ACTA SCIENTIARUM POLONORUM
Acta Sci. Pol. Hortorum Cultus, 19(4) 2020, 95–103
https://czasopisma.up.lublin.pl/index.php/asphc ISSN 1644-0692 e-ISSN 2545-1405 DOI: 10.24326/asphc.2020.4.9
ORIGINAL PAPER
Accepted: 17.10.2019

EXTENDING THE VASE LIFE OF CUT HYDRANGEA FLOWERS BY PRESERVATIVE SOLUTIONS

Soner Kazaz[1], Tuğba Kılıç[2]✉, Elçin Gözde Ergür Şahin[1]

[1] Faculty of Agriculture, Department of Horticulture, Ankara University, 66130 Ankara, Turkey
[2] Faculty of Agriculture, Department of Horticulture, Yozgat Bozok University, 66200 Yozgat, Turkey

ABSTRACT

Vase life is one of the most important factors determining the marketability of cut flowers and influenced by water balance strongly. In recent years, the consumption of hydrangeas as a cut flower has gradually increased. However, the vase life of cut hydrangea flowers is short depends on wilting. Thus, this study was conducted to determine the effects of different treatments [thymol (100, 150 and 200 mgL^{-1}), 8-hydroxyquinoline sulfate (8-HQS) (200 mgL^{-1})], and their combination with and without 1% sucrose on the vase life, relative fresh weight, daily (solution uptake for 3 days) and total solution uptake of hydrangeas (*Hydrangea macrophylla* 'Green Shadow') harvested freshly. Distilled water was used as the control. Compared to the control, thymol 150 mgL^{-1} treatment with 1% sucrose significantly increased the vase life of hydrangeas flowers in 5.80 days (from 10.7 to 16.5 days). It was also determined that same treatment increased the total solution uptake and delayed relative fresh weight loss. These results indicated that thymol treatments in combination with sucrose can be used to extend the vase life of cut hydrangea.

Key words: cut flowers, *Hydrangea macrophylla*, vase solution, thymol, 8-HQS, sucrose

INTRODUCTION

Hydrangeas (*Hydrangea* spp.) are very popular ornamental plant cultivated as a cut flower, a garden and potted plant in many countries. The demand for cut hydrangea flowers has been increasing in recent years. According to data of Dutch auctions, sales of hydrangea flowers amounted to € 51 million and hydrangea ranked 10th among the cut flowers in 2016 [Royalfloraholland 2018]. As a cut flower, hybrids of *Hydrangea macrophylla* are frequently used [Kitamura et al. 2017a]. *Hydrangea macrophylla* is a deciduous shrub to 3 meter that is native to eastern Asia. Inflorescences of *H. macrophylla* are classified as mophead (hortensia) and lacecap into two types based on the arrangement of florets [Servis et al. 2016]. The colorful part of its flower is actually a bract and can be blue, red, pink, light purple or dark purple [Savona et al. 2012]. Its vase life ranges from 7 to 15 days [Thomas and Gollnow 2013].

As in all cut flowers, the vase life of cut hydrangeas is a commercially important parameter in floriculture industry. It can exceed 2 weeks under favorable conditions but is often cut short by vascular plugging [Florissant 2018]. Stem of flowers that is placed in water often develops a negative water balance due to vascular plugging by microorganisms, air emboli and physiological responses of stems to cutting. Their rate of water uptake becomes lower than the transpiration rate and it causes water stress [Ichimura et al. 1999, Elhindi 2012]. Because of water stress, the flowers especially large ones can easily become dehydrated.

✉ tugba.kilic@bozok.edu.tr

Losing substantial water is resulted quickly wilt, the browning petals and reduction of cut flower longevity [Ranwala 2010]. Flower preservatives are used to prevent these problems in many cut flowers. Germicides, acidifiers or surfactants such as 8-HQS, silver thiosulfate (STS), silver nitrate ($AgNO_3$) etc. have been found to be successful in increasing the vase life of cut flowers [Elgimabi and Ahmed 2009, Asrar 2012]. 8-HQS is considered to be of particular importance as it has both germicide and surfactant properties [Kesarisinh 2015]. Essential oils also have been used to improve vase life of cut flowers due to their antimicrobial and antioxidant activity [Bayat et al. 2013]. Thymol and carvacrol are the most active compounds of essential oils and they are effective in prolonging vase life [Bayat et al. 2013, Dhifi et al. 2016].

There are very few studies about flower preservative effects on the cut hydrangea vase life. Some studies had been made for cut hydrangea vase life and they focused on stomatal conductance [Kitamura et al. 2017b], inflorescence type [Kitamura et al. 2017c], different harvest stage [Kitamura et al. 2017a], holding solution [Thaneswari 2014, Aros et al. 2016], different fertilization levels [Thaneswari 2014, Chunne 2015]. In this study, we investigated the effects of different flower preservatives that thymol, 8-hydroxyquinoline sulfate (8-HQS), and their combination with 1% sucrose on the vase life of cut hydrangeas.

MATERIALS AND METHODS

The present study was carried out in the postharvest laboratory, Department of Horticulture, Faculty of Agriculture, Ankara University in Ankara, Turkey in June 2016. Cut hydrangea (*Hydrangea macrophylla* 'Green Shadow') flowers used in the experiment were grown under the gothic roof type-butterfly vent greenhouse which was covered with plastic and located in the Department of Horticulture in the Faculty of Agriculture at Ankara University (39°57'40.2"N, 32°51'51.7"E). *Hydrangea macrophylla* 'Green Shadow' is a dark red cultivar. Its inflorescence type is mophead and it differs from the others because it shows dark green spots at the end of the sepals. It is known that as a contemporary modern cultivar [Anonymous 2018].

The flowers were harvested at the commercial harvest stage (approximately 80% of the decorative florets in the inflorescence had developed the cultivar-specific color) [Kitamura et. al. 2017c] placed in buckets containing tap water and transferred to the postharvest laboratory within half an hour of harvest. At the laboratory, the stems were re-cut to a length of 45 cm and only one upper leaves were retained on each stem. They were then placed in glass bottles (1000 ml) containing 500 ml of vase solutions which were thymol (100, 150 and 200 mgL^{-1}) (Sigma, CAS:89-83-8) with and without %1 sucrose, 8-hydroxyquinoline sulfate (8-HQS) (200 mgL^{-1}) (Aldrich, CAS:207386-91-2) with and without 1% sucrose, 1% sucrose and distilled water as control (Tab. 1). All solutions were freshly prepared at the beginning of the experiment. The flowers were kept in a temperature-controlled chamber at 21 ±1°C temperature, 65 ±5% relative humidity (RH) and 1000 lux illumination (cool-white fluorescence lamps) for 12 h photoperiod.

During the experimental period, decorative value was characterized by vase life, fresh weight and solution uptake. Vase life was terminated when wilting, sepal browning, or sepal desiccation became apparent on approximately 80% of decorative florets in an inflorescence based on daily observations [Kitamura et al. 2017b]. Fresh weight and solution uptake were recorded by measuring the weights of the vases with and without flowers once every 3 days. Fresh weight change was measured as relative fresh weight (RFW) and it was calculated as: $RFW\ (\%) = (W_t/W_{t-0}) \times 100$, where W_t is the weight of stem (g) at t = day 0,1,2, etc. and W_{t-0} is the weight of the same stem (g) at t = day 0 [He et al. 2006, Lü et al. 2010]. Solution uptake was measured and calculated as daily and total solution uptake. Daily solution uptake (DSU) means solution uptake for 3 days and was calculated as: DSU ($g\ stem^{-1}\ day^{-1}$) = $(S_{t-1} - S_t)$, where S_t is the weight of vase solution (g) at t = days 1, 2, 3 etc. and S_{t-1} is the weight of vase solution (g) on the previous day [He et al. 2006].

The experimental design was a Randomized Plot Design (RPD) with different concentrations of thymol, 8-HQS and distilled water with and without sucrose × ten replications × one cut flower per treatment. Statistical analysis of recorded data was accomplished using analysis of variance (ANOVA) using IBM SPSS Statistics 20.0. Mean differences were established by Duncan's test ($P < 0.05$).

Table 1. Treatments used in this experiment

Treatments	
C	Control
C+S	Control + 1% sucrose
8-HQS	8-hydroxyquinoline sulfate
8-HQS+S	8-hydroxyquinoline sulfate + 1% sucrose
T100	Thymol (100 mgL^{-1})
T100+S	Thymol (100 mgL^{-1}) + 1% sucrose
T150	Thymol (150 mgL^{-1})
T150+S	Thymol (150 mgL^{-1}) + 1% sucrose
T200	Thymol (200 mgL^{-1})
T200+S	Thymol (200 mgL^{-1}) + 1% sucrose

C – control-distilled water, S – sucrose, T – thymol

RESULTS AND DISCUSSIONS

The effects of different preservative solutions on vase life, relative fresh weight, daily and total solution uptake in cut hydrangea flowers were found statistically significant. Variance analysis was shown in Table 2.

Vase life. The results showed that the thymol 100 mgL^{-1} with and without 1% sucrose, thymol 150 and 200 mgL^{-1} with sucrose treatments significantly increased the vase life of flowers compared with the control. The vase life of flowers treated with 150 mgL^{-1} + 1% sucrose was found 5.80 days longer than that of control. Thymol 200 mgL^{-1} (8.2 day) had the lowest vase life (Fig. 1).

According to our results, all treatments containing sucrose except distilled water extended the vase life than sucrose-free treatments. It is known that sugar supply increases the vase life of many cut flowers [Elgimabi 2011]. While sucrose may act as a source of nutrition for tissues, it may also act as an osmotically active molecule organizing water relations [Yagi and Elgimabi 2014]; thereby it might have been extend the vase life of cut hydrangea. Distilled water in combination with %1 sucrose was shortened the vase life because the sugar may have promoted microorganism growth which block the xylem. It was reported that sucrose should be used along with an antimicrobial agent [Elhindi 2012].

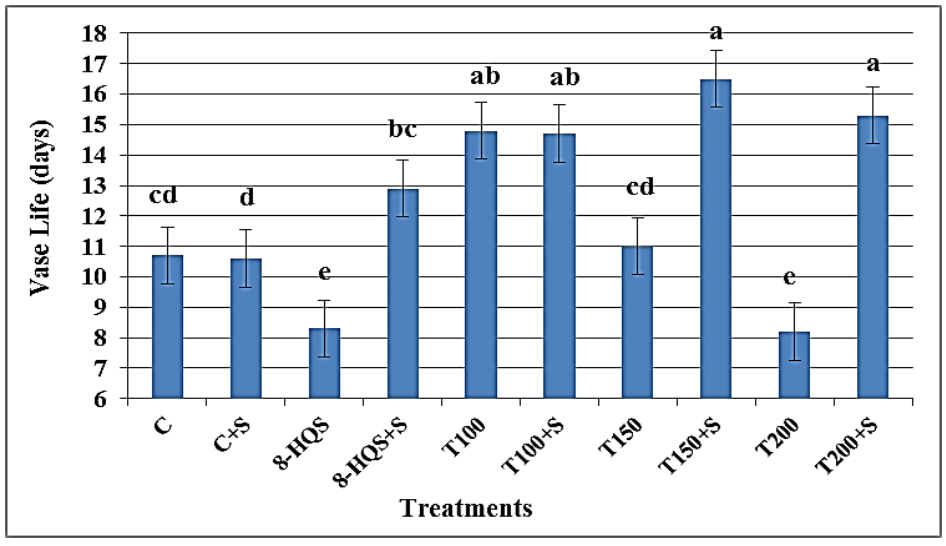
Thymol and 8-HQS used in this study are antimicrobial agents [Yagi and Elgimabi 2014, Memar et al. 2017]. Many studies on vase life of cut flowers have shown that thymol and 8-HQS are effective in extending the vase life of some cut flowers [Asrar 2011, Babarabie et al. 2015]. According to our results, thymol 100 mgL^{-1} extended the vase life of cut hydrangeas. These results may be due to the role of thymol as antimicrobial agent and hence, it might have reduced stem plugging. But reduction in the vase life of flowers was detected at the increasing doses of thymol without sucrose. Similar results were obtained by Pourianejad et al. [2014]. Essential oils such as thymol had a phytotoxic effect because of herbicidal activity in various plant systems and caused electrolyte leakage resulting in cell death [Kordali et al. 2008]. In this study high concentrations of the thymol treatments may be toxic and cause cell damage, thereby resulting in a shorter vase life than the control. Similar to thymol, 8-HQS also reduced the vase life. Its concentration may be high or 8-HQS may be toxic to flowers of hydrangea. It was reported that 8-HQS is toxic for some rose [Ichimura et al. 2006] and waxflowers [Dung et al. 2016] cultivars, causing a short vase life.

Solution uptake. The daily solution uptake increased during the first 3 days of the vase life in all treatments after that, gradually decreased until end of the vase life. The daily solution uptake in 150 mgL^{-1} thymol in combination with sucrose 1% was much higher than the other treatments from the 6th day until the 21th day whereas 200 mgL^{-1} thymol was the lowest treatment (Tab. 3).

Table 2. Variance analysis of vase life, RFW, DSU and TSU in cut hydrangea flowers

	Source of variation	df	Mean square	F	p
Vase life	Treatments	9	87.733	15.811	0.000*
	Error	90	5.549		
	Total	100			
TSU	Treatments	9	12695.225	7.805	0.000*
	Error	90	1626.544		
	Total	100			
DSU (3rd day)	Treatments	9	120.146	1.782	0.082
DSU (6th day)			217.262	3.123	0.003*
DSU (9th day)			484.606	8.275	0.000*
DSU (12th day)			445.131	9.565	0.000*
DSU (15th day)			309.796	10.095	0.000*
DSU (18th day)			157.023	7.532	0.000*
DSU (21th day)					
RFW (3rd day)	Treatments	9	152.633	1.065	0.396
RFW (6th day)			334.629	1.640	0.116
RFW (9th day)			1703.365	5.931	0.000*
RFW (12th day)			3283.506	9.159	0.000*
RFW (15th day)			3592.936	10.739	0.000*
RFW (18th day)			2669.348	10.449	0.000*
RFW (21th day)					

TSU – total solution uptake, DSU – daily solution uptake, RFW – relative fresh weight
*$p < 0.05$



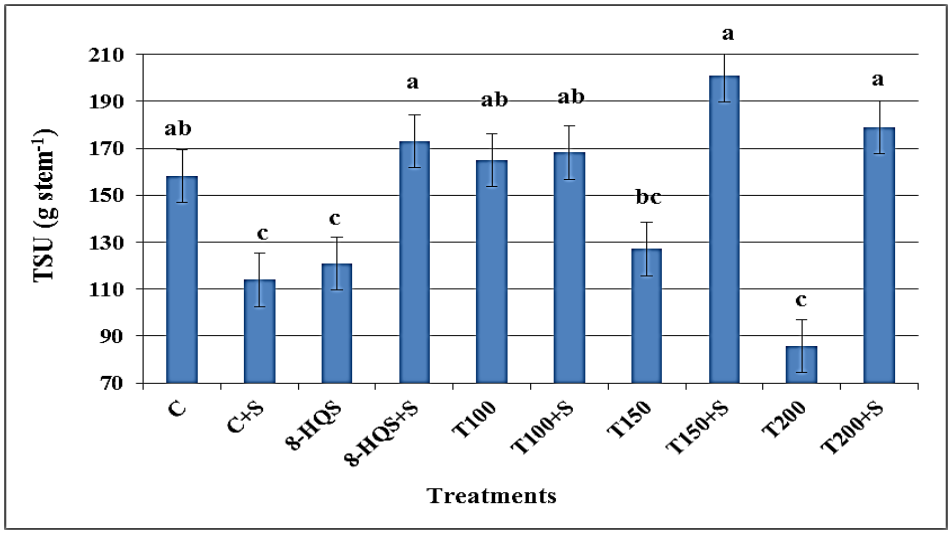
C – distilled water, S – sucrose, 8-HQS – 8-hydroxyquinoline sulfate, T100 – 100 mgL^{-1} thymol, T150 – 150 mgL^{-1} thymol, T200 – 200 mgL^{-1} thymol

Fig. 1. Effects of the treatments on the vase life of cut hydrangea flowers

Table 3. Effects of the treatments on the daily solution uptake of cut hydrangea flowers

Treatments	DSU							
	3th day	6th day	9th day	12th day	15th day	18th day	21th day	Avg.
C	39.80 ns	35.14 a	26.88 ab	21.18 bc	16.24 cde	13.53 bc	5.99 bc	22.68 B
C+S	32.57 ns	29.51 ab	19.83 bc	10.99 de	9.33 f	7.68 d	4.24 c	16.31 C
8-HQS	36.29 ns	25.57 b	18.31 cd	14.09 de	12.55 ef	9.26 cd	5.27 bc	17.33 C
8-HQS+S	40.89 ns	36.89 a	31.54 a	24.39 ab	18.52 bcd	13.31 bc	8.05 b	24.80 AB
T100	33.73 ns	30.15 ab	28.26 a	24.96 ab	22.21 ab	14.43 ab	7.53 b	23.04 B
T100+S	38.84 ns	34.97 a	31.43 a	24.84 ab	18.42 bcd	9.04 cd	4.03 c	23.08 B
T150	32.85 ns	29.90 ab	24.57 bcd	17.08 cd	13.24 def	6.37 d	3.44 c	18.21 C
T150+S	36.93 ns	35.08 a	31.99 a	28.54 a	25.64 a	17.99 a	11.36 a	26.79 A
T200	30.30 ns	23.03 b	11.85 d	9.65 e	8.74 f	5.70 d	3.36 c	13.23 D
T200+S	37.19 ns	35.14 a	31.98 a	25.25 ab	20.61 abc	12.22 bc	6.06 bc	24.07 B
Avg.	35.93 A	31.54 B	25.66 C	20.10 D	16.55 E	10.95 F	5.93 G	

Means followed by the same letter in the column did not differ significantly from each other, Duncan, $p < 0.05$



C – distilled water, S – sucrose, 8-HQS – 8-hydroxyquinoline sulfate, T100 – 100 mgL^{-1} thymol, T150 – 150 mgL^{-1} thymol, T200 – 200 mgL^{-1} thymol

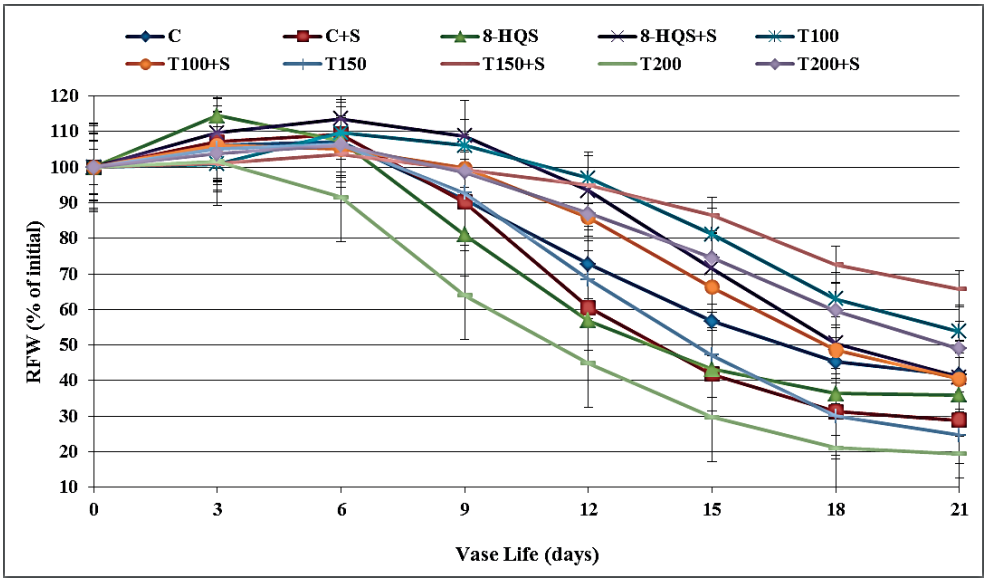
Fig. 2. Effects of treatments on the total solution uptake of cut hydrangea flowers

The maximum total solution uptake among the treatments during vase life was obtained at thymol 150 mgL^{-1} in combination with 1% sucrose (187.52 g $stem^{-1}$), whereas the minimum total solution uptake was obtained at thymol 200 mgL^{-1} (92.6220 g $stem^{-1}$) (Fig. 2).

In this study, except 100 mgL^{-1} thymol, all concentrations of thymol and 8-HQS treatments with sucrose had been more effective than sucrose free treatment on solution uptake. It is known that sucrose increases osmotic concentration and improving their ability to water uptake [Halevy et al. 1978]. Hence, addition of sucrose to the vase solution might have led to increased uptake of the vase solution. It was reported in previous researches that in combination with sucrose and 8-HQS [Asrar 2012, Elhindi 2012] or thymol [Solgi et al. 2009, Tuna 2012] improved solution uptake more than application of 8-HQS or thymol alone.

Thymol and 8-HQS are very effective antimicrobial agents and they prevented growth of the microorganisms in xylem vessels of the cut flower stems, and hence, they maintain solution uptake [Salehi Sardoei et al. 2014, Elgimabi and Yagi 2016]. According to our results, thymol 100 mgL^{-1} increased solution uptake. This is thought to be due to the antimicrobial activity of thymol. On the other hand, higher concentrations of thymol decreased solution uptake. The negative effects of high concentrations of thymol on solution uptake were reported in previous studies [Bazaz and Tehranifar 2011, Salehi Sardoei et al. 2014]. It was also reported that the concentration of essential oils such as thymol is very critical and need further explanation [Mirdehghan and Aghamolayi 2016]. Similar to thymol, 8-HQS reduced the solution uptake. In light of previous studies, the negative effects on solution uptake of 8-HQS alone are not associated with vascular blockage by microorganisms' growth. Because it had positive effects on solution uptake of its in combination with sucrose. In short, higher concentrations of thymol and 8-HQS seem to be toxic to some cut hydrangea flowers. The positive effects of 8-HQS and thymol on the solution uptake of many cut flowers were reported in several researches [Banaee et al. 2013, Hashemi et al. 2013], but it is known that species even cultivars has a significant effect on solution uptake of cut flowers [Gebremedhin et al. 2013].

Relative fresh weight. The relative fresh weights of the flowers in all solutions including control increased



C – distilled water, S – sucrose, 8-HQS – 8-hydroxyquinoline sulfate, T100 – 100 mgL^{-1} thymol, T150 – 150 mgL^{-1} thymol, T200 – 200 mgL^{-1} thymol

Fig. 3. Effect of treatments on relative fresh weight of cut hydrangea flowers

on the first 3 days of the vase life after that, fresh weight of flowers treated 8-HQS, 100 mgL^{-1} thymol + 1% sucrose and 200 mgL^{-1} thymol decreased end of the vase life. The fresh weight of the other treatments decreased from 6th day. Maximum of fresh weight was observed in flowers kept in the solutions which contained 150 mgL^{-1} thymol in combination with 1% sucrose whereas the most decrease in relative fresh weight observed in 200 mgL^{-1} thymol at the end of vase life (Fig. 3).

According to our results about relative fresh weight, 8-HQS with 1% sucrose and 150 mgL^{-1} thymol with 1% sucrose treatments delayed the fresh weight loss compared to other treatments. Thymol 200 mgL^{-1} and 8-HQS treatments hadn't been effective preventing fresh weight loss. These results of fresh weight are similar to solution uptake grades which was effected positively by 8-HQS with 1% sucrose and 150 mgL^{-1} thymol with 1% sucrose whereas it were affected negatively by 200 mgL^{-1} thymol and 8-HQS treatments. Increment of solution uptake and reduction of transpiration rate prevent water loss of cut flowers and hence, fresh weight might have effected positively. It was reported in previous studies that there is a relationship between solution uptake and fresh weight [Alaey et al. 2011, Amin 2017].

All treatments in combination with sucrose except distilled water and thymol 100 mgL^{-1} were more effective than sucrose free treatment on relative fresh weight. Previous studies showed that effect of antimicrobial agents in combination with sucrose on fresh weight of cut flowers was much greater than that of alone [Ichimura et al. 1999, Ichimura and Shimizu-Yumoto 2007]. Sucrose plays a role as a source of energy; it affects petal growth positively [Norikoshi et al. 2016]. Better petal growth may have occurred in including sucrose and it may have increased fresh weight. At the same time, sucrose may have a positive effect on keeping higher fresh weights by inducing stomatal closure in the leaves which reduced water loss [Marousky 1972]. For these reasons, sucrose may have caused delaying fresh weight loss in cut hydrangea. Thymol 100 mgL^{-1} treatment with %1 sucrose hadn't been more effective than thymol 100 mgL^{-1}. This contradictory result may be based on more specifically reduction of the solution uptake from 15th day to at the end of the vase life in 100 mgL^{-1} thymol with 1% sucrose according to 100 mgL^{-1} thymol.

CONCLUSIONS

The effects of different preservative solutions on the vase life of cut hydrangea flowers were investigated in the study. Application of thymol in combination with sucrose extended the vase life of cut hydrangea. Lower concentration of thymol without sucrose was also effective on extension of cut hydrangea vase life. The most important suggestions for the professional growers and contributors are as follows: the application of sucrose very useful to extend the vase life of cut hydrangea flowers and the treatment with thymol solution is recommended in order to control the growth of microorganisms. On the other hand, more studies are needed about the vase life of cut hydrangeas and determining the actual concentration of thymol and sucrose.

REFERENCES

Acharyya, P., Mukherjee, D., Chakraborty, S., Chakraborty, L. (2013). Effects of flower preservatives on the vase life of gerbera (*Gerbera jamesonii* H. Bolus) flowers. Acta Hortic., 970, 287–292. DOI: 10.17660/ActaHortic.2013.970.35

Anonymous (2018). Hortensia 'Green Shadow'. Available: https://www.mijntuin.org/plants/6154-hortensia-green-shadow [date of access: 25.08.2018].

Alaey, M., Babalar, M., Naderi, R., Kafi, M. (2011). Effect of pre and postharvest salicylic acid treatment on physio-chemical attributes in relation to vase-life of rose cut flowers. Postharvest Biol. Technol., 61, 91–94. DOI: https://doi.org/10.1016/j.postharvbio.2011.02.002

Amin, O.A. (2017). II-Effect of some chemical treatments on keeping quality and vase life of cut chrysanthemum flowers. Middle East J. Agric. Res., 6(1), 221–243.

Aros, D., Silva, C., Char, C., Prat, L., Escalona, V. (2016). Role of flower preservative solutions during postharvest of Hydrangea macrophylla cv. Bela. Cien. Inv. Agr., 43 (3), 418–428. DOI: http://dx.doi.org/10.7764/rcia.v43i3.1731

Asrar, A.W.A. (2012). Effects of some preservative solutions on vase life and keeping quality of snapdragon (*Antirrhinum majus* L.) cut flowers. J. Saudi Soc. Agric. Sci., 11, 29–35. DOI: https://doi.org/10.1016/j.jssas.2011.06.002

Babarabie, M., Zarei, H., Varasteh, F. (2015). The Effect of rosemary essential oils and thymol on vase life and some physiological characteristics of Alstroemeria cut flowers. Inter J. Agri. Biosci., 4(3), 122–126.

Banaee, S., Hadavi, E., Moradi, P. (2013). Interaction effect of sucrose, salicylic acid and 8-hydroxyquinoline sulfate on vase-life of cut gerbera flowers. Curr. Agric. Res., 1(1), 39–43. DOI: http://dx.doi.org/10.12944/CARJ.1.1.05

Bayat, H., Geimadil, R., Saadabad, A.A. (2013). Treatment with essential oils extends the vase life of cut flowers of lisianthus (*eustoma grandiflorum*). J. Med. Plants Byprod., 2, 163–169.

Bazaz, A.M., Tehranifar, A. (2011). Effect of ethanol, methanol and essential oils as novel agents to improve vase-life of alstroemeria flowers. J. Biol. Environ. Sci., 5(14), 41–46.

Chunne, T. (2015). Studies on postharvest handling of cut hydrangea (*Hydrangea macrophylla* Thunb.) as influenced by preharvest fertilization. Dr. Yashwant Singh Parmar University of Horticulture and Forestry MSc Thesis, India.

Dhifi, W., Bellili, S., Jazi, S., Bahloul, N., Mnif, W. (2016). Essential oils' chemical characterization and investigation of some biological activities: a critical review. Medicines, 3(25), 16 p. DOI: 10.3390/medicines3040025

Dung, C.D., Seaton, K., Singh, Z. (2016). Factors affecting variation in the vase life response of waxflower cultivars (Myrtaceae: *Chamelaucium* Desf. and *Verticordia* spp. Desf.) tested under various vase solutions. Folia Hortic., 28(1), 41–50. DOI: 10.1515/fhort-2016-0006

Elgimabi, M.N., Ahmed, O.K. (2009). Effects of bactericides and sucrose-pulsing on vase life of rose cut flowers (*Rosa hybirida*). Bot. Res. Inter., 2(3), 164–168.

Elgimabi, M.N. (2011). Vase life extension of rose cut flowers (*Rosa hybrida*) as influenced by silver nitrate and sucrose pulsing. Am. J. Agric. Biol. Sci., 6(1), 128–133.

Elgimabi, M.N., Yagi, M.I. (2016). Different preservative solutions enhanced the vase life of carnation cut flowers (*Dianthus caryophyllus*). World J. Pharm. Life Sci., 2(5), 32–41.

Elhindi, M.K. (2012). Evaluation of several holding solutions for prolonging vase life and keeping quality of cut sweet pea flowers (*Lathyrus odoratus* L.). Saudi J. Biol. Sci., 19, 195–202. DOI: 10.1016/j.sjbs.2011.12.001.

Florissant (2018). Treatment for hydrangea. Available: http://www.horticentre.co.nz/file/Flor

issant-Range/florissant-treatment_hydrangea_ts.pdf [date of access: 21.07.2018].

Gebremedhin, H., Tesfaye, B., Mohammed, A., Tsegay, D. (2013). Influence of preservative solutions on vase life and postharvest characteristics of rose (*Rosa hybrida*) cut flowers. Int. J. Biotechnol. Mol. Biol. Res., 4(8), 111–118. DOI: 10.5897/IJBMBR2013.0171

Halevy, A.H., Byrne, G.T., Kofranek, A.M., Farnham, D.S., Thompson, J.F., Hardenburg, R.E. (1978). Evaluation of postharvest handling methods for transcontinental truck shipments of cut carnations, chrysanthemums and roses. J. Am. Soc. Hortic. Sci., 103, 151–155.

Hashemi, M., Mirdehghan, S.H., Farahmand, H. (2013). The Effects of thymol, menthol and eugenol on quality and vase-life of chrysanthemum cut flowers. Iran Agric. Res., 32(2), 55–70.

He, S., Joyce, D.C., Irving, D.E., Faragher, J.D. (2006). Stemend blockage in cut grevillea 'crimson yul-lo' inflorescences. Postharvest Biol. Technol., 41, 78–84. DOI: https://doi.org/10.1016/j.postharvbio.2006.03.002

Ichimura, K., Kojima, K., Goto, R. (1999). Effects of temperature, 8-hydroxyquinoline sulphate and sucrose on the vase life of cut rose flowers. Postharvest Biol. Technol., 15, 33–40. DOI: https://doi.org/10.1016/S0925-5214(98)00063-5

Ichimura, K., Taguch, M., Norikoshi, R. (2006). Extension of the vase life in cut roses by treatment with glucose, isothiazolinonic germicide, citric acid and aluminum sulphate solution. Jpn. Agric., 40, 263–269. DOI: https://doi.org/10.6090/jarq.40.263

Ichimura, K., Shimizu-Yumoto, H. (2007). Extension of the vase life of cut roses by treatment with sucrose before and during simulated transport. Bull. Natl. Inst. Flor. Sci., 7, 17–27.

Kesarisinh, C.P. (2015). Standardization of holding solutions on keeping quality and vase life of torch ginger (*etlingera elatior* (Jack) R.M.Sm.I) (Master's Thesis). Forestry Navsari Agricultural University, Navsari.

Kitamura, Y., Ueno, S., Aizawa, H., Teoh, W. (2017a). Differences in vase lives of cut hydrangea flowers harvested at different developmental stages. Hort. J., 87(2), 274–280. DOI: 10.2503/hortj.OKD-111

Kitamura, Y., Kato, Y., Yasui, T., Aizawa H., Ueno, S. (2017b). Relation between increases in stomatal conductance of decorative sepals and the quality of antique-stage cut hydrangea flowers. Hortic. J., 86(1), 87–93. DOI: https://doi.org/10.2503/hortj.MI-128

Kitamura, Y., Uemachi, T., Kato Y. (2017c). Non-decorative floral organs largely contribute to transpiration and vase life of cut hydrangea flowers with lacecap inflorescence. Hortic. J., 86(2), 263–268. DOI: https://doi.org/10.2503/hortj.MI-160

Kordali, S., Çakır, A., Özer, H., Çakmakçı, R., Kesdek, M., Mete, E. (2008). Antifungal, phytotoxic and insecticidal properties of essential oil isolated from Turkish Origanum acutidens and its three components, carvacrol, thymol and p-cymene. Bioresour. Technol., 99, 8788–8795.

Lü, P., Cao, J., He, S., Liu, J., Li, H., Cheng G., Ding Y., Joyce, D.C. (2010). Nanosilver pulse treatments improve water relations of cut rose cv. 'movie star' flowers. Postharvest Biol. Technol., 57, 196–202. DOI: https://doi.org/10.1016/j.postharv bio.2010.04.003

Marousky, F.J. (1972). Water relations, effects of floral preservatives on bud opening and keeping quality of cut flowers. Hortic. Sci., 7, 114–116.

Memar, Y.M., Raei, P., Alizadeh, N., Aghdam, M.A., Kafil, H.S. (2017). Carvacrol and thymol: strong antimicrobial agents against resistant isolates. Rev. Med. Microbiol., 28(2), 63–67. DOI: 10.1097/MRM.0000000000000100

Mirdehghan, S.H., Aghamolayi, Z. (2016). Application of various concentrations of essential oils of savory, ajowan and thyme to maintain quality and shelf life of gladiolus cut flower. Int. J. Hortic. Sci. Technol., 3(1), 33–41. DOI: 10.22059/IJHST.2016.58159

Norikoshi, R., Shibata, T., Niki, T., Ichimura, K. (2016). Sucrose treatment enlarges petal cell size and increases vacuolar sugar concentrations in cut rose flowers. Postharvest Biol. Technol., 116, 59–65. DOI: https://doi.org/10.1016/j.postharvb io.2016.01.003

Pouranejad, F., Hasanzadeh, N., Kalatejarei, S. (2014). The effect of herbal essential oil in preservative solution, on quantitative, vase life, bacteria-induced stem xylem blockage of Lisianthus var. echo. Agrivita, 36(2), 174–181.

Ranwala, A. (2010). Hydrangea vase life effects with postharvest treatment. Floralife: the care and handling experts. Res. Update, 12(10), 1–2.

Royalfloraholland (2018). Annual report. Available: annualreport.royalfloraholland.com [date of access: 15.07.2018].

Salehi Sardoei, A., Mohammadi, G.A., Shahdadneghad, M. (2014). Interaction effect of temperature and thyme essential oil on vase life of cut narcissus flowers. Eur. J. Exp. Bio., 4(2), 82–87.

Savona, M., Sacco, E., Ruffoni, B. (2012). Improving micropropagation performances in hydrangea spp.: temporary immersion shoot culture and induction of morphogenetic events. Acta Hortic., 961, 457–464. DOI: 10.17660/ActaH ortic.2012.961.60

Serviss, B.E., Peck, J.H., Maddox, V.L. (2016). *Hydrangea macrophylla* (Hydrangeaceae) adventive in the arkansas flora. Phytoneuron, 66, 1–6.

Solgi, M., Kafi, M., Taghavi, S.T., Naderi, R. (2009). Essential oils and silver nanoparticles (snp) as novel agents to extend vase-life of gerbera (*Gerbera jamesonii* cv. 'Dune') flowers. Postharvest Biol. Technol., 53(2009), 155–158. DOI: https://doi.org/10.1016/j.postharvbio.2009.04.003

Thaneshwari, B.S. (2014). Effect of nitrogen and potassium on growth and flowering of hydrangea (*Hydrangea macrophylla* Thunb.). Dr. Yashwant Singh Parmar University of Horticulture and Forestry MSc. Thesis, India.

Thomas, D., Gollnow, B. (2013). What cut flower is that?: The essential care and handling guide for cut flower porfessionals. ACT Rural Industries Research and Development Corporation, Barton, 196 pp.

Tuna, S. (2012). Possibilities of using some essential oils and their main compounds to extend vase life of cut rose and gerbera flowers. University of Suleyman Demirel, MSc. Thesis.

Yagi, M.I., Elgemabi, M.N. (2014). Effect of bactericides and sucrose pulsing on longevity and vase life of rose cut flowers. Int. J. Sci., Basic Appl. Res., 14(2), 117–129.