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Effects of Grape Marc on Vase Life of Carnation Flowers

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ABSTRACT
In carnation, vase life is shortened due to ethylene and water stress, resulting in petal curling, browning, and wilting symptoms. Preservative solutions are used to prolong the vase life of cut flowers in the world, and natural substances with antimicrobial properties have been preferred as preservatives in recent years. It is thought that benefiting from the antimicrobial properties of plant wastes will be beneficial for both the cut flower industry and waste management because they are natural. This research was carried out to determine the effect of grape marc extract (GME) on the vase life of cut carnation. *D. caryophyllus* cv. 'Baltico' was used as a plant material. The plants were placed in vases containing two different concentrations of GME (100 µL L^{-1}, 200 µL L^{-1}). The vase life, relative fresh weight (RFW), daily solution uptake (DSU), lipid peroxidation, proline content, and antioxidant enzyme activities were measured during and at the end of the experiment. In the study, it was determined that GME was effective on the vase life of cut carnation flowers and GME at 200 µL L^{-1} concentration (22.67 days) extended the vase life by 6.50 days and 40.2% compared to the control [(16.17 days), (distilled water)]. At the same time, GME was found to be effective on the post-harvest stress mechanisms of cut carnation flowers. GME improved vase life by increasing both DSU, and antioxidant enzyme activities, and reducing RFW loss. It also reduced the accumulation of MDA and proline.

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Üzüm Cibresinin Karanfil Çiçeklerinin Vazo Ömrüne Etkileri

ÖZET
Karanfillerde taç yapraklarda içe kıvrılma, kahverengileşme ve solma semptomları ile sonuçlanan yaşlanma ve su stresi nedeniyle vazo ömrü kısalmaktadır. Dünyada kesme çiçeklerde vazo ömrünü uzatmak amacıyla koruyucu solüsyonlar kullanılmakta ve son yıllarda koruyucu olarak antimikrobiyal özelliklere sahip doğal maddeler tercih edilmektedir. Doğal olmaları nedeniyle bitkisel atıkların antimikrobiyal özelliklerinden faydalanılmasının hem kesme çiçek sektörü hem de atık yönetimi açısından faydalı olacağı düşünülmektedir. Bu araştırma, üzüm cibresi ekstraktının (GME) kesme karanfilin vazo ömrüne etkisini belirlemek amacıyla yürütülmüştür. Bitkisel materyal olarak *D. caryophyllus* türüne ait 'Baltico' çeşidi kullanılmıştır. Bitkiler, iki farklı konsantrasyonda GME (100 µL L^{-1}, 200 µL L^{-1}) içeren vazolara yerleştirilmiş ve bitkilerde deneme süresince ve deneme sonunda vazo ömrü, oransal taze ağırlık (RFW), günlük solüsyon alımı (DSU), lipid peroksidasyonu, prolin içeriği ve antioksidan enzim aktiviteleri belirlenmiştir. Çalışmada, GME'nin çiçeklerin vazo ömrü üzerine etkili olduğu ve 200 µL L^{-1} konsantrasyonundaki GME'nin (22.67 gün) vazo ömrünü, kontrole [(16.17 gün), (saf su)] göre 6.50 gün ve %40.2 oranında uzattığı belirlenmiştir. Aynı zamanda kesme çiçeklerin hasat sonrası stres mekanizmaları üzerinde GME'nin etkili olduğu saptanmıştır. GME, DSU ile antioksidan enzim aktivitelerini artırarak ve RFW kaybını azaltarak vazo ömrünü iyileştirmiş; MDA ve prolin birikimini azaltmıştır.

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INTRODUCTION

Carnation (*Dianthus caryophyllus* L.) is one of the most popular plants that belongs to the Dianthus genus in the family of Caryophyllaceae (Şevik & Saruhan, 2010). It is native to the Mediterranean region and is produced in many countries as cut flowers, pots, bedding, border, and rock garden plants (Tah & Mamgain, 2013). Carnation, especially as a cut flower has great commercial value because of its excellent keeping quality, a wide array of colors, and forms. According to the data of 2020, 1.4 billion pieces of cut carnation with a value of 217 million € were exported worldwide (AIPH, 2021). However, the vase life is the most critical criterion for determining the commercial value of cut carnation. The vase life varies considerably according to the carnation varieties, and it is stated that the vase life varies between 7-14 days on average (Anonymous, 2022). Depending on the storage and transportation conditions, a 15% reduction in vase life can be observed at carnations (Kazaz, 2015). Improving the cut carnations' vase life is the main issue for increasing their market value in the floral industry (Patel et. al., 2016).

The cut carnations' vase life is mainly affected by two factors that cause loss of flower quality, such as in-rolling and wilting of petals and leaves or even falling (Satoh et. al. 2005). One of the factors is the blockage of the vascular system (Khenizy et. al., 2014). The cut flower stems that are placed in a vase solution develops a negative water balance due to occlusion in the xylem by microorganisms, air emboli, and physiological responses of stems to cut. When water uptake becomes lower than the transpiration rate, it results in water stress (Damunupola et. al., 2010; Elhindi, 2012). The other factor is ethylene. Carnation is a climacteric flower that is highly sensitive to ethylene (Kazemi et. al., 2012). Ethylene is responsible for inducing many of the biochemical processes leading to programmed cell death (Ebrahimzadeh et. al., 2013), such as the acceleration of senescence, increasing respiration rate, and production of reactive oxygen species (ROS) (Saeed et. al., 2014). Ethylene production causes a sharp increase in the production of ROS (Zamani et. al., 2011) and the ROS react with and degrade lipids, proteins, and nucleic acids leading to the ultimate death. The involvement of ROS in the senescence process has gained considerable attention recently (Ezhilmathi et. al., 2007).

It is possible to prolong the vase life by using different solutions, which reduce microbial growth and vascular blockage, increase water uptake of the stem, and decrease the negative effect of ethylene (Shanan, 2017; Ghadimian & Danaei, 2020). Many chemical compounds such as silver thiosulfate, 8-hydroxyquinolines, and aluminum sulfate are used in the vase solution. They are effective on vase life extension (Elhindi, 2012; Amin, 2017). But some of these chemicals have side effects on human health and the environment. Also, some of them have a high cost. Substitution of chemicals with natural compounds is important to maximize the damage control and to minimize their side effects and costs (Ebrahimzadeh et. al., 2019). For these reasons, natural plant extracts or essential oils, which have antifungal, antibacterial, and antioxidative properties have recently been preferred to be used in the vase solution (Rahman et. al., 2012; Adam, 2021).

Grape (*Vitis* spp.) is one of the most famous species among plants that have antimicrobial and antioxidative activities (Gökçen et. al., 2017). It is a crucial crop for human nutrition in the world and has different usage areas such as fresh fruit, wine, and molasses. The waste material comes out while making wine and molasses. Three tons of grapes for winemaking yield about one ton of waste. This waste material is called grape marc and it can cause environmental pollution due to significant accumulation at production areas (Eleonora et. al., 2014). However, grape marc represents an important source of resveratrol and other bioactive compounds that can be a valuable source of antioxidants and antimicrobials due to their poor extraction during the winemaking process (Luchian et. al., 2019). Moreover, it is cheap and is not harmful to human health. For these reasons, grape marc is thought that using as a vase solution is important in terms of its potential to reduce/inhibit microbial growth and to prevent senescence by decreasing ROS affect. This study has been aimed extending the vase life of the carnation using different concentrations of grape marc extract (GME) in the vase solution and to be the opportunity to use a waste material which is in large quantities as winery waste every year.

MATERIAL and METOD

Plant Material

Flowers of *D. caryophyllus* L. cv. 'Baltico' was used as a plant material. Flowers were obtained from a commercial company and were grown under the greenhouse covered with plastic and located in Antalya (30°93′75.6″N 30°76′23.1″E). The flowers were harvested in the early morning at the paintbrush stage, which is a recommended harvesting period for long-distance transportation (Jawaharlal et. al., 2007).

Vase Life Room Conditions

This study was conducted out at the vase life room in the Department of Horticulture, Faculty of Agriculture, Yozgat Bozok University in Yozgat, Turkey in May. Vase life room conditions were a photoperiod of 12 h light/dark cycles, 1000 lux light intensity, 22 °C ± 2 °C room temperature and 55 % ± 5 % relative humidity.

Transporting Flowers and Placing Them in Vases

Harvested flowers were immediately placed in a bucket containing tap water in cold storage at 2-4 °C overnight. After that, they were transported dry to the vase life room within 12 hours. At the vase life room, the stems were re-cut to a length of 40 cm and only one upper leaf was held on each stem to decrease contamination. They were then put in glass bottles containing 100 ml of vase solutions, which were GME (100 µL L^{-1}, and 200 µL L^{-1}) and distilled water as control.

Preparation of Grape Marc Extract (GME)

The extraction of the grape marc was made according to Kiselev et. al. (2007). The marc of the 'Cardinal' grape variety was dried at 65 ºC and pulverized. After the oil removal process, 50 g of sample was taken and 100 ml solvent that included acetone: water: acetic acid (90: 9.5: 0.5) mixture was added. After extracting the Soxalette for 8 hours, the liquid part was removed, and evaporation was carried out in the rotary evaporator. The remaining part was dissolved in 10 ml of methanol.

Measurement and Analysis

The measured traits in the experiment were vase life, RFW, DSU, lipid peroxidation, proline content, antioxidant enzyme activities, bacterial activity, and pH value of vase solutions. Vase life was recorded daily and was terminated when flowers wilt and formed necrotic points on petals (Ebrahimzadeh et. al., 2013). RFW and DSU recorded daily measurement of the weights of the vase with and without flowers. The RFW change and DSU were calculated using formula that were given by He et. al. (2006) and RFW was expressed % of initial and DSU was g stem-1 day-1. Lipid peroxidation was determined by the method modified according to Madhava Rao & Sresty (2000). The amount of MDA that is the last product of lipid peroxidation was calculated from the extinction coefficient of 155 mM^{-1} cm^{-1} and expressed as M kg^{-1} FW. Proline content was estimated by the method modified according to Bates et. al. (1973). The amount of proline was calculated from a previously plotted standard curve and expressed in M kg^{-1} FW. Catalase (CAT; EC 1.11.1.6) enzyme activity was estimated by the method modified according to Çakmak et. al. (1993), superoxide dismutase (SOD; EC 1.15.1.1) was by the method Gong et. al. (2005), ascorbate peroxidase (APX; EC 1.11.1.11) was by the method Nakano and Asada (1981). The amount of enzyme that reduces the absorbance by 1 M in 1 min at 25 ºC was accepted as 1 enzyme Unit and the results were expressed as enzyme U kg^{-1} protein. In the measurement of biochemical/physiological analysis except antioxidant enzyme activities; all petal samples from glass bottles were taken from at the end of the vase life. For antioxidant enzyme activities, samples were taken from glass bottles at four different stages: the period when 1/3 of the flowers opened (Stage 1) and the period when the symptoms such as necrotic points and wilting begin to appear (Stage 2). Bacterial activity of vase solutions was determined according to Kazemi and Ameri (2012)'s method has been modified and plant count agar was used as nutrient solution. The samples were taken two different times (1st day of the vase life and end of the vase life) and the results were given average CFU mL^{-1}. The pH value of vase solution was measured beginning the experiment by pH meter (Mettler Toledo pH/Ion meter s220).

Antimicrobial Activity and pH Value of GME

In the study, antimicrobial activity of GME was also determined. The antimicrobial activity of the GME was made as described below: Bacterial strains (Mc Farland OD: 0.5, 6.0x108 bacteria mL^{-1}), used in the study were inoculated into nutrient broth and activated for 24 hours at 37 ºC. Yeast strains (1.5x106 yeast mL^{-1}) were inoculated into sabouraud dextrose broth and activated for 24 h at 30 ºC (Anonymous, 1999). Mueller hinton agar, which was sterilized in test tubes and cooled down to 45-50 ºC, was inoculated with 24 h broth culture of bacterial strains prepared as above, and yeast strains in 24 h broth on sabouraud dextrose agar medium. The homogenized medium mixture was transferred to sterile petri dishes with a diameter of 9.0 cm. To determine the antimicrobial activities of GME, 100 µL of methanol extracts were taken and absorbed into sterile antibiotic disks with a diameter of 10 mm. Disks impregnated with essential oil were placed on solidified agar by pressing lightly (Bağcı & Dığrak, 1997). Petri dishes prepared in this way were incubated at 4 °C for 2 h, then bacteria-inoculated petri dishes were incubated at 37 °C for 24 h, and yeast-inoculated petri dishes were incubated at 30 °C for 24-48 h (Bradshaw, 1992; Collins et. al., 1987; Bağcı & Dığrak, 1996). At the end of the period, the inhibition zones formed on the medium were evaluated in mm.

Statistical Analysis

The experiment was established in a Completely Randomized Design with three replicates. There were fourteen flowers per replication. Statistical analysis

was performed using IBM SPSS Statistics vs. 20.0. Analysis of variance (ANOVA) was applied to the data and Duncan's test was used to determine differences between means (*p<0.05).

RESULTS and DISCUSSION

Results

Effects of GME on the Vase Life, RFW and DSU

Based on the statistical analysis, the GME significantly affected the vase life, RFW, and DSU of the cut carnation 'Baltico'. All concentrations of GME extended the vase life. The highest vase life was found at 200 µL L^{-1} GME. The highest concentration of GME extended the vase life by 6.50 d compared to the control. The control had the lowest vase life (Figure 1).

During the vase life period, the RFW of flowers kept in distilled water (control) and 100 µL L^{-1} GME increased until day 3, while 200 µL L^{-1} GME was until day 4. From d 3 and 4 onwards, RFW gradually decreased with time. 200 µL L^{-1} GME was determined more successful than lower concentration and control maintaining RFW. The least RFW loss from day 1 to the end of the vase life was observed at 200 µL L^{-1} GME (47.90 %) where the highest RFW loss was in 100 µL L^{-1} GME (58.22 %) (Figure 2).

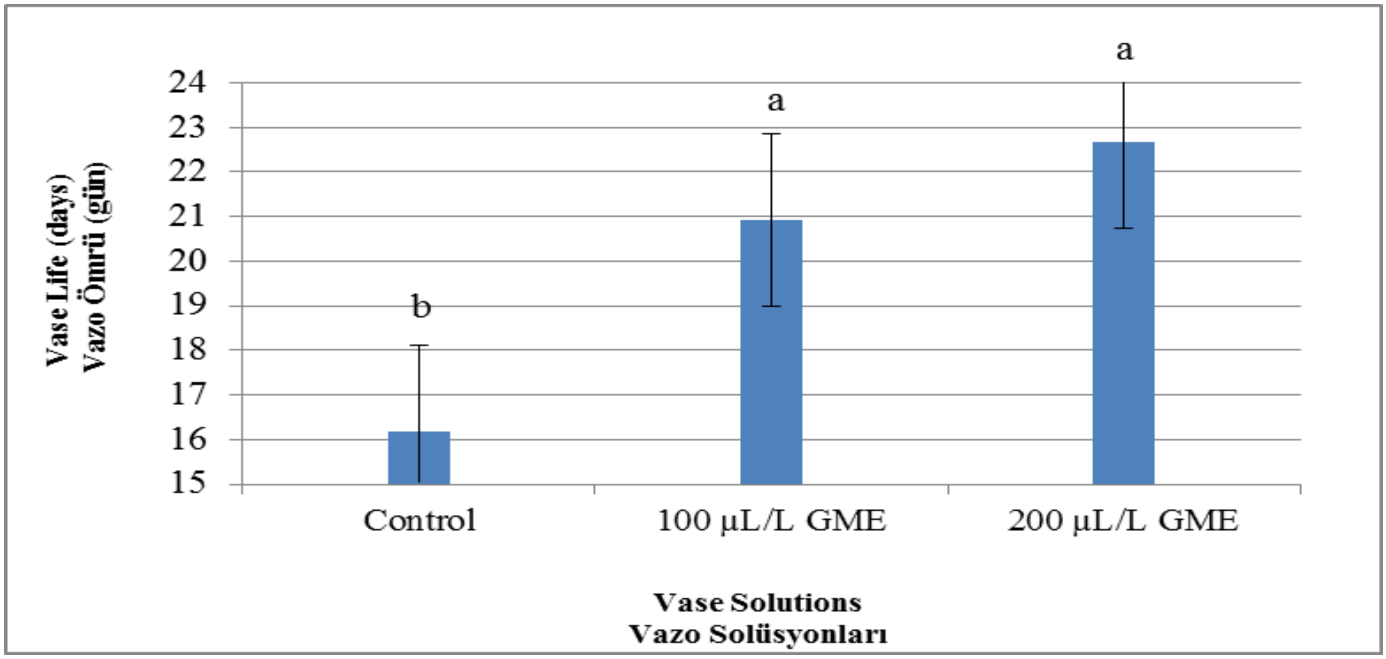

Figure 1. Vase life of cut carnation 'Baltico' according to different concentrations of GME (Error bars represent ± standard deviation, *P < 0.05)

*Şekil 1. Farklı konsantrasyonlarda GME'nin 'Baltico' çeşidinin vazo ömrüne etkileri (Hata çubukları ± standart sapmayı temsil eder, *P < 0.05)*

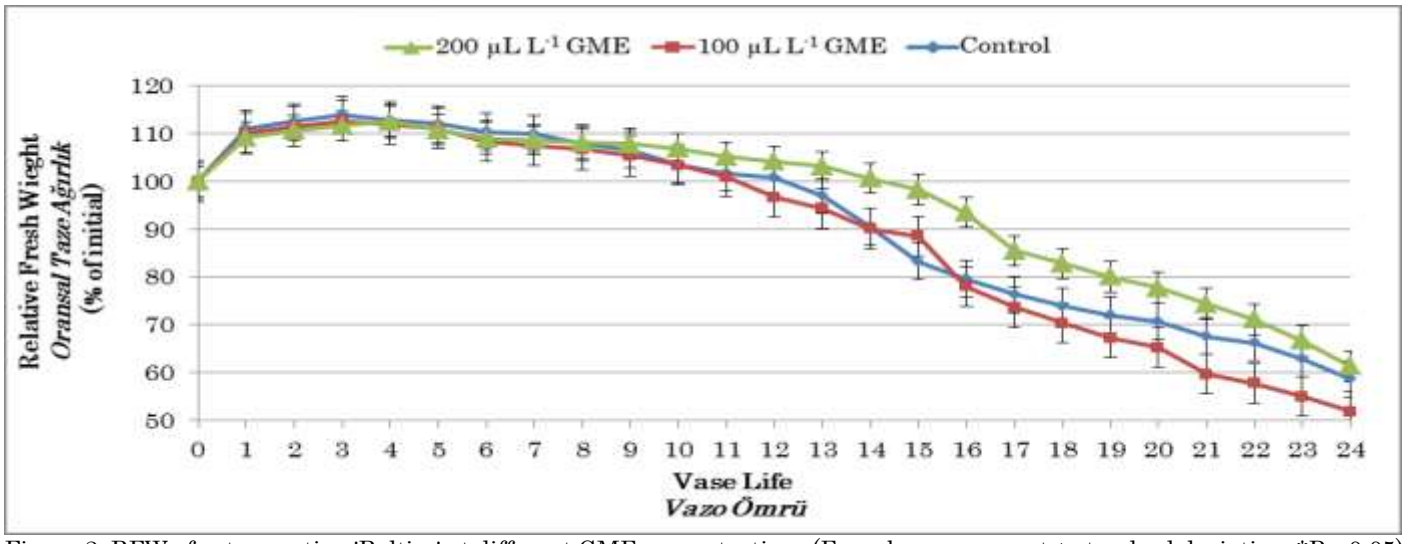

Figure 2. RFW of cut carnation 'Baltico' at different GME concentrations (Error bars represent ± standard deviation, *P < 0.05)

*Şekil 2. Farklı konsantrasyonlarda GME uygulanan 'Baltico' çeşidine ait OTA değerleri (Hata çubukları ± standart sapmayı temsil eder, *P < 0.05)*

Similar to vase life and RFW results, the 200 µL L^{-1} GME showed the best DSU. However, from day 1 onwards, DSU gradually decreased with time. The highest DSU on the1st day belonged to flowers in 100 µL L^{-1} GME, where the highest DSU on the last day was in 200 µL L^{-1} GME. From day 6 to the end of the vase life; flowers of control had the lowest DSU. The highest average DSU value (87.30 %) was obtained in 200 µL L^{-1} GME with 1.51 ± 1.05 g $stem^{-1}$ day^{-1}. The lowest average DSU value was 1.25 ± 0.99 g $stem^{-1}$ day^{-1} in control (Figure 3).

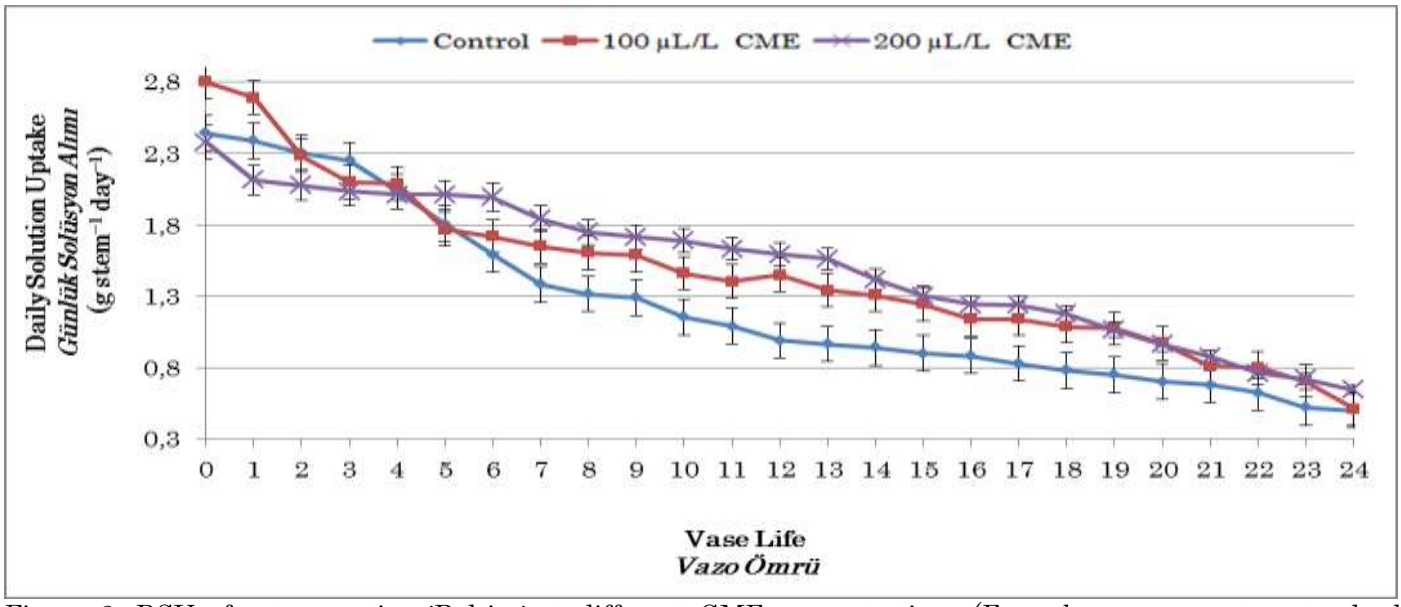

Figure 3. DSU of cut carnation 'Baltico' at different GME concentrations (Error bars represent ± standard deviation, *P < 0.05)

*Şekil 3. Farklı konsantrasyonlarda GME uygulanan 'Baltico' çeşidine ait GSA değerleri (Hata çubukları ± standart sapmayı temsil eder, *P < 0.05)*

Effects of GME on Lipid Peroxidation and Proline Content

The GME treatments on the MDA content of the 'Baltico' variety were found to be statistically significant. The highest MDA content was determined in the control group. The lowest MDA content was recorded in 100 µL L^{-1} GME. However, 100 µL L^{-1} GME was in the same statistical group as the 200 µL L^{-1} GME. The highest GME concentration used in the study reduced MDA content by 34.46 % compared to the control (Figure 4).

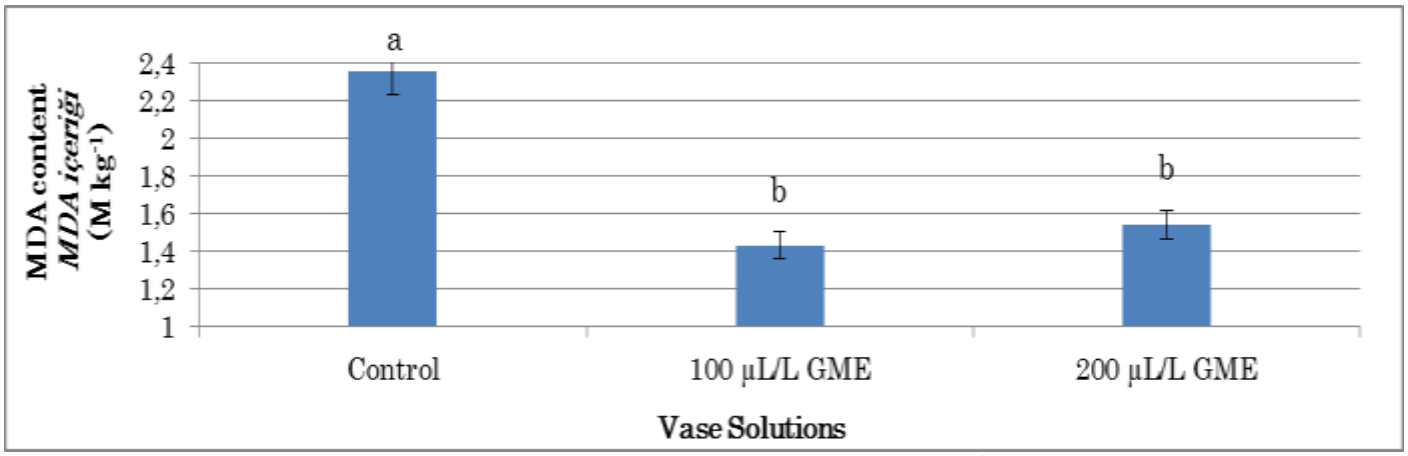

Figure 4. MDA of cut carnation 'Baltico' at different GME concentrations (Error bars represent ± standard deviation, *P < 0.05)

*Şekil 4. Farklı konsantrasyonlarda GME uygulanan 'Baltico' çeşidinin MDA içerikleri (Hata çubukları ± standart sapmayı temsil eder, *P < 0.05)*

Proline content of the 'Baltico' affected significantly by the vase solutions. All concentrations of GME decreased the proline content. The highest proline content was recorded in the control, whereas the lowest proline content was 200 µL L-1 GME. However, 200 µL L-1 GME and 150 µL L-1 GME were in the same statistical group. The highest GME concentration decreased the proline content by 41.30 % compared to the control (Figure 5).

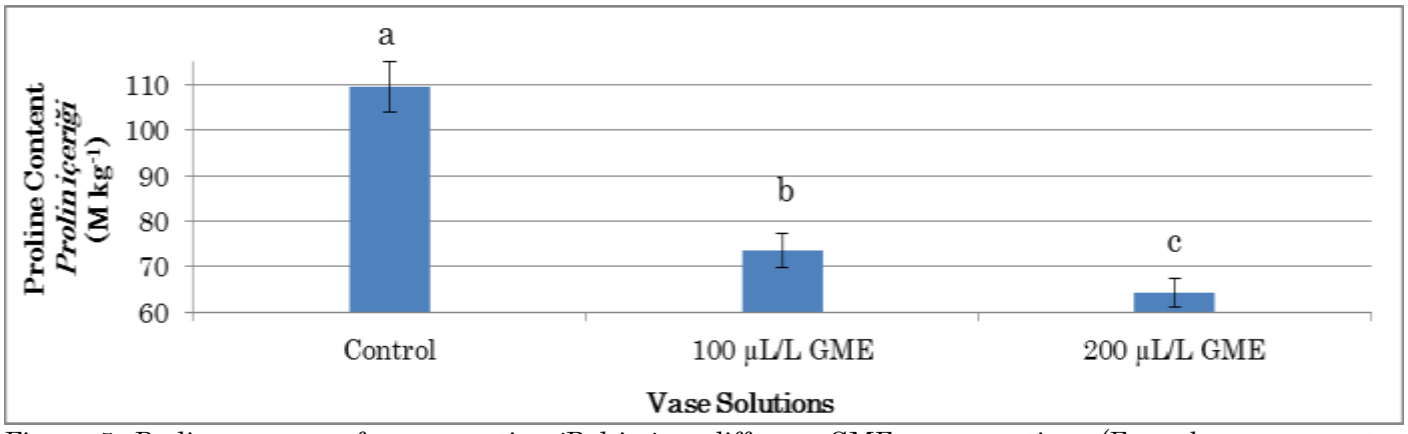

Figure 5. Proline content of cut carnation 'Baltico' at different GME concentrations (Error bars represent ± standard deviation, *P < 0.05)

*Şekil 5. Farklı konsantrasyonlarda GME uygulanan 'Baltico' çeşidinin prolin içerikleri (Hata çubukları ± standart sapmayı temsil eder, *P < 0.05)*

Effects of GME on Antioxidant Enzyme Activity

The antioxidant enzyme activity of the 'Baltico' variety showed a statistically significant difference according to the vase solutions and different stages (Figure 6). In stage 1, the highest CAT enzyme activity was found in 100 µL L^{-1} GME, which was the same statistical group as 200 µL L^{-1} GME. The highest CAT enzyme activity was recorded in 200 µL L^{-1} GME both in stage 1 and stage 2. The greatest increase in CAT enzyme activity from stage 1 to stage 2 was at the highest GME concentration. It increased the CAT enzyme activity 1.3 times compared to the control.

Similar to CAT enzyme activity, SOD enzyme activity also showed an increase from stage 1 to stage 2 at all GME concentrations. However, the SOD enzyme activity of control showed a decrease from stage 1 to stage 2 in contrast to CAT enzyme activity. The highest SOD enzyme activity in stage 1 was found in the control that was the same statistical group with 100 µL L^{-1} and 200 µL L^{-1} GME whereas the highest SOD enzyme activity was recorded in 200 µL L^{-1} GME in stage 2. The lowest SOD enzyme activity in stage 2 was determined in the control. The highest increase in SOD enzyme activity was found at the highest GME concentration.

In terms of APX enzyme activity, it was determined that there was an increase in all treatments from stage 1 to stage 2. Although there was no statistical difference between the treatments within stage 2, the highest APX enzyme activity in stage 1 was found control and 200 µL L^{-1} GME. They were in the same statistical group. However, the least increase rate was found in the control. The highest increase rate was recorded 100 µL L^{-1} GME that was the same statistical group as the 200 µL L^{-1} GME.

The Antimicrobial Activity of GME, Bacterial Activity and pH in Vsse Solutions

The data on the antimicrobial activity of GME is given in Table 1. According to Table 1, GME was tested on 10 strains of microorganisms, 6 bacteria, and 4 yeast. Gentamicin, amoxicillin (antibiotic), and nystatin (antifungal) active ingredient was also applied to understand the antimicrobial activity of GME. The results showed that GME was more effective on 5 bacteria (*Bacillus subtilis, Staphylococcus aureus, Bacillus megatherium, Pseudomonas aeroginosa, Enterobacter aerogenes*) than the Gentamicin active ingredient and a bacteria *Staphylococcus aureus* than the amoxicillin active ingredient. Moreover, the GME was at least as effective as nystatin on *Candida albicans.*

The data on bacterial activity of vase solutions are given in Table 2. According to Table 2, the highest bacterial activity was determined at control and 100 µL L^{-1} GME respectively, whereas the lowest bacterial activity was found at 200 µL L^{-1} GME. The data on the pH value of GME is also given in Table 2. According to Table 2, all concentrations of GME had a lower pH than the control and 200 µL L^{-1} GME was the lowest.

DISCUSSIONS

In this study, which was conducted to improve postharvest quality in the cut carnation 'Baltico', it

was determined that GME prolonged the vase life by increasing DSU and antioxidant enzyme activities and maintaining RFW. Moreover, GME caused lower MDA and proline accumulation.

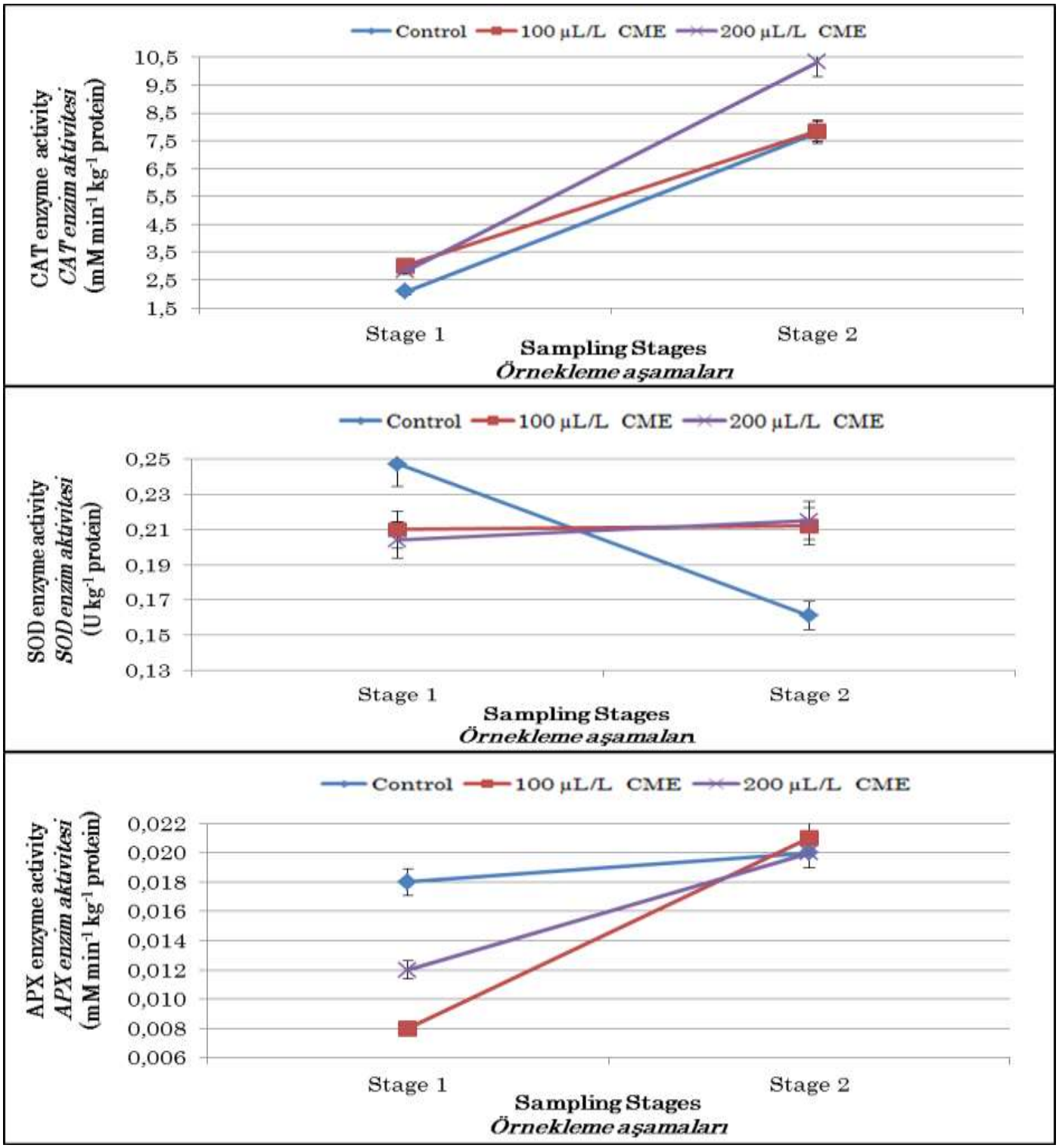

Figure 6. Antioxidant enzyme activities of cut carnation 'Baltico' at different GME concentrations (Error bars represent ± standard deviation, *P < 0.05)

*Şekil 6. Farklı konsantrasyonlarda GME uygulanan 'Baltico' çeşidinin antioksidan enzim aktiviteleri (Hata çubukları ± standart sapmayı temsil eder, *P < 0.05)*

Table 1. Antimicrobial activity of GME
Çizelge 1. GME'nin antimikrobiyal aktivitesi

Microorganisms	GME	Control (Methanol)	Gentamicin 10mcg	Amoxicillin/ clavulanic acid (30mcg)	Nystatin*
Gram Positive Bacteria					
Bacillus subtilis	18[1]	-[2]	23	-	NT
Staphylococccus aureus	20	-	21	30	NT
Bacillus megaterium	14	-	16	-	NT
Gram negative bacteria					
Klebsiella pneumoniae	19	-	16	-	NT
Pseudomonas aeroginosa	14	-	17	15	NT
Enterobacter aerogenes	15	-	16	-	NT
Yeast					
Candida albicans	36	-	NT	NT	36
Candida utilis	-	-	NT	NT	35
Saccharomyces cereviciae	-	-	NT	NT	36
Yarrowia lipolytica	-	-	NT	NT	37

(*): Each disc contains 10 microliters of 100,000 UNIT nystatin per ml.
(1): inhibition zone, mm; (2): Inhibition zone could not be determined; NT: could not be tested

Table 2. Bacterial activity and pH value of vase solutions
Çizelge 2. Vazo solüsyonlarının bakteriyel aktivitesi ve pH değerleri

Vase Solution	CFU mL^{-1}	pH value
Control (distilled water)	516 a ± 15.23	5.72 a ± 0.48
100 µL L^{-1} GME	510 a ± 14.39	5.39 b ± 0.33
200 µL L^{-1} GME	492 b ± 10.19	5.20 c ± 0.36

Solution uptake of cut flowers is one of the most important factors affecting their vase life (Frew et. al., 2018). When solution uptake decreases, the balance of solution uptake and transpiration is disturbed. Because of water stress, early wilting and premature senescence occurred and the longevity of the cut flowers' vase life is shortened (Lou et. al., 2021). In this study, the rate of decrease in solution uptake was higher in the control compared to the highest GME concentration (Figure 3) and it is found that GME decreased microbial activity in vase solutions (Table 2). The enhancement of solution uptake might be related to that GME improved the solution uptake by decreasing or preventing microbial proliferation. Ha et. al. (2019), Kılıç et. al. (2020), and Nguyen and Lim (2021) determined similar results. They reported that some compounds used as vase solutions reduced microbial activity and increased solution uptake because of their antimicrobial properties. In this study, GME was found effective on *Bacillus subtilis, Staphylococcus aureus, Bacillus megatherium, Pseudomonas aeroginosa, Enterobacter aerogenes* (Table 1). The biodiversity of microorganisms inhabiting vase solutions can change due to the microflora on stems of cut flowers. However, it was determined that microorganisms such as *Bacillus* spp., *Pseudomonas* spp., *Staphylococcus equorum*, and *Enterobacter agglomerans* were found in the samples taken from the vase solutions where different researchers kept cut carnations (Shanan et.al., 2010; Pang et.al., 2021).

RFW plays a critical role in the quality and vase life of cut flowers (Shokalu et. al., 2021) and to improve the vase life, maintaining the RFW is important. RFW of cut flowers changes during the vase life due to respiration and transpiration rate, senescence, water, and nutrient content in cut flowers (Paul et. al., 2021; Song et. al., 2021). In this study, the rate of decreasing RFW of cut carnation flowers was lower at the highest concentration of GME compared to the control. Elansary (2020), Lou et. al. (2021), and Song et. al. (2021) obtained similar results about that some compounds added in vase solutions maintain RFW and reduce RFW loss of cut flowers. The solution uptake helps maintain RFW (Ha et. al. 2019) and there is a positive correlation between solution uptake and RFW (Alkaç et. al., 2020). The lower rate of decrease in solution uptake of GME might have resulted in a better RFW in GME. Moreover, the GME might have helped to reduce the transpiration losses by stomatal regulation because of its antioxidant capacity. GME has been determined to increase CAT, SOD, and APX antioxidant enzyme activities and reduce MDA content which is known as a marker of the antioxidant activity (Figure 6, 8, 9, 10). The report of Zhang et. al. (2010) indicates that the antioxidant system might have influenced the stomatal regulation. They found that the channels by which hydrogen peroxide (H_2O_2) mediates the induction of stomatal closure are by increasing the activities of antioxidative enzymes such as SOD, CAT, GPX, APX, and GR in plant tissues. Besides solution uptake and transpiration rate,

another reason why RFW is found to be higher in GME treatment in this study may be delaying senescence. When RFW begins to decline, it marks the beginning of the senescence period (Gomes et al., 2010). So, the fact that GME delayed RFW loss by one day suggests that it has the ability to delay senescence. Carnation is an ethylene-sensitive species however, senescence in cut flowers is not only dependent on ethylene but also oxidative stress and/or water stress and they accelerate the senescence processes (Skutnik et. al., 2020). GME might have delayed senescence by reducing water stress and oxidative stress due to its antioxidant activity. Similar results about some compounds that have antioxidant activity, delay senescence in cut flowers were reported (Lama et. al., 2015; Maity et. al., 2019). In this study, it was also found that the RFW increased up to the first 4 d in 200 µL L^{-1} GME and up to the first 3 d in the 100 µL L^{-1} and control. The decrease in RFW of the highest GME concentration started one day later than control. Although the reduction of solution uptake, the reason why the RFW increased up at first 4 d in the highest concentration may be that the transpiration rate was lower at the end of the vase life. The lower transpiration rate may be related to the flowers have not reached the full opening. Flowers, which harvested paintbrush stage, were used in the experiment. Azad et. al. (2004) indicated that when petals open, the transpiration rate gradually increased. It is thought that the highest GME concentration might have delayed flowering by one day. There is another research showing that the RFW increases up to a certain time depending on the solution applied, the conditions to keep of flowers, and the cut flower species (Horibe & Makita, 2019; Kılıç et. al., 2020; Yang et. al., 2021).

Lipid peroxidation acts a critical role in the balance of oxidative stress (Bat et. al., 2020) that regulate in the vase life of cut flowers between prooxidants such ROS and antioxidant activities (Aalifar et. al., 2020). Because of lipid peroxidation caused by senescence and/or oxidative stress, cell membranes lose their stability, and MDA that is a toxic aldehyde that is an indicator for determining lipid peroxidation occurs. The damage of membrane lipids and the end-products of its reactions are dangerous for cell viability, even tissues (Mylonas & Kouretas, 1999). In this study, MDA content reached the highest value in the control, while it was lowest at the highest GME concentration. Similar results were obtained by Dar and Tahır (2018), Langroudi et. al. (2019), and Teerarak et. al. (2019). They reported that some compounds that have antioxidant and anti-ethylene properties reduced MDA content. Reducing MDA accumulation by decreasing lipid peroxidation of GME might have been related to its antioxidant activity. SOD, CAT, and APX antioxidant enzyme activity that protects the cell membrane of GME were found higher compared to the control (Figure 8, 9, and 10). Therefore, it reduced lipid peroxidation and stabilized the cell membrane of flowers. Alternatively, the higher electrolytic leakage from petal tissue might have occurred in control due to a result of higher lipid peroxidation. It is indicated that the cell membranes lose their stability; they produce different ROS which results in enhancing the electrolyte leakage (Iqbal et. al., 2017).

Proline is one of the most important soluble osmosis-regulator and proteinogenic amino acids (Alvarez et. al., 2021; Yang et. al., 2021). Increment of proline in flowers is a general adaptive response to cellular dehydration caused by water stress. In this study, GME had lower proline content than control flowers. Similar results about some compounds reducing proline accumulation were obtained by Kazemi et. al. (2011) and Skutnik et. al. (2021). The lower proline content might have been related to that GME act as the antioxidant defense factor and protects flowers against cellular dehydration or GME might have increased proline dehydrogenase (PRODH) activity in the petals. Alternatively, the reason for the higher proline content in the control flowers may be the higher protein degradation because of the water and/or oxidative stress. Proline content can increase due to the breakdown of proteins and increase in free amino acids in petal cells with senescence or uplifted stress over time (Mohammadi et. al., 2020; Koentjoro et. al., 2021).

Antioxidant enzymes, such as APX, SOD, and CAT play a key role in improving the vase life of cut flowers by maintaining the ROS balance (Wang et. al., 2021). When ROS producing rate exceeds that of the cell's defense ability, oxidative stress occurs. ROS such as H_2O_2 is generated, damaging cells, and hastening their death. In this study, all antioxidant enzymes increased at GME treatments from Stage 1 to Stage 2. There are many researchers who have determined that antioxidant enzyme activities increase with substances added to the vase solutions (Maity et. al., 2019; Aziz et. al., 2020; Hassanzadeh-Naemi et. al., 2021). Hassanzadeh-Naemi et. al. (2021) found that CAT and SOD activity decreased during the postharvest life and that this activity was improved with treated plant growth regulators. Similarly, CAT and APX activities increased from Stage 1 to Stage 2, while SOD enzyme activity decreased in the control. It is thought that cut carnation 'Baltico' flowers may have defended themselves against oxidative or water stress by increasing the proline content instead of SOD enzyme activity in the control. As a matter of fact, the proline content in the study was found to be higher in the control. The formation of enzymatic and non-enzymatic antioxidants responsible for ROS detoxification under stress conditions are important defense systems against stress (Hassanuzzaman et.

al., 2020). GME might have supported the enzymatic defense system in cut flowers. Although CAT and APX increased in all treatments, the results differed between the treatments and GME is better vase life compared to the control. This might be related to the SOD activity being more distinct and important in the scope of protecting membrane damage by the scavenging of ROS on flowers that exposure to water stress. Du et. al. (2014) reported that the correlation between SOD activity and MDA content was significant compared to CAT and APX enzyme activity, and SOD acted more effectively than ascorbic acid done in the superoxide quenching.

Although the SOD decreased in the control, the increase in the CAT enzyme showed that in the control flowers have occurred H_2O_2. SOD is a metalloenzyme that catalyzes the dismutation of superoxide to H_2O_2. H_2O_2 formed directly or by the dismutation of superoxide radicals is detoxified by converting it into the water by GPx and CAT enzymes. The CAT enzyme has significant efficacy in cases where H_2O_2 formation is increased (Koç & Üstün, 2008). CAT increased despite the reduction in SOD at control; indicating that H_2O_2 formation is increased non-enzymatic pathways. Moreover, more oxygen radicals that can cause damage to the cell membrane might have accumulated in control flowers due to the decreasing of SOD activity. This coincides with the increase in MDA content at control. Similar to in this results, Panda and Khan (2004) reported that oxidative damage occurs when the production rate of superoxide radicals exceeds the SOD activity. In this study, SOD enzyme activity may have decreased due to the reduction of synthesis of SOD enzyme or enhancing degradation of this enzyme at control group. Decreasing the SOD activity in the control may have accelerated senescence and caused short vase life. Wang et. al. (2016) reported that the increasing of SOD activity and efficient ROS-scavenging capacity contributed largely to the delay of senescence.

There are many substances used to prolong the vase life of carnations, and the commercially preferred STS is a proven substance. In research with STS, it has been determined that the vase life can be extended from 1 to about 14 days, depending on the variety, concentration, and trial conditions (Hassan, 2004). However, STS is harmful to both human health, and the environment. As an alternative to this substance, cheap materials that are friendly to human health and the environment should be determined. The use of plant wastes to increase post-harvest life is important in terms of both overcoming post-harvest problems of cut flowers and ensuring waste management. It is thought that grape marc is important in terms of post-harvest studies, especially because it is available throughout the year, can be easily supplied, has no storage problems, is inexpensive, does not have any harm in terms of human and environmental health, and provides an economic return by evaluating a waste material (Sarıçiçek & Kılıç, 2002). Studies are needed to standardize grape marc which affects the stress mechanism in cut flowers after harvest by determining the appropriate doses and to use it as a commercial preparation if proven.

CONCLUSION

In conclusion, GME has the potential to improve the vase life of the cut flowers. The GME treatment prolonged the vase life of cut carnation, and the 200 µL L^{-1} GME was the best treatment in terms of investigated parameters. GME stimulated the defense ability of cut carnation flowers. It is thought that this is related to the antioxidant activities of GME. Moreover, it decreased the bacterial activity in vase solution due to its antibacterial properties. It is recommended that the effects of higher concentrations of GME should be researched the vase life of cut flowers. Investigation of antioxidant activities of GME is also important to contribute to future research. Different GME obtained from other grape varieties can be researched which has better antioxidant and antibacterial activity. If the effectiveness of GME on vase life is proven, it is possible that it can be standardized and converted into a commercial preparation form. This research also is showing that waste materials can be added to a vase solution.

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Contribution of the Authors as Summary

Authors declares the contribution of the authors is equal.

Statement of Conflict of Interest

Authors have declared no conflict of interest.

REFERENCES

Aalifar, M., Aliniaeifard, S., Arab, M., Mehrjerdi, M. Z., Daylami S. D., Serek, M., Woltering, E., & Li, T. (2020). Blue light improves vase life of carnation cut flowers through its effect on the antioxidant defense system. *Frontiers in Plant Science 11*, 511. https://doi.org/10.3389/fpls.2020.00511.

Adam, A. I. (2021). Effect of essential oils on vase life of cut flowers of *Solidago canadensis* L. (Golden rod). *Scientific Journal of Agricultural Sciences 3*(1), 46-55. https://doi.org/10.21608/sjas.2021. 75270. 1096.

AIPH, 2021. International Statistics Flowers and

Plants Yearbook 2021. Union Fleurs.

Alkaç, O. S., Öcalan, O. N., & Güneş, M. 2020. The effect of some solutions on the vase life of star flowers. *Ornamental Horticulture 26*(4), 607-613. https://doi.org/10.1590/2447-536x.v26i4.2184.

Alvarez, M. E., Savoure, A., & Szabados, L. (2021). Proline metabolism as regulatory hub. *Trends in Plant Science 27*(1), 39-55. https://doi.org/10.1016/ j.tplants.2021.07.009.

Amin, O. A. 2017. II-Effect of some chemical treatments on keeping quality and vase life of cut chrysanthemum flowers. *Middle East Journal of Agriculture Research 06*(01), 221-243.

Anonymous, 1999. *NCCLS (National Committee for Clinical Laboratory Standards). Performance Standards for Antimicrobial Susceptibility Testing*. The 9th International Supplement, M100-S9. Villanova, PA. (Date: 20.05.2019).

Anonymous, 2022. *Carnations. Care Tips.* https:/ bloomiq.com/cutflowers/13.(Date: 20.05. 2019).

Azad, A. K., Sawa, Y., Ishikawa, T., & Shibata, H. (2004). Phosphorylation of plasma membrane aquaporin regulates temperature-dependent opening of tulip petals. *Plant Cell Physiology 45*(5), 608-617. https://doi.org/10.1093/pcp/pch069.

Aziz, S., Younis, A., Jaskani, M. J., & Ahmad, R. (2020). Effect of pgrs on antioxidant activity and phytochemical in delay senescence of lily cut flowers. *MDPI Agronomy 10*(11), 1704. https://doi.org/10.3390/agronomy10111704.

Bağcı, E., & Dığrak, M. (1996). Antimicrobial activities of essential oils of some forest trees. *Turkish Journal of Biology 20*, 191-198.

Bağcı, E., & Dığrak, M. (1997). In vitro antimicrobial effects of some fir species essential oils. *Turkish Journal of Biology 21*, 273-281.

Bat, M., Tunçtürk, R., & Tunçtürk, M. (2020). Effect of drought stress and seaweed applications on some physiological parameters in *Echinacea* (*Echinacea purpurea* L.). *KSU Journal of Agriculture and Nature 23*(1), 99-107. https://doi.org/10.18016/ ksutarimdoga.vi.535210.

Bates, L. S., Waldren, R. P., & Teare, I. D. (1973). Rapid determination of free proline for water-stress studies. *Plant and Soil 39*(1), 205-207. https://doi.org/10.1007/bf00018060.

Bradshaw, L. J. 1992. *Laboratory of Microbiology*. Fourth Edition. Saunders College Publishing, Printed in U.S.A., 435 p.

Çakmak, I., Strbac, D., & Marschner, H. (1993). Activities of hydrogen peroxide-scavenging enzymes in germinated wheat seeds. *Journal of Experimental Botany 44*(1), 127-132. https:// doi.org/10.1093/jxb/44.1.127.

Collins, C. H., Lyne, P. M., & Grange, J. M. (1987). *Microbiological Methods*. Butterworths and Co. (Publishers) Ltd. London, 450 p.

Damunupola, J. W., Qian, T., Muusers, R., Joyce, D.C., Irving, D.E., & Van Meeteren, U. (2010). Effect of s-carvone on vase life parameters of selected cut flower and foliage species. *Postharvest Biology and Technology 55*(1), 66-69.

Dar, R. A., & Tahır, I. (2018). Effect of ethylene antagonist silver thiosulphate on the flower longevity of *Clarkia pulchella* Pursh.. *Journal of Horticultural Research 26*(1), 5-12. https://doi.org/ 10.2478/johr-2018-0001.

Du, F., Shi, H., Zhang, X., & Xu, X. (2014). Responses of reactive oxygen scavenging enzymes, proline and malondialdehyde to water deficits among six secondary successional seral species in *Loess plateau*. *PLoS One 9*(6), e98872. https://doi.org/ 10.1371/journal.pone.0098872.

Ebrahimzadeh, A., Jimenez-Becker, S., Chaparro-Torres, L. A., Fernandez-Trujillo, P. J., Serrano-Mula, M., & Lao-Arenas, M.T. (2013). Postharvest petal senescence of two cultivars of carnation flowers with different vase lifes. *Australian Journal of Crop Science 7*(12), 1829-1835.

Ebrahimzadeh, M. A., Fathi, H., Ziar, A., & Mohammadi, H. (2019). Attenuation of brain mitochondria oxidative damage by *Albizia julibrissin* Durazz: neuroprotective and antiemetic effects. *Drug and Chemical Toxicology 42*(2), 122-129. https://doi.org/10.1080/01480545.2017.1413106.

Elansary, H. O. (2020). Tree bark phenols regulate the physiological and biochemical performance of gladiolus flowers. *MDPI Processes 8(1),* 71. https://doi.org/10.3390/pr8010071.

Eleonora, N., Dobrei, A., Dobrei, A., Bampidis, V., & Valeria, C. (2014). Grape pomace in sheep and dairy cows feeding. *Journal of Horticulture, Forestry and Biotechnology 18*(2), 146-150.

Elhindi, K. M. (2012). Effects of postharvest pretreatments and preservative solutions on vase life longevity and flower quality of sweet pea (*Lathyrus odoratus* L.). *Photosynthetica 50*(3), 371-379. https://doi.org/10.1007/s11099-012-0053-3.

Ezhilmathi, K., Singh, V. P., Arora, A., & Sairam, R. K. (2007). Effect of 5-sulfosalicylic acid on antioxidant activity in relation to vase life of gladiolus cut flowers. *Plant Growth Regulation 51*(2), 99-108. https://doi.org/10.1007/s10725-006-9142-2.

Frew, A., Weston L. A., Reynolds, O. L., & Gurr, G. M. (2018). The role of silicon in plant biology: a paradigm shift in research approach. *Annals of Botany 121*(7), 1265-1273. https://doi.org/10.1093/ aob/mcy009.

Ghadimian, S., & Danaei, E. (2020). Influences of ascorbic acid and salicylic acid on vase life of cut flowers rose (*Rosa hybrida* cv. Black Magic). *The Journal of Environment, Agriculture and Biological Sciences 2*(1), 1-6. https://doi.org/10.29252/ alkhass. 2.1.1.

Gökçen, İ. S., Keskin, N., Kunter, B., Cantürk, S., & Karadoğan, B. (2017). Grape phytochemicals and research on grape cultivars grown in Turkey. *Turkish Journal of Forest Science 1*(1), 93-111. https://doi.org/10.32328/turkjforsci.285695.

Gomes, M. H. T., de Carvalho, S. M. P., & de Almeida, D. P. F. (2010). Pectin solubility and water relations during vase life of cut flowers. *Horticulture, Environment, and Biotechnology 51*(4), 262-268.

Gong, H., Zhu, X., Chen, K., Wang, S., & Zhang, C. (2005). Silicon alleviates oxidative damage of wheat plants in pots under drought. *Plant Science 169*(2), 313-321. https://doi.org/10.1016/j.plantsci.2005.02.023.

Ha, S. T. T., Lim, J. H., & In, B. C. (2019). Extension of the vase life of cut roses by both improving water relations and repressing ethylene responses. *Korean Journal of Horticultural Science and Technology 37*(1), 65-77. https://doi.org/10.12972/kjhst.20190007.

Hassan, F., Schmidt, G., Hafez, Y. M., Pogany, M., Ankush, J. (2004). 1-MCP and STS as ethylene inhibitors for prolonging the vase life of carnation and rose cut flowers. *International Journal of Horticultural Science 10*(4), 101-107.

Hassanuzman, M., Bhuyan, M. H. M. B., Zulfigar, F., Raza, A., Mohsin, S.M., Mahmud, J., Fujita, M., & Fotopoulos, V. (2020). Reactive oxygen species and antioxidant defense in plants under abiotic stress: revisiting the crucial role of a universal defense regulator. *MDPI Antioxidants 9*(8), 681. https://doi.org/10.3390/antiox9080681.

Hassanzadeh-Naemi, M., Jari, S. K., Zarrinnia, V., & Fatehi, F. (2021). The effect of exogenous methyl jasmonate and brassinosteroid on physicochemical traits, vase life, and gray mold disease of cut rose (*Rosa hybrida* L.) flowers. *Journal of Saudi Society of Agricultural Sciences 20*(7), 467-475. https://doi.org/10.1016/j.jssas.2021.05.007.

He, S., Joyce, D. C., Irving, D. E., & Faragher, J. D. (2006). Stemend blockage in cut grevillea 'crimson yul-lo' inflorescences. *Postharvest Biology and Technology 41*(1), 78-84. https://doi.org/10.1016/j.postharvbio.2006.03.002.

Horibe, T., & Makita, M. (2019). Methyl jasmonate treatment delays flower opening and petal wilting of three cut rose cultivars. *Journal of Horticultural Research 27*(2), 1-10. https://doi.org/10.2478/johr-2019-0016.

Iqbal, N., Khan, N. A., Ferrante, A., Trivellini, A., Francini, A., & Khan, M. I. R. (2017). Ethylene role in plant growth, development, and senescence: interaction with other phytohormones. *Frontiers in Plant Science 8,* 475. https://doi.org/10.3389/fpls.2017.00475.

Jawaharlal, M., Ganga,, M., Padmadevi, R., Jegadeeswari, V., & Kartikeyan, S. (2007). *A Technical Guide on Carnation. Department of Floriculture and Landscaping,* Horticultural College and Research Institute, Tamil Nadu Agricultural University, 56 p. India.

Kazaz,, S. (2015). Factors affecting post harvest lifes in cut flowers. *Turkish Seed Association Journal 4*(14), 42-45.

Kazemi, M., & Ameri, A. (2012). Response of vase-life carnation cut flower to salicylic acid, silver nanoparticles, glutamine and essential oil. *Asian Journal of Animal Sciences 6*(3), 122-131. https://doi.org/10.3923/ajas.2012.122.131.

Kazemi, M., Aran, M., & Zamani, S. (2011). Extending the vase life of lisianthus (*Eustoma grandiflorum* Mariachi. cv. Blue) with different preservative. *American Journal of Plant Physiology 6*(3), 167-175. https://doi.org/10.3923/ajpp.2011.167.175.

Kazemi, M., Gholami, M., Asadi, M., Aghdasi, S., & Almasi, M. (2012). Response of carnation (*Dianthus caryophyllus* L.) to salicylic acid and glutamine. *Asian Journal of Biochemistry 7*(3), 158-164. https://doi.org/10.3923/ajb.2012.158.164.

Khenizy, S., Abd El-Moneim, A., & Abdel-Fattah, G. H. (2014). Effect of natural extracts on vase life of gypsophila cut flowers. *Scientific Journal of Flowers and Ornamental Plants 1*(1), 1-16. https://doi.org/10.21608/SJFOP.2014.4000.

Kiselev, K. V., Dubrovina, A. S., Veselova, M. V., Bulgakov, V. P., Fedoreyev, S. A., & Zhuravlev, Y. N. (2007). The Rol-B gene-induced over production of resveratrol in *Vitis amurensis* transformed cells. *Journal of Biotechnology 128*(3), 681-692.

Kılıç, T. , Kazaz, S. , Doğan, E. & Ergür Şahin, E. G. (2020). Effects Of Some Essentıal Oil Compounds On Vase Life Of Cut Hydrangea Flowers . Ziraat Fakültesi Dergisi, Türkiye 13. Ulusal, I. Uluslararası Tarla Bitkileri Kongresi Özel Sayısı , 172-179 . Retrieved from https://dergipark.org.tr/en/pub/ sduzfd/issue/52563/650745

Koç, E., & Üstün, A. S. (2008). Defence against pathogen in plants and antioxidants. *Erciyes University Journal of the Institute of Science and Technology 24*(1-2), 82-100.

Koentjoro, Y., Sukendah, S., Purwanto, E., & Purnomo, D. (2021). The role of silicon on content of proline, protein, and abscisic acid on soybean under drought stress. *Earth and Environmental Science 637,* 012086. https://doi.org/10.1088/1755-1315/637/1/012086.

Lama, B., Ghosal,, M., Kumar-Gupta, S., & Mandal, P. (2015). Assessment of different preservative solutions on vase life of cut roses. *Journal of Ornamental Plants 3*(3), 171-181. https://doi.org/10.11623/frj.2017.25.3.02.

Langroudi, E. M., Hashemabadi, D., Kalatejari, S., & Asadpour, L. (2019). Effect of silver nanoparticles, spermine, salicylic acid and essential oils on vase life of alstroemeria. *Revista de Agricultura Neotropical 6*(2), 100-108. https://doi.org/10.32404/

rean.v6i2.2366.

Lou, X., Anwar, M., Wang, Y., Zhang, H., & Ding, J. (2021). Impact of inorganic salts on vase life and postharvest qualities of the cut flower of perpetual carnation. *Brazilian Journal of Biology 81*(2), 228-236. https://doi.org/10.1590/1519-6984.221502.

Luchian, C. E., Cotea, V. V., Vlase, L., Toiu, A. M., Colibaba, L. C., R˘aschip, I. E., Nad˘as, G., Gheldiu, A. M., Tuchilus, C., & Rotaru, L. (2019). Antioxidant and antimicrobial effects of grape pomace extracts. BIO Web of Conferences 15, 04006, 42nd World Congress of Vine and Wine. https://doi.org/10.1051/bioconf/20191504006.

Madhava Rao, K. V., & Sresty, T. V. S. (2000). Antioxidative parameters in the seedlings of pigeonpea (*Cajanus cajan* L. Millspaugh) in response to zn and ni stress. *Plant Science 157*(1), 113-128. https://doi.org/10.1016/s0168-9452(00) 00273-9.

Maity, T. R., Samanta, A., Saha, B., & Datta, S. (2019). Evaluation of piper betle mediated silver nanoparticle in post-harvest physiology in relation to vase life of cut spike of gladiolus. *Bulletin of the National Research Centre 43*(1), 1-11. https://doi.org/10.1186/s42269-019-0051-8.

Mohammadi, M., Aelaei, M., & Saidi, M. (2020). Pre-Harvest and pulse treatments of spermine, γ- and ß-aminobutyric acid increased antioxidant activities and extended the vase life of gerbera cut flowers 'Stanza'. *Ornamental Horticulture 26*(2), 306-316. https://doi.org/10.1590/2447-536x.v26i2. 2120.

Mylonas, C., & Kouretas, D. (1999). Lipid peroxidation and tissue damage. *In Vivo 13(3)*, 295-309.

Nakano, Y., & Asada, K. (1981). Hydrogen peroxide is scavenged by ascorbate-specific peroxidase in spinach chloroplast. *Plant and Cell Physiology 22*(5), 867-880. https://doi.org/10.1093/oxford journals. pcp.a076232.

Nguyen, T. K., & Lim, J. H. (2021). Do eco-friendly floral preservative solutions prolong vase life better than chemical solutions?. *MDPI Horticulturae 7*(10), 415. https://doi.org/10.3390/ horticultura 7100415.

Panda, S. K., & Khan, M. H. (2004). Changes in growth and superoxide dismutase activity in *Hydrilla verticillata* L. under abiotic stress. *Brazilian Journal of Plant Physiology 16*(2), 115-118.

Pang, Z., Li, H., Lin, G., Sun, Y., Zhou, H., & He, S. (2021). One-Step green preparation of nano-silver aqueous solution, characterization, and its antibacterial potential for cut carnation flowers. Research Square in press. https://doi.org/10.21203/ rs.3.rs-284927/v1.https://assets.researchsquare. com/files/rs-284927/v1/ea041389-45cf-483a-8e0f-1419d41e4074.pdf?c=1631878822

Patel, R., Thakkar, A., & Mankad, A. (2016). Effect of chemical preservative on water relation and vase-life of *Tithonia rotundifolia* Blake cut flower. *Annals of Biological Research 7*(1), 27-30.

Paul, D., Jannat, A., Mahmud, A., Akhter, M.J., & Mahmood, S. (2021). Preservative solutions on vase life and quality of cut *Polianthes tuberosa* L.. *Ornamental Horticulture 27*(3), 417-424. https://doi.org/10.1590/2447-536X.v27i3.2375.

Rahman, M. M., Ahmad, S. H., & Lgu, K. S. (2012). *Psidium guajava* and *Piper betle* leaf extracts prolong vase life of cut carnation (*Dianthus caryophyllus*) flowers. *The Scientific World Journal 2*(1), 102805. https://doi.org/10.1100/2012/102805.

Saeed, T., Hassan, I., Abbasi, N. A., & Jilani, G. (2014). Effect of gibberellic acid on the vase life and oxidative activities in senescing cut gladiolus flowers. *Plant Growth Regulation 72*(1), 89-95. https://doi.org/10.1007/s10725-013-9839-y.

Sarıçiçek, B. Z., & Kılıç, Ü. (2002). An investigation on determining of feed values of grape pomace. *The university of Ondokuz Mayıs Journal of Faculty of Agriculture 17*(1), 9-12.

Satoh, S., Shibuya, K., Waki, K., & Kosugi, Y. (2005). Mechanism of senescence in carnation flowers (oral presentation). Acta Horticultureae 669 VIII International Symposium on Postharvest Physiology of Ornamental Plants, Doorwerth, Netherlands, 1 Februrary, pp. 191-198. https://doi.org/10.17660/actahortic.2005.669.24.

Şevik, M. A., & Saruhan, İ. (2010). Plant protecton problems in carnation (*Dianthus caryophyllus* L.). *Turkish Journal of Scientific Reviews 3*(2), 33-41.

Shanan, N. T. (2017). Optimum pH value for improving postharvest characteristics and extending vase life of *Rosa hybrida* cv. Tereasa cut flowers. *Asian Journal of Advances in Agricultural Research 1*(3), 1-11. https://doi.org/10.9734/ajaar/ 2017/34655.

Shokalu, A. O., Israel, J., Mosunmola, O., Eniola, O., Gift, E., Adebayo, A., & Henry, A. (2021). Aloe vera and STS solution on microbial population and vase life of heliconia cut flowers. *Ornamental Horticulture 27*(4), 470-475. https://doi.org/ 10.1590/2447 - 536x.v27i4.2356.

Skutnik, E., Jedrzejuk, A., Rabiza-Swider, J., Rochala-Wojciechowska, J., Latkowska, M., & Lukaszewska, A. (2020). Nanosilver as a novel biocide for control of senescence in garden cosmos. *Scientific Reports 10*(1), 10274. https://doi.org/10.1038/s41598-020-67098-z.

Skutnik, E., Lukaszewska, A., & Rabiza-Swider, J. (2021). Effects of postharvest treatments with nanosilver on senescence of cut lisianthus (*Eustoma grandiflorum* (Raf.) Shinn.) flowers. *MDPI Agronomy 11*(2), 215. https://doi.org/10.3390/ agronomy11020215.

Song, J., Li, Y., Hu, J., Lee, J., & Jeong, B. R. (2021). Pre- and/or postharvest silicon application prolongs the vase life and enhances the quality of cut peony

(*Paeonia lactiflora* Pall.) flowers. *MDPI Plants 10* (8), 1742. https://doi.org/10.3390/plants100 81742.

Tah, J., & Mamgain, A. (2013). Variation in different agronomical characters of some carnation (*Dianthus caryophyllus*) cultivars. *Research Journal of Biology 1*, 10-23.

Teerarak, M., & Laosinwattana, C. (2019). Essential oil from ginger as a novel agent in delaying senescence of cut fronds of the fern (*Davallia solida* (G. Forst.) Sw.). *Postharvest Biology and Technology 156*, 110927. https://doi.org/ 10.1016/j.postharvbio.2019.06.001.

Wang, F., Liu, J., Zhou, L., Pan, G., Li, Z., Zaidi, S. H. R., & Cheng, F. (2016). Senescence-specific change in ros scavenging enzyme activities and regulation of various sod isozymes to ros levels in psf mutant rice leaves. *Plant Physiology and Biochemistry 109*, 248-261. https://doi.org/10.1016/j.plaphy. 2016.10. 005.

Wang, P., Fang, H., Gao, R., & Liao, W. (2021). Protein persulfidation in plants: function and mechanism. *MDPI Antioxidants 10*(10), 1631. https://doi.org/ 10.3390/antiox10101631.

Yang, X., Lu, M., Wang, Y., Wang, Y., Liu, Z., & Chen, S. (2021). Response mechanism of plants to drought stress. *MDPI Horticulturae 7*(3), 50. https://doi.org/ 10.3390/horticulturae7030050.

Zamani, S., Hadavi, E., Kazemi, M., & Hekmati, J. (2011). Effect of some chemical treatments on keeping quality and vase life of chrysanthemum cut flowers. *World Applied Sciences Journal 12*(11), 1962-1966.

Zhang, Sg., Han, Sy., Yang, Wh., Wei, Hl., Zhang, M., & Qi, Lw. (2010). Changes in H_2O_2 content and antioxidant enzyme gene expression during the somatic embryogenesis of *Larix leptolepis*. *Plant Cell Tissue and Organ Culture (PCTOC) 100*(21), 21-29. https://doi.org/10.1007/s11240-009-9612-0.