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The effect of melatonin and 6-Benzylaminopurine application on the post-harvest quality of cut roses (*Rosa* x *alba*)

Abstract. Roses are known as a high-value commodity frequently used in various important events. However, they are susceptible to postharvest quality deterioration, which can affect their vase life and appearance. In this study, roses with a blooming stage of approximately 25–50% were immersed in melatonin and 6-benzylaminopurine (BAP) solutions at different concentrations. This research aims to analyze the effect of melatonin and BAP application on the freshness of cut roses. The parameters observed included flower vase life, flower wilting angle, increase in flower diameter, fresh weight, solution uptake, and chlorophyll content. The results showed that melatonin and BAP, applied individually or in combination, effectively extended the freshness of cut roses by up to eight days by maintaining solution uptake, flower quality, and chlorophyll content. This study provides new insights for farmers and researchers in improving the quality and longevity of cut roses through the use of plant hormones, particularly cytokinin.

Keywords: Cytokinin · Melatonin · Postharvest · Quality · Rose

Submitted: 17 June 2025, Accepted: 10 August 2025, Published: 14 August 2025
DOI: https://doi.org/10.24198/kultivasi.v24i2.62477

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Putri AT, Mubarok S, Budiarto R. 2025. The effect of melatonin and 6-Benzylaminopurine application on the post-harvest quality of cut roses (*Rosa* x *alba*). Jurnal Kultivasi, 24 (2): 177-184.

ISSN: 1412-4718, eISSN: 2581-138x

Introduction

Ornamental plants, particularly roses (*Rosa* x *alba*), have become a high-value commodity around the world. Roses are known for their beauty, color, and fragrance, making them one of the most popular ornamental plants (Bilad, 2021). Roses not only have aesthetic value but also significantly contribute to the economy and create opportunities for cultivators (Suparyana *et al.,* 2022). One of the common innovations in rose cultivation is cut roses, as they are widely used in various important events such as weddings and traditional celebrations (Abbas et al., 2024).

Some ornamental plants may experience a loss of quality due to various factors such as wilting or abscission of leaves and petals (Lamsal, 2024). Furthermore, water availability, light quality, ethylene, temperature, and humidity can lower cut flower quality (Verdonk et al., 2023). Environmental factors and proper Treatments have a big impact on the quality of ornamental plants. Cutting flower stems causes oxidative damage, resulting in excess production of reactive oxygen species (ROS). During post-harvest quality degradation of cut roses, ROS levels increase sharply and are accompanied by activities related to the antioxidant system (Jing & Li, 2015).

In response to these challenges, the application of melatonin (MT) and 6-benzylaminopurine (BAP) in cut roses has gained considerable attention from researchers and growers alike. Melatonin, known as a powerful antioxidant, plays an important role in plant aging by reducing oxidative stress and increasing the activity of antioxidant enzymes. This process helps maintain cell integrity and extends the vase life of flowers, and protects the plant from harmful reactive oxygen (Liang et al., 2015; Xu et al., 2019). In a study conducted by Mazrou et al. (2022), it was shown that melatonin with a concentration of 0.2 mM increased the activity of CAT, APX, and GR enzymes until the 10^{th} day in carnation flowers. Based on this study, melatonin delayed carnation aging and extended vase life by maintaining the initial level of fresh weight, membrane stability index, bioactive compounds, and antioxidant activity. This is supported by research from Wang et al. (2024), which found that a 50 µM concentration of melatonin was effective in preserving the shelf life of peony flowers for up to seven days during storage.

Meanwhile, 6-benzylaminopurine application in cut roses can prevent wilting and maintain flower quality by delaying leaf senescence and inhibiting chlorophyll degradation during storage (Man et al., 2016; Zhou et al., 2023). A study conducted by Lone et al. (2021) showed that the application of BAP at a concentration of 50 µM resulted in the best increase in flower vase life and significantly improved the post-harvest performance of calendula cut flowers. Based on the study, cut flowers stored in a 50 µM BAP solution showed the longest vase life, reaching 13 days. This occurs because cytokinins prolong vase life by enhancing photosynthetic output directed toward developing flower buds, which improves water uptake and promotes greater turgidity in the petal tissues (Singh & Tiwari, 2021).

This study was conducted with the aim of analyzing the effect of melatonin and 6-benzylaminopurine on the freshness of cut roses and determining the best concentration of melatonin and 6-benzylaminopurine to maintain the vase life. This study examines the potential benefits of melatonin and 6-benzylaminopurine on cut roses, offering insights for researchers and growers to enhance cut rose production quality and vase life.

Materials and Methods

Research Site. This research was conducted from April to June 2024. The location is situated at the Laboratory of Post-Harvest Analysis of Horticultural Crops, Faculty of Agriculture, Universitas Padjadjaran, Jatinangor District, Sumedang Regency, West Java Province.

Materials. The materials used were cut roses, *Rosa alba* cv. Avalanche with blossom criteria of ± 25–50%, 1% sucrose solution, melatonin (from Nutrilabs), 6-benzylaminopurine (from PhytoTech Lab), methanol, ethanol, HCl, and distilled water solutions. The equipment comprised 460 mL glass bottle, plastic container, cutting scissors, bow, measuring cup, vernier caliper, analytical balance, UV-VIS spectrophotometer, cuvette, volumetric flask, pipette, falcon tube, mortar, magnetic stirrer, and thermohygrometer.

Research Methods. This study used a simple completely randomized design (CRD) with nine treatments, consisting of a control that used sucrose solution (A), melatonin 0,1 mM (B), melatonin 0,5 mM (C), BAP 25 μM (D), BAP 50 μM (E), Melatonin 0,1 mM + BAP 25 μM (F), Melatonin 0,1 mM + BAP 50 μM (G), Melatonin 0,5 mM + BAP 25 μM (H), and Melatonin 0,5 mM + BAP 50 μM (I). There were 9 Treatments with 3 replications, where each treatment consisted of 2 stems for flower freshness observation and 2 stems for deconstruction; the total experiment consisted of 108 flower stems.

Observation variables. The observation parameters consisted of vase life (d), flower angle petals (°), flower diameter increment (mm), flower fresh weight (g), solution uptake (ml), and chlorophyll content (mg/g). Vase life was measured on experimental flowers daily until they deteriorated or lost their freshness. Signs of deterioration included fading color, browning, and changes in the flower curl angle (Mubarok et al., 2018). Flower angle petals were measured daily using a bow, and if the petal angle is more than 120°, the flower is considered deteriorated (Mubarok et al., 2018).

Flower diameter was measured every two days using a caliper, and the increase in diameter was calculated by subtracting the data on day n after treatments from the data on day 0 after treatments (Mubarok et al., 2018). The formula used is:

$$D = \frac{d1 + d2}{2}$$

Description:
D = average diameter
d_1 = longest diameter (mm)
d_2 = shortest diameter (mm)

The study measured the fresh weight of flowers using analytical scales before they lost their freshness or wilted. The solution uptake was calculated by comparing the initial and final amount of solution after the flowers were immersed. The experiment was conducted at the beginning and end of the experiment (Adam & Eldeeb, 2021). The formula used is:

Solution uptake = Amount of initial solution - Amount of final solution

Chlorophyll content was measured on the 4th day after treatments, and the top leaf sample was crushed, extracted with ethanol, and incubated for 15 minutes. The supernatant solution was then measured for absorbance using a UV-VIS spectrophotometer at 647, 664, and 700 nm (Lezoul et al., 2022). Chlorophyll content was calculated using the formula:

$$CC = (5.24 \times (A_{664} - A_{700}) + (22 \times A_{647} - A_{700}))$$

Description:
CC = Chlorophyll content (mg/g)

Data Analysis. Data analysis was conducted using analysis of variance (ANOVA) with a linear model of a completely randomized design (CRD) at a significant level of 5% and followed by Duncan's Multiple Range Test at the 5% as a post hoc test.

Result and Discussion

Vase Life. The study analyzed the length of flower freshness on experimental roses from the first day until they lost their freshness. Treatments H, D, and E had the longest freshness, reaching 8 days, but were significantly different from treatments A, which only reached 5 days. The single and combination treatments of BAP concentrations, MT 0.5 mM + BAP 25 μM, significantly impacted flower freshness. Therefore, the provision of BAP, both single and a combination of BAP and melatonin in the soaking solution, can maintain freshness in cut roses (Table 1).

Melatonin, when applied at a concentration of 0.2 mM, can extend the vase life of carnation flowers by maintaining water relations and antioxidant defense systems (Mazrou et al., 2022). This helps reduce oxidative damage and regulates stomatal opening. Melatonin increases the activity of Superoxide Dismutase (SOD) and Ascorbate Peroxidase (APX) enzymes, which reduce hydrogen peroxide (H_2O_2) radicals. H_2O_2 is the main reactive oxygen species (ROS) in plants, as it can easily penetrate the cell wall and trigger stomatal closure (Jensen et al., 2023). Wang et al. (2024) reported that 50 μM melatonin extended the shelf life of peony flowers by preserving water and inhibiting early opening through modulating ethylene and ABA. Water loss accelerates the aging of cut flowers as it reduces quality, so water absorption must exceed water loss (Chen et al., 2018). This

ISSN: 1412-4718, eISSN: 2581-138x

research supports the use of melatonin in preserving the health and longevity of plants.

Lone et al. (2021) found that applying BAP at a concentration of 50 µM increased flower vase life by delaying flower aging by increasing water absorption, metabolic content, reducing ethylene hormone production, and preventing membrane lipid peroxidation. Cytokinins provide more photosynthetic products to developing flower buds, increasing water absorption and making the crown tissue more turgid (Singh & Tiwari, 2021). Based on research conducted by Zhou et al. (2023) showed that BAP application can activate aging-related transcription factors and increase gene expression of antioxidant enzymes. Cytokinin increases the activity of antioxidant enzymes, helping to protect cells from excess ROS by converting superoxide ions into water and oxygen (Ul Haq et al., 2022). BAP also increases the enzyme invertase, which delays plant aging (Hönig et al., 2018).

Flower Diameter Increment. The study analyzed the increase in flower diameter every two days; treatments C, D, E, F, and H had the largest change, with values ranging between 12.3 (H) – 16.2 (D), compared to treatment A (Control) with a value of 6.1 mm (Table 1). The flowers were harvested in half-bloom condition, and the flower crown would bloom one by one until perfect bloom. Treatments with flowers soaked in BAP and melatonin solution lasted longer than the control. This is due to BAP's role in cell division and elongation, which increases the growth and expansion of plant tissues, including flower crowns (Lezoul et al., 2022). The availability of sufficient carbohydrates supports the respiration process, allowing flowers to bloom completely (Amiarsi & Tejasarwana, 2016). BAP application can increase flower diameter due to the accumulation of sugars in flower tissue, which increases turgidity through endosmosis, resulting in larger flower size (Ul Haq et al., 2022). Flower decay occurs more rapidly when water loss exceeds water absorption, resulting in plasmolysis. Treatments with BAP can increase water absorption, ensuring the plant's condition remains turgid.

Morphological analysis of cut flowers showed that exogenous application of melatonin increased flower diameter and water absorption (Yang et al., 2025). The rate of change in flower diameter is an important indicator to assess the blooming process and aging rate in cut flowers. Based on research conducted by Wang et al. (2024) on the 'Qi Hua Lu Shuang' variety, melatonin treatments showed an increase in maximum flower diameter by 5.88% and 11.76% respectively, compared to the control group. Melatonin delays the change in water balance value from positive to negative by regulating the opening and closing of stomata so that a balance between transpiration and water absorption is achieved (Wu et al., 2025).

Flower Fresh Weight. Fresh weight measurements were taken on day zero and the last day of storage, and a decrease in fresh weight is characteristic of flower senescence. Treatments B, D, E, F, G, and H had the largest values, ranging between 13.3 (F, G) – 18.3 (D). The lowest average was in the control (6.7 g). The provision of BAP solution, both single and combined with melatonin, can significantly influence the fresh weight of flowers (Table 1).

Table 1. The effect of melatonin and 6-benzylaminopurine application on flower freshness, flower diameter increment, fresh weight, and solution uptake of cut rose cv. Avalanche

Code	Treatment	Vase life (DAT)	Flower Diameter Increment (mm)	Fresh Weight (g)	Solution Uptake (ml)
A	Control	5.3 a	6.1 a	6.7 a	48.3 a
B	Melatonin 0.1 mM	7.3 bcd	9.3 ab	15.0 bc	73.3 de
C	Melatonin 0.5 mM	6.7 b	13.1 bc	11.7 ab	68.3 cd
D	BAP 25 µM	8.3 de	16.2 c	18.3 c	85.0 f
E	BAP 50 µM	8.0 cde	14.4 bc	15.0 bc	73.3 de
F	Melatonin 0.1 mM + BAP 25 µM	7.0 bc	13.3 bc	13.3 bc	66.7 bcd
G	Melatonin 0.1 mM + BAP 50 µM	7.3 bcd	9.2 ab	13.3 bc	63.3 bc
H	Melatonin 0.5 mM + BAP 25 µM	8.7 e	12.3 abc	16.7 bc	80.0 ef
I	Melatonin 0.5 mM + BAP 50 µM	6.7 b	9.1 ab	11.7 ab	58.3 b

Note: Means followed by the same lowercase alphabet in the same column are not significantly different based on Duncan's multiple range test at 5 %.

Table 2. The effect of melatonin and 6-benzylaminopurine application on the cut flower angle petals of rose cv. Avalanche from day 0 to day 8.

Code	Treatment	Flower Angle Petals (°)				
		day-0	day-2	day-4	day-6	day-8
A	Control	36.7 abc	70.0 d	113.3 d	120.0 c	120.0 b
B	Melatonin 0.1 mM	43.3 cd	56.7 c	86.7 c	116.7 bc	120.0 b
C	Melatonin 0.5 mM	46.7 d	56.7 c	83.3 c	120.0 c	120.0 b
D	BAP 25 µM	30.0 a	33.3 a	56.7 ab	76.7 a	113.3 b
E	BAP 50 µM	30.0 a	36.7 a	53.3 a	76.7 a	113.3 b
F	Melatonin 0.1 mM + BAP 25 µM	33.3 ab	43.3 ab	73.3 bc	103.3 b	120.0 b
G	Melatonin 0.1 mM + BAP 50 µM	43.3 cd	53.3 bc	80.0 c	103.3 b	116.7 b
H	Melatonin 0.5 mM + BAP 25 µM	40.0 bcd	43.3 ab	56.7 ab	73.3 a	106.7 a
I	Melatonin 0.5 mM + BAP 50 µM	43.3 cd	56.7 c	83.3 c	120.0 c	120.0 b

Note: Means followed by the same lowercase alphabet in the same column are not significantly different based on Duncan's multiple range test at 5 %.

Ali et al. (2021) found that the application of BAP produced the highest fresh weight of flowers compared to the control (5.2 g). This is due to BAP is a cytokinin hormone that stimulates cell division and growth, thus increasing the fresh weight of flowers. When damage occurs to the cell membrane, BAP could maintain the stability of the cell membrane, thereby reducing the occurrence of lipid peroxidation (Cubría-Radío et al., 2017).

Research conducted by Hosseini et al. (2025) showed that the administration of 200 µM melatonin produced the highest fresh weight compared to the control. The study found that melatonin maintained water balance during vase storage, a crucial balance between organ dehydration and water absorption index for maintaining cell turgor in cut flowers. Membrane stability by melatonin plays a role in maintaining high tissue water content, enhancing antioxidant defense, and reducing lipid peroxidation, which is significantly affected by stress factors such as aging (Lezoul et al., 2022).

Solution Uptake. Observations were conducted at the beginning and end of the experiment. Results showed that treatments with different types and concentrations of solutions had a significant effect on absorption. Treatments D and H had the highest absorption of 85 ml (D), while treatment H had an absorption of 80 ml. Treatment A (Control) had the lowest absorption at 48.3 ml (Table 1). This aligns with research by Saptorini et al. (2015), which found that the application of BAP caused orchid flower cells to become hypotonic, allowing water to enter and expand. This is an optimal condition for plant cells, as reduced water absorption can accelerate wilting and decrease cell turgor (Nento et al., 2017). Lower transpiration in petals and other plant tissues can also influence solution absorption (Lezoul et al., 2022). Water absorption is crucial in preventing solution dehydration caused by transpiration.

Hosseini et al. (2025) reported that decreased solution uptake in control plants was due to membrane damage, ion leakage, and increased respiration that accelerated dehydration. Melatonin reduces water loss and extends postharvest life in ornamental plants (Wang et al., 2024). The mechanism of melatonin administration in absorbing solutions by reducing ion leakage, balancing hormones, inhibiting ROS production, increasing water absorption, and stimulating protein synthesis (Zhou et al., 2023).

Flower Angle Petals. The angle between petals and stem indicates deterioration in cut flowers, while flower senescence is characterized by wilted petals and an increased stem angle. The flower angle must reach over 120° to indicate the flower is no longer fresh (Mubarok et al. 2018).

Table 2 demonstrates that a combination of BAP and melatonin can maintain the flower angle, with treatment H having the smallest flower angle (106.7°) on the 8^{th} day. Melatonin and 6-benzylaminopurine application can significantly maintain the decay of cut roses, characterized by a smaller droop angle. In line with research conducted by Hu et al. (2023) that the concentration of 0.1 mM melatonin can reduce damage characterized by wilting in

ISSN: 1412-4718, eISSN: 2581-138x

carnation. Melatonin application also affects water balance, as a decrease in water absorption and loss can cause cut flowers to wilt (Wang et al., 2024; Yu et al., 2024). Melatonin plays a role in increasing aquaporin activity, optimizing water distribution in plants, and maintaining cell turgor. Overall, melatonin can help maintain the angle of cut roses.

Research by Saptorini et al. (2015) found that a 20 ppm dose of BAP can inhibit flower bud wilting in cut flowers of orchid Vanda cv. Douglas. BAP, a cytokinin hormone, regulates the plant life cycle, including flowering, increasing productivity, and reducing wilting. The cytokinin hormone contains nitrogen compounds that play a role in optimizing the synthesis of amino acids and proteins. Amino acids and proteins are utilized by plants for leaf growth (Ayuningtias et al., 2024). It also inhibits ethylene production by inhibiting the enzyme 1-aminocyclopropane-1-carboxylic acid (ACC) synthase, which is crucial for aging and flower senescence. Combining BAP and melatonin can maintain and inhibit flower senescence.

Chlorophyll Content. Observations of leaf chlorophyll content were conducted on the fourth day while the flowers were still fresh. According to Table 3, treatment D had the highest total chlorophyll content at 31.3 mg/g, which was not significantly different from treatment E at 30.4 mg/g, whereas treatment A (control) had the lowest content at only 10.7 mg/g (Table 3). This indicates that treatment D had a significant effect on chlorophyll content and was significantly different from the control solution. The high chlorophyll content in treatments D and E is due to the important role of BAP compounds in inhibiting chlorophyll degradation (Man et al., 2016). Based on research conducted by Rasouli et al. (2015) cut flowers treated with 25 and 75 µM cytokinin showed significant differences in chlorophyll content compared to the control. This occurs because chlorophyll plays a crucial role in photosynthesis; the higher the chlorophyll content, the greater the photosynthetic output, which is then utilized by the plant for growth. Photosynthesis in plants depends on light-dependent reactions, chlorophyll and other pigments capture light energy to drive redox reactions in the electron transport chain in the thylakoid membrane of chloroplasts (Guo et al., 2023). In a study conducted by Yan et al. (2021), it was shown that higher chlorophyll content increased photosynthesis efficiency and increased carbohydrate production. Chlorophyll changes are closely related to photosynthesis; exogenous application or genetic overproduction of cytokinins can significantly delay senescence (Hönig et al., 2018).

Table 3. The effect of melatonin and 6-benzylaminopurine application on the chlorophyll content of cut rose |Cv. Avalanche

Code	Treatment	Chlorophyll Content (mg/g)
A	Control	10.7 a
B	Melatonin 0.1 mM	15.1 ab
C	Melatonin 0.5 mM	17.6 bc
D	BAP 25 µM	31.3 d
E	BAP 50 µM	30.4 d
F	Melatonin 0.1 mM + BAP 25 µM	13.5 ab
G	Melatonin 0.1 mM + BAP 50 µM	11.8 a
H	Melatonin 0.5 mM + BAP 25 µM	21.1 c
I	Melatonin 0.5 mM + BAP 50 µM	11.0 a

Note: Means followed by the same lowercase alphabet in the same columnares not significantly different based on Duncan's multiple range test at 5 %.

Conclusion

The application of melatonin and 6-benzylaminopurine solution, applied individually or in combination, significantly influenced the freshness of cut roses compared to the control. The 25 µM BAP treatments showed the best results in maintaining vase life, maintaining fresh weight, increasing flower diameter growth, total chlorophyll content, and enhancing solution uptake.

Acknowledgment

The authors express their gratitude to Universitas Padjadjaran for providing support and resources that facilitated our reference study on the effects of melatonin and 6-benzylaminopurine application on cut roses.

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