Effect of Nano-Silver treatments on Some Vegetative and Floral Growth Characteristics of Freesia (*Freesia hybrida* L.) Corms

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Abstract

This study was conducted during the period from October 2025 to June 2026 in the wooden shade house of the Department of Horticulture and Landscape Engineering / College of Agriculture / Tikrit University, to investigate the effect of silver nanoparticles treatments (soaking and spraying) on vegetative growth characteristics, floral characteristics, and some post-harvest traits of *Freesia hybrida L*. The experiment was carried out using a Randomized Complete Block Design (RCBD) with three replications. The study included five treatments: control treatment (S0), soaking in nano-silver for one hour at concentrations of 5 and 10 mg L^{-1} (S1 and S2), and spraying at concentrations of 5 and 10 mg L^{-1} (S3 and S4). The results showed that Nano-silver treatments led to a significant improvement in some vegetative growth characteristics, as they contributed to increasing leaf area, total chlorophyll content, and inflorescence stalk length. The spraying treatments, particularly spraying at a concentration of 10 mg L^{-1}, were superior in giving the best results compared to the soaking treatments and the control treatment. The results also showed an improvement in floral characteristics, as Nano-silver treatments led to earlier flowering and reduced the number of days required for 50% inflorescence opening, in addition to improving some other floral characteristics. Regarding post-harvest traits, Nano-silver treatments increased vase life and the amount of solution absorbed, and reduced the deterioration of flowers after harvest, indicating their role in improving the water status and extending the marketability of the flowers.

Keywords: Freesia, nano-silver, soaking, spraying, vegetative growth, floral characteristics, vase life, post-harvest.

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Introduction

Freesia (*Freesia hybrida L.)* is one of the most famous flowering plants in the world, belonging to the Iridaceae family, which includes more than 50 plant genera. Freesia is distinguished by its unique fragrance and is grown primarily for the production of indoor ornamental plants and cut flowers. It is also considered one of the most important ornamental bulbs globally due to its long vase life, attractive scent, and diverse colors. The native habitat of freesia is South Africa, and its cultivation spread to Europe during the 18th century. Under Iraqi climatic conditions, freesia is treated as an annual winter bulbous plant. They are herbaceous plants growing from conical corms, from which bundles of narrow leaves emerge, and are characterized by fragrant, funnel-shaped flowers (1). Developments in nanotechnology have enabled the production of specific nanoparticles with unique properties and a wide range of practical applications. Nanoparticles are characterized by their small size, light weight, and high surface-to-volume ratio. In the agricultural sector, they are increasingly used as components of new fertilizers, plant protection products, herbicides, and preparations for extending the vase life of cut flowers. Recently, nanoparticles and nanomaterials have been proposed as potential biostimulants that may improve plant propagation and growth, and enhance plant stress resistance. The use of nanoparticles can bring many benefits to agriculture and horticulture. Among the most interesting metallic nanoparticles are silver nanoparticles (AgNPs), which exhibit strong biological activity, affecting plants at many different levels such as stimulating germination, activating growth, and increasing biomass (2). Aim of the Study To study the effect of soaking and spraying with nano-silver on the growth and flowering of Freesia plants and the post-harvest life of the flowers.

Materials and Methods

The experiment was conducted in the wooden shade house of the Department of Horticulture and Landscape Engineering / College of Agriculture / Tikrit University during the 2025 agricultural season. *Freesia hybrida* corms were obtained The corms were one year old at the beginning of the experiment. from Al-Hamzawi Nursery in Kirkuk Governorate, where they were stored inside perforated bags. The growing medium was prepared using a mixture of peat moss and sandy loam soil free of impurities, with the two components mixed homogeneously at

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a ratio of (1:2). Agricultural practices were carried out as recommended for Corms planting. The Corms were planted in plastic pots (20 cm height, 20 cm diameter) filled with the prepared growing medium. The study included soaking and spraying treatments with nano-silver at five concentrations, denoted as S:

The study included five treatments arranged sequentially as follows

- S0: Soaking in water only (control)
- S1: Soaking at a concentration of 5 mg L^{-1}
- S2: Soaking at a concentration of 10 mg L^{-1}
- S3: Spraying at a concentration of 5 mg L^{-1}
- S4: Spraying at a concentration of 10 mg L^{-1}

The experiments were conducted according to a Randomized Complete Block Design (RCBD) with three replications. Each replication contained 5 treatments, and each treatment contained 5 pots. Each pot contained 3 Corms, resulting in 15 Corms per treatment. The total number of pots in the experiment was 45 pots, calculated as: 3 replications × 5 treatments × 3 pots = 45 pots.

The corms were soaked for only one hour according to (3). Spraying was carried out in three applications: the first one month after planting, the second three weeks after the first application, and the third three weeks after the second application.

The following traits were studied:

Vegetative Growth Traits

- Leaf area per plant (cm²): Leaf area was measured using Digimizer software for digital image analysis. Leaves were photographed against a white background with a known scale for calibration. Images were imported into the software, leaf boundaries were defined, and leaf area was calculated in cm². Image analysis is considered an accurate and rapid method for measuring leaf area in plant studies (4,5).

- Total chlorophyll (SPAD): A Chlorophyll meter was used to measure the chlorophyll content in leaves directly in the field (6).

- Fresh weight of the vegetative shoot (g): Plants were taken and weighed using a sensitive balance (7).

Floral Growth Traits

- Length of the inflorescence stalk (cm):The height of the inflorescence

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carrier was measured from its emergence from the plant to the end of the carrier (8).

- Diameter of florets (cm): The distance between the two farthest points of a single floret was measured in more than one direction using a Digital Vernier caliper after full opening (9).

- Flowering date (day): The number of days from the planting date of the corms until the opening of the first buds on the first inflorescence of the plant was (10) .

- Number of days to 50% inflorescence opening (day): The number of days required for 50% of the flower inflorescences to open was calculated by recording the days from the planting date until 50% of the plants in each treatment had open flowers (11).

- Vase life (day): The period (days) from the opening of 50% of the flower inflorescences in the pot until the day of initial color loss in each pot was calculated (12).

Post-Harvest Flower Traits

- Vase life (day): The vase life (days) of *Freesia hybrida L*. flowers resulting from the corms was measured by calculating the number of days from the harvest date of the inflorescences until the flowers lost their aesthetic value. Flowers were harvested at the stage when the first flower on the inflorescence opened. Inflorescence stalk lengths were standardized by cutting them equally, then placed in 200 ml glass containers containing a SUSPENSION SOLUTIOIN (20 g sugar - 200 mg citric acid - 1 mg calcium hypochlorite $Ca(OCl)_2$), inside a room at a temperature of (20–25)°C with moderate relative humidity and under natural laboratory lighting. Flowers were monitored daily, and wilting of more than 50% of the flowers on the inflorescence, drooping, or color change was considered the criterion for the end of vase life (13).

-Amount of solution absorbed (ml): The amount of absorbed water (ml) was measured by calculating the difference between the initial solution volume and the remaining volume from the time the inflorescences were placed in 200 ml glass containers until flower wilting. Environmental conditions inside the room were fixed at a temperature of (20–25)°C. The amount of absorbed water is expressed as the difference between the two volumes after subtracting the evaporation value (14).

- Loss of fresh weight of inflorescences (g): The loss in fresh weight of the flower inflorescences was estimated by weighing the

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inflorescences at the beginning of the experiment, then re-weighing them at the end of the vase life. The amount of loss was calculated and expressed in grams (14).

Results and Discussion

Leaf Area

It is evident from Figure (1) that nano-silver treatments significantly affected the leaf area of Freesia plants. The control treatment (S0) recorded the lowest value of 28.53 cm², followed by the nano-silver soaking treatments for one hour at concentrations of 5 and 10 mg L⁻¹ (S1 and S2), with values of 31.23 and 32.17 cm² respectively, as well as the spraying treatment at 5 mg L⁻¹ (S3) with a value of 31.43 cm², with no significant differences among them. Meanwhile, the spraying treatment at 10 mg L⁻¹ (S4) recorded the highest value of 40.27 cm², significantly outperforming all other treatments.

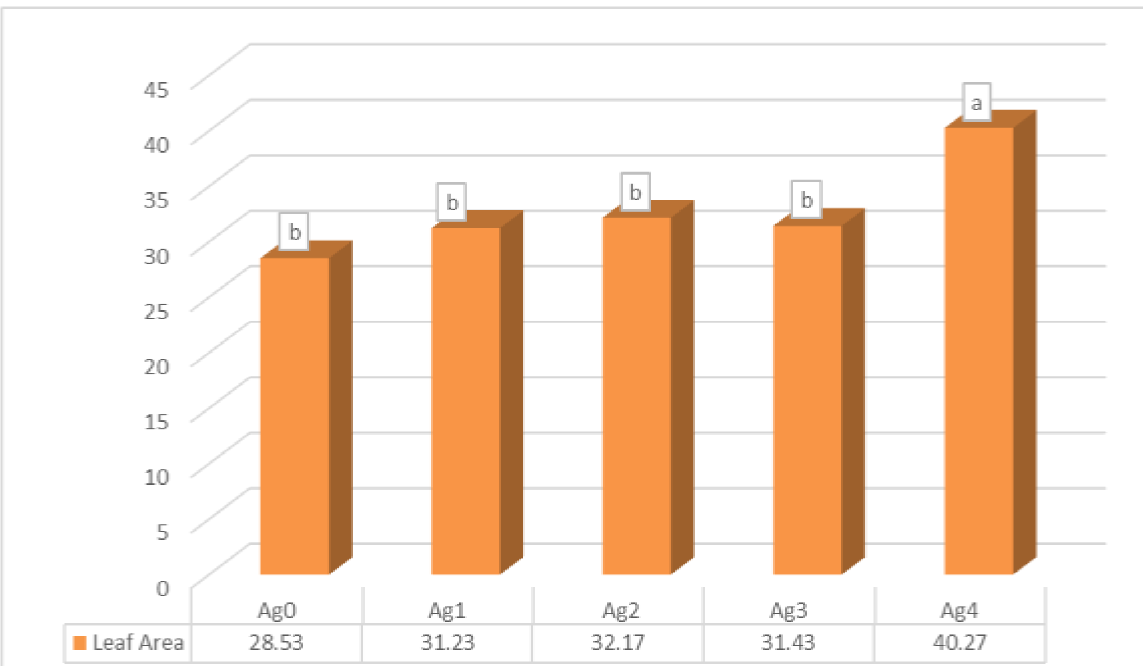

Figure (1): Effect of nano-silver soaking and spraying on leaf area of Freesia plants (cm²)

Total Chlorophyll

It is evident from Figure (2) that nano-silver treatments significantly affected the total chlorophyll content of Freesia plants. The control

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treatment (S0) recorded the lowest value of 45.97, followed by the soaking treatment at 5 mg L^{-1} (S1) with a value of 46.33, with no significant differences between them. Meanwhile, the soaking treatment at 10 mg L^{-1} (S2) and the spraying treatment at 10 mg L^{-1} (S4) recorded the highest values of 51.70 and 52.20 respectively, significantly outperforming the other treatments, with no significant difference between them. The spraying treatment at 5 mg L^{-1} (S3) recorded a value of 49.93, with no significant differences compared to the superior treatments.

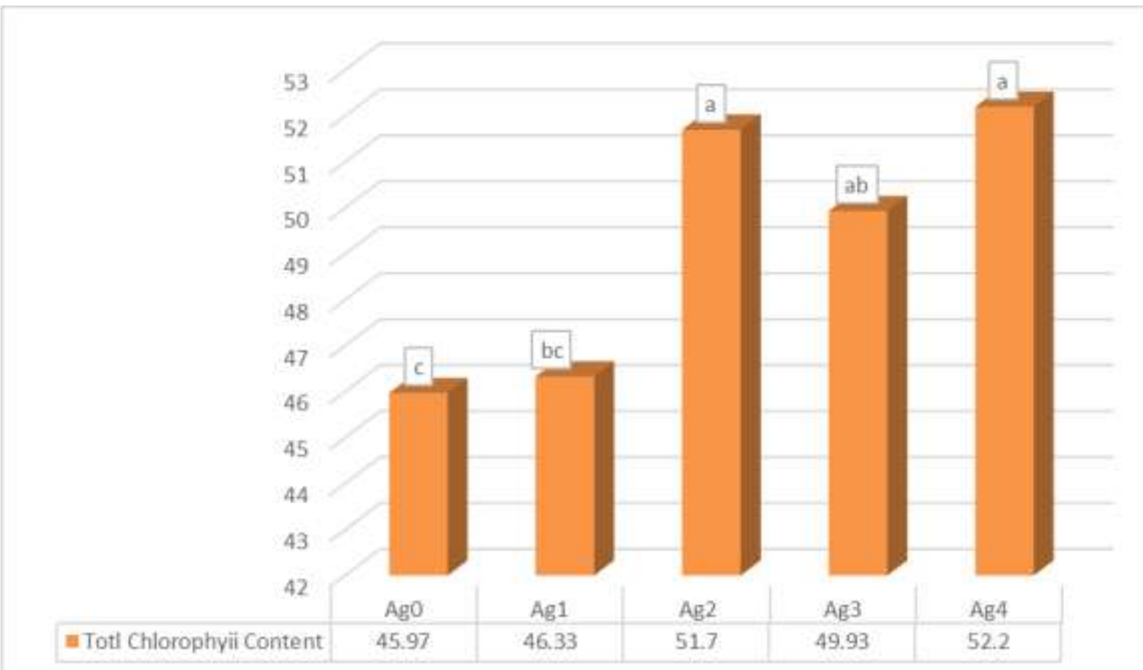

Figure (2): Effect of nano-silver on total chlorophyll of Freesia plants

Fresh Weight

Figure (3) shows no significant differences between Nano-silver treatments in the fresh weight of Freesia plants, despite variation in values. The control treatment (S0) recorded the lowest value of 24.33 g, while the spraying treatment at 10 mg L^{-1} (S4) recorded the highest value of 35.30 g, with the remaining treatments ranging between these two values.

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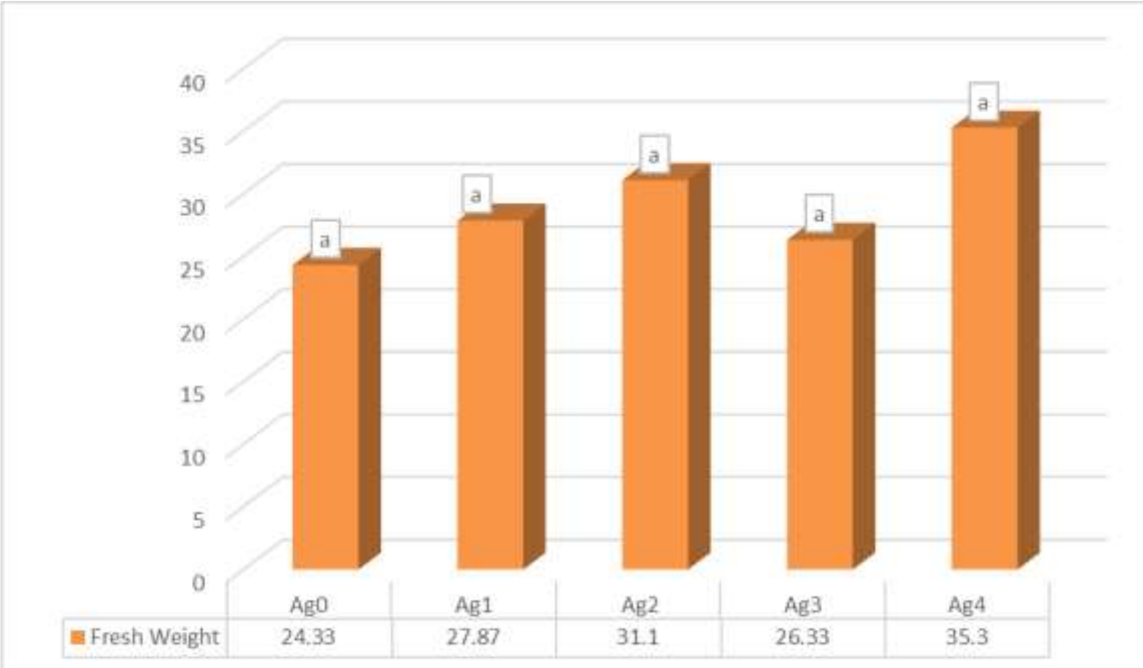

Figure (3): Effect of nano-silver soaking and spraying on fresh weight of Freesia plants (g)

Inflorescence Stalk Length

Figure (4) shows that nano-silver treatments significantly affected the inflorescence stalk length of Freesia plants. The control treatment (S0) recorded the lowest value of 34.60 cm, followed by the nano-silver soaking treatments for one hour at concentrations of 5 and 10 mg L^{-1} (S1 and S2) and the spraying treatment at 5 mg L^{-1} (S3), with values of 35.67, 36.23, and 35.73 cm respectively, with no significant differences among them. Meanwhile, the spraying treatment at 10 mg L^{-1} (S4) recorded the highest value of 42.00 cm, significantly outperforming all other treatments.

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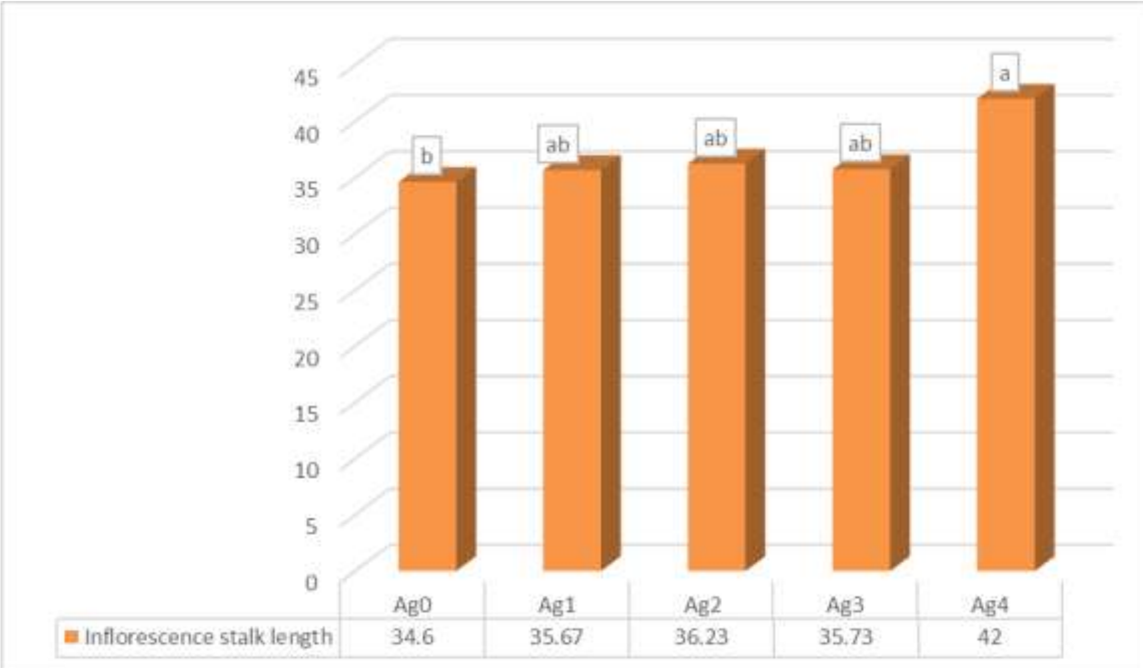

Figure (4): Effect of nano-silver soaking and spraying on inflorescence stalk length of Freesia plants (cm)

Flower Diameter

Figure (5) shows no significant differences between Nano-silver treatments in flower diameter, as all treatments showed the same statistical letter (a), indicating similar values and no significant treatment effect. Nevertheless, the spraying treatment at 10 mg L^{-1} (S4) recorded the highest value of 53.2 mm, followed by the soaking treatment at 10 mg L^{-1} (S2) with a value of 53 mm, while the control treatment (S0) recorded the lowest value of 50 mm, with the remaining treatments showing similar recorded values.

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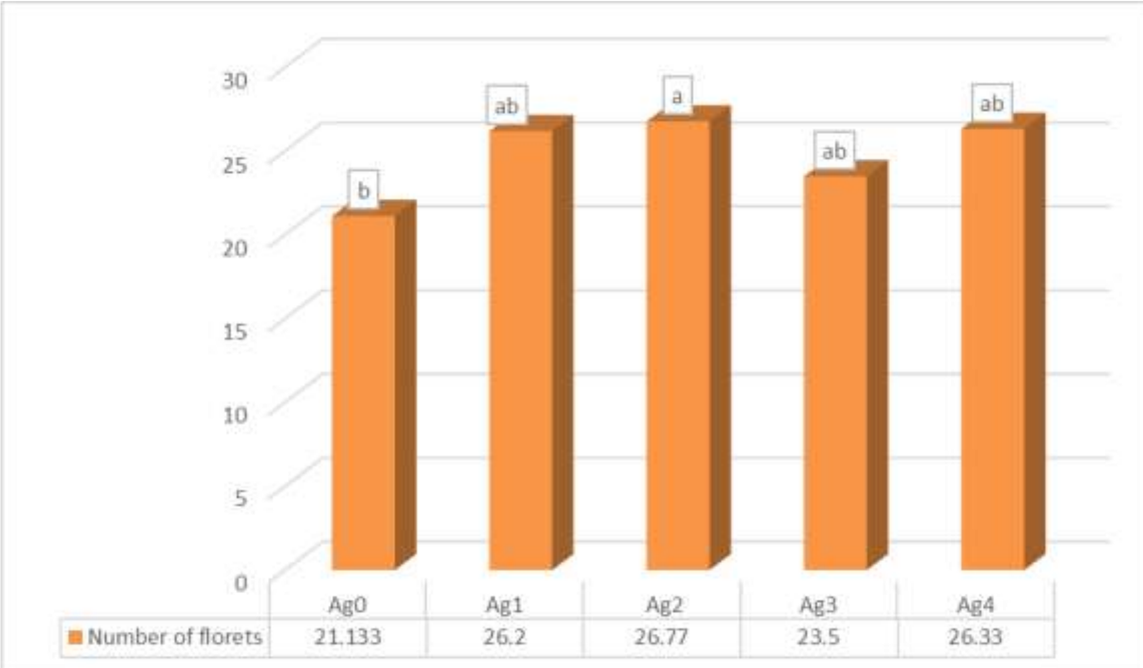

Figure (5): Effect of nano-silver soaking and spraying on flower diameter of Freesia plants (mm)

Flowering Date

Figure (6) shows significant differences between nano-silver treatments in flowering date of Freesia plants. The control treatment (S0) recorded the highest number of days, reaching 154.67 days, significantly later than all other treatments. Meanwhile, the soaking treatment at 10 mg L^{-1} (S2) recorded the shortest duration of 147.67 days, indicating a significant earliness in flowering date. The soaking treatment at 5 mg L^{-1} (S1) and the spraying treatments at 5 and 10 mg L^{-1} (S3 and S4) showed intermediate values that did not significantly differ from each other but outperformed the control treatment in reducing the number of days required for flowering.

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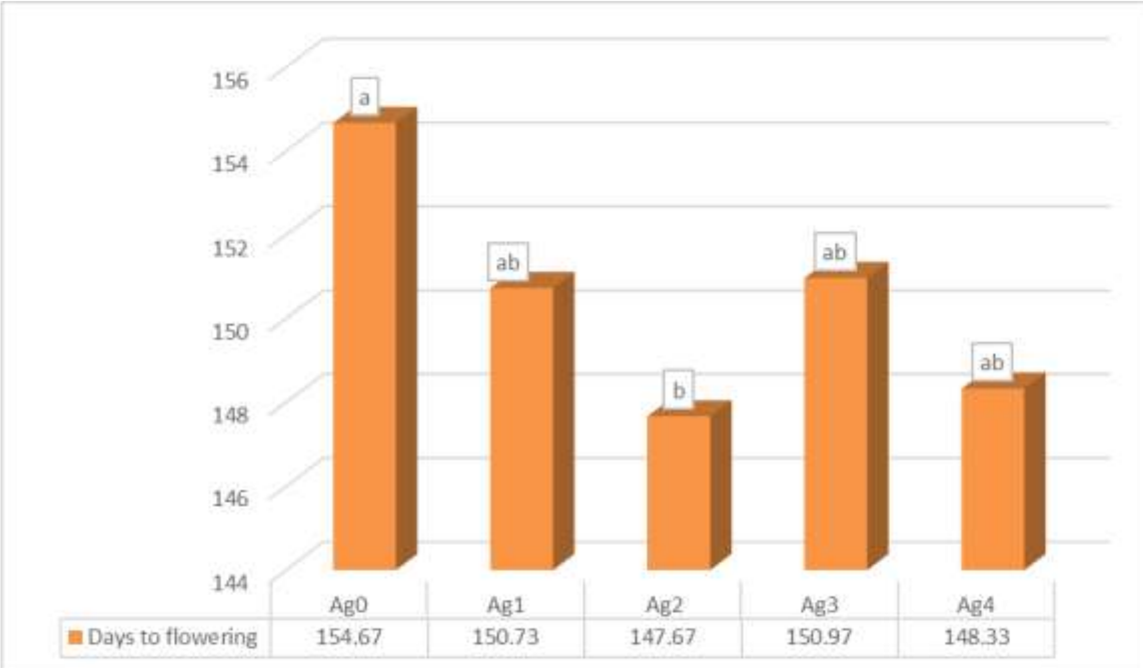

Figure (6): Effect of nano-silver soaking and spraying on flowering date of Freesia plants (day)

Time to 50% Inflorescence Opening

Figure (7) shows that nano-silver treatments significantly affected the time to 50% inflorescence opening of Freesia plants.

The control treatment (S0) recorded the longest period, reaching 156.67 days.

Nano-silver soaking treatments at concentrations of 5 and 10 mg L^{-1} (S1 and S2) reduced the number of days to 149.33 and 148.33 days, respectively.

Similarly, spraying treatments at the same concentrations (S3 and S4) recorded 148.00 and 148.00 days, respectively.No significant differences were observed among nano-silver treatments, whereas all treatments significantly outperformed the control .

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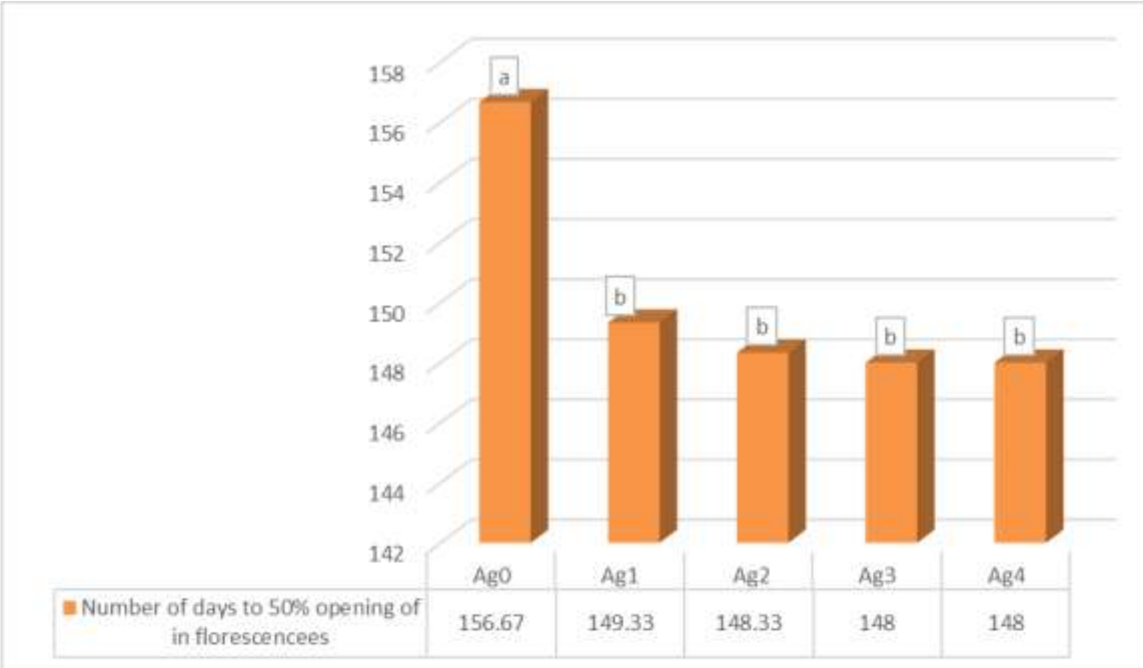

Figure (7): Effect of nano-silver soaking and spraying on 50% inflorescence opening of Freesia plants (day)

Vase Life on Plant

Figure (8) shows no significant differences between nano-silver treatments in the vase life on the plant (longevity) of Freesia flowers. Despite variation in values, the control treatment (S0) recorded the shortest duration of 14.73 days, while the spraying treatment at 10 mg L^{-1} (S4) recorded the longest duration of 17.37 days, with the remaining treatments ranging between these two values.

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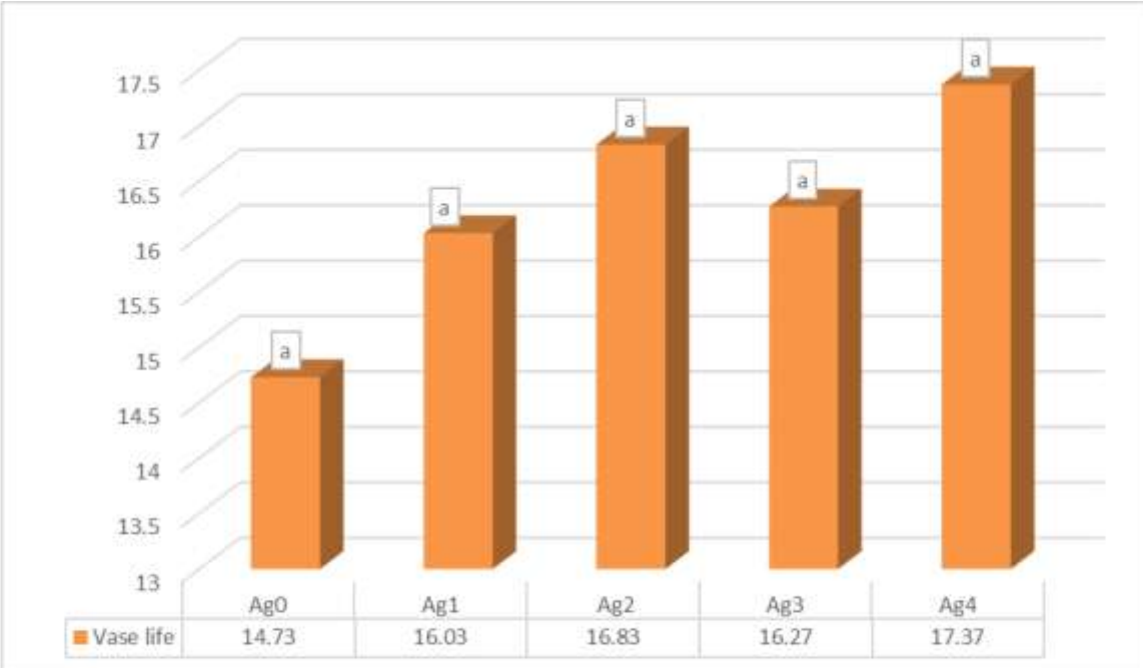

Figure (8): Effect of nano-silver soaking and spraying on vase life on plant of Freesia flowers (day)

Post-Harvest Change in Dry Weight of Flowers

Figure (9) shows significant differences between nano-silver treatments in the change in post-harvest dry weight of flowers. The spraying treatment at 5 mg L^{-1} (S3) recorded the highest value of 2.2 g, significantly outperforming all other treatments. Meanwhile, the control treatment (S0) recorded the lowest value of 0.9 g. The soaking treatment at 10 mg L^{-1} (S2) showed a value of 1.64 g, ranking second, followed by the spraying treatment at 10 mg L^{-1} (S4) and the soaking treatment at 5 mg L^{-1} (S1) with similar values of 1.4 and 1.3 g respectively, with significant differences among them according to statistical letters.

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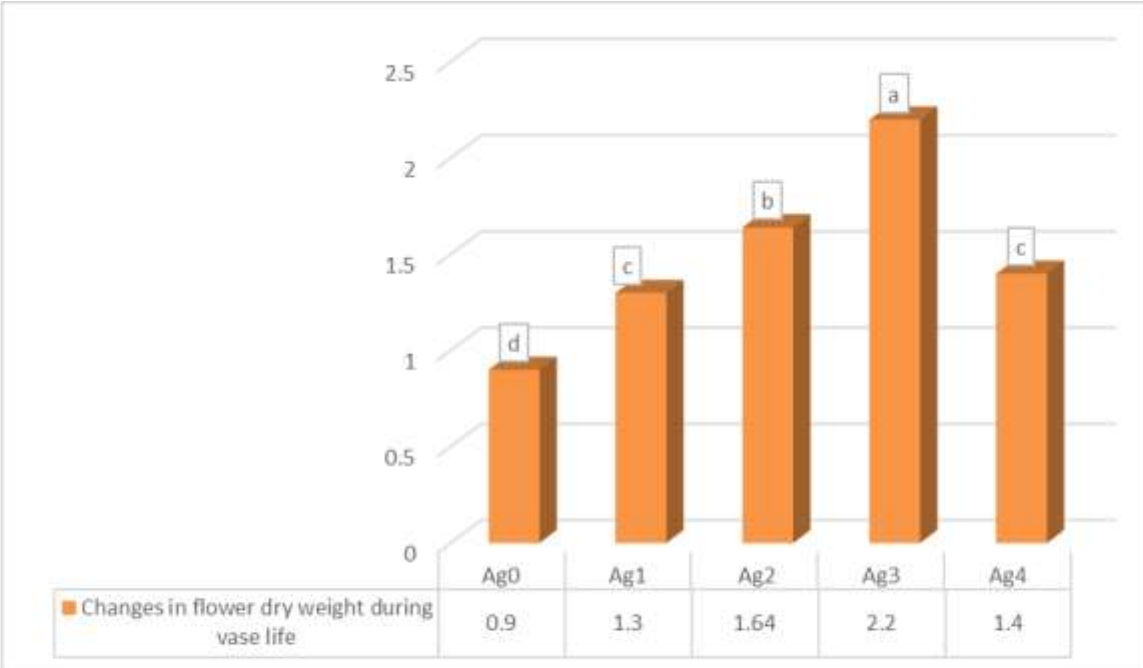

Figure (9): Effect of nano-silver soaking and spraying on post-harvest change in dry weight of Freesia flowers (g)

Amount of Solution Absorbed

Figure (10) shows significant differences between nano-silver treatments in the amount of solution absorbed. The spraying treatment at 5 mg L^{-1} (S3) recorded the highest value of 27.6 ml, significantly outperforming all other treatments. Meanwhile, the control treatment (S0) recorded the lowest value of 21.5 ml. The soaking treatment at 10 mg L^{-1} (S2) showed a value of 25.2 ml, ranking second, followed by the spraying treatment at 10 mg L^{-1} (S4) and then the soaking treatment at 5 mg L^{-1} (S1), with values of 24.6 and 23.8 ml respectively, with significant differences among them according to statistical letters.

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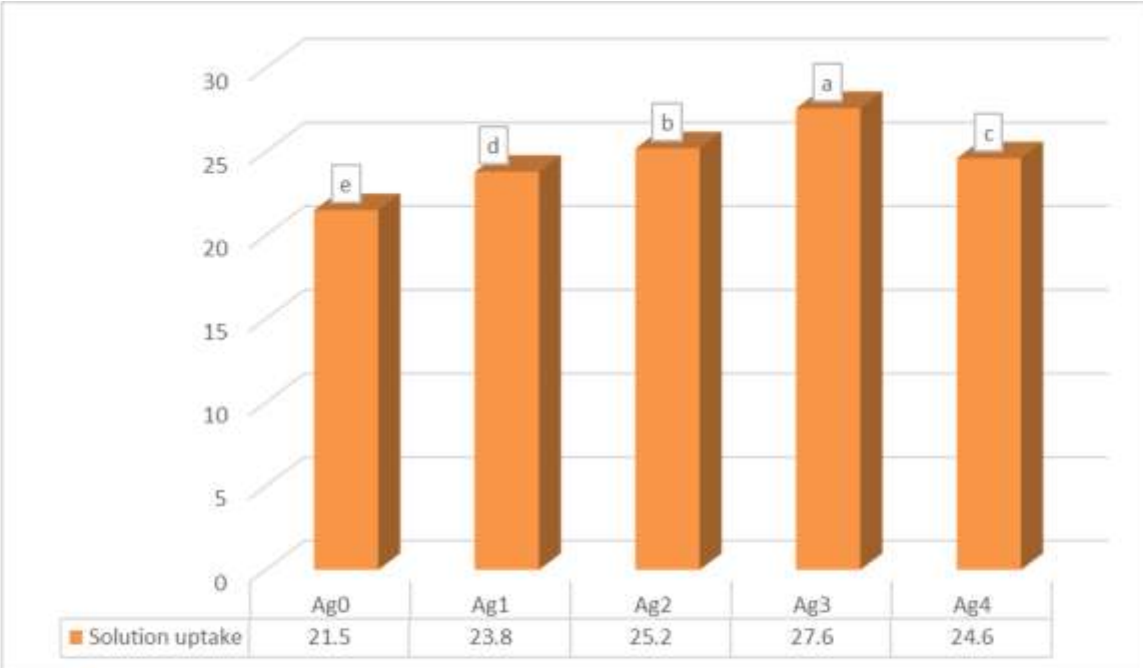

Figure (10): Effect of nano-silver soaking and spraying on solution absorbed by Freesia flowers (ml)

Vase Life (Post-Harvest)

Figure (11) shows significant differences between nano-silver treatments in the vase life of flowers. The spraying treatment at 5 mg L^{-1} (S3) recorded the longest vase life of 13.4 days, significantly outperforming all other treatments. Meanwhile, the control treatment (S0) recorded the shortest vase life of 10.6 days. The soaking treatment at 10 mg L^{-1} (S2) showed a value of 12.4 days, ranking second, followed by the spraying treatment at 10 mg L^{-1} (S4) and the soaking treatment at 5 mg L^{-1} (S1), with values of 11.9 and 11.5 days respectively, with significant differences among them according to statistical letters.

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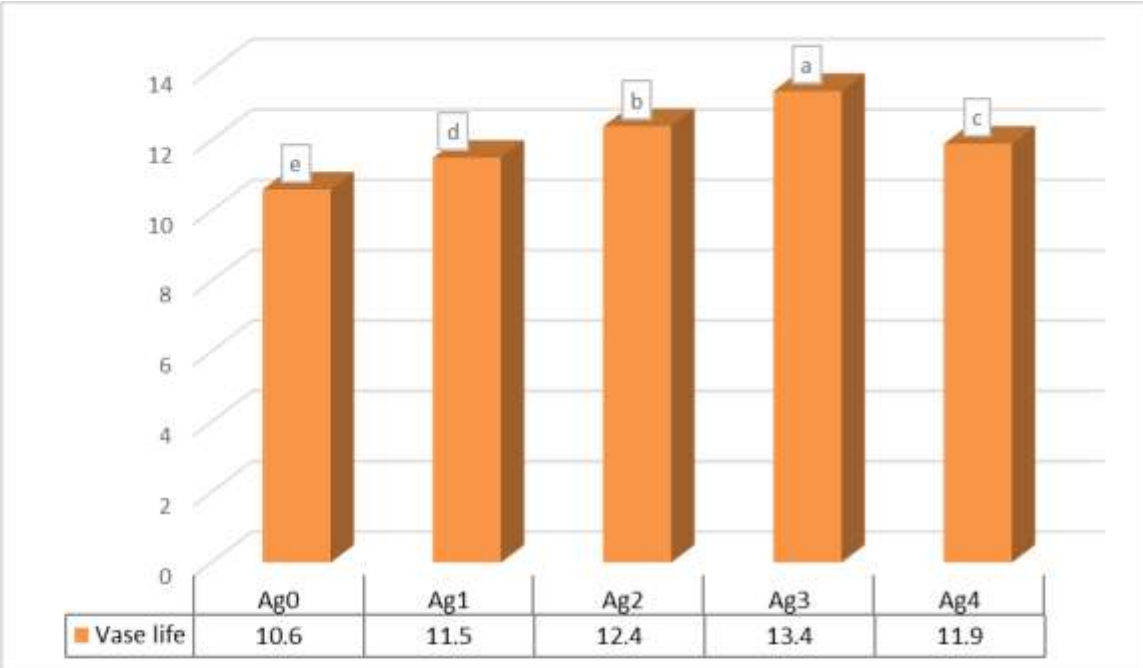

Figure (11): Effect of nano-silver soaking and spraying on vase life of Freesia flowers (day)

Discussion of Vegetative, Floral, and Post-Harvest Traits

The results of the study showed that nano-silver treatments (soaking and spraying) led to a significant improvement in the vegetative growth characteristics of Freesia plants, as these treatments positively affected leaf area, total chlorophyll, fresh and dry weight. Some treatments, particularly spraying at 5 mg L^{-1} (S3), achieved the highest values compared to the control treatment. This is attributed to the vital role of nano-silver in improving the efficiency of physiological processes within the plant, as it increases photosynthetic efficiency by maintaining chloroplast integrity and reducing oxidative stress, in addition to enhancing the absorption of nutrients and water, which reflects on increased vegetative growth (10, 15)

The results also showed the superiority of nano-silver treatments in floral characteristics, as they increased inflorescence stalk length and flower diameter, as well as earlier flowering and reduced number of days required to reach the flowering stage compared to the control treatment. This indicates the role of nano-silver in regulating hormonal balance within the plant, particularly by inhibiting the effect of ethylene, which is responsible for delaying flowering, thus accelerating the transition from vegetative to reproductive growth (16,17).

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Regarding post-harvest traits, the results showed that nano-silver treatments led to a clear improvement in vase life and increased the amount of solution absorbed, as well as reducing the loss in dry weight of flowers after harvest. Some treatments, especially (S3), recorded the best results in extending vase life and increasing absorption efficiency. This is attributed to the antimicrobial effect of nano-silver, as it reduces the growth of bacteria and fungi within the vascular tissues, preventing blockage and maintaining continuous water transport, thereby improving the water status of flowers and slowing down senescence processes (18,19)

In general, the results indicate that the use of nano-silver, particularly by spraying, was more efficient than soaking in improving most of the studied traits. This is attributed to its rapid absorption and translocation within plant tissues, enhancing its physiological effect. These results confirm the importance of using nanotechnologies as a modern approach to improve the growth and productivity of ornamental plants and extend their post-harvest life.

Conclusions

Through this study, the following can be concluded:

1. Nano-silver treatments led to a significant improvement in some vegetative growth characteristics of Freesia plants, especially leaf area, total chlorophyll content, and inflorescence stalk length.
2. Nano-silver spraying treatments, particularly at a concentration of 10 mg L^{-1}, were superior in improving most of the studied traits compared to soaking treatments and the control treatment.
3. Nano-silver treatments contributed to earlier flowering and reduced the number of days required for 50% inflorescence opening, indicating their role in improving the floral development of the plant.
4. Some traits, such as fresh weight, vase life on the plant (longevity), and flower diameter, did not show clear significant differences between treatments, despite a slight improvement in the recorded values.
5. Spraying with silver nanoparticles at a concentration of 10 mg L^{-1} gave the best results in improving post-harvest traits, including vase life, solution uptake, and reducing flower deterioration after harvest..
6. Nano-silver showed an effective role in improving the water status of flowers and extending their marketability by reducing microbial growth within vascular tissues and improving water absorption.

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7. Nano-silver can be adopted as a modern and effective method to improve the quality and productivity of Freesia plants, especially in cut flower production.

Recommendations

Based on the results shown by this study, the following recommendations can be made:

1. It is recommended to use nano-silver in the production of Freesia plants due to its effective role in improving some vegetative, floral, and post-harvest characteristics.
2. The nano-silver spraying method is preferred as it showed higher efficiency compared to the soaking method in improving most of the studied traits.
3. It is recommended to use a concentration of 10 mg L^{-1} of nano-silver as it gave the best results for most of the studied traits.
4. Nano-silver can be used in post-harvest treatment programs to extend vase life and improve the quality of cut flowers by increasing water absorption and reducing deterioration.
5. It is recommended to conduct future studies to test different concentrations of nano-silver, soaking durations, and their effects on other ornamental plants.
6. Study the possibility of interaction between nano-silver and other plant growth regulators to obtain the best response in growth, flowering, and post-harvest traits.
7. Expand the study of the physiological and biochemical effects of Nano-silver on Freesia and other ornamental plants under different environmental conditions.

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