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1 **β -cyclodextrin-based nanosponges improve 1-MCP efficacy in extending the**
2 **postharvest quality of cut flowers**

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13

14 **Abstract**

15 Investigations of the effect of the β -cyclodextrin-based nanosponge-1-
16 methylcyclopropene (1-MCP) complex (β -CD-NS complex) on six ethylene-sensitive
17 cut flowers were performed. *Anemone coronaria* L. multicolor, *Ranunculus asiaticus* L.
18 ‘Minou Abrown’, *Helianthus annuus* L. ‘Sunrich Orange’, *Rosa hybrida* L. ‘Jupiter’,
19 *Paeonia lactiflora* L. ‘Sarah Bernhardt’, and *Papaver nudicaule* L. multicolor
20 underwent four different treatments: a vase placement in a suspension of β -CD-NS
21 complex ($0.25 \mu\text{L L}^{-1}$), exposure to gaseous 1-MCP ($0.25 \mu\text{L L}^{-1}$) for 6 h, exposure to
22 exogenous ethylene ($1 \pm 0.2 \mu\text{L L}^{-1}$) for 24 h, and placement in tap water.

23 β -cyclodextrin-based nanosponges proved to enhance 1-MCP efficacy in all the tested
24 species. According to the species, senescence symptoms were decreased or delayed.
25 Anemone and poppy had a longer aesthetic flower quality and vase life, and a reduced

26 petal abscission. In ranunculus, β -CD-NS complex improved longevity. In sunflower, it
27 also maintained longer chlorophyll leaf content and cut flower ornamental value. Peony
28 opened more slowly and rose maintained its ornamental quality longer than 1-MCP
29 treated flowers. This study opens possibilities for commercial use of the β -CD-NS
30 complex in the floriculture industry.

31

32 *Keywords:* Ethylene inhibitor; Flower longevity; Nano-carrier; Preservative;
33 Senescence; Vase life.

34

35 *Abbreviations:* CD, cyclodextrin; 1-MCP, 1-methylcyclopropene; β -CD-NS, β -CD-
36 based-nanosponge; β -CD-NS complex, 1-MCP included in β -CD-NS

37

38 **1. Introduction**

39 Postharvest performance is of crucial importance to the value of cut flowers. The life
40 span of flowers is generally determined by the time to abscission of petals that are still
41 turgid, or by the time to petal wilting or withering. In many species, these phenomena
42 are regulated by ethylene (Woltering and Van Doorn, 1988; van Doorn, 2001).
43 Premature senescence and abscission resulting from exposure to exogenous or
44 endogenous ethylene can be controlled several ways including ethylene action inhibitors
45 (Martínez-Romero et al., 2007) quite commonly.

46 In particular, while 1-methylcyclopropene (1-MCP), has proved itself to be a very
47 effective preventer of negative ethylene responses, its gaseous nature makes treatment
48 difficult (Serek and Sisler, 2005; Serek et al., 2006).

49 Recently, we developed a non-volatile formulation of 1-MCP in a β -cyclodextrin-
50 based nanosponge (β -CD-NS 1:8) structure. Supplied in the conservation solution, this

51 formulation (β -CD-NS complex) prolonged the vase life of carnation cut flowers (Seglie
52 et. al., 2011a, b), and controlled *B. cinerea* damage (Seglie et al., 2012) better than
53 gaseous 1-MCP.

54 While carnation is generally used in studies on postharvest preservation of ethylene-
55 sensitive flowers (Woltering and van Doorn, 1988; Serek et al., 1995a, b); it is not a
56 universal paradigm for flower senescence. The response to ethylene varies widely
57 according to species (Reid and Wu, 1992). Therefore, our study evaluated the
58 effectiveness of the β -CD-NS complex to improve cut flower vase life on a number of
59 ethylene-sensitive species.

60

61 2. Materials and methods

62 The flower market of Sanremo (UCFlor, Liguria, Italy) seasonally provided cut
63 flowers of *Anemone coronaria* L. multicolor, *Ranunculus asiaticus* L. ‘Minou Abrown’,
64 *Helianthus annuus* L. ‘Sunrich Orange’, *Rosa hybrida* L. ‘Jupiter’, *Paeonia lactiflora*
65 Pall. ‘Sarah Bernhardt’, and *Papaver nudicaule* L. multicolor.

66 Stems were transferred to the postharvest laboratory of the Department of
67 Agricultural, Forest and Food Sciences at the University of Turin. Experimental
68 evaluations of vase life were performed in an imitated inside environment (IE)
69 maintained at $20\pm 2^\circ$ C, 60 % RH, and 12 h daily of $46 \mu\text{mol m}^{-2} \text{s}^{-1}$ cool white light
70 (meter model HT307; HT, Faenza, Italy).

71 Cut flowers were re-cut, labeled and re-watered. Each species sample was divided
72 into sub-groupings of six cut stems (each 30 cm long after re-cutting). Each sub-group
73 was then treated according to the following schemes: in vases with an aqueous
74 suspension of β -CD-NS complex to supply $0.25 \mu\text{L L}^{-1}$ of active ingredient; in an air
75 tight cabinet (112 L) exposed to equal concentrations of volatile 1-MCP (3.3% a. i.,

76 SmartFreshTM, AgroFresh Inc., USA) for 6 h; in another air tight cabinet exposed to
77 exogenous ethylene ($1 \pm 0.2 \mu\text{L L}^{-1}$) for 24 h; and in vases of tap water as a control. The
78 experiment was performed twice for each species.

79 Endogenous ethylene production of the control flowers was measured using a digital
80 Agilent Technologies gas chromatograph, 7890A Network GC system (Santa Clara,
81 California). N_2 at 40 mL min^{-1} was used as the gas carrier at a column temperature 60
82 °C and calibration range between 0.5-3 ppm. For each species, six samples were
83 considered.

84 Flower postharvest performance was measured and visual checks for symptoms of
85 variation in senescence were performed daily. In particular, we monitored senescence
86 level (1 = initial senescence, 2 = complete senescence; Seglie et al., 2011a), flower
87 opening stage (1 = initial opening, 2 = half opening, 3 = full opening; Guo et al., 2004,
88 modified), and abscission. Chlorophyll content was indirectly measured in leaves
89 through the Chlorophyll Meter SPAD-502 instrument (Konica Minolta Sensing Inc.,
90 Osaka, Japan).

91 Analysis of variance (ANOVA) was performed to assess statistical significance
92 among mean values using the Ryan–Einot–Gabriel–Welsch’s multiple step-down F
93 (REGW-F) test ($p \leq 0.05$) with SPSS Software (Chicago, USA).

94

95 3. Results and Discussion

96 Senescence performance and ethylene sensitivity are highly species related (van
97 Doorn, 2001). Large variabilities have been observed even among cultivars, such as the
98 Asian buttercup (Kenza et al., 2000; Scariot et al., 2009), rose (Chamani et al., 2005),
99 and peony (Hoffman et al., 2010; Eason et al., 2002). Flowers that respond to low
100 concentrations of exogenous ethylene are probably those in which ethylene is naturally

101 involved in senescence (Reid and Wu, 1992). In this study, ethylene hastened the
102 symptoms of natural senescence in all species. However, a climacteric pattern was
103 observed only in poppy (ethylene up to 12 $\mu\text{L L}^{-1}$ at day 5) while in peony and
104 sunflower ethylene production was not detected (data not shown).

105 Anemone cut flowers lose their decorative value in a very short period. Pedicels
106 elongate excessively and petals wilt, lose their color, become translucent, and abscise
107 (Meir, 2007). Previous studies have already demonstrated the ethylene sensitivity of the
108 anemone (Armitage, 1993) and the efficacy of ethylene antagonists (silver nitrate and
109 silver thiosulphate, STS) in extending its vase life and preventing petal abscission
110 (Sharifani et al., 2005). In this study, the application of β -CD-NS complex was found to
111 prolong cut flower aesthetic quality and longevity for up to 1.5 additional days, (Fig. 1),
112 slow stage 1 and 2 of flower opening (Tab. 1), and completely prevent abscission (Fig.
113 2) more effectively than gaseous 1-MCP. Petal rolling over and stem folding (Sharifani
114 et al., 2005), which usually occur in anemone cut flowers, were also limited.

115 Asian buttercup flower senescence is characterized by loss of turgor and petal colour
116 change followed by petal wilting and drop when lightly touched. Previous tests of the
117 effects of silver thiosulphate (STS) and aminooxyacetic acid (AOA) on buttercup
118 postharvest performance have yielded unsatisfactory results in enhancing vase life
119 (Shahri et al., 2011). In this study, ethylene antagonists were effective in delaying
120 senescence symptoms with β -CD-NS complex; they outperformed gaseous 1-MCP as
121 demonstrated by delay of complete senescence (9.7 *versus* 8 days; Fig. 1) and original
122 flower colour maintenance (data not shown).

123 Previous studies of sunflower have shown exogenous ethylene applications result in
124 short vase life, flower abscission (Redman et al., 2002), and in largely, wilted basal
125 foliage immediately after anthesis (Pallez et al., 2002; Castro et al., 2011). Furthermore,

126 ethylene antagonist treatment has failed to limit or delay senescence (Redman et al.,
127 2002). In this study, chlorophyll degradation was restrained by ethylene antagonist
128 application. At day 5, the SPAD value was 26.2 ± 0.63 units for control flowers and on
129 average 33.7 ± 0.19 units for flowers treated with ethylene antagonists. β -CD-NS
130 complex was more effective than gaseous 1-MCP at prolonging vase life (9 *versus* 7
131 days, respectively; Fig. 1) and at slowing flower opening (stages 1 and 2; Tab. 1).

132 In rose, flower opening seemed to be affected by exogenous ethylene (Reid et al.,
133 1989). Ethylene induced abscission of fully turgescient, non-senescent petals or the
134 entire corolla (Serek et al., 2006), which suggests that anti-ethylene compounds could
135 retard the behavior (Serek et al., 1995b) and extend vase life (Mor et al., 1989).
136 Precedent studies have noted decreased leaf and bud abscission by application of 1-
137 MCP along with increased display life in both ethylene-contaminated and ethylene-free
138 air (Muller et al., 2000; Serek et al., 1994). This study showed β -CD-NS complex
139 performed better than commercial 1-MCP as evidenced by extension of ornamental rose
140 quality (5.0 and 3.5 days, respectively; Fig. 1), and slowed flower opening (stages 2 and
141 3; Tab. 1).

142 Peony has been found by Jia et al. (2008) to have a high ethylene sensitivity; they
143 correlated it to an increased flower diameter during senescence. On the other hand,
144 Hoffman et al. (2010) have found 1-MCP ineffective at increasing storage longevity and
145 quality of cut peony flowers. Our study results show that both 1-MCP applications
146 significantly increased the longevity of peony to almost 2 days (7 days) beyond that of
147 the control (5 days; Fig. 1), and limited abscission (Fig. 2). Also, β -CD-NS complex
148 outperformed the commercial product in slowing flower opening (Fig. 2).

149 The vase life of poppy is usually 5 days in untreated flowers; it ends when petals
150 shatter or crinkle, discolor or turn brown, and the stem collapses (Dole et al., 2009).

151 This research indicated that gaseous 1-MCP was ineffective at delaying these symptoms
152 of senescence while β -CD-NS complex, on the other hand, was shown to extend
153 ornamental flower quality for up to 5.8 days and increased the vase life to as long as 8.7
154 days (Fig. 1). Moreover, this compound significantly reduced petal abscission (Fig. 2)
155 and retarded flower opening (Tab. 1). Therefore, β -CD-NS complex use could increase
156 the commercial market for poppy cut flowers, albeit one that will continue to be limited
157 by high production costs (Dole and Greer, 2009).

158 In conclusion, β -CD-NS 1:8 was shown to enhance the efficacy of 1-MCP in six
159 ethylene-sensitive species, as was previously seen in carnation (Seglie et al., 2011a, b).
160 1-MCP is a high unstable and reactive gas that very quickly dimerizes even at room
161 temperature. This dimer has not antiethylenic activity. Most likely β -CD-NS stabilize to
162 a great extent the included 1-MCP thus preserving its properties.

163 The present study opens the possibilities of commercial use of the β -CD-NS complex
164 in the floriculture industry.

165

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172

173 **References**

174 Armitage, A.M., Laushman, J.M., 1993. Specialty cut flowers: the production of
175 annuals, perennials, bulbs, and woody plants for fresh and dried cut flowers. Timber
176 press Inc. Portland, Oregon.

177 Castro, A.M.C., Sato, O., Rando, E.M., Santos, K.H.D., Silva, D.P.Da, Chimbo, JR.A.,
178 Carvalho, F.K., Braga, C.DeL., 2011. Uso de fontes de nitrogênio visando retardar a
179 senescência em girassol ornamental. *Scientia Agraria Paranaensis* 10, 83-90.

180 Chanami, E., Khalighi, A. Joyce, D.C., Irving, D.E., Zamani, Z.A., Mostofi, Y., Kafi,
181 M., 2005. Ethylene and anti-ethylene treatment effects on cut 'First Red' rose. *J.*
182 *Applied Hortic.* 7, 3-7.

183 Dole, J.M., Fonteno, W.C., Blankenship, S. L., 2005. Comparison of silver thiosulphate
184 with 1-methylcyclopropene on 19 cut flower taxa. *Acta Hortic.* 682, 249-256.

185 Dole, J.M., Vilorio, Z., Fanelli, F.L., Fonteno, W., 2009. Postharvest evaluation of cut
186 dahlia, linaria, poppy, rudbeckia, trachelium, and zinnia. *HortTechnology.* 19, 593-
187 600.

188 Dole, J.M., Greer, L., 2009. Production protocol development for greenhouse cut
189 *Linaria*, *Lupinus*, and *Papaver* flowers. *Sci. Hortic.* 122, 233-237.

190 Eason, J., Pinkney, T., Heyes, J., Brash, D., Bycroft, B., 2002. Effect of storage
191 temperature and harvest bud maturity on bud opening and vase life of *Paeonia*
192 *lactiflora* cultivars. *New Zeal. J. Crop Hort.* 30, 61-67.

193 Guo, W., Chen, R., Dong, R., 2004. The postharvest characteristic and water balance of
194 some cultivars of tree-peony cut flowers. *Sci. Silvae Sin.* 40, 89-93.

195 Hoffman, G.D., Mattinson, D.S., Fellman, J.K., 2010. 1-MCP shortens peony vase life.
196 *Acta Hort.* 857, 169-178.

197 Kenza, M., Umiel, N., Borochoy, A., 2000. The involvement of ethylene in senescence
198 of ranunculus cut flowers. *Postharvest Biol. Technol.* 19. 287-290.

199 Jia, P., Zhou, L., Guo, W., Wang, L., Dong, L., 2008. Postharvest behavior and
200 endogenous ethylene pattern of *Paeonia suffruticosa* cut flowers. *Acta Hort.* 768,
201 445-450.

202 Martínez-Romero, D., Bailén, G., Serrano, M., Guillén, F., Valverde, J.M., Zapata, P.,
203 Castillo, S., Valero, D., 2007. Tools to maintain postharvest fruit and vegetable
204 quality through the inhibition of ethylene action: a review. *Crit. Rev. Food Sci.* 47,
205 543-560.

206 Meir, S., Salim, S., Chernov, Z., Philosoph-Hadas, S., 2007. Quality improvement of
207 cut flowers and potted plants with postharvest treatments based on various cytokinins
208 and auxins. *Acta Hort.* 755, 143-154.

209 Mor, Y., Johnson, F., Faragher, J.D., 1989. Preserving the quality of cold-stored rose
210 flowers with ethylene antagonists. *Hortic. Sci.* 24, 640-641.

211 Muller, R., Sisler, E.C., Serek, M., 2000. Stress induced ethylene production, ethylene
212 binding, and the response to the ethylene action inhibitor 1-MCP in miniature roses.
213 *Sci. Hortic.* 83, 51-59.

214 Pallez, L.C., Dole, J.M., Whipker, B.E., 2002. Production and postproduction studies
215 with potted sunflowers. *HortTechnology* 12, 206-210.

216 Redman, P.B., Dole, J.M., Maness, N.O., Anderson, J.A., 2002. Postharvest handling of
217 nine specialty cut flower species. *Sci. Hortic.* 92, 293-303.

218 Reid, M.S., Evans, R.Y., Dodge, L.L., Mor, Y., 1989. Ethylene and silver thiosulphate
219 influences opening of cut rose flower. *J. Am. Soc. Hortic. Sci.* 114, 436-440.

220 Reid, M.S., Wu, M.J., 1992. Ethylene and flower senescence. *Plant Growth Regul.* 11,
221 37-43.

222 Scariot, V., Larcher, F., Caser, M., Costa, E., Beruto, M., Devecchi, M., 2009. Flower
223 longevity in ten cultivars of cut *Ranunculus asiaticus* L. as affected by ethylene and
224 ethylene inhibitors. *Europ. J. Hort. Sci.* 74, 137-142.

225 Seglie, L., Martina, K., Devecchi, M., Roggero, C., Trotta F., Scariot, V., 2011a. The
226 effects of 1-MCP in cyclodextrin-based nanosponges to improve the vase life of
227 *Dianthus caryophyllus* cut flowers. *Postharvest Biol. Technol.* 59, 200-205.

228 Seglie, L., Martina, K., Devecchi, M., Roggero, C., Trotta F., Scariot, V., 2011b. β -
229 cyclodextrin-based nanosponges as carriers for 1-MCP in extending the postharvest
230 longevity of carnation cut flowers. An evaluation of different degrees of cross-
231 linking. *Plant Growth Regul.* 65, 505-511.

232 Seglie, L., Spadaro, D., Trotta, F., Devecchi, M., Gullino, M.L., Scariot, V., 2012. Use
233 of 1-methylcyclopropene in cyclodextrin-based nanosponges to control grey mould
234 caused by *Botrytis cinerea* on *Dianthus caryophyllus* cut flowers. *Postharvest Biol.*
235 *Technol.* 64, 55-57.

236 Serek, M., Sisler, E.C., Reid, M.S., 1994. Novel gaseous ethylene binding inhibitor
237 prevents ethylene effects in potted flowering plants. *J. Am. Hort. Sci.* 119, 1230-
238 1233.

239 Serek, M., Sisler, E.C., Reid, M.S., 1995a. Effects of 1-MCP on the vase life and
240 ethylene response of cut flowers. *Plant Growth Regul.* 16, 93-97.

241 Serek, M., Sisler, E.C., Reid, M.S., 1995b. 1-methylcyclopropene, a novel gaseous
242 inhibitor of ethylene action, improves the vase life of fruits, cut flowers and potted
243 plants. *Acta Hort.* 394, 337-346.

244 Serek, M., Sisler, E.C., 2005. Impact of 1-MCP on postharvest quality of ornamentals.
245 In: *APEC Symp. Quality Management of Postharvest System Proceedings*, 121-128.

246 Serek, M., Sisler, E.C., Frello, S., Sriskandarajah, S., 2006. Postharvest technologies for
247 extending the shelf life of ornamental crops. *Int. J. Postharvest Technol. Inn.* 1, 69-
248 75.

249 Sharifani, M., Parizadeh, M., Mashayekhi, K., 2005. The effects of pre-storage on
250 postharvest quality of cut anemone (*Anemone coronaria*) flowers. *Acta Hort.* 682,
251 701-707.

252 van Doorn, W.G., 2001. Categories of petal senescence and abscission: a re-evaluation.
253 *Ann. Bot.* 87, 447-456.

254 Woltering, E.J., van Doorn, W.G., 1988. Role of ethylene in senescence of petals--
255 morphological and taxonomical relationship. *J. Exp. Bot.* 39, 1605-1616.

256

257

258 **Figure captions**

259 **Fig. 1** Longevity of six species of cut flowers according to four treatments: placement in
260 a vase suspension of β -CD-NS complex ($0.25 \mu\text{L L}^{-1}$), exposure to gaseous 1-MCP
261 ($0.25 \mu\text{L L}^{-1}$) for 6 h, exposure to exogenous ethylene ($1 \pm 0.2 \mu\text{L L}^{-1}$) for 24 h, and
262 placement in tap water. The count of days to reach the initial stage of senescence (Level
263 1, line) and complete senescence (Level 2, dotted line) was measured.

264 *Mean separation within bars by the Ryan-Einot-Gabriel-Welsch's multiple stepdown F
265 (REGW-F) test, $P \leq 0.001$.

266

267 **Fig. 2** Petal abscission in six flower species according to four treatments: placement in a
268 vase suspension of β -CD-NS complex ($0.25 \mu\text{L L}^{-1}$), exposure to gaseous 1-MCP (0.25
269 $\mu\text{L L}^{-1}$, for 6 h, exposure to exogenous ethylene ($1 \pm 0.2 \mu\text{L L}^{-1}$) for 24 h, and placement

270 in tap water. For each species, abscission (%) was calculated as the total number of
271 abscised petals/the mean number of petals in three flowers * 100.

272 *Mean separation within bars by the Ryan-Einot-Gabriel-Welsch's multiple stepdown F
273 (REGW-F) test, $P \leq 0.001$.

274