Ethylene and the postharvest performance of cut camellia flowering branches

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Abstract: Camellias are potentially appreciated as cut branches due to their deep and bright green foliage with a high number of flower buds. The present research investigated the role of ethylene in postharvest flower and leaf abscission of seven cultivars of *Camellia japonica* and evaluated the effect of inhibitors of ethylene action on their vase life. Cut flowering branches were shipped from private companies, mimicking a long and short supply chain. Plant materials were treated with commercial Chrysal, gaseous 1-MCP, and 1-MCP included in β-cyclodextrin-based nanosponges and compared to cut branches exposed to exogenous ethylene (1 ± 0.2 µl l^{-1}) for 24 h and control in tap water. Visual checks for symptoms of variation in senescence, flower opening stage, flower abscission, leaf chlorophyll content (SPAD) and gloss, in addition to ethylene production levels were monitored daily. Cut branches placed in tap water lost ornamental value after *ca* 5.5 days of vase life and reached complete senescence after about 10 days in all the studied cultivars, regardless of supply chain, with the exception of 'Il Tramonto' with 10 and 20 days, respectively. Exogenous ethylene application reduced camellia cut branch longevity in 'Debbie' and 'R.H. Wheeler', while the other cultivars lasted as long as the control. Anti-ethylene treatments prolonged the vase life only in 'Korun Koku' and 'Il Tramonto'.

1. Introduction

Camellia japonica L. is an important ornamental shrub commonly used as potted plant and for landscaping (Accati *et al*., 2006; Scariot *et al*., 2007). Generally, camellia flowers on the plants last for seven to ten days, and flower senescence is mainly characterised by browning regions on the petals and by floral organ abscission. On the contrary, when flowers are removed from the plant, they usually wilt quickly unless they are held at low temperatures and high humidity (Bonner and Honda, 1950). For this reason the use of camellia as cut flower has been restricted to situations where longevity is not especially important, even if the deep and bright green foliage with a high number of flower buds make camellias potentially appreciated also as cut flowering branches. Only a few studies have been performed on this topic. In the 1950's considerable efforts were made to find treatments to extend camellia cut flower vase life by Cothran (1958). This author showed that poor water relations lead to early wilting of cut camellia blooms. Therefore, most of the efforts were directed towards the reduction of vapour pressure deficit or to prevent water loss from the petals. For better conservation, Threlkeld (1962) suggested harvesting flowers with no stem, holding them at high humidity. More recently, Doi and Reid (1996) reported that in the first day of vase life, the camellia flower is unable to acquire sufficient water from the vase solution to supply the needs of petal expansion and transpiration.

The role of ethylene in camellia senescence have been also envisaged. Woolf *et al*. (1992) reported that abscission of camellia flower buds was induced by a foliar spray with 2-4 ml l^{-1} ethephon [(2-chloroethyl)phosphonic acid] and that the vegetative buds and leaves were less sensitive to ethephon than flower buds. Doi and Reid (1996) used silver thiosulphate (STS) to prevent flower abscission.

The negative effects of ethylene can be significantly delayed by treatment with inhibitors of ethylene action, such as 1-methylcyclopropene (1-MCP) (Serek *et al*., 2006). The possible value of such treatment in improving the life of cut camellia flowering branches has not been explored. Recently, a non-volatile formulation of 1-MCP in β-cyclodextrin-based nanosponges (β-CD-NS 1:8) was developed (Seglie *et al*., 2011 a, b). This structure, supplied in the conservation solution, prolonged the vase life of several cut flowers better than gaseous 1-MCP (Seglie *et al*., 2013).

Since there is a lack of knowledge on postharvest characteristics of *C. japonica* cut flowers and foliage, the objectives of this study were to evaluate the role of ethylene in postharvest flower and leaf abscission of seven cultivars

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of *C. japonica* and investigate the effect of inhibitors of ethylene action (commercial Chrysal, commercial 1-MCP and 1-MCP included in β-cyclodextrin-based nanosponges) on camellia flowering branch vase life.

2. Materials and Methods

Flower budded branches (50 cm in length) of seven *C. japonica* cultivars were supplied to the postharvest laboratory of the Department of Agricultural, Forest and Food Sciences (DISAFA) at the University of Torino (Italy) as listed in Table 1. The long supply chain (three days long) was simulated as follows: (1) cut branches were harvested at Verbania (Italy) at two companies (F.lì Savioli and Società Cooperativa Val Intrasca) and kept in cold storage overnight; (2) transportation to the flower market of Sanremo (Imperia, Italy) by refrigerated truck; and (3) shipment to DISAFA the next day. In the short supply chain (one day long), cut branches were collected at Verbania and then directly transferred to DISAFA.

At DISAFA, branches were recut to 20 cm length and ten branches per treatment were used. Three treatments were compared with a tap water control: Chrysal Professional 2 (10 ml l^{-1}) for 24 h followed by the application of Chrysal Professional 3 (10 mg l^{-1}) for all the experiment; commercial gaseous 1-MCP (3.3% ai, SmartFresh™, AgroFresh Inc., USA) (0.25 µl l^{-1}) for 6 h in a gas-tight cabinet (112 l); and β-cyclodextrin-based nanosponge - 1-MCP complex (β-CD-NS 1:8) (0.25 µl l^{-1}). Ten branches were also sealed in a box (112 L) and exposed to exogenous ethylene (1±0.2 µl l^{-1}) for 24 h. Subsequently, six branches per cultivar were individually enclosed in sealed tubes (1 L) containing 300 ml tap water, to quantify the daily production of endogenous ethylene.

The study was undertaken during spring 2012 in a controlled room at 20±2°C day/night temperature, 60% relative humidity, and 46 µmol m^{-2} s^{-1} cool white light (meter model HT307; HT, Faenza, Italy).

Every day, the postharvest performance of the branches was evaluated considering both flowers and foliage characteristics, according to the following factors: visual check for symptoms of variation in senescence, flower opening stage, flower abscission, leaf chlorophyll content (SPAD), gloss, and endogenous ethylene production. Variation in senescence was rated on a scale from 0 to 2, in which 0 = no visible senescence, 1 = initial senescence, and 2 = complete senescence. The loss of ornamental value of branches was considered when they reached level 1 on the scale (Seglie *et al*., 2010). Variation in flower opening stage was evaluated on the basis of the following scale: 1 = initial opening, 2 = half opening, and 3 = full opening (Guo *et al*., 2004, modified). Chlorophyll content was indirectly measured in leaves through a Chlorophyll Meter SPAD-502 instrument (Konica Minolta Sensing Inc., Osaka, Japan). Gloss variation was measured in leaves using a Spectrophotometer CM-2600 (Konica Minolta Sensing Inc., Osaka, Japan).

Ethylene concentration was monitored by a digital Agilent Technologies gas chromatograph, 6890N Network GC system (Santa Clara, California). The gas carrier was N_2 at 40 ml min^{-1}, and column temperature was 60°C.

Photo-documentation at different stages of senescence was carried out. Data were registered until all the cut branches appeared completely damaged. Petal, flower, and bud abscission percentages were mathematically transformed using arcsin$\sqrt{P/100}$. Differences were initially subjected to the homogeneity of the variance test and then the analysis of variance (ANOVA) was established using Ryan-Einot-Gabriel-Welsch-F (REGW-F) post-hoc test. The critical value for statistical significance was $P < 0.05$. All the data were computed by means of the SPSS statistical package (version 21.0; SPSS Inc., Chicago, Illinois).

Table 1 - The studied *Camellia japonica* cultivars and their supply chain length

Cultivar	Supply chain
´Korun Koku´	Long
´Debbie´	Long
´Bonomiana´	Long
´Colonel Firey´	Long
´Charles Cobb´	Short
´R.H. Wheeler´	Short
´Il Tramonto´	Short

Long= 3 days; Short= 1 day.

3. Results

Camellia cut flowering branches placed in tap water lost ornamental value after approximately 5.5 days of vase life and reached complete senescence after about 10 days in all studied cultivars, regardless of supply chain, with the exception of ‘Il Tramonto’ (Fig. 1) in which senescence symptoms started to appear after 10 days and complete senescence was reached at day 20. Exogenous ethylene application reduced camellia cut branch longevity in ‘Debbie’ and ‘R.H. Wheeler’, while the other treated cultivars lasted as long as the control. Only in ‘Charles Cobb’ did cut branches treated with exogenous ethylene last longer, reaching complete senescence at day 14. The two anti-ethylene treatments (1-MCP and β-CD-NS) similarly prolonged vase life up to 10 days, slightly better than Chrysal in ‘Korun Koku’ and ‘Colonel Firey’. On the contrary, Chrysal outperformed the anti-ethylene treatments in ‘Il Tramonto’, prolonging its vase life up to 27 days.

Flowers fully opened on branches of ‘Korun Koku’ treated with β-CD-NS, ‘Debbie’ treated with both Chrysal and 1-MCP, ‘Bonomiana’ in tap water, ‘Colonel Firey’ treated with both exogenous ethylene and 1-MCP, and ‘Il Tramonto’ in all treatments with the exception of β-CD-

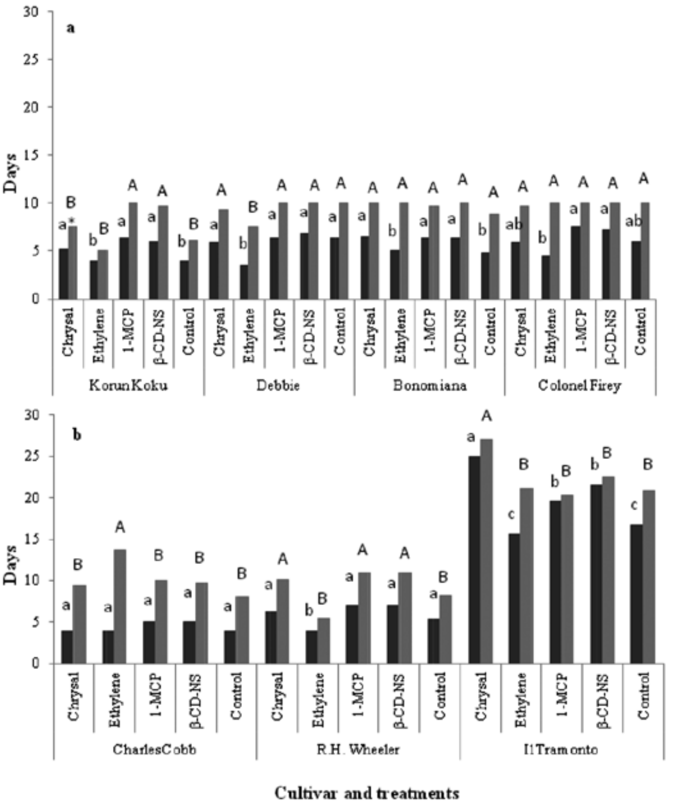

Fig. 1 - Cut flowering branch longevity of the studied *Camellia japonica* cultivar according to five treatments and two supply chains (a. Long, b. Short). The number of days to reach the initial stage of senescence (stage 1, black bar) and complete senescence (stage 2, grey bar) was measured. Mean separation within bars of stage 1 (lower case) and stage 2 (upper case) were computed by the Ryan-Einot-Gabriel-Welsch's multiple stepdown *F* (REGW-F) test, $P \leq 0.05$.

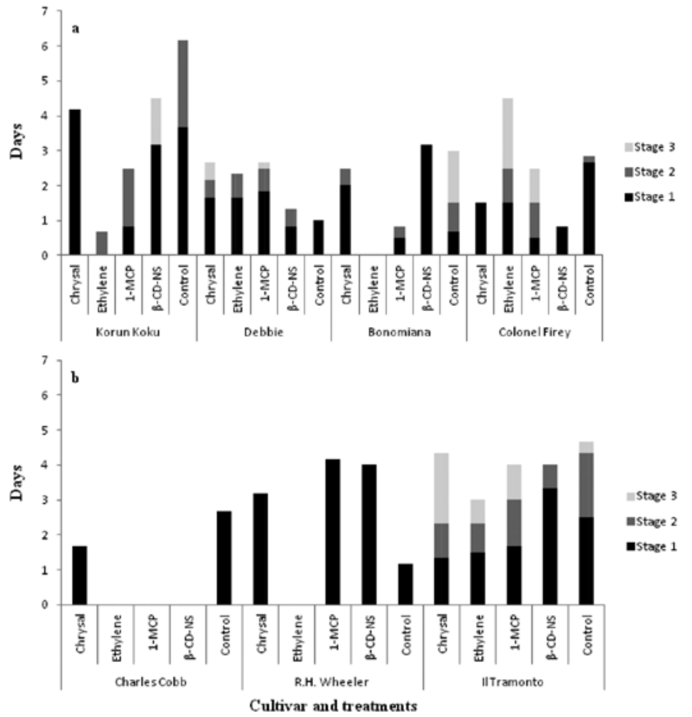

Fig. 2 - Variation in flower opening stages (stage 1 = initial opening, stage 2 = half opening, and stage 3 = full opening) of the studied *Camellia japonica* cultivar according to five treatments and two supply chains (a. Long, b. Short).

NS (Fig. 2). Branches of 'Charles Cobb' and 'R.H. Wheeler' reached, at maximum, stage 1 (initial opening).

Exogenous ethylene increased petal, flower, and bud abscission more than control in 'Korun Koku' (16.67% of flowers), 'Bonomiana' (100% of buds), 'Colonel Firey' (100% of petals and 100% of flowers), and 'Il Tramonto' (50% of buds) (Table 2). Among the other treatments, an increase in abscission was noted in branches of 'Bonomiana' and 'Colonel Firey' treated with β-CD-NS (25 % of flowers and 75 % of petals, respectively), in 'Charles Cobb' and in 'Il Tramonto' treated with Chrysal (25 and 75% of flowers, respectively), and in 'Il Tramonto' also treated with 1-MCP (50% of buds). However, no correlations were found between abscission levels and applied treatments.

Generally, leaf SPAD and gloss values were not affected by treatments. Only in 'Korun Koku', 'R.H. Wheeler', and 'Il Tramonto' were slight differences found. In 'Korun Koku' Chrysal outperformed the anti-ethylene treatments, and conversely in 'R.H. Wheeler' and 'Il Tramonto'.

Figure 3 shows differences in ethylene production among the studied *Camellia* cultivars. A general trend was observed during the experiment with an ethylene increase until day 11. 'Korun Koku', 'Colonel Firey', and 'Bonomiana' produced up to 1.42, 1.10, and 1.04 µl l^{-1}, respectively. On the contrary, in 'Charles Cobb', 'Debbie', and 'R.H. Wheeler', 0.75, 0.67 and 0.66 µl l^{-1} were recorded, respectively. 'Il Tramonto' followed a similar but postponed trend. This latter cultivar started to produce ethylene at day 10 until day 24. Also the ethylene production was much higher (2.10 µl l^{-1} at day 20).

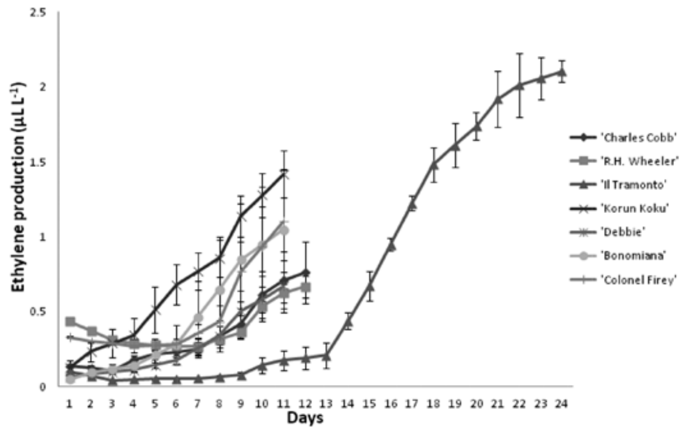

Fig. 3 - Mean values of the endogenous ethylene production in the studied cut flowering branches of *Camellia japonica* cultivars placed in tap water.

Table 2 - Petal, flower, and bud abscission of the studied *Camellia japonica* cultivars subjected to five treatments and measured at the end of the experiment

Cultivar	Treatments	Petal abscission (%)	Flower abscission (%)	Bud abscission (%)
´Korun Koku´	Chrysal	35.71 b [z]	0.00 b	35.71 b
	Ethylene	100.00 a	16.67 a	83.33 a
	1-MCP	60.00 ab	0.00 b	60.00 ab
	β-CD-NS	66.67 ab	0.00 b	66.67 ab
	Control	44.44 ab	0.00 b	44.44 ab
	P	*	**	*
´Debbie´	Chrysal	66.67 a	16.67 ab	50.00 ab
	Ethylene	100.00 a	66.67 a	33.33 ab
	1-MCP	20.00 b	0.00 b	20.00 b
	β-CD-NS	87.50 a	4.17 b	83.33 a
	Control	100.00 a	37.50 ab	62.50 ab
	P	**	*	*
´Bonomiana´	Chrysal	27.27	27.27 b	0.00 b
	Ethylene	100.00	0.00 b	100.00 a
	1-MCP	18.75	0.00 b	18.75 b
	β-CD-NS	25.00	25.00 a	0.00 b
	Control	14.29	0.00 b	14.29 b
	P	NS	**	**
´Colonel Firey´	Chrysal	11.11 b	0.00 b	11.11
	Ethylene	100.00 a	100.00 a	0.00
	1-MCP	25.00 b	0.00 b	25.00
	β-CD-NS	75.00 a	0.00 b	75.00
	Control	12.50 b	0.00 b	12.50
	P	**	*	NS
´Charles Cobb´	Chrysal	75.00	25.00 a	50.00
	Ethylene	80.00	0.00 b	80.00
	1-MCP	100.00	0.00 b	100.00
	β-CD-NS	100.00	0.00 b	100.00
	Control	100.00	0.00 b	100.00
	P	NS	*	NS
´R.H. Wheeler´	Chrysal	100.00 a	10.00	90.00 a
	Ethylene	37.50 b	0.00	37.50 b
	1-MCP	41.67 b	0.00	41.67 b
	β-CD-NS	54.55 b	0.00	54.44 b
	Control	100.00 a	0.00	100.00 a
	P	***	NS	**
´Il Tramonto´	Chrysal	75.00	75.00 a	0.00 b
	Ethylene	50.00	0.00 c	50.00 a
	1-MCP	75.00	25.00 b	50.00 a
	β-CD-NS	33.33	33.33 b	0.00 b
	Control	20.00	20.00 b	0.00 b
	P	NS	*	**

[z] Different letter indicates significant differences at the 0.05 level, Ryan-Einot-Gabriel-Welsch (F) post hoc test.

4. Discussion and Conclusions

Camellias are important ornamental species worldwide. Their morphological (Corneo and Remotti, 2003) and genetic (Ueno *et al*., 1999; Caser *et al*., 2010) diversity as well as multiplication techniques and cultivation practices (Larcher *et al*., 2011; Berruti and Scariot, 2013) were previously evaluated for their breeding and production.

In this study, we investigated camellia attitude to be used as cut flowering branches. In 2001, van Doorn stated that senescence performance and ethylene sensitivity are highly species related. Here, we observed a great variability among cultivars, similarly to what was found in buttercup by Kenza *et al*. (2000), Scariot *et al*. (2009), and Seglie *et al*. (2013), in rose by Chanami *et al*. (2005), in peony by Hoffman *et al*. (2010), and in bluebell by Scariot *et al*. (2008). Exogenous ethylene application in this study anticipated the senescence only in 'Debbie' and 'R.H. Wheeler'. Anti-ethylene treatments prolonged the vase life only in 'Korun Koku' and 'Il Tramonto'. Therefore, precautions against exposure to ethylene cannot be generalised for camellia cultivars. The provided data could be of benefit to growers and those involved in shipping.

In conclusion, 'Il Tramonto' was the most interesting genotype as cut branches. This cultivar kept its ornamental value up to 27 days (when treated with Chrysal), its flowers fully opened, and its foliage maintained colour and brightness during the vase life.

This information could be useful to bring new produce to the flower market and to stimulate further research on postharvest techniques for camellia flowering branches.

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