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PHYSIOLOGICAL AND ANATOMICAL STUDIES ON THE BENDING IN ROSE AND GERBERA CUT FLOWERS TREATED WITH SILVER NANOPARTICLES AND THYME OIL

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ABSTRACT: Bent neck or stem bending is the most essential problem of some cultivars of rose and gerbera cut flowers in the postharvest stage, as it decreases vase life as well as its commercial value. This research was conducted to evaluate the effectiveness of silver nanoparticles (SNPs) at 9 mg/l, 0.2 ml/l thyme oil and 200 mg/l 8-hydroxyquinoline sulfate (8-HQS) as holding solutions and 20 mg/l silver nanoparticles as a pulsing solution compared to distilled water (control) in delaying bent neck in *Rosa hybrida* cv. Avalanche and stem bending in *Gerbera jamesonii* cv. Julia cut flowers (these are more cultivars sensitive to bending). Our results indicated a positive effect of SNPs and thyme oil on delaying the bent neck and decreasing bacterial counts. The flowers placed in 9 mg/l SNPs significantly delayed the bending, reduced the number of bacteria, improved water relations, maintained a higher lignin percentage, and extended longevity in both flowers compared to control and other treatments. The results of scanning microscopy pictures of the bending area indicated that 9 mg/l SNPs prevented vessel blockage and maintain anatomical structures such as epidermis cells, parenchyma cells, and vascular bundles in both cut rose and gerbera flowers. The results indicated that SNPs are superior to thyme oil in improving the quality, prolonging vase life, and delaying the bending of rose and gerbera cut flowers.

Keywords: Bent neck, stem bending, postharvest, silver nanoparticles, thyme oil, rosa, gerbera.

INTRODUCTION

Rosa (*Rosa hybrida*, L.) family Rosaceae and gerbera (*Gerbera jamesonii*, Bolus Ex Hook) family Asteraceae are among the most popular cut flowers. They are among the top ten most important cut flowers of economic importance in the international market. Neck or stem bending is one of the most important problems which cause the short vase life in the cut flowers of several rose and gerbera cultivars, which affects their commercial value (Perik *et al*., 2014; García-González *et al*., 2022; El-Shawa *et al*., 2023). Bending is due to bacteria in the preservation solution, which causes the accumulation of microorganisms at or within the stem end and vascular blockages that prevent water from reaching the flower (van Meeteren, 1978; Steinitz, 1983; Van Meetern *et al*., 2001; Perik *et al*., 2014; Lear *et al*., 2022). Other factors induce stem bending during the vase life period. Bending is due to the wilting of the pedicle tissue, which occurs when water uptake decreases than transpiration, which leads to water loss from the flower stem, especially in the bent area in gerbera (Perik *et al*., 2012). Also, bending due to a reduction of mechanistic power in the upper portion of the stems is caused by the lack in the thickness of sclerenchyma cylinder in this area and low stem lignin levels (Ferrante *et al.*, 2007; Perik, *et al.*, 2012; Perik *et al.*, 2014; Ge *et al.*, 2019; Cheng *et al.*, 2020). To preserve the best quality of cut flowers after harvest and reduce vase life problems, the development of postharvest treatments is essential. Rose and gerbera-cut flowers usually require vase solutions containing a carbohydrate supply and antimicrobial materials to increase vase life. Sucrose generally supports the essential operations for extending the vase life of flowers, such as keeping the structure and functions of mitochondria, maintaining water balance by regulating transpiration, and increasing water uptake (Nowak and Rudnicki, 1990). To reduce bending, antimicrobial compounds namely, 8-hydroxyquinoline sulfate (8-HQS), silver nanoparticles and thyme oil were examined during this investigation. 8-hydroxyquinoline sulfate (8-HQs) is a very important antimicrobial substance used in vase solutions as it increases the vase life (van Doorn, 1998).

Silver nanoparticles (SNPs) had an efficient antibacterial activity that leads to extending the vase life of the cut flower (Solgi, 2014). It acts as an effective antimicrobial agent due to the high surface area-to-volume ratio and their physical and chemical properties (Rai *et al.*, 2012; Nazari and Saba, 2017; Rahman *et al*., 2019; Rashidiani *et al*., 2020). The antimicrobial action of SNPs can be explained by the adhesion of SNPs to microbial cells, breakthrough inside the cells and the destruction of intracellular structures (vacuoles, ribosomes, and mitochondria) and biomolecules (lipids, protein, and DNA), generation of free radicals and ROS, which cause oxidative stress and cellular toxicity, and modification of microbial signal transmission pathways (Dakal *et al.*, 2016; Mikhailova, 2020). Silver nanoparticles break through the cells of bacteria, damage the respiration chain, and cause disorder in cell division, eventually, cell death (Azarhoosh *et al*., 2021). Hassan *et al.* (2014) reported that SNPs significantly prolonged the vase life and prevented microbial growth in the vase solution while maintaining chlorophyll content, relative water content, relative fresh weight as well as membrane stability index. In addition, SNPs decreased ethylene production, stomatal conductance, malondialdehyde (MDA) and hydrogen peroxide (H_2O_2) production while superoxide dismutase (SOD), catalase (CAT), and peroxidase (POX) activities were increased. El-Shawa *et al.* (2019) showed that SNPs enhanced the postharvest quality and inhibited the growth of bacteria in the stem end and vase solutions of cut gerbera. SNPs prolonged the vase life and improved the water relations of cut rose (Ha *et al.*, 2021).

Essential oils are organic natural materials, safe, and environmentally friendly. They are also used as alternatives to chemicals in vase solutions due to their strong antimicrobial properties. Essential oils are secondary metabolites of plants and have been used mainly for their various biological properties as antimicrobial and antioxidant (Basak and Guha, 2018). The essential oils are chemically a complex mixture of terpenes (sesquiterpenes, monoterpenes hydrocarbons, and their oxygenated derivatives, such as aldehydes, alcohols, ethers, esters, phenols, ketones, and oxides), and Phenylpropanoids and phenolic compounds (Bakkali *et al.*, 2008). The role of essential oils as antimicrobial agents can be due to these components. The essential oil mode of action includes the interaction of its hydrophobic components with the lipids of the cell membrane of the microorganism, leading to metabolic damage and cell death (Silva *et al.*, 2021). Also, the antimicrobial effect of essential oils is due to their ability to disrupt cell walls and cytoplasmic membrane, and cytoplasm coagulates, leading to spoilage of cellular organelles and leakage of macromolecules (Hyldgaard *et al*., 2012). Mallahi *et al.* (2018) showed that Shirazi thyme oil increased the vase life, relative fresh weight, and water uptake of gerbera-cut flowers. Thyme oil prolonged the vase life and improved water relation and relative fresh weight, as well as increased the chlorophyll a, b, and carotenoids contents, decreased the bacterial growth, showed xylem vessels in their prime state compared with the control (El-Sayed and El-Ziat, 2021). Thymol prolongs vase life and fresh weight and improves the solution uptake of gerbera-cut flowers (Babarabie *et al.,* 2017).

Rosa hybrida cv. Avalanche and *Gerbera jamesonii* cv. Julia are more sensitive to bending. As bending is a primary reason for the short vase life and quality of cut flowers, which menace flower producers and consumers. So, this study aimed to examine the impact of SNPs and thyme oil as new compounds compared with traditional compounds such as 8-HQS in delaying the bending of rose and gerbera cut flowers by evaluating several factors associated with bending. We selected these treatments from a previous study for their superiority in maintaining the quality characteristics of gerbera flowers, according to El-Shawa *et al.* (2019).

MATERIALS AND METHODS

Plant material:

The present research was done during the 2020 and 2021 seasons. Uniform cut flowers of *Rosa hybrida* cv. Avalanche and *Gerbera jamesonii* cv. Julia were obtained from commercial greenhouses located in Giza Governorate, Egypt. Uniform flowers were harvested early in the morning at the commercial stage of cutting when the sepals start to reflex for rose and (when pollen grains appear in the outer row of ray flowers for gerbera). Flowers were kept with ice gel bags inside the ice box and transported within 3 h of harvesting to the laboratory at Mansoura Horticulture Research Station, Horticulture Research Institute, Agriculture Research Center, Egypt. In the laboratory, uniform flowers are used. All the leaves of cut rose were removed, except for the three uppermost leaves on the stem. Flower stems of rose and gerbera were re-cut under distilled water to approximately 50 cm in length. Cut roses were placed individually in a graduated cylinder (100 ml), but gerbera flowers were placed in glass bottles (250 ml) both filled with designated solutions.

Experimental solutions:

The designated solutions were as follows:

1. Control (distilled water).
2. 8-Hdroxyquinoline sulfate (8-HQS) at 200 mg/l + 20 g/l sucrose for rose and 30 g/l sucrose for gerbera.
3. Thyme oil at 0.2 ml/l + 20 g/l sucrose for rose and 30 g/l sucrose for gerbera (plus 0.1 ml/l tween-20).
4. SNPs at 9 mg/l + 20 g/l sucrose for rose and 30 g/l sucrose for gerbera.
5. SNPs at 20 mg/l for 24 h as pulsing treatment, after that the cut flowers were placed in 8-HQS at 200 mg/l + 20 g/l sucrose for rose and 30 g/l sucrose for gerbera as holding solutions to complete their vase life.

The preparation of silver nanoparticles (SNPs) was done according to Hebeish *et al.* (2013).

Throughout the experiment, the flowers were left in a ventilated laboratory at 22 °C ± 2 °C, 60 ± 5% RH, and light by using cool white fluorescent lamps (1500 Lux) for 24 hours.

Data recorded:

1. Bent neck or bending stem score:

The bending was specified every 2 days by measuring the angle between the major stem and the stem just below the flower capitulum. The flowers were rated as follows: 0 for bending to 15°; 1 for bending between 15° and 25°; 2 for bending between 25° and 65°; 3 for bending between 65° and 90°; and 4 for flowers bending more than 90° according to Çelikel and Reid (2002).

2. Water relations:

Water uptake (g/flower) was measured every 2 days during the vase life periods by recording decreases in solution weight after correction with the evaporation rate of the same solution without cut flowers. Also, transpiration loss (g/flower) was calculated as the difference between the change in fresh weight and the amount of water uptake every 2 days. Moreover, water balance (± g/flower/2 days) was calculated by applying the following formula:

Water balance = water uptake - transpiration loss.

3. Bacterial counts:

The number of bacteria Log_{10} (CFU/ml) in vase solutions was recorded on the 8th day of treatments, according to the method described by De Witte and Van Doorn (1988).

4. Lignin (%):

Lignin (%) in the stem from the bending area was determined according to the method described by A.O.A.C (2000).

5. The vase life (days):

The vase life (days) was estimated by calculating the number of days from the beginning of the postharvest treatments to the day when the petals wilting at 50%, flower bending, petals falling, or showed discolouration for both rose and gerbera cut flowers.

6. Anatomical studies:

The samples of the rose were 5 mm in length and were taken from the pedicles just below the head of the flower on the 12th day from the start of treatments in the second season in rose. In gerbera, the samples were also 5 mm in length but were taken 10 cm from below the head of the flower on the 8th day from the start of treatments. Slides were investigated by light microscopic and photography, as described by Nassar and ElSahhar (1998).

4. Experimental design and statistical analysis:

The five preservative treatments were arranged in a randomized complete block design (RCBD). Both cut flowers were analyzed separately. Each treatment had three replicates each of which contained 9 individual flowers. The experiment was repeated twice. Analysis of variance (ANOVA) for collected data was performed using CoStat computer software version 6.303. Treatment means were compared using the least significant difference (LSD) at a 5% significance level according to (Gomez and Gomez, 1984).

RESULTS

1. Bent neck or bending stem score:

Illustrated data in Figures (1 and 3A) shows that SNPs treatments and thyme oil significantly decreased the bent neck of *Rosa hybrida* cv. Avalanche until the 12th day compared with 8-HQS and control treatment. The cut flowers treated with 9 mg/l SNPs had bent neck delayed until the 12th day from the beginning of the investigation compared with all other preservative treatments. Descending order for the minimum values of bent neck score were observed for preservative solutions containing 9 mg/l SNPs holding solution, 20 mg/l SNPs pulsing solution, then thyme oil was used, respectively. The maximum value of the bent neck was observed in the control treatment in the two seasons. In the context of the presented data, it should be underlined that the application of SNPs and thyme oil had significant effects on stem bending delay of *Gerbera jamesonii* cv. Julia cut flowers when compared to 8-HQS and the control (Figures, 2 and 3B). In general, gerbera cut flowers that held in the preservative solution contained SNPs at 9 mg/l had no stem bending until the 8th day of the starting treatment, while the flower stem of control treatment started bending slightly from the 4th day, and this bending increased sharply on the 8th day.

2. Water relations:

a. Water uptake:

As shown in Figure (4) the highest values of solution uptake were recorded by

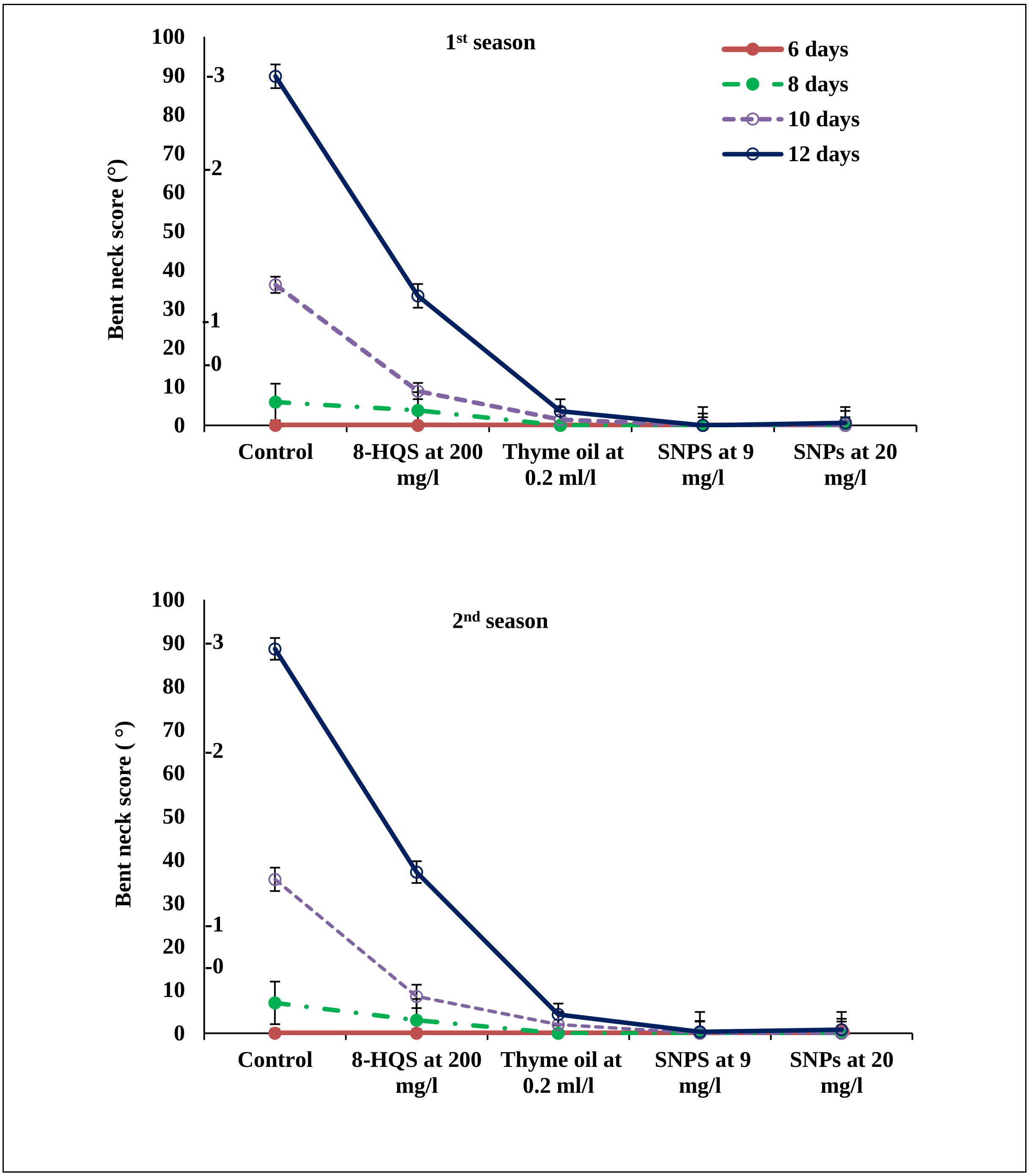

Fig. 1. Impact of 8-HQS, thyme oil, and SNPs treatments during 6th, 8th, 10th, and 12th day on the bent neck (°) through the vase life interval of *Rosa hybrida* L. cv. Avalanche cut flowers in the 2020 and 2021 seasons.

LSD (5%) of the 1st season; 8 days=4.72, 10 days=2.09, 12 days= 3.05

LSD (5%) of the 2nd season; 8 days=4.91, 10 days= 2.70, 12 days= 2.51

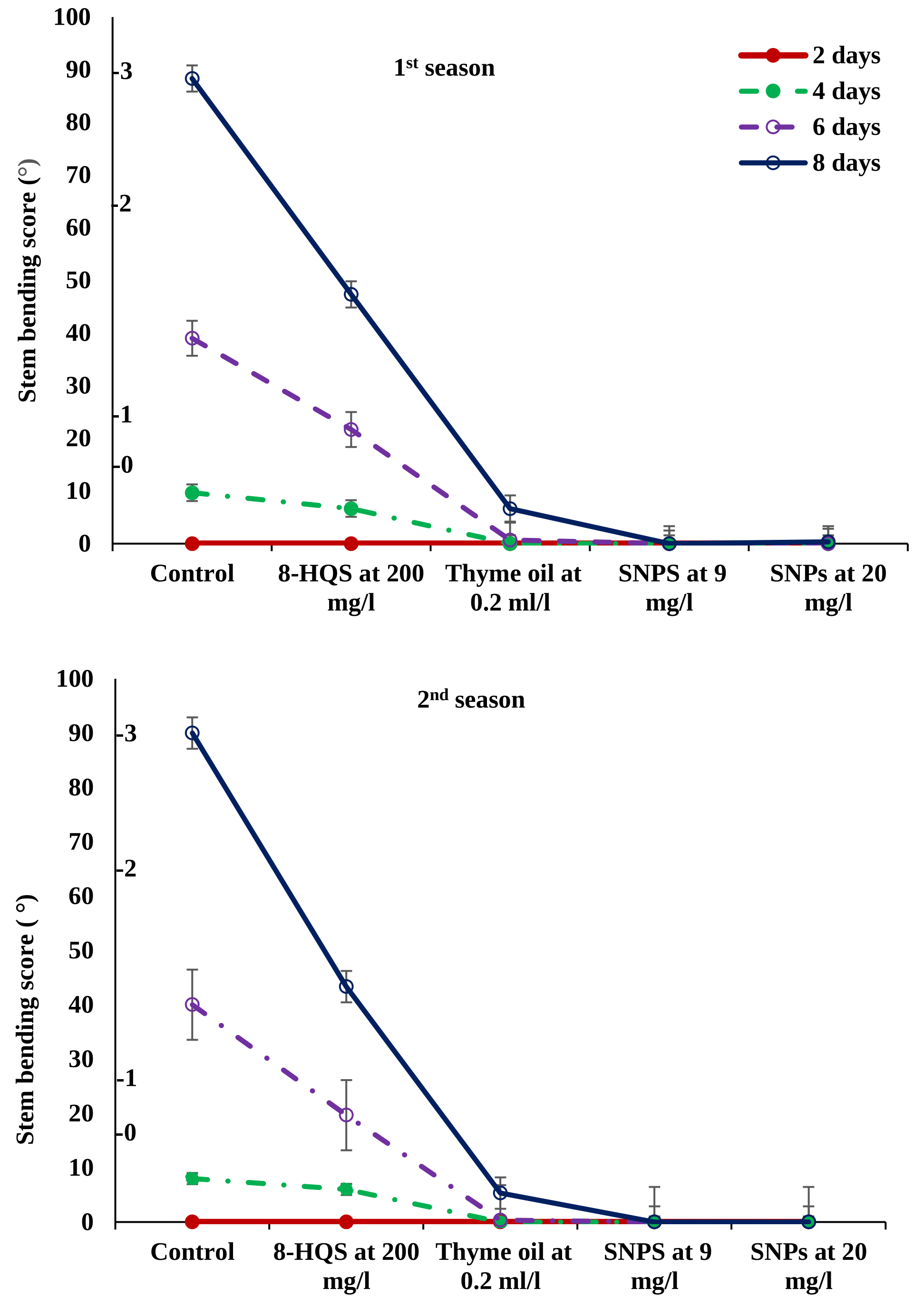

Fig. 2. Impact of 8-HQS, thyme oil, and SNPs treatments during 2nd, 4th, 6th, and 8th day on the stem bending (°) through the vase life interval of *Gerbera jamesonii* cv. Julia cut flowers in the 2020 and 2021 seasons.

LSD at (5%) of the 1st season; 4 days=1.58, 6 days=3.32, 8 days=2.49

LSD at (5%) of 2nd season; 4 days=1.03, 6 days=6.46, 8 days=2.90

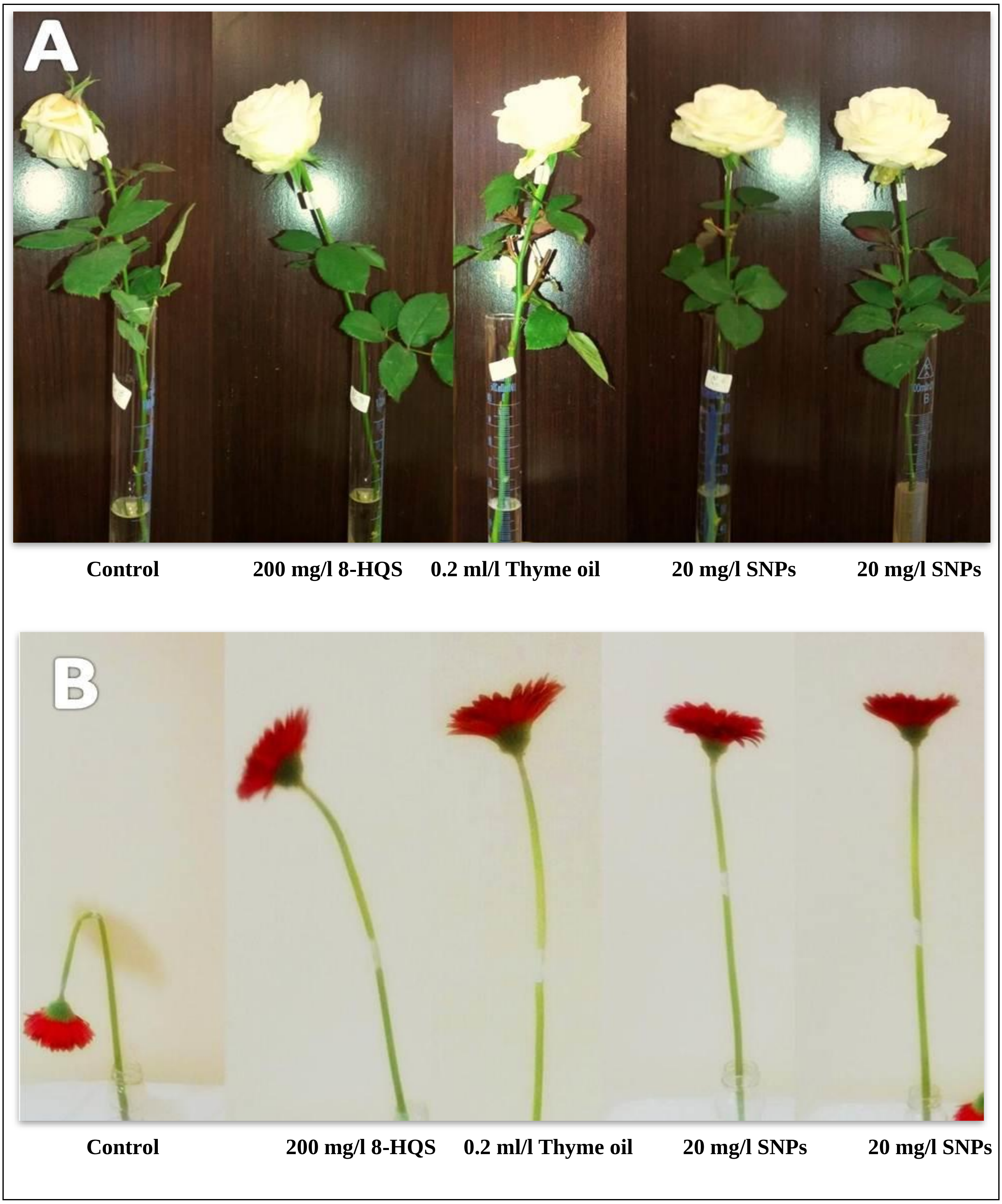

Fig. 3. Impact of 8-HQS, thyme oil, and SNPs on the bent neck of *Rosa hybrida* L. cv. Avalanche (A) on 12th day and stem bending of *Gerbera jamesonii* cv. Julia cut flowers (B) on the 8th day.

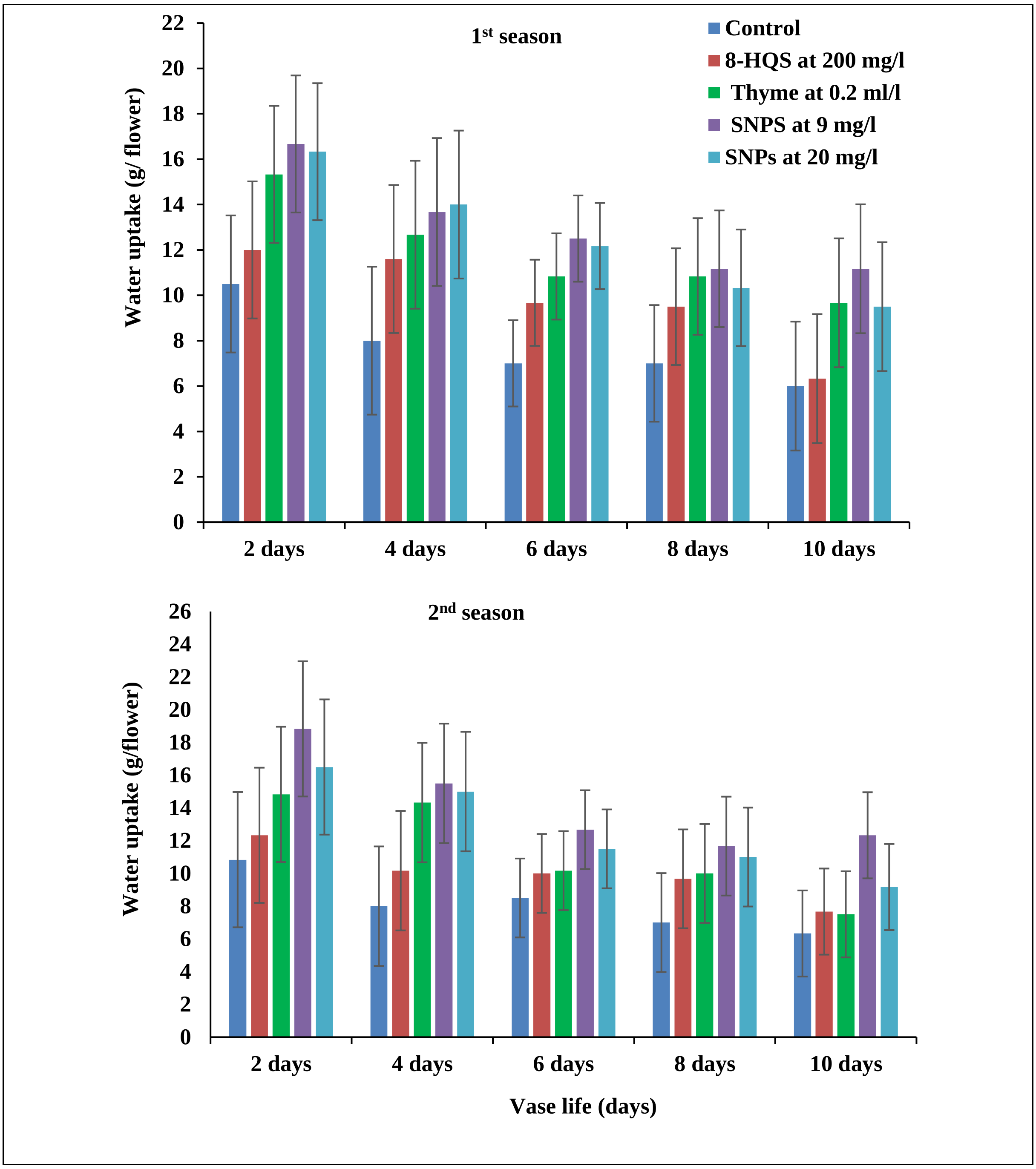

Fig. 4. Impact of 8-HQS, thyme oil, and SNPs on water uptake (g/flower) every 2 days through the vase life interval of *Rosa hybrida* L. cv. Avalanche cut flowers in the 2020 and 2021 seasons.

LSD at 5% of the 1st season; 2 days =3.02, 4 days=3.26, 6days=1.9, 8 days=2.57, 10 days= 2.84
LSD at 5% of the 2nd season; 2 days =4.13, 4 days=3.65, 6days=2.41, 8 days=3.02, 10 days= 2.63

rose cut flowers held in 9 mg/l SNPs preservative solution. Moreover, treatments that included 20 mg/l SNPs pulsing solution or thyme oil holding solution had the best values of solution uptake compared with the control treatment, which had the lowest values of water uptake during the longevity period in the two seasons. Data, illustrated in Figure (5) showed that the gerbera cut flowers treated with SNPs increased water uptake compared to other treatments and control. Also, gerbera cut flowers treated with thyme oil or 8-HQS recorded the best values of water absorption during vase life in both seasons compared with the control treatment which had a sudden decrease in absorption after the 4th day of the vase life. SNPs at 9 mg/l recorded the highest values of water uptake in the two seasons.

b. Transpiration loss:

It could observe from the data in Figure (6) that all treatments showed a similar trend for transpiration loss mentioned above in water uptake. SNPs treatments recorded the highest transpiration loss during the vase life periods of rose-cut flowers. It is clear from the data in Figure (7) that there were non-significant differences in transpiration loss between treatments on most days of the vase life period. The highest transpiration loss was recorded with 9 mg/l SNPs in both seasons of gerbera cut flowers.

c. Water balance:

Data in Figure (8) showed that the water balance of all treatments started to decline gradually from the 4th day of the vase life of rose cut flowers, but with different values between treatments. The water balance of the control flowers became negative after the 4th and 6th days in the two seasons, respectively, and continued to decrease until the end of the vase life period. Rose cut flowers held in 9 mg/l SNPs + 20 g/l sucrose maintained a more favorable water balance compared to other treatments and control. It is noticeable from the data in Figure (9) that during the two seasons, gerbera cut flowers treated with 9 mg/l SNPs as a holding solution or pulsing in 20 mg/l of SNPs exhibited positive water balance values up to the sixth day, after which they rapidly dropped. In addition, the aforementioned treatments outperformed the control treatment in terms of water balance throughout the longevity period in both seasons, which saw a rapid decline in water balance after the second day of vase life in both seasons.

3. Bacterial counts:

It is obvious that after the eighth day of treatment for rose and gerbera cut flowers, the vase solution of flowers treated with 9 mg/l SNPs had the lowest number of bacterial counts among all treatments, while the control treatment recorded a significantly higher number of bacteria colonies compared with all other treatments. The vase solutions fortified with 20 mg/l SNPs or 0.2 ml/l thyme oil treatments had fewer bacteria compared to both 200 mg/l 8-HQS and control treatments (Tables, 1 and 2).

4. Lignin content:

It was observed from Tables (1 and 2) that SNPs and thyme treatments significantly maintained higher levels of lignin than 8-HQS treatment in rose and gerbera cut flowers. However, SNPs treatments gained better than essential oils treatments and 9 mg/l holding solution was the most effective in maintaining the higher lignin percentage followed by 20 mg/l SNPs pulsing solution. The highest lignin percent was obtained by 9 mg/l SNPs holding solution while the lowest lignin percent was recorded with control.

5. Vase life:

As presented in Table (1), the most extended vase life of cut rose flowers (21.83 and 21.67 days, respectively in both seasons) was obtained when holding solution supplemented with 9 mg/l SNPs was used, which was much more prolonged than the control and all other treatments. Additionally, the greatest vase life of gerbera cut flowers was attained by utilizing a 9 mg/l SNPs holding solution (17.00 and 18.33 days in both seasons, respectively), followed by a 20 mg/l SNPs pulsing solution (Table, 2).

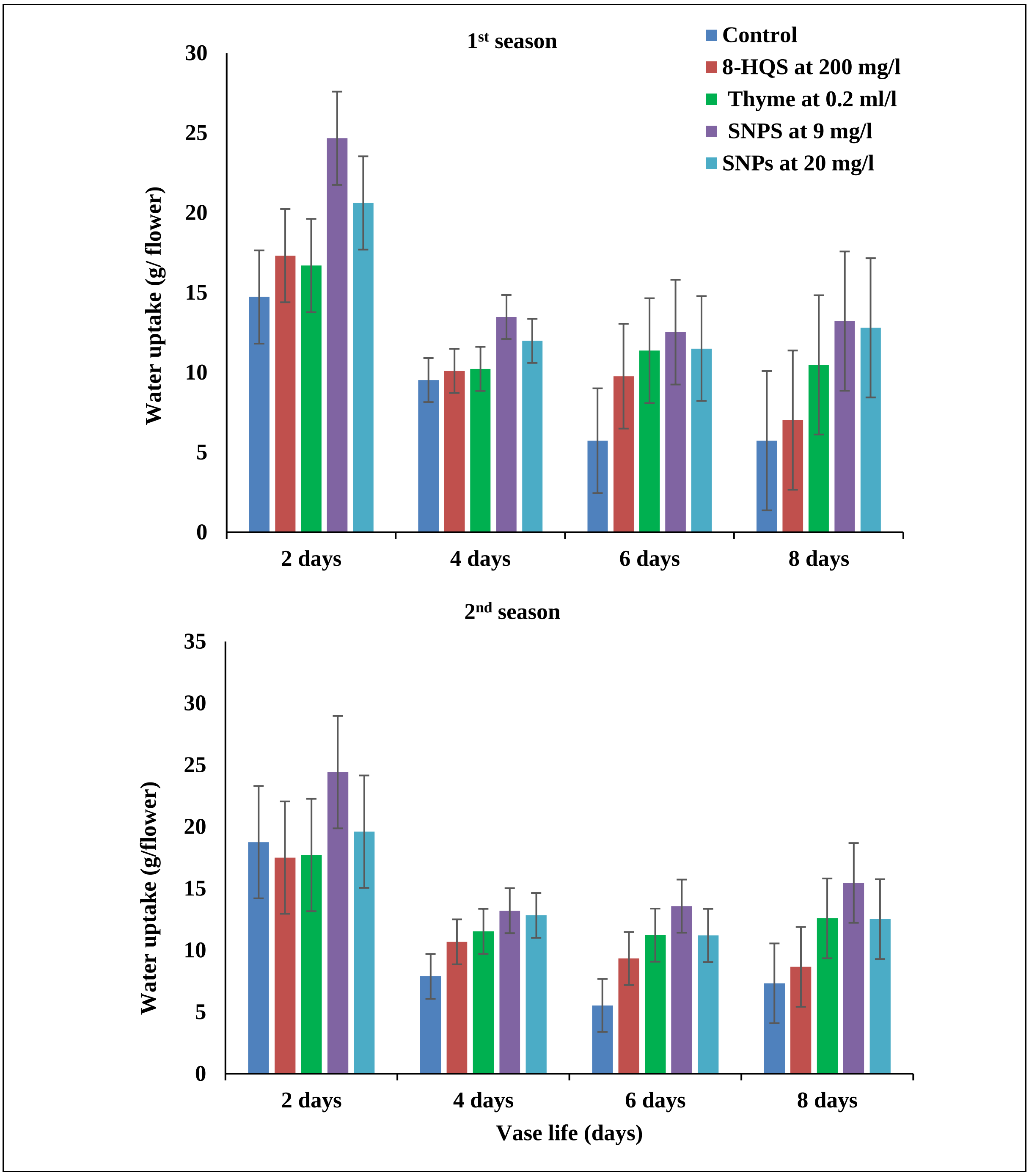

Fig. 5. Impact of 8-HQS, thyme oil, and SNPs on water uptake (g/flower) every 2 days through the vase life interval of *Gerbera jamesonii* cv. Julia cut flowers in the 2020 and 2021 seasons.

LSD at 5% of the 1st season; 2 days =2.92, 4 days=1.38, 6 days=3.28, 8 days=2.57
LSD at 5% of the 2nd season; 2 days =4.55, 4 days=1.82, 6days=2.15, 8 days=3.23

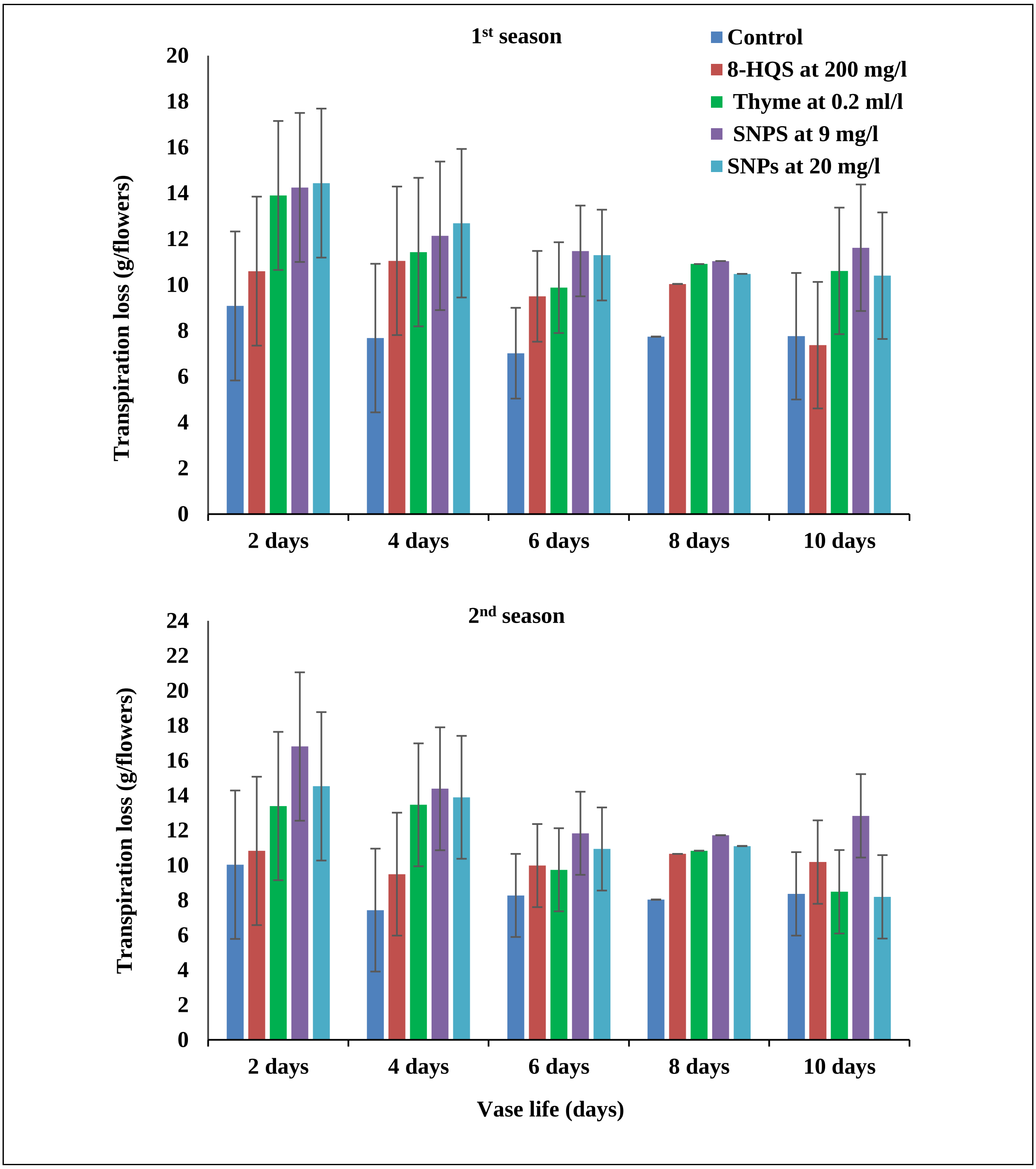

Fig. 6. Impact of 8-HQS, thyme oil, and SNPs on transpiration loss (g/flower) every 2 days through the vase life interval of *Rosa hybrida* L. cv. Avalanche cut flowers in the 2020 and 2021 seasons.

LSD at 5% of the 1st season; 2 days =3.51, 4 days=3.24, 6 days=1.98, 8 days=NS,10 days= 2.83
LSD at 5% of the 2nd season; 2 days =4.25, 4 days=3.52, 6 days=2.38, 8 days=NS, 10 days= 2.39

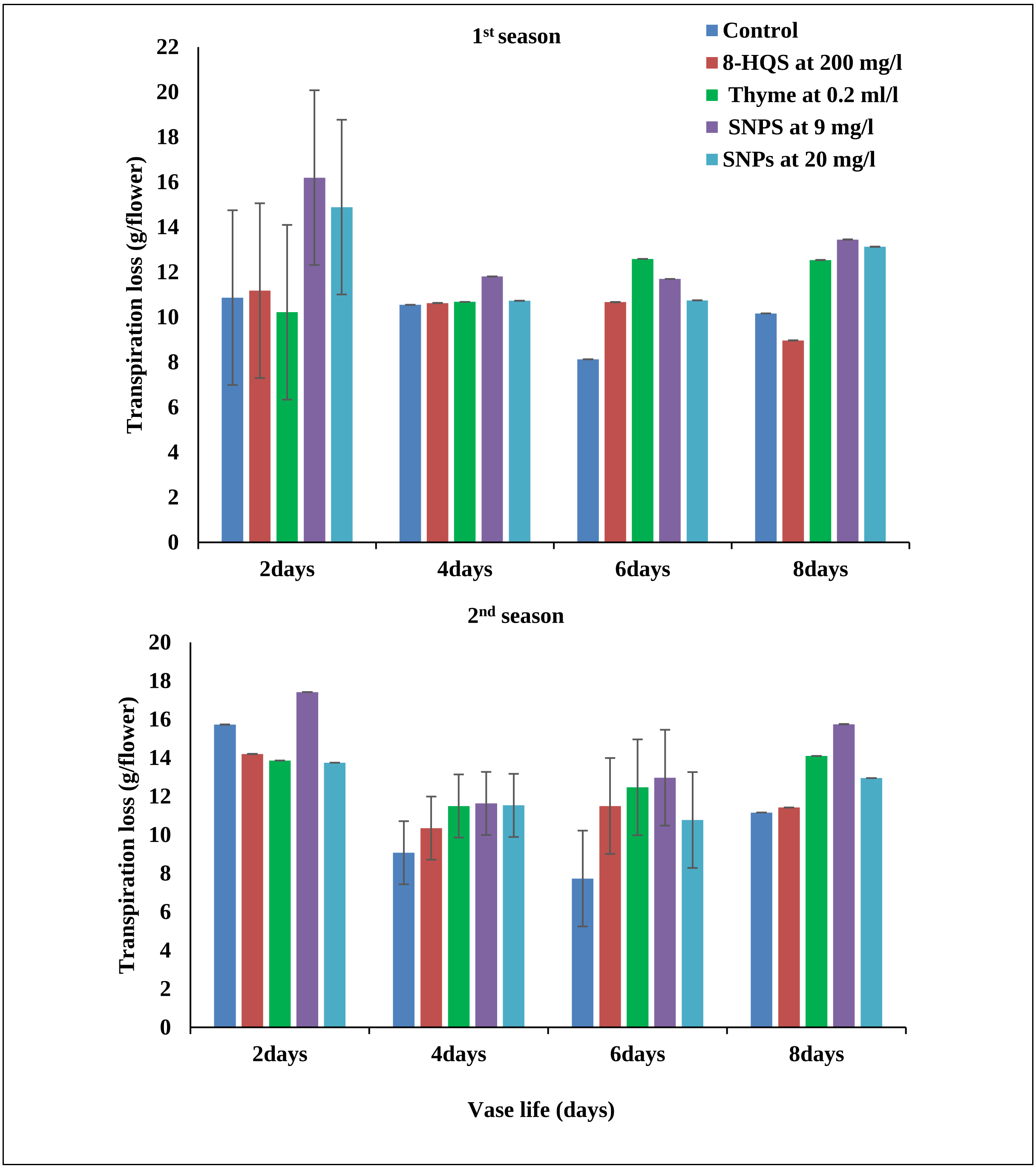

Fig. 7. Impact of 8-HQS, thyme oil, and SNPs on transpiration loss (g/flower) every 2 days through the vase life interval of *Gerbera jamesonii* cv. Julia cut flowers in the 2020 and 2021 seasons.

LSD at 5% of the 1st season; 2 days = 3.88, 4 days= NS, 6 days= NS, 8 days =NS
LSD at 5% of the 2nd season; 2 days = NS, 4 days= 1.64, 6 days= 2.49, 8 days =NS

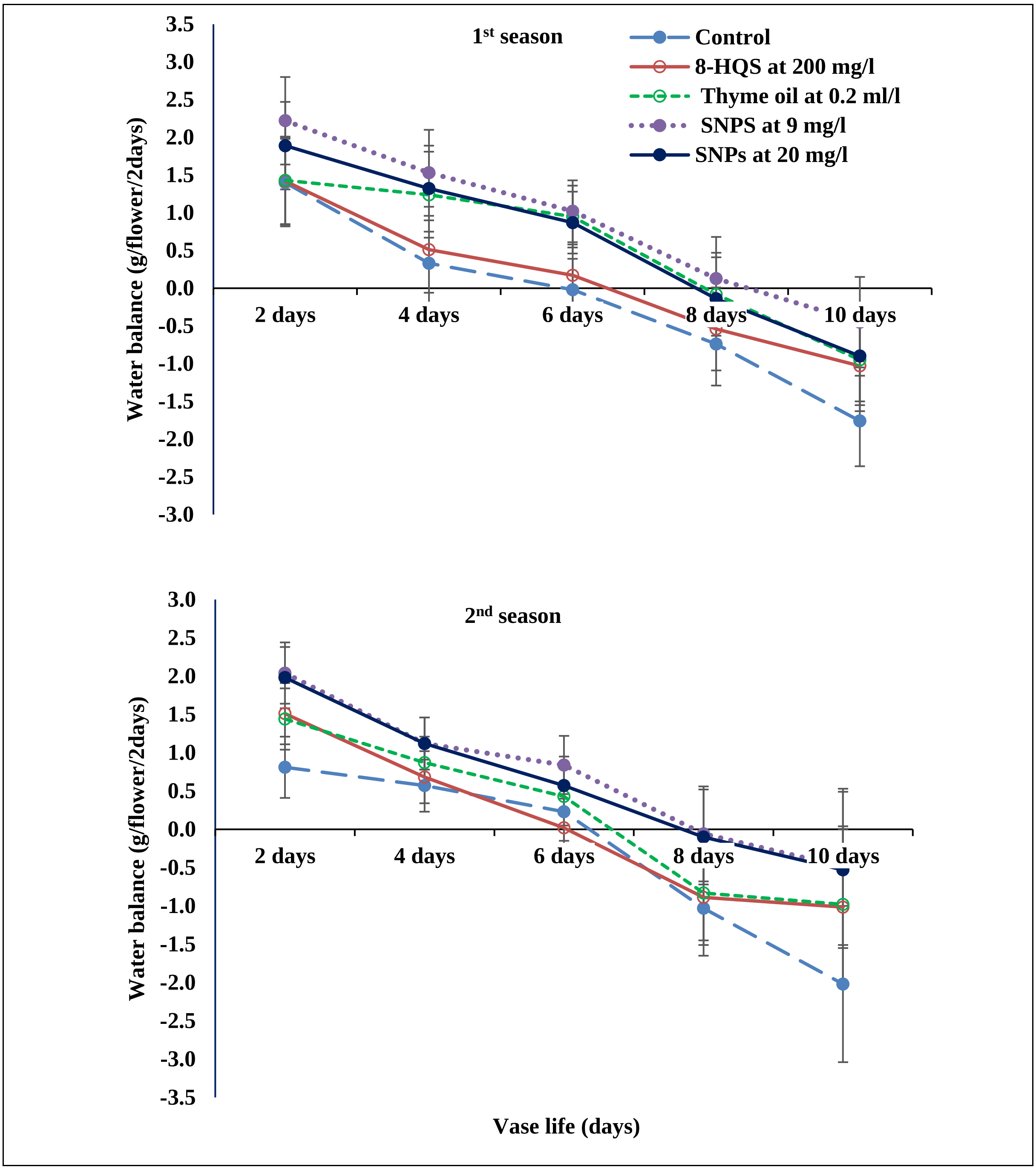

Fig. 8. Impact of 8-HQS, thyme oil, and SNPs on water balance (g/flower/2 days) through the vase life interval of *Rosa hybrida* L. cv. Avalanche cut flowers in the 2020 and 2021 seasons.

LSD at 5% of the 1st season; 2 days =0.58, 4 days=0.57, 6 days=0.41, 8 days=0.55, 10 days= 0.60
LSD at 5% of the 2nd season; 2 days =0.40, 4 days=0.34, 6 days=0.38, 8 days=0.62, 10 days= 1.02

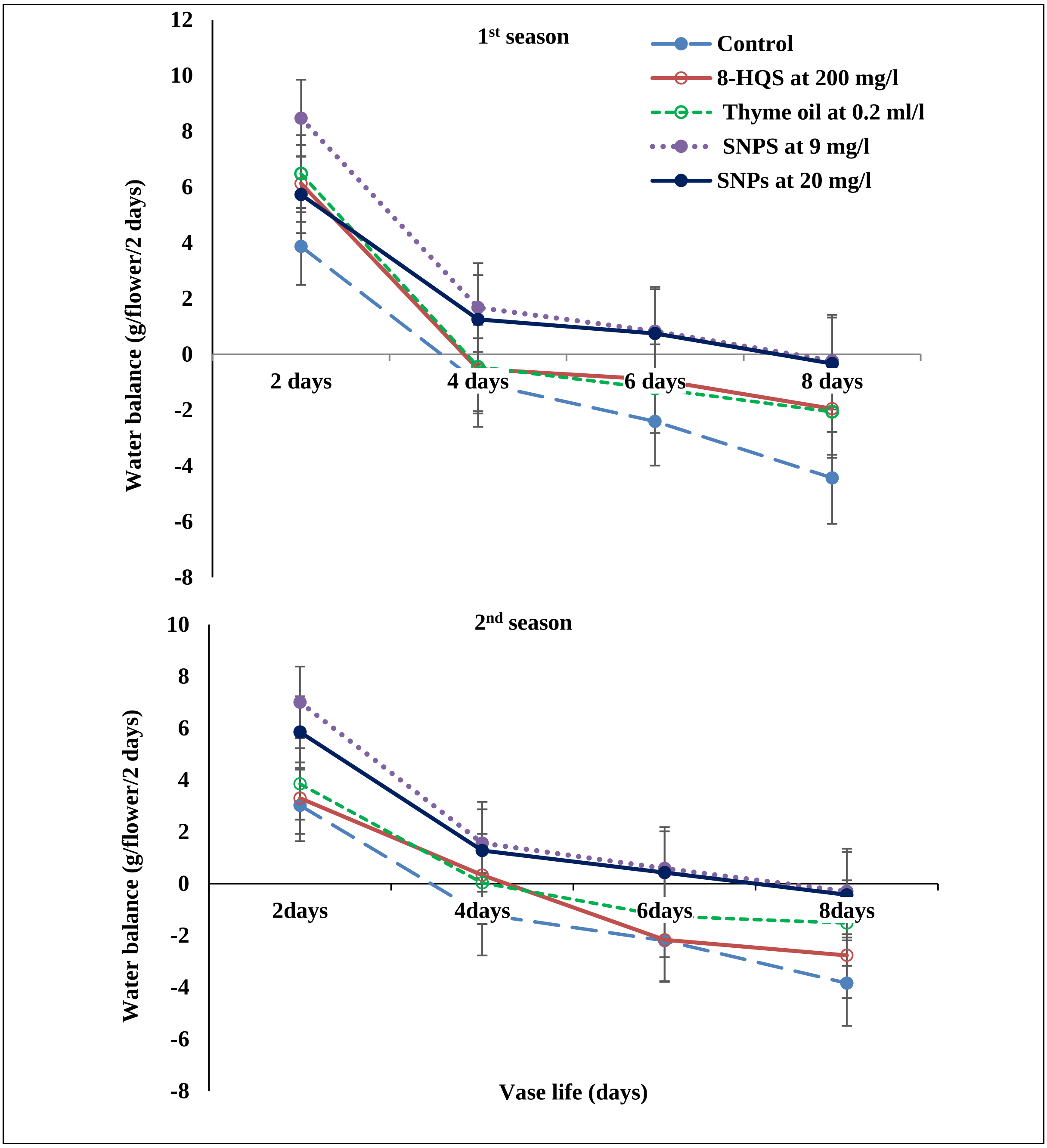

Fig. 9. Impact of 8-HQS, thyme oil, and SNPs on water balance (g/flower/2 days) through the vase life interval of *Gerbera jamesonii* cv. Julia cut flowers in the 2020 and 2021 seasons.

LSD at 5% of the 1st season; 2 days =1.38, 4 days=1.59, 6 days=1.59, 8 days=1.65
LSD at 5% of the 2nd season; 2 days =2.82, 4 days=1.61, 6 days=0.76, 8 days=2.29

Table 1. Impact of 8-HQS, thyme oil, and SNPs on No. of bacteria, lignin percentage and vase life (days) of *Rosa hybrida* L. cv. Avalanche cut flowers in the 2020 and 2021 seasons.

Treatments	Bacteria No. $\log_{10}$ (CFU/ml)	Lignin (%)	Vase life (days)	
			1st season	2nd season
Control	10.23	3.26	13.76	12.83
8HQS at 200 mg/l	8.59	3.83	15.50	15.17
Thyme oil at 0.2 ml/l	7.32	4.94	17.50	18.00
SNPs at 9 mg/l	6.06	6.66	21.67	21.83
SNPs at 20 mg/l	6.30	6.10	18.00	18.67
L.S.D (5%)	0.96	0.05	3.37	1.96

Table 2. Impact of 8-HQS, thyme oil, and SNPs on No. of bacteria, lignin percentage and vase life (days) of *Gerbera jamesonii* cv. Julia cut flowers in the 2020 and 2021 seasons.

Treatments	Bacteria No. $\log_{10}$ (CFU/ml)	Lignin (%)	Vase life (days)	
			1st season	2nd season
Control	10.87	1.59	8.11	8.67
8HQS at 200 mg/l	8.80	1.78	10.00	10.67
Thyme oil at 0.2 ml/l	6.41	2.55	12.67	13.33
SNPs at 9 mg/l	5.57	3.45	17.00	18.33
SNPs at 20 mg/l	6.24	3.19	16.00	17.33
L.S.D (5%)	0.49	0.15	1.42	1.52

6. Anatomical structure of the rose neck and gerbera stem:

The transversal sections of necking peduncles of cut rose and gerbera flowers showed a clear difference in the anatomy structures between the non-treated (control plants) and the treated cut flowers Figures (10 and 11). It clearly showed the undulation and broken cells of the epidermis layer with greater shrinkage of the parenchyma cells of non-treated rose and gerbera flowers (Figures, 10A and 11A). Among the other rose and gerbera flowers transverse sections Figures (10 and 11) showed clearly slight undulation of the epidermis layer with 8-HQS and thyme oil treatments compared to the SNPs treatments. Additionally, parenchyma layers appeared slightly compact and contained some necrotic cells of cut stems which were treated with SNPs at 20 mg/l compared to other treatments. Also, we observed a slight breakage of the vascular bundle cells of non-treated cut rose and gerbera flowers (Figures, 10A and 11A). There was a clear blockage in the xylem vessels in the control sections and a slight blockage in the other treatments, except for the SNPs at 9 mg/l treatment of both cut rose and gerbera flowers.

DISCUSSION

In this study, the treatments of SNPs and thyme oil significantly decreased the bending of cut rose and gerbera compared with 8-HQS and the control treatments. The bending degree results were correlated with improvement in water relations, a lower number of bacteria in the vase solution, and maintenance of the lignin content in the flower stem, and this led to the extension of the vase life period. Bending is mostly caused by an air embolism or the growth of bacteria in the vase solution and cumulating of microorganisms at or inside the stem end which leads to the clogging of vessels and

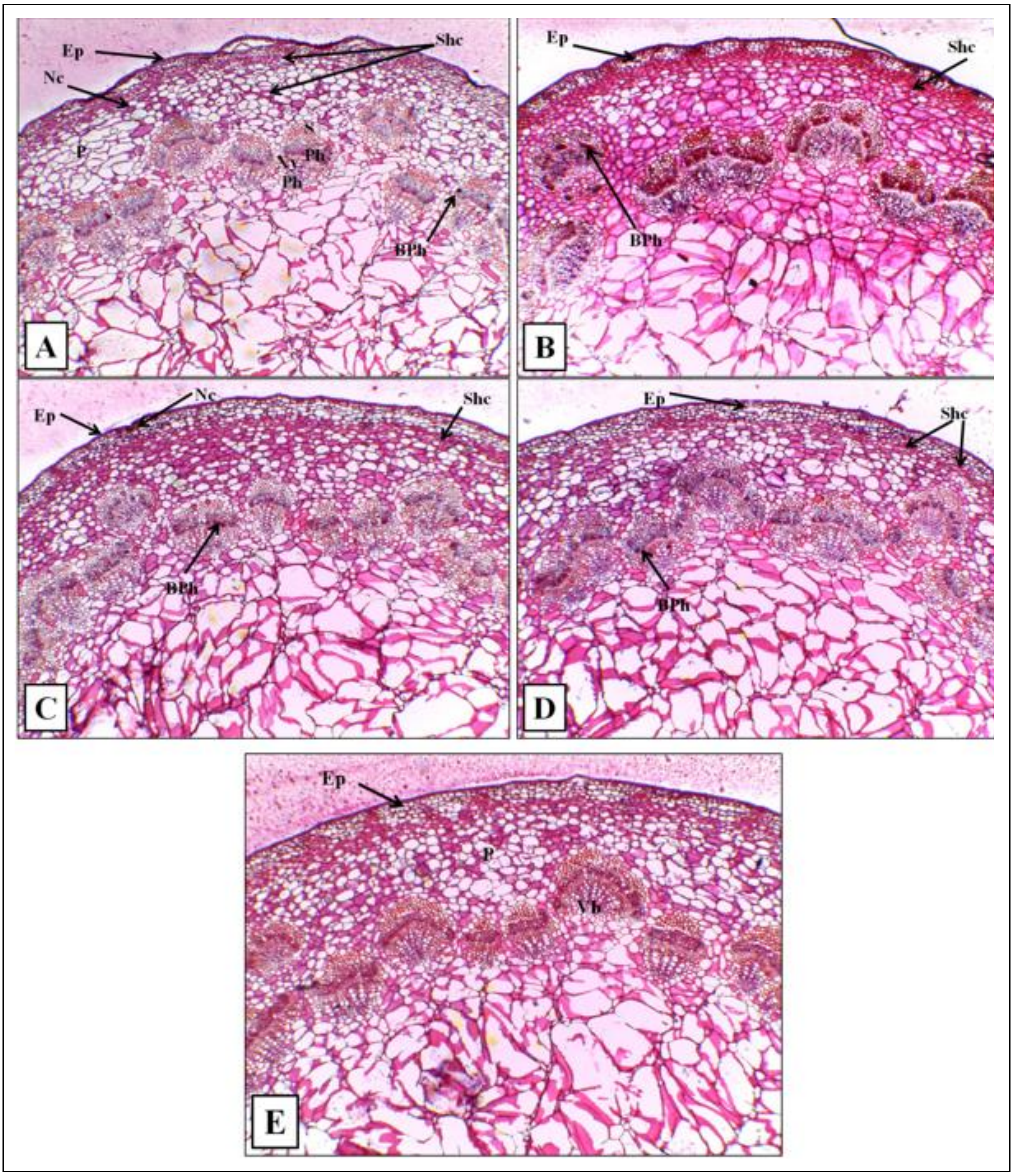

Fig. 10. The anatomical structure of *Rosa hybrida* L. cv. Avalanche cut flowers in the second season. Since (A): control, (B): 8-HQS at 200 mg/l, (C): thyme oil at 0.2 ml/l, (D): SNPs at 20 mg/l, (E): SNPs at 9 mg/l, Ep: epidermis, P: parenchyma, Vb: vascular bundle, Xy: xylem, Ph: phloem, S: sclerenchyma, Nc: necrotic cells, Bp: blocked phloem, and Shc: shrinkage cells (Magnification 40X).

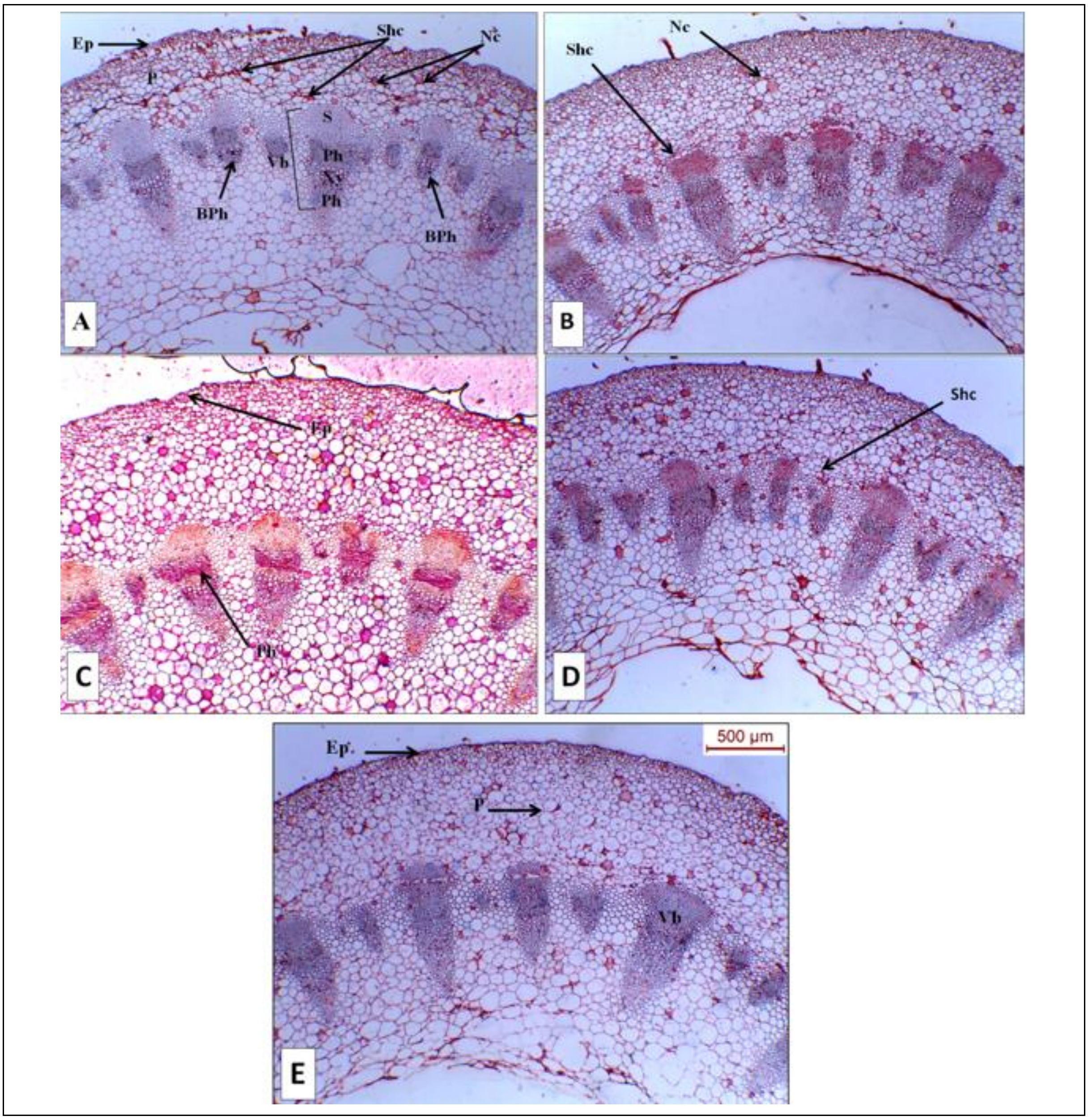

Fig. 11. The anatomical structure of *Gerbera jamesonii* cv. Julia cut flowers in the second season. Since (A): control, (B): 8-HQS at 200 mg/l, (C): thyme oil at 0.2 ml/l, (D): SNPs at 20 mg/l, (E): SNPs at 9 mg/l, Ep: epidermis, P: parenchyma, Vb: vascular bundle, Xy: xylem, Ph: phloem, S: sclerenchyma, Nc: necrotic cells, Bp: blocked phloem, and Shc: shrinkage cells (Magnification 40X).

prevention of absorption water (Lear *et al*., 2022). The bending stem in gerbera was correlated with lignin levels in the stem and transpiration from the stem (Perik *et al*., 2012). Some researchers indicated that xylem occlusion with bacteria at the stem ends may be the most common reason for stem bending and water deficit during postharvest in gerbera (Naing *et al*., 2017; Li *et al*., 2019; Liu *et al*., 2021).

In the current studies, the bending of rose and gerbera cut flowers were significantly delayed by holding in SNPs at 9 mg/l solutions. Our findings are agreeing with the studies of (Solgi *et al*., 2011; Liu *et al*., 2021) on gerbera. Probably the reason for delaying bending is the positive effect of SNPs on preventing bacterial growth in vase solution, preventing occlusion of water-conducting tissues, and therefore improving water uptake.

The findings of this investigation demonstrated that the lowest number of bacteria was recorded by holding solutions containing SNPs at 9 mg/l on the 8th day of treatment. Similar results on cut flowers were obtained by (Abdel-Kader, 2012 on rose; El-Shawa *et al*., 2019 and Liu *et al*., 2021 on gerbera). Because SNPs have a relatively high surface area and make better contact with microbes than other salts, they offer effective antibacterial characteristics that limit the development of microorganisms (Rai *et al*., 2009). SNPs get attached to the surface of the bacterial cell wall, then immediately get inside the bacteria and quickly interact with sulfhydryl (-SH) of metabolic oxygenic enzyme and thus disrupt them and prevent metabolism, inhalation, and throttle the bacteria (Niemietz and Tyermann, 2002). Additionally, SNPs cause cell death by attacking the respiratory chain and cell division (Morones *et al.*, 2005). In our study, the use of SNPs at 9 mg/l + 20 and 30 g/l sucrose is enhancing water uptake and maintains water balance in rose and gerbera cut flowers, respectively. Similar results on lisianthus cut flowers were obtained by (Skutnik *et al*., 2021) and showed that the highest water uptake and transpiration rate were gained by flowers held in SNPs + sucrose solution. SNPs treatments reduced stomatal conductance and transpiration rate, thus decreasing the water loss (Rafi and Ramezanian, 2013; Hassan *et al*., 2014) on cut rose. The decreased number of bacteria in the vase solution may be the cause of the beneficial effect of SNPs treatment on improving water relations.

Our results showed that lignin content had been maintained by using SNPs at 9 mg/l + sucrose holding solution. Similar results were obtained on gerbera-cut flowers by El-Shawa *et al.* (2019). Low lignin content debilitates the hardness of the stem and the vascular tissue, which led to decreasing the mechanical resistance to the whole flower as well as obstructing water and mineral transfer to flowers, thereby leading to speedy stem bending on snapdragon (Naing *et al*., 2021; Soe *et al*., 2022). The maintenance of lignin content by SNPs could be associated with the inhibitory effect of SNPs on ethylene production and increasing antioxidant enzyme activities (CAT, SOD, and POX), which has been reported in rose (Hassan *et al*., 2014).

These studies showed that the vase life of rose and gerbera cut flowers was extended by delaying the bending, decreasing the bacterial number on the vase solution, improving the water relations, and maintaining lignin content. By applying 9 mg/l SNPs, the highest vase life in both flowers was obtained. Our results agree with those of Atefepour *et al*., 2021 on gerbera, and Skutnik *et al*., 2021 on lisianthus. In this study, thyme oil at 0.2 ml/l showed positive effects on delaying bending, reducing the bacterial number in vase solution, and maintaining lignin in cut flowers rose, and gerbera compared to the control and 8-HQS treatments. The results of this research agreed with those of El-Sayed and El-Ziat (2021) on cut chrysanthemum who reported that the lowest bacterial counts were recorded with 500 mg/l thyme oil. Thyme oil at 0.1 mg/l reduced the bending stem and extended the vase life on the gerbera cut flower (Amini *et al.*, 2014). The antibacterial effect of some essential oils has been attributed to aldehydes, alcohols, phenols, esters, thymol, carvacrol, and eugenol (Bassole and Juliani, 2012). Thymol and carvacrol can disintegrate the external membrane of the bacterial cell membrane and mitochondria, increase the permeability of the cytoplasmic membrane to ATP, release lipopolysaccharides (LPS) and leading to leakage of cell contents, therefore exerting their antibacterial effect (Burt, 2004).

The results under discussion showed that the application of 9 mg/l SNPs maintained the anatomical structures in the bending area of rose and gerbera cut flowers and prevented blockage in xylem vessels compared to the control. This may be related to the effect of the SNPs which could reduce the bacterial growth in preservative solutions and cut stem ends, improve the water uptake, and maintain the water balance. This has led to the freshness of the flower. These results agree with Abdel-Kader *et al.*, 2017 on rose; El-Shawa *et al.* (2019) on gerbera.

CONCLUSION

SNPs are superior to thyme oil in improving the quality and delaying bending by inhibiting bacterial growth, regulating flower water balance and maintaining the lignin content, maintaining anatomical structure thus prolonging the vase life of *Rosa hybrida* cv. Avalanche' and *Gerbera jamesonii* cv. Julia cut flowers (these are more cultivars sensitive to bending). We could recommend using SNPs at 9 mg/l + 20 and 30 g/l sucrose as holding solutions to delay bending in the preservative solutions of both cut rose and gerbera flowers, respectively.

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دراسات فسيولوجية وتشريحية علي الإنحناء فى أزهار الورد والجربيرا المعاملة بجزيئات الفضة النانوية و زيت الزعتر

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إنحناء العنق أو الساق من أهم مشاكل أزهار بعض أصناف الورد والجريبرا خلال مرحلة ما بعد الحصاد، حيث أنها تقلل من عمر الأزهار المقطوفة في الفازه ومن قيمتها التجارية. تم إجراء هذا البحث لتقييم فاعلية جزيئات الفضة النانوية بتركيز ٩ ملجم/لتر وزيت الزعتر بتركيز ٠,٢ مل/لتر و٨-هيدروكسي كنولين سلفات بتركيز ٢٠٠ ملجم/لتر كمحاليل تثبيت وجزيئات الفضة النانوية بتركيز ٢٠ ملجم/لتر كمحلول نقع بالمقارنة بالماء المقطر في تقليل الإنحناء بأزهار الورد صنف أفلانش والجربيرا صنف جوليا (وهما من أكثر الأصناف حساسية للإنحناء). أشارت النتائج إلي التأثير الإيجابي للنانو فضة وزيت الزعتر في تأخير الإنحناء وتقليل عدد البكتريا بمحلول الحفظ والأنسجة الوعائية. أدي تثبيت الأزهار في محلول يحتوى على ٩ ملجم/لتر نانوفضة إلي تأخير الإنحناء بشكل كبير وحسنت من العلاقات المائية، كما قللت من عدد البكتريا وحافظت على نسبة مئوية مرتفعة من اللجنين وإطالة عمر الأزهار مقارنة بالمعاملات الأخري والكنترول. أظهرت نتائج المسح المجهري التشريحى لمنطقة الإنحناء أن المعاملة بالنانو فضة بتركيز٩ ملجم/لتر قد منعت إنسداد الأوعية وحافظت على التركيب التشريحي لخلايا البشرة وخلايا البرانشيما وحزم الأنسجة الوعائية في كلا من أزهار الورد والجربيرا. أشارت النتائج إلي أن النانو فضة قد تفوقت علي زيت الزعتر في تحسين الجودة وإطالة عمر الأزهار وتأخير الإنحناء في الورد والجربيرا.