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Flow cytometric analysis of programmed cell death in rose (*Rosa hybrida* cv. Dolce vita+) as influenced by physico-chemical treatments

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6 ABSTRACT

7 This study aimed to increase the vase life of cut rose flowers by improving the regulation of

8 Programmed Cell Death (PCD). Experiments were carried out on cut rose (*Rosa hybrida* cv.

9 Dolce vita⁺) flowers under either physical treatment of Static Magnetic Field (SMF; 15 and 25

10 mT) for 3 hours, or chemical treatments of silver nano particle (Nano-Ag; 5 and 10 ppm), 6-

11 Benzyladenine (BA; 25 and 50 mg L^{-1}), 1% sucrose, and combinations of 5 and 10 ppm nano-

12 Ag with 3 and 6% sucrose. Results showed that a 15 mT-SMF significantly increased vase life

up to 25 days, compared to the controls and to all chemical treatments. Among the chemicals,

14 5 ppm Nano-Ag and 1% (w/v) sucrose increased vase life to 23 and 18 days, respectively. The

smallest decline in fresh weight was observed in the 15 mT-SMF physical treatment. Markedly,

16 the 15 mT-SMF treatment led to the least reduction in Chlorophyll (Chl) content. On the 17th

17 day of the applied different treatments, both Water Uptake (WU) and Relative Fresh Weight

18 (RFW) showed an inverse significant relationship with PCD in cut rose flowers, verifying there

19 markable delayed PCD which is favored the market. As a whole, the most effective induced

20 treatments (15 mT-SMF, 5 ppm Nano-Ag, and 1% Sucrose) are suggested to be promising for

21 enhancing postharvest quality and prolonged vase life of cut rose flowers.

Keywords: Silver nanoparticle (Nano-Ag), 6-Benzyladenine (BA), Static Magnetic Field
 (SMF), Sucrose, Vase life.

ABBREVIATIONS: BA: 6-Benzyladenine, Chl: Chlorophyll, EMF: Electromagnetic
Field; FCM: Flow Cytometry, FW: Fresh Weight, MFs: Magnetic Fields, PCD:
Programmed Cell Death, PI: Propidium Iodide, PVP: Polyvinylpyrrolidone, RCBD:
Randomized Complete Block Design, RF: Radio frequency, RFW: Relative Fresh Weight,
RH: Relative Humidity, SMF: Static Magnetic Field, WU: Water Uptake.

31 INTRODUCTION

Rosa hybrida is a flowering plant of the *Rosa* genus. This genus is found in temperate
regions of the northern hemisphere, including North America, Europe, Asia, and the Middle
East. The largest variety of species is found in western China (Philips and Rix, 1988). It is

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globally considered as one of the most significant ornamental plants, and its flowers are
commercially sold as potted plants or cut flowers (Ross, 1991; Liao *et al.*, 2000). Despite the
significance of roses in the cosmetics industry as a provider of aromatic oils, volatile
compounds (Ryu *et al.*, 2020), and their medicinal benefits (Choi and Hwang, 2003; Yang *et al.*, 2013), cut roses have a limited life span in vases (Lee *et al.*, 2016).

Vase life can be affected by post-harvest factors such as temperature, humidity, water 40 relations and conditioning (Gupta and Dubey, 2018). In addition to issues related to improper 41 harvesting, handling, and storage of roses, harvested fresh-cut flowers have a short vase life 42 43 due to limited water uptake, loss of water after cutting, low energy source, and susceptibility to ethylene (Fanourakis et al., 2013; Scariot et al., 2014; Khunmuang et al., 2019; Gun et al., 44 2023). Therefore, it is crucial to maintain the freshness and the quality of the flowers from 45 harvesting until they reach the consumers. Although the vase life of cut flowers depends on the 46 flower's type, conditions of the variety and its growth, it can be widely influenced by 47 postharvest treatment (Celikel et al., 2011; Ramezanizadehet al., 2012; Hosseinzadeh et al., 48 49 2014). Inadequate water uptake can be enhanced with the proper wetting agent or surfactants (such as triton X-100, tween 20; Aros et al., 2016; El-Shoura and Arafa, 2017) while xylem 50 blockage can be prevented with silver nano particles (Shuqin et al., 2019). Applications of 51 52 exogenous plant growth regulators are known to influence postharvest quality (Janowska and Andrzejak, 2023). In the natural environment, living things are exposed to abiotic stress 53 54 induced by MFs due to the distribution of varied types of instruments and equipment and SMF is an important environmental factor that can influence the growth and development of plants 55 56 (Bhatnagar and Deb, 1977; De Souza et al., 2005, 2006). In Allium cepa, mitotic activity was increased under SMF at 0.06T (Hozayn et al., 2015). In a study on carnation cut flowers, it was 57 58 stated that an Electromagnetic Field (EMF) with a flux density of 160 mT has a profound impact on prolonging the vase life of its cut bloom (Ayesha et al., 2023). However, the impact 59 60 of non-ionizing radiation, such as the EMF, on the quality of cut flowers is still unknown. We did not find any noteworthy investigations about the effect of SMF on the vase life of roses. 61 The life of a flower typically ends in senescence, culminating in a form of PCD (Rogers, 2013). 62 In fact, PCD is a genetically regulated process of cell suicide that is central to the development, 63 homeostasis, and integrity of multi cellular organisms (Ameisen, 2002). In plants, PCD is 64 involved in a variety of situations, including responses to environmental stresses, the 65 hypersensitive response to pathogen attack, plant senescence and fruit ripening (Pennell and 66 Lamb, 1997; O'Brien et al., 1998). Various methods have been employed for the detection of 67 plants' PCD, one of those is FCM, which is utilized in numerous studies. This method is 68

convenient, fast, and reliable (Doležel *et al.*, 2007; Abedi *et al.*, 2015; Tavan *et al.*, 2015; Javadian *et al.*, 2017; Sayadi *et al.*, 2022; Mehravi *et al.*, 2022; Rasekh and Karimzadeh, 2023; Khakshour *et al.*, 2024). During cell death, the capability of the cell to scatter light alters as a result of morphological changes such as cell shrinkage, chromatin condensation, and nucleosomal fragmentation (Givan, 1992; Doležel *et al.*, 2007). So, this event can be detected by FCM methods. The current study was aimed to identify the most effective physico-chemical treatments to reduce PCD, with the goal of increasing the vase life of cut rose flowers.

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77 MATERIALS AND METHODS

78 Plant Material and Experimental Treatments

79 Fresh cut flowers of rose (Rosa hybrida cv. Dolce vita⁺) were obtained from a local 80 commercial greenhouse in Tehran, Iran. In tight bud stage, flowers were cut from the plants between 9:00 and 12:00 AM and re-cut to 50 cm in length. Detached flowers were immediately 81 82 transported to the laboratory and placed in distilled water. All experiments were performed in a controlled environmental growth room ($20 \pm 1^{\circ}$ C, $80 \pm 10^{\circ}$ RH, 12 hours photoperiod). The 83 84 cut flowers were kept in a 1,000 ml-vessel containing 500 ml solution in 11 treatments (without control): T0 = distilled water (control), T1 = Nano-Ag (5 ppm), T2 = Nano-Ag (10 ppm), 85 $T3 = BA (25 \text{ mg } L^{-1}), T4 = BA (50 \text{ mg } L^{-1}), T5 = Nano-Ag (5 \text{ ppm}) \times \text{sucrose } (3\%),$ 86 T6 = Nano-Ag (5 ppm) × sucrose (6%), T7 = Nano-Ag (10 ppm) × sucrose (3%), T8 = Nano-87 Ag (10 ppm) \times sucrose (6%), T9 = Static magnetic field (SMF; 15 mT), T10 = SMF; 25 mT, 88 and T11 =Sucrose (1%, w/v). To exert different intensities of SMF, a magnetic field generator 89 device consisting of two strong magnets (in repelling mode with the ability to adjust the 90 distance) was used. The strength of the magnetic field was measured, using Teslameter 91 (Leybold-Heraeus 51652, Germany). The cut flowers were placed between the different 92 strength of magnet poles. It should also be noted that all methods were performed in accordance 93 with relevant guidelines and regulations." 94

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96 Measurement of Chlorophyll (Chl)

97 To determinate of leaf Chl content, leaf blades were sampled on days of 1, 5, 10, and 17 98 during the vase life period. Chl content was evaluated according to Lichtenthaler (1987) by 99 extracting in 80% (v/v) ethanol for 10 minutes at 75°C, with the process repeated until all 100 pigments were extracted from the samples. Absorption was measured, using a UV/V 101 Spectrophotometer (Scinco, UV S-2100, USA) at wavelengths of 700, 664, and 647 nm. Chl 102 concentration was then calculated, using the following equation: 103 Chl a+b = 5.24 (A664 – A700) + 22.24 (A647 – A700)

Where, A700, A664 and A647 were Absorbance at the three wavelengths. 104

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Measurement of Water Uptake (WU) and Relative Fresh Weight (RFW) 106

The weights of vases with and without cut stems were measured on day 0 and continued 107 daily (on days 3, 5, 7, 10, 12, 14, 17, 20) during the vase life period. WU and RFW were then 108 calculated, using the following formulae: 109

WU (g g⁻¹ initial fresh weight-FW) = $B_{n-1}-B_n/Initial$ FW (A₀ - B₀) 110

RFW (%) = $[(A_n - B_n)/(A_0 - B_0)] \times 100$ 111

A is used to denote the weight of the vase containing the cut stem, including the vase, 112 solution, and stem (g). Meanwhile, B represents the weight of the vase without the cut stem, 113 114 comprising the vase and solution only (g). Bn-1 denotes the weight from the previous day (g), while A0 and B0 indicate the weights measured on day 0 (g). An and Bn represent the weights 115 measured on day n, with n ranging from 1 onwards (Celikel et al., 2011). 116

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118 Flow Cytometric Analysis for PCD Measurements

Flow cytometric analysis was performed, using a Partec PAS flow cytometer (PAS, 119 Expandable by many light sources, Münster, Germany) on days 10, 18, and 25 of the vase life 120 periods. On the 10th day of the experimental protocol, the PCD% was determined in flowers 121 treated with T3, T4, T5, T6, T7, and T8 treatments, which showed more effects on wilting 122 compared to the control flowers (T0). Control flowers started wilting on day 18, when the 123 PCD% was simultaneously measured in the treated flowers. On the 25th day, the control flowers 124 were completely wilted, when the PCD% was measured in flowers treated with T1, T2, T9, 125 T10, and T11, which showed early symptoms of wilting. Samples were prepared according to 126 127 Partec protocol by Cystain PI absolute Code No. 05-5022, Germany (Anonymous, 2014). 30 mg of fresh uppermost leaf tissue was chopped without veins, using a sharp razor blade in a 128 129 glass petri dish, containing 0.5 ml extraction buffer and 0.25 ml PVP. Fresh leaf tissue of an internal reference standard (Parsley, Petroselinum crispum, 2C DNA= 4.45 pg) was 130 131 simultaneously chopped in a glass petri dish. After 60 seconds of incubation in extraction 132 buffer, the isolated nuclei were filtered through a Partec (Partec, Münster, Germany) 30 µm green nylon mesh to remove cell debris. The nuclear suspension of each sample was then 133 treated with 50 µg mL⁻¹ RNase (Sigma-Aldrich Corporation, MO, USA) to prevent staining of 134 double-stranded RNA, followed by staining with 50 µg mL⁻¹ propidium iodide (PI, Fluka). The 135 Relative fluorescence intensity of stained nuclei was measured on a linear scale, and typically, 136

137 at least 5000 nuclei were analyzed per sample. According to previous studies (Darzynkiewicz

- *et al.*, 1992; Dive *et al.*, 1992; Weir, 2001; Riccardi and Nicoletti, 2006) cycling cells can be
- 139 distinguished from dead cells with FCM, using fluorescent dye PI (for DNA staining) with
- 140 PVP (1% w/v) in cell suspension. In the present experiments, PCD percentage was calculated,
- 141 using the following equation:
- 142 PCD (%)= [Count (PCD)/Count (PCD+G1]×100
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144 Statistical Analysis

The experiments were arranged as a Randomized Complete Block Design (RCBD) in three 145 replicates. The data were analyzed, using ANOVA based on RCBD. The data underwent a 146 normality test, using SAS (SAS Institute Inc 2009). Mean comparisons were carried out, using 147 148 Duncan's multiple range test in SPSS (v19.0; IBM SPSS Statistics, Chicago, IL, USA) statistical software. ANOVA, correlation, and polynomial regression analyses were also 149 performed, using Minitab (Minitab[®] ver. 16.1.0, Minitab Ltd.) software. Gating region range 150 was defined on FCM histograms, using Partec FloMax ver.2.4e (Partec, Münster, Germany) 151 152 software.

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154 **RESULTS**

To increase the vase life of cut rose (*Rosa hybrida* cv. Dolce vita⁺) flowers by assessing the 155 PCD, 12 treatments including control, nine chemical, and two physical treatments were 156 examined. On the 10th day, flowers treated by T3, T4, T5, T6, T7, and T8 wilted earlier than 157 the control flowers (T0). Hence, these six treatments appeared to be ineffective treatments. On 158 the other hand, on the 25th day, flowers treated with other five treatments of T1, T2, T9, T10, 159 and T11 showed early wilting symptoms, while the control flowers were completely wilted at 160 161 this time. Thus, on the basis of flow cytometric analysis of PCD and of WU and RFW, the latter treatments performed to be effective treatments, on which will be discussed in more 162 163 detail.

165 Flow Cytometric Analysis of PCD

The results of ANOVA on PCD% showed significant differences among treatments on days 10, 18 and 25 (P< 0.01; Table 1). On the 10th and 18th day, flowers treated with in effective treatments (T3, T4, T5, T6, T7, T8) unexpectedly showed more remarkable PCD% (Figure 1) compared to control flowers (T0), resulted in more wilting. On the other hand, flowers treated with five effective treatments (T1, T2, T9, T10, T11) showed significantly (P< 0.01, Table 1) less PCD% compared to the controls on both experimental days of 18, and 25 (Figures 2, and

3). The cut rose flowers exposed toSMF-15 Mt (T9) started wilting on day 25, reaching 172 completely wilting after three days (day 28). Non-treated flowers (control) were wilted on day 173 18, but flowers treated by T9 remained alive and did not wilt. T9 treatment caused the least 174 PCD% at all sampling times among all exposed chemical and physical treatments. The PCD% 175 of flowers treated by T9 on days 18 and 25 was estimated as 22.64 and 23.19%, respectively 176 (Figure 3). The flowers treated with 1% sucrose (T11) began wilting on day 18, showing slow 177 senescence, followed no clear changes during a week after (day 25, Figures 2, and 3). In fact, 178 the cut flowers treated with T11 (1% sucrose) were more rejuvenated compared to the control 179 on day 18; roses were withering on the 25th day (Figure 2). On the other hand, based on data 180 achieved from FCM analysis of PCD% for cut rose flowers treated with 1% sucrose, the PCD% 181 on days 18 and 25 were estimated as 31.12 and 31.85%, respectively. 182

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184 Morphological traits

Three morphological traits including relative RFW, WU, and Chl content were studied in 185 the current study. The result of ANOVA showed significant differences (P < 0.01; Table 2) 186 187 between treatments for RFW and WU and between sampling times for all three traits. The changes of RFW during days 1-21 for effective treatments (T1, T2, T9, T10, T11) shown in 188 189 Figure 4. These treatments had a positive effect on increasing the vase life of roses and delaying the PCD. Since the 14th day, the flowers treated by effective treatments showed a slower rate 190 of RFW loss compared to control (Figure 4). Among effective treatments, T9, T10, and T11 191 192 treatments showed lower levels of RFW loss. T-test results showed no significant difference between these three treatments. 193

In the present study, Figure 5 indicates the relative changes of WU during days 1-21 for the 194 effective treatment (T1, T2, T9, T10, T11) on postharvest life. Both untreated control and 195 treated flowers with T1, T2, T9, and T11 showed a declining trend in WU untilthe14th day, but 196 since that time, the treated flowers absorbed more water compared to the controls (Figure 5). 197 198 The *t*-test results between two physical induction treatment (T9 and T10) and also between two chemical treatments (T1 and T2) at a significance level of P< 0.05 showed that T9 and T2 199 200 treatments had higher water uptake compared to T10 and T1, respectively. BA treatments (T3, T4) as well as combined treatments (T5, T6, T7, T8) displayed a downward trend in the amount 201 of water absorption until the 14th day. After this day, the amount of water absorption increased. 202 T6, T7, and T8 treatments showed less reduction in WU compared to other ineffective 203 204 treatments. The changes of Chl content during days 1-18 for effective treatments (T1, T2, T9,

T10, T11) are shown in Figure 6. Chl content had increased until day 4 in all treatments. T9showed the least reduction in Chl amount.

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208 Relationship between morphological traits and PCD%

The data of RFW, WU, and Chl were correlated with PCD%, where significant correlations 209 were identified, they were regressed upon PCD% on the 10th and 17th days of the experimental 210 protocol. All morphological characteristics except Chl showed a remarkable relationship with 211 PCD%. Hence, polynomial regression analysis between the PCD% and RFW of rose cut 212 flowers on the 10^{th} day showed a significant linear regression (P< 0.01, Table 3, Figure 7-a). 213 No significant correlation was identified between the PCD% and WU on the 10th day. On the 214 18th day, the PCD% had a significant correlation with RFW and WU (P< 0.01, Tables 3, and 215 216 4, Figure 7). There was no significant correlation among these traits on other days. The highly significant inverse linear relationship was identified between PCD% and RFW on day 10 217 (Figure 6-a). Significance inverse linear relationship was detected between PCD% and either 218 RFW (Figure 7-b) or WU (Figure 7-c) on day 18. 219

220 Based on the study results, the treatments that have been more effective in increasing the vase life of flowers were Nano-Ag 10 ppm (T2), Static Magnetic Field 15 mT (T9), and Sucrose 221 222 1% (w/v) (T11). Nano-Ag treatments resulted in reduced wilting symptoms and delayed wilting, leading to increased vase life. Conversely, BA and Nano-Ag×sucrose treatments 223 224 appeared ineffective, causing increased wilting symptoms and reduced vase life. In summary, ineffective treatments (T3 to T8, T10) led to earlier wilting compared to the control (T0), 225 indicating a shorter vase life. Conversely, effective treatments (T1, T2, T9, T11) resulted in 226 reduced wilting symptoms and delayed wilting, significantly increasing the vase life of treated 227 flowers. 228

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230 **DISCUSSION**

231 Applied chemical and physical treatments differently affected the cell viability (Table 1, Figure 3) and postharvest life of cut rose flowers. BA (T3 and T4) and Nano-Ag×sucrose (T5, 232 233 T6, T7, and T8) treatments increase the effects of wilting and PCD% in flowers (Figures1, and 234 3). Therefore, these six treatments appeared to be ineffective treatments. In the final stage of 235 PCD, endonuclease attacks the connection between the nucleosomes and converts DNA into many small pieces about 18 bp. Staining with a DNA fluorochrome such as PI, which is capable 236 237 of binding and labeling whole DNA, makes it possible to obtain a rapid and precise evaluation 238 of cellular DNA content by FCM. These small DNA subpopulations appear as a sub-G1 or

hypodiploid nuclei population, commonly known as the PCD peak (Darzynkiewicz et al., 1992; 239 Dive et al., 1992; Weir, 2001; Riccardi and Nicoletti, 2006). Flowers treated with Nano-Ag 240 (T1: 5 ppm and T2: 10 ppm), SMF (T9: 15 mT and T10: 25 mT), and sucrose 1% (T11) showed 241 higher longevity and lower PCD% compared to T0 on days 18 and 25 (Figures 2, and 3), 242 indicating effective treatments. Nano-Ag, with effective antibacterial activity can absorb and 243 decompose ethylene (Hu and Fu, 2003). Many studies have shown the importance of Nano-Ag 244 particles as an antibacterial agent (Alt et al., 2004; Son et al., 2004; Morones et al., 2005; Lok 245 et al., 2007). Study of Liu et al. (2009) showed that Nano-Ag treatment inhibited bacterial 246 247 growth in the vase solution and at the cut stem ends of cut gerberas. In the current study, Nano-Ag (5 and 10 ppm)×sucrose (3 and 6%) treatments appeared to be ineffective. However, Lü et 248 al. (2010) reported that the treatment with Nano-Ag 10 mg $L^{-1} \times 5\%$ sucrose solution for 24 249 hours, followed by holding samples in Nano-Ag 0.5 mg $L^{-1} \times 2\%$ sucrose solution, not only 250 reduced and delayed vascular blockage caused by bacterial contaminations, but also inhibited 251 stomatal conductance so that the water balance in cut roses was significantly improved and the 252 vase life of the cut rose flowers was prolonged by 11.8 days. These differences may be related 253 to different treatment times. In this study, applications of Nano-Ag resulted in extending vase 254 life, possibly due to its antibacterial effect. Sucrose can work as an energy source (Moalem-255 256 Beno et al., 1997) and osmotic regulator (Bieleski, 1993) thereby playing a role in flower opening and subsequent water balance regulation (Kuiper et al., 1995). Among effective 257 258 treatments, flowers treated with T9 (SMF-15 mT, 3 hours) possessed the lowest rate of PCD (3.14, 22.64, and 23.19% on days 1, 18, and 25, respectively), followed by T10 (SMF-25 mT, 259 260 3 hours) and T11 (1% sucrose). These treatments appeared to be the most effective. In accordance with observations, the wilting process in cut rose flowers treated with T11 was 261 262 slower than that in those exposed to other chemical treatments. In Ramezanizadeh et al. (2012) report, the physical treatment of 10 mT-SMF caused a remarkable decrease in PCD, resulting 263 264 in the best vase life time of 14 d. MFs affect the synthesis of DNA and RNA as well as cellular proliferation. Additionally, MFs in both Extremely Low Frequency (ELF) and Radio 265 Frequency (RF) activate the cellular stress response, a protective mechanism that induces the 266 expression of stress response genes (Ruediger, 2009). Several studies have investigated the 267 effects of MFs on plant antioxidant systems (Abdolmaleki et al., 2007). Various effective 268 treatments such as silver thiosulfate, 8-hydroxyquinoline sulfate, and sucrose have been 269 utilized by researchers (e.g. Liao et al., 2000; Ramezanizadeh et al., 2012; Hosseinzadeh et al., 270 2014) to examine their effects on PCD, aiming to increase the vase life of roses. The obtained 271 272 results showed that these treatments significantly improved the flower quality and the vase life.

Effective treatments had a slower rate of fresh weight loss compared to control from the 14th 273 day. Mean fresh weight loss was used for more accurately determining which treatments had 274 the most or the least effect. Hence, three treatments of T9, T10, and T11, appeared to cause the 275 least weight loss among all treatments examined (Figure 4); there was no significant difference 276 among these three treatments. However, since T9 had a lower level of PCD, it was preferable 277 to other treatments. The flowers treated with effective treatments absorbed more water 278 compared to control which indicates that they are more durable and absorbed more water 279 compared to control. T9 treatment amongst physical induction treatments, and T2 treatment 280 281 amongst chemical treatments, were superior in the terms of WU. BarbazEsfahani et al. (2013) reported that flowers kept in preservation solution with 4% sucrose had more solution absorbed 282 than the flowers maintained only in pure distilled water. In Basiri et al. (2011) report, the most 283 extended vase life cut flowers of carnation (Dianthus caryophyllus L.) was obtained from 5 284 ppm Nano-Ag combined with sucrose 6%. Furthermore, different levels of Nano-Ag 285 concentrations had no significant effect on the RFW of cut carnations. Alimoradi et al. (2013) 286 reported that the best treatment to enhance postharvest factors of cut Alstroemeria flowers was 287 the exact 15 ppm Nano-Ag. This treatment could be proposed as additional substance for 288 Alstroemeria postharvest quality increment. On the other hand, results of BarbazEsfahani et al. 289 290 (2013) indicated that cut rose cv. Dolce vita⁺ flowers maintained in pure distilled water had more RFW reduction than those kept in 4% sucrose solution on the 11th day, meaning that 291 dH₂O-kept flowers were in more stress. Similar results were found in Mortazavi's (2006) study, 292 using (0, 2, 4, 8%) sucrose in preservation solution had the greatest effect on increasing of vase 293 294 life of Elona rose cultivar. The highly significant inverse linear relationship was identified between PCD% and RFW on day 10 (Figure 7-a). A significant inverse linear relationship was 295 296 detected between PCD% and either RFW (Figure 7-b), or WU (Figure 7-c) on day 17. Using 297 chemical treatments, Ramezanizadeh et al. (2012) reported a significantly negative relationship 298 of vase time (d) of cut rose (Rosa hybrida cv. Dolce vita⁺) flowers with PCD%. In other words, flower vase time reduced significantly ($b=-0.312^*$) as PCD increased when cut flowers were 299 chemically treated. No such relationship was detectable in their physical treatments. As 300 conclusion, it can be stated that T11 [sucrose 1% (w/v)] and T9 (SMF; 15 Mt) treatments 301 302 caused the highest longevity among chemical and physical treatments examined; hence they 303 are suggested for extending the vase time of cut rose (cv. Dolce vita⁺) flowers. The treatments 304 had varying effects on the studied traits, including PCD percentage, RFW, WU, and Chl content. The study explores various chemical and physical treatments to enhance the vase life 305 of cut roses. Results reveal that treatments with Nano-Ag at 10 ppm, SMF of 15 mT, and 1% 306

307 sucrose were the most effective in prolonging vase life and reducing cellular death in cut roses. Conversely, treatments involving BA, combinations of Nano-Ag and sucrose, and a static 308 magnetic field with 25 mT intensity were less effective in extending vase life. A combination 309 of mechanisms including ethylene inhibition, antioxidant activity, enhanced water and nutrient 310 uptake, likely contributes to the effectiveness of these treatments in delaying PCD and 311 extending vase life. T1 and T2 treatments may work by inhibiting ethylene production or 312 action, thus delaying plant senescence, while T9, and T11 treatments likely function through 313 antioxidant mechanisms, protecting cells from oxidative damage. Additionally, these 314 315 treatments may improve water uptake and prevent microbial growth in the vase solution, ensuring a longer vase life (Abdolmaleki et al. 2007; Khunmuang et al., 2019; Gun et al., 316 2023). The Chl content is crucial for increasing the vase life and improving the market quality 317 of cut roses. The findings of this study are consistent with other research, which has shown that 318 treatments such as silver nanoparticles aid in preserving Chl content and enhancing water 319 absorption (Jowkar et al., 2013; Hassan et al., 2014). Overall, the study demonstrates the 320 potential of specific treatments in improving the vase life and the quality of cut roses, providing 321 valuable insights for the optimization of storage and marketing processes for these products. 322

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324 CONCLUSIONS

This study investigates methods to extend the vase life of cut roses by delaying Programmed 325 Cell Death (PCD). Different treatments were applied, including chemicals like silver 326 Nanoparticles (Nano-Ag) and Benzyladenine (BA), sucrose solution, and physical treatments 327 involving Static Magnetic Field (SMF) at various intensities. Among the investigated 328 treatments, a Static Magnetic Field (SMF) applied at 15 mT proved to be the most effective, 329 with flowers exhibiting the lowest PCD levels and slowest decline in fresh weight throughout 330 the experiment. A 1% sucrose, while not as effective as the SMF treatment, also delayed wilting 331 332 and maintained higher water uptake compared to the control group. Silver nanoparticles (Nano-Ag) showed some initial effectiveness in delaying wilting, but their overall impact was less 333 significant compared to SMF and sucrose solution. Overall, the study suggests that applying a 334 15 mT static magnetic field or a 1% sucrose solution can significantly improve the vase life of 335 336 cut roses by delaying PCD.

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344 **REFERENCES**

- Abdolmaleki, P., Ghanati, F., Sahebjamei, H., and Sarvestani, A.S., 2007. Peroxidase activity,
 lignification and promotion of cell death in tobacco cells exposed to static magnetic field.
 The Environmentalist, 27: 435-440.
- Abedi, R., Babaei, A., and Karimzadeh, G., 2015. Karyological and flow cytometric studies of
 Tulipa (Liliaceae) species from Iran. Plant Syst. Evol., 301: 1473-1484.

Alimoradi, M., Jafararpoor, M., and Golparvar, A., 2013. Improving the keeping quality and

vase life of cut *Alstroemeria* flowers by post-harvest nano silver treatments. Int. J. Agri.
Crop Sci., 6: 632-635.

- Alt, V., Bechert, T., Steinrucke, P., Wagener, M., Seidel, P., Dingeldein, E., Domann, E., and
 Schnettler, R., 2004. An *in vitro* assessment of the anti-bacterial properties and cytotoxicity
 of nanoparticulate silver bone cement. Biomaterials, 18: 4383-4391.
- Ameisen, J.C., 2002. On the origin, evolution, and nature of programmed cell death: a timeline
 of four billion years. Cell Death Differ., 9: 367-393.
- Anonymous 2014. Partec protocol by Cystain PI absolute Code No. 05-5022.
 https://us.sysmex-flowcytometry.com.
- Aros, D., Silva, C., Char, C., Prat, L., and Escalona, V., 2016. Role of flower preservative
 solutions during postharvest of *Hydrangea macrophylla* cv. Bela. Cien. Inv. Agr., 43: 418428.
- Ayesha, R., Hassan, I., Abbasi, N.A., Ahmed Hafiz, I., and Saifullah Khan, K., 2023. Preexposure impact of electromagnetic field radiation on carnation plant growth and quality cut
 flower production. Pak. J. Bot., 55: 367-377.
- BarbazEsfahani, M., Jafar Pour, M., Mortazaeinezhad, F., and Eghbal Saeed, S., 2013. The
 effect of nano copper, nano silver and sucrose on vase life of cut rose Dolce vita. Intl. J.
 Agri. Crop Sci., 5: 36-38.

Basiri, Y., Zarei, H., and Mashayekhi, K., 2011. Effects of nano-silver treatments on vase life
of cut flowers of carnation (*Dianthus caryophyllus* cv. 'White Librity'). J. Adv. Lab. Res.
Biol., 2: 50-55.

- Bieleski, R.L., 1993. Fructan hydrolysis drives petal expansion in the ephemeral daylily flower.
- 373Plant Physiol., 103: 213-219.
- Bhatnagar, D. and Deb, A.R., 1977. Some effect of pre-germination exposure of wheat seeds
 to magnetic fields: effect on some physiological process. Seed Res., 5: 129-137.
- Çelikel, F.G., Joyce, D.C., and Faragher, J.D., 2011. Inhibitors of oxidative enzymes affect
 water uptake and vase life of cut *Acacia holosericea* and *Chamelaucium uncinatum* stems.
 Postharvest Biol. Tec., 60: 149-157.
- Choi, E.M. and Hwang, J.K. 2003. Investigations of anti-inflammatory and antinociceptive
 activities of *Piper cubeba*, *Physalis angulate*, and *Rosa hybrida*. J. Ethnopharmacol., 89:
 171-175.
- Darzynkiewicz, Z., Bruno, S., Del Bino, G., Gorczyca, W., Hotz, M.A., Lassota, P., and
 Traganos, F., 1992. Features of apoptotic cells measured by flow cytometry. Cytometry, 13:
 795-808.
- De Souza, A., Garcia, D., Sueiro, L., Gilart, F., Porras, E., and Licea, L., 2006. Pre-sowing
 magnetic treatments of tomato seeds increase the growth and yield of plants.
 Bioelectromagnetics, 27: 247-257.
- De Souza, A., Garcia, D., Sueiro, L., Licea, L., and Porras, E., 2005. Pre-sowing magnetic
 treatment of tomato seeds effect on the growth and yield of plants cultivated late in the
 season. Span. J. Agric. Res., 3: 113-122.
- Dive, C., Gregory, C.D., Phipps, D.J., Evans, D.L., Milner, A.E., and Wyllie, A.H., 1992.
 Analysis and discrimination of necrosis and apoptosis (programmed cell death) by multi
 parameter flow cytometry. Biochim. Biophys. Acta., 1133: 275-285.
- Doležel, J., Greilhuber, J., and Suda, J., 2007. Flow Cytometry with Plant Cells: Analysis of
 Genes, Chromosomes and Genomes. Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim,
 Germany.
- El-Shoura, H.A.S. and Arafa, F.F., 2017. Effect of pH, 8-Hydroxyquinoline sulphate, sucrose
 and wetting agents on vase life and quality of *Chrysanthemum* cut flowers cv. Zembla
 White. Middle East J. Agric. Res., 6: 1328-1331.
- Fanourakis, D., Heuvelink, E., and Carvalho, S.M., 2013. A comprehensive analysis of the
 physiological and anatomical components involved in higher water loss rates after leaf
 development at high humidity. J. Plant Physiol., 170: 890-898.
- 403 Givan, A.L., 1992. Flow Cytometry: First Principles, 2nd Ed." Wiley-Liss, New York, USA.

- Gun, S., Uzun, L., Tuysuz, M., Erturk, O., Ilhan, H., Acıkgoz, M.A., and Ozturk, B., 2023.
 Nanofiber mats containing lavender oil and methyl jasmonate as an innovative treatment to
 extend vase life in cut rose flowers. Postharvest Biol. Technol., 201: 112343.
- Gupta, J. and Dubey, R.K. 2018. Factors affecting post-harvest life of flower crops. Int. J. Curr.
 Microbiol. App. Sci., 7: 548-557.
- 409 Hassan, F.A.S., Ali, E.F., and El-Deeb, B., 2014. Improvement of postharvest quality of cut
- 410 rose cv. 'First Red' by biologically synthesized silver nanoparticles. Sci. Hortic., 179: 340411 348.
- Hosseinzadeh, E., Kalatejari, S., Zarrinnia, V., Mashhadi Akbar Boujar, M., and Hosseinzadeh,
 S., 2014. Investigating the impact of nanoparticles on postharvest quality and vase life of
 the cut roses. Plant and Ecosyst., 10(40): 73-85. (In Persian with English abstract).
- 415 Hozayn, M., Amal, A.A.E., and Abdel-Rahman, H.M.H., 2015. Effect of magnetic field on
- germination, seedling growth and cytogenetic of onion (*Allium cepa* L.). Afr. J. Agric. Res.,
 10: 859-867.
- Hu, A.W. and Fu, Z.H., 2003. Nano technology and its application in packaging and packaging machinery. Packag. Eng., 24: 22-24.
- Janowska, B. and Andrzejak, R. 2023. Plant growth regulators for the cultivation and vase life
 of geophyte flowers and leaves. Agriculture, 13: 855.
- Javadian, N., Karimzadeh, G., Sharifi, M., Moieni, A., and Behmanesh, M., 2017. *In vitro*polyploidy induction: changes in morphology, podophyllotoxin biosynthesis, and
 expression of the related genes in *Linum album* (Linaceae). Planta, 245: 1165-1178.
- Jowkar, M.M., Khalighi, A., Kafi, M., and Hassanzadeh, N., 2013. Nano silver application
 impact as vase solution biocide on postharvest microbial and physiological properties of
 'Cherry Brandy' rose. J. Food Agric. Environ., 11: 1045-1050.
- Khakshour, A., Karimzadeh, G., Sabet, M.S., and Sayadi, S., 2024. Karyomorphological and
 genome size variation in Iranian endemic populations of coriander (*Coriandrum sativum*L.). Cytologia, 89(1): 21-27.
- Khunmuang, S., Kanlayanarat, S., Wongs-Aree, C., Meir, S., Philosoph-Hadas, S.,
 Orenshamir, M., Ovadia, R., and Buanong, M., 2019. Ethylene induces a rapid degradation
 of petal anthocyanins in cut Vanda 'Sansai Blue' orchid flowers. Front. Plant Sci., 10:
 e1004.
- Kuiper, D., Ribot, S., Van Reenen, H.S., and Marissen, N., 1995. The effect of sucrose on the
 flower bud ripening of Madelon cut roses. Sci. Hort., 60: 325-336.

- Lee, S., Won, S.Y., Park, S.L., Song, J., Noh, D., Kim, H., and Moon, S., 2016. *Rosa hybrida*extract suppresses vascular smooth muscle cell responses by the targeting of signaling
 pathways, cell cycle regulation and matrix metalloproteinase-9 expression. Int. J. Mol.
 Med., 37: 1119-1126.
- Liao, L.J., Lin, Y.H., Huang, K.L., Chen, W.S., and Cheng, Y.M., 2000. Postharvest life of cut
 rose flowers as affected by silver thiosulfate and sucrose. Bot. Bull. Acad. Sin., 41: 299303.
- Lichtenthaler, H.K., 1987. Chlorophylls and carotenoids: pigments of photosynthetic
 biomembranes. Methods Enzymol., 148: 350-382.
- Liu, J., He, S., Zhang, Z., Cao, J., Lv, P., He, S., Cheng, G., and Joyce, D.C., 2009. Nano-silver
 pulse treatments inhibit stem-end bacteria on cut gerbera cv. Ruikou flowers. Postharvest
 Biol. Technol., 54: 59-62.
- 449 Lok, C.N., Ho, C.M., Chen, R., He, Q.Y., Yu, W.Y., Sun, H.Z., Tam, P.K.H., Chiu, J.F., and
- Che, C.M., 2007. Silver nanoparticles: Partialoxidation and antibacterial activities. J. Biol.
 Inorg. Chem., 12: 527-534.
- Lü, P., He, S., Li, H., Cao, J., and Xu, H.L., 2010. Effects of nano-silver treatment on vase life
 of cut rose cv. Movie Star flowers. J. Food Agric. Environ., 8: 1118-1122.
- Mehravi, S., Karimzadeh, G., Kordenaeeh, A., and Hanifei, M., 2022. Mixed-ploidy and
 dysploidy in *Hypericum perforatum*: A karyomorphological and genome size study. Plants,
 11: 3068: 1-19
- Moalem-Beno, D., Tamari, G., Leitner-Dagan, Y., Borochov, A., and Weiss, D., 1997. Sugardependent gibberellin-induced chalcone synthase gene expression in *Petunia* corollas. Plant
 Physiol., 13: 419-424.
- Mortazavi, S., 2006. Effect of different levels of sucrose on vase life and protein and enzymes
 changes on Elona rose cultivar. Ph.D. Thesis. University of Tehran, Faculty of Agriculture,
 Department of Horticulture, Tehran, Iran. (In Persian).
- Morones, J.R., Elechiguerra, J.L., Camacho, A., Holt, K., Kouri, J.B., Ramirez, T.J., and
 Yacaman, M. J., 2005. The bactericidal effect of silver nanoparticles. Nanotechnology, 16:
 2346-2353.
- O'brien, I.E.W., Baguley, B.C., Murray, B.G., Morris, B.A.M., and Ferguson, I.B., 1998. Early
 stages of the apoptotic pathway in plant cells are reversible. Plant J., 13: 803-814.
- 468 Pennell, R.I. and Lamb, C., 1997. Programmed cell death in plants. Plant Cell, 9: 1157-1168.
- 469 Phillips, R. and Rix, M., 1988. Roses. Random House Publishing pp. 224.

- 470 Ramezanizadeh, R., Karimzadeh, G., and Babaei, A., 2012. Programmed cell death in rose
- 471 (*Rosa hybrida* cv. Dolce vita⁺) cut flowers as influenced by chemical or physical factors. In:
- 472 The Proceedings of the World Academy of Science, Engineering and Technology. ICANRE
- 473 2012: International Conference on Agricultural and Natural Resources Engineering, Issue

474 62, 19-21 Feb, 2012, Pacific Regency Hotel Suites, Kuala Lumpur, Malaysia, pp. 508-509.

- 475 Rasekh, S.Z. and Karimzadeh, G., 2023. Chromosomal and genome size variations in opium
 476 poppy (*Papaver somniferum* L.) from Afghanistan. Caryologia,76(4): 15-22.
- 477 Riccardi, C. and Nicoletti, I., 2006. Analysis of apoptosis by propidium iodide staining and
 478 flow cytometry. Nat. Protoc., 1: 1458-1461.
- 479 Rogers, H.J., 2013. From model to ornamentals: how is flower senescence regulated? Plant
 480 Mol. Biol., 82: 563-574.
- Ross, D., 1991. The Ross Guide to Rose Growing. Lothian Publishing Company Pty Ltd, Port
 Melbourne, Victoria, Australia, p. 117.
- 483 Ryu, J., Lyu, J.I., Kim, D.G., Kim, J.M., Jo, Y.D., Kang, S.Y., Kim, J.B., Ahn, J.W., and Kim,
- 484 S.H., 2020. Comparative analysis of volatile compounds of gamma-irradiated mutants of
 485 Rose (*Rosa hybrida*). Plants, 9: 1221.
- 486 SAS Institute Inc. 2009. SAS/STAT 9.2 User's Guide. Cary, North Carolina, USA.
- 487 Sayadi, V., Karimzadeh, G., Naghavi, M.R., and Rashidi Monfared, S., 2022. Interspecific
 488 genome size variation of Iranian Endemic *Allium* species (Amaryllidaceae). Cytologia, 87:
 489 335-338.
- Scariot, V., Paradiso, R., Rogers, H., and De Pascale, S., 2014. Ethylene control in cut flowers:
 Classical and innovative approaches, Postharvest Biol. Technol., 97: 83-92.
- Shuqin, L., Hongmei, L., Xijin, X., Xiaohui, L., Zhenpei, P., Jiping, L., and Shenggen, H.,
 2019. Nano-silver pretreatment delays wilting of cut *Gardenia foliage* by inhibiting
 bacterial xylem blockage, Sci. Hortic., 246: 791-796.
- Son, W.K., Youk, J.H., Lee, T.S., and Park, W.H., 2004. Preparation of antimicrobial ultrafine
 cellulose acetate fibers with silver nanoparticles. Macromol. Rapid Commun., 25: 16321637.
- Tavan, M., Mirjalili, M.H., and Karimzadeh, G., 2015. *In vitro* polyploidy induction: changes
 in morphological, anatomical and phytochemical characteristics of *Thymus persicus*(Lamiaceae). Plant Cell Tiss. Organ. Cult., 122: 573-583.
- 501 Weir, I.E., 2001. Analysis of apoptosis in plant cells. Methods Cell Biol., 163: 505-526.

- 502 Yang, G., Park, D., Lee, S.H., Bae, D.K., Yang, Y.H., Kyung, J., Kim, D., Choi, E.K., Hong,
- 503 J.T., and Jeong, H. S., 2013. Neuroprotective effects of a butanol fraction of *Rosa hybrida*
- petals in a middle cerebral artery occlusion model. BiomolTher. (Seoul), 21: 454-461.

506 Table 1. Mean Squares (MS) of the ANOVA for PCD% cut rose flowers sampled on days 10, 18, and 507 25.

SOV	Df	MS	CV%
Day 10	6	2.910**	14.1
Day 18	11 10	32.800**	2.6
Day 25	5 (0.047**	2.4
**Significant	difference	at 1%	probability
level.			

Table 2. Mean Squares (MS) of the ANOVA for Relative Fresh Weight (RFW), Water Uptake (WU) and 511 512 Chlorophyll (Chl) treated cut rose flowers in different sampling times

SOV	Df	MS		Df	MS
	DI -	RFW	WU	DI	Chl
Blocks	2	4.83**	1.9*	2	3.45**
Treatments (T)	11	1.66^{**}	7.6^{**}	11	0.56
Sampling Times (ST)	7	15.70^{**}	9.5**	3	13.20**
T×ST	77	0.16	0.7^{*}	33	0.92
Error	190	0.33	0.5	94	0.61

^{*,} and ** Significant differences at 5 and 1% probability levels, respectively. 513

rose flowers at 10th day. 516

SOV	Df	MS
Regression	3	1261.9**
Linear	1	3466.2**
Quadratic	1	53.9
Cubic	1	265.7
Error	17	206.5

** Significant difference at 1% 517 probability level.

520 Table 4. Polynomial regression analysis between the PCD% with Relative Fresh Weight (RFW) and Water Uptake (WU) cut rose flowers at 18th day for all treatments. 521

Parameters	SOV	Df	MS
RFW	Regression	3	1187.9^{**}
	Linear	1	1884.9^{**}
	Quadratic	1	447.4
	Cubic	1	1231.3
	Error	32	244.8
WU	Regression	3	944.3**
	Linear	1	1939.1**
	Quadratic	1	5.6
	Cubic	1	887.2
	Error	32	267.6

522

** Significant difference at 1% probability level.

⁵¹⁴

Table 3. Polynomial regression analysis between PCD% and Relative Fresh Weight (RFW) of cut 515





Figure 1. A: Control [T0, distilled water] and treated cut rose flowers with ineffective treatments, including: T3 [BA (25 mg 1^{-1})], T4 [BA (50 mg 1^{-1})], T5 [Nano-Ag (5 ppm)×Sucrose (3%)], T6 [Nano-Ag (5 ppm)×Sucrose (6%)], T7 [Nano-Ag (10 ppm)×Sucrose (3%)], and T8 [Nano-Ag (10 ppm)×Sucrose (6%)] and related FCM histograms of PCD% on day 10 of harvesting time. **B:** Control [T0, distilled water] and treated cut rose flowers with ineffective treatments, including T3 [BA (25 mg 1^{-1})], T4 [BA (50 mg 1^{-1})], T5 [Nano-Ag (5 ppm)×Sucrose (6%)], T6 [Nano-Ag (5 ppm)×Sucrose (6%)], T7 [Nano-Ag (10 ppm)×Sucrose (3%)], and T8 [Nano-Ag (10 ppm)×Sucrose (3%)], and T8 [Nano-Ag (10 ppm)×Sucrose (3%)], and T8 [Nano-Ag (10 ppm)×Sucrose (6%)], and T8 [Nano-Ag (10 ppm)×Sucrose (3%)], and T8 [Nano-Ag (10 ppm)×Sucrose (3%)], and T8 [Nano-Ag (10 ppm)×Sucrose (6%)], and T8 [Nano-Ag (10 ppm)×Sucrose (3%)], and T8 [Nano-Ag (10 ppm)×Sucrose (6%)], and T8 [Nano-Ag (10 ppm)×Sucrose (3%)], and T8 [Nano-Ag (10 ppm)×Sucrose (3%)], and T8 [Nano-Ag (10 ppm)×Sucrose (6%)], and T8 [Nano-Ag (10 ppm)×Sucrose (6\%)], and T8 [



Relative nuclear DNA content (Arbitrary units)



Figure 2. A: Control [T0, distilled water] and treated cut rose flowers with ineffective treatments, including: T1
[Nano-Ag (5 ppm)], T2 [Nano-Ag (10 ppm)], T9 [Static Magnetic Field (SMF; 15 mT)], T10 [SMF; 25 mT], T11
[Sucrose (1%, w/v)] and related FCM histograms of PCD% on day 18 of harvesting time. B: Control [T0, distilled
water] and treated cut rose flowers with ineffective treatments including T1 [Nano-Ag (5 ppm)], T2 [Nano-Ag
(10 ppm)], T9 [Static Magnetic Field (SMF; 15 mT)], T10 [SMF; 25 mT], T11 [Sucrose (1%, w/v)] and related
FCM histograms of PCD% on day 25 of harvesting time.



Figure 3. Programmed Cell Death (PCD%) of cut rose treated and control flowers on 10th day (a), 18th day (b),
and 25th day (c). T0= distilled water (control), T1= Nano-Ag (5 ppm), T2= Nano-Ag (10 ppm), T3= BA (25 mg
1⁻¹), T4= BA (50 mg 1⁻¹), T5= Nano-Ag (5 ppm)×Sucrose (3%), T6= Nano-Ag (5 ppm)×Sucrose (6%),
T7 = Nano-Ag (10 ppm)×Sucrose (3%), T8= Nano-Ag (10 ppm)×Sucrose (6%), T9= Static Magnetic Field (SMF;
15 mT), T10= SMF; 25 mT, and T11= Sucrose (1%, w/v). Means with the same letter are not significantly different
from each other (P> 0.05).



Sampling times (d)

Figure 4. Changes of mean Relative Fresh Weight (RFW) of cut rose flowers treated with T1 (Nano-Ag (5 ppm),
(a), T2 (Nano-Ag (10 ppm) (b), T9 (c), T10 (d) and T11 (e; solid lines) and the controls (dotted lines). Values are
means±SE.



Figure 5. Changes of mean Water Uptake (g g⁻¹ initial FW) of cut rose flowers treated with T1 (a), T2 (b), T9 (c), T10 (d), and T11 (e; dotted lines) and the controls (solid lines). Values are means \pm SE, but where bars are absent, the variation about the mean was less than the diameter of the symbol.



Figure 6. Changes of mean chlorophyll content (µg ml⁻¹) of cut rose flowers treated with T1 (a), T2 (b), T9 (c), T10 (d), and T11 (e; dotted lines) and the controls (solid lines). Values are means ± S.E.



Figure 7. The relationship between the PCD% of treated cut rose flowers and either Relative Fresh Weight (RFW) on 10th day (a) and on 17th day (b), or Water Uptake (WU) on 17th day (c).

آنالیز فلوسایتومتریک مرگ سلولی برنامه ریزی شده در گل رز (+Rosa hybrida cv. Dolce vita) تحت تأثیر تیمارهای فیزیکوشیمیایی

قاسم کریم زاده، سعید فرهادی، امین باقی زاده، و وحید صیادی

این مطالعه با هدف افزایش عمر گلدانی گلهای رز شاخه بریده از طریق بهبود تنظیم مرگ برنامه ریزی شده سلولی (PCD) انجام گردید. آزمایشها روی گلهای رز شاخه بریده (+ Ason Dolce vita cv. Dolce vita) تحت تأثیر تیمارهای فیزیکی میدان مغناطیسی ایستا (SMF ۵ و ۲۵ میلی تسلا) به مدت ۳ ساعت و تیمارهای فیزیکوشیمیایی نانو ذرات نقره (-Nano Ag ۵ و ۱۰ پی پی ام)، 6-بنزیل آدنین (BA و ۵۲ میلی گرم در لیتر)، ۱ درصد ساکارز (وزن/حجم) و ترکیبهای ۵ و ۱۰ پی پی ام نانو نقره با ۳ و ۶ درصد ساکارز انجام شد. نتایج نشان داد که SMF ۵ میلی تسلا به طور قابل توجهی عمر گلدانی را تا ۲۵ روز افزایش داد. از میان تیمارهای شیمیایی، نانو نقره ۵ پی پی ام و ۱ درصد ساکارز عمر گلدانی را به ترتیب تا ۲۳ و ۱۸ روز افزایش داد. از میان تیمارهای شیمیایی، نانو نقره ۵ پی پی ام و ۱ درصد ساکارز عمر گلدانی را به ترتیب تا ۲۳ و ۱۸ روز افزایش دادند. کمترین کاهش وزن تر در تیمار فیزیکیSMF ۵ میلی تسلا مشاهده گردید. این تیمار منجر به کمترین کاهش در محتوای کلروفیل (Chl) گردید. در روز هفدهم بعد از اعمال تیمارها، جذب آب (WU) و وزن تر نسبی (RFW) رابطه معکوس قابل ملاحظه ای با CD در گلهای رز شاخه بریده نشان دادند، که تأخیر در CD را تایید میکند. به طور کلی، تیمارهای القایی SMF را تیما می تسلا، نانو نقره ۵ پی پی م و ۱ درصد ساکارز برای بهبود کیفیت پس از برداشت و افزایش معر گلدانی گلهای رز شاخه بریده پیشنهاد میشوند.