Ruscus hypophyllum* L. as a cut foliage crop. The treatment combining 100 g N + 20 kg FYM consistently demonstrated superior performance across growth parameters, resulting in significant enhancements in plant vigor and marketable yield. Conversely, the decline in growth at the highest nutrient level (150 g N + 30 kg FYM) highlights the detrimental effects of over-fertilization, emphasizing the importance of precise nutrient management. These offers evidence-based recommendations for nutrient management strategies, potentially enhancing crop quality and yield, and improving the economic viability of cut foliage production. This research contributes valuable insights to *R. hypophyllum* cultivation, providing a foundation for sustainable and efficient practices in the rapidly growing cut foliage sector of the floriculture industry.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

Table 1. Summary of treatments and results

Treatment	Plant Height (cm)	Plant Spread (cm)	Stem Diameter (cm)	Leaf Breadth (cm)	Leaf Length (cm)	Number of Leaves	Harvestable Stems
Control	66.87	41.25	1.18	3.56	7.95	109.66	16.66
T2	69.45	43.67	1.37	3.84	7.55	114.53	18.33
T3	73.34	45.12	1.55	4.03	8.05	120.46	20.5
T4	70.18	44.77	1.29	3.87	7.01	117.88	19.5

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